The appraisal of transport infrastructure projects in the municipal sphere of government in South Africa, with reference to the City of Tshwane

IC Schutte

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The appraisal of transport infrastructure projects in the municipal sphere of government in South Africa, with reference to the City of Tshwane

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IGNATIUS CHRISTIAAN SCHUTTE

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SUMMARY

The annual budget cycle in urban road/transport authorities by implication requires transport infrastructure projects to be ranked in terms of their relative value, to enable project selection by starting from the most deserving proposal. This follows from the fact that the total cost of feasible projects practically always exceeds available funds, signalling the need for some kind of selection protocol. Cost benefit analysis (CBA), when applied in a narrow sense, is not suitable for this purpose as it focuses on economic efficiency only. Attempts to broaden it have been criticized by some scholars. Although the diversity of impacts points to a multi-criteria analysis (MCA) approach, this is considered unscientific in certain quarters; at best, its practical value needs to be demonstrated. In the case of the City of Tshwane (CoT), problems with current project appraisal are evident in that different methods – none of which is defensible – are used, sometimes resulting in rankings that are contradictory.

This thesis therefore attempts the following: (a) to develop a basic approach that combines the best elements of traditional methods; (b) to customize this approach to the specific context and needs of road authorities in the municipal sphere of government, using CoT as an example; and (c) to demonstrate the application of the resulting appraisal framework, utilizing appropriate decision-support software for this purpose.

Recommendations include the following: An appraisal framework should combine CBA and MCA by adopting an overall MCA approach with economic efficiency – focusing on the optimal allocation of scarce resources – as one of the decision criteria. For completeness' sake, three additional decision criteria are deemed necessary: equity (focusing on income distribution impacts); sustainability (focusing on environmental impacts); and compatibility (focusing on the alignment of projects with stated goals and objectives). This framework may well apply to road authorities in other spheres of government – the optimum application in each case will depend on the composition of the relevant decision-making team. The inherent nature of project appraisal requires a two-phased approach in all cases: the evaluation of mutually exclusive alternatives, followed by the ranking of independent projects. State-of-the-art decision support software is indispensable for implementing this framework.

KEY TERMS

Key terms are listed below in alphabetical order:

Cost-benefit analysis (CBA); Decision criteria; General equilibrium analysis; Multi-criteria analysis (MCA); Partial equilibrium analysis; Project appraisal; Project feasibility; Project impacts; Economic efficiency; Project prioritization (ranking); Project selection; Transport infrastructure (projects).

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FREQUENTLY USED ABBREVIATIONS

CBA	Cost benefit analysis
CoT	City of Tshwane
Eff EUAC	Efficiency Equivalent Uniform Annual Cost
Eff IRR	Efficiency Internal Rate of Return
Eq B/C ratio	Equity Benefit Cost ratio
Eq NPV	Equity Net Present Value
MCA	Multi-criteria analysis
MCDM	Multi-criteria decision making
TI	Transport infrastructure

1. INTRODUCTION

1.1 Background

Contrary to popular belief, decision making in the public sector does not necessarily take place in a scientific and orderly fashion, and decisions are not always well-informed. According to Lauden and Lauden (1998:596) (in Cloete, 2003:31-32), "decision making at … high levels of government … is often portrayed as rational decision processes. But in fact, decision making involves managing issues that are forced on decision makers with varying and shifting priorities. Issues circulate continuously; they enter and exit through participants and are resolved in the sense that they dissolve or go away or are overtaken by other issues. The issues are themselves complex, poorly defined, interdependent … Information is voluminous but unreliable and qualitative". In the case of transport infrastructure, though, there have long been various attempts world-wide, aimed at "rationalizing" decision making; this has involved subjecting capital projects to a cost benefit analysis (CBA), the origins of which can be traced back to the middle of the nineteenth century.

The inadequacy of CBA as a decision making tool owing to its limited focus on economic efficiency led over time to a broadening of its scope. This was accomplished by increasing the categories of impacts and the range of objectives considered in the analysis. But this was not generally accepted, and decision makers were consequently left with a dilemma: if CBA were applied in a traditional sense, only a partial answer to the decision making problem would result. This would further mean that the initial objective of CBA – to formalize decision making – would only be partially met.

This debate aside, it is clear that transport infrastructure, in addition to fulfilling its primary function of meeting transport needs, affords authorities in all spheres of government the opportunity to further other, non-transport, policy goals and objectives. This means that, at the very least, authorities must ensure that anticipated impacts of new or improved infrastructure are not jeopardizing stated policy goals and objectives. As a "first prize", though, they must strive to ensure that transport infrastructure (TI) projects are optimally aligned with identified goals and objectives – by selecting portfolios of projects that imply a "best fit" between stated goals and objectives, and anticipated impacts.

1.2 Key concepts and theoretical context

1.2.1 Perspectives on transport infrastructure

The Development Bank of Southern Africa (DBSA, 1998:4) distinguishes between *economic* and *social* infrastructure. Economic infrastructure is described as that part of the economy's capital stock that produces services to facilitate economic production, serves as inputs to production (such as electricity, roads and ports), or are consumed by households (such as water, sanitation and electricity). It can be divided into three categories: (a) public utilities (such as electricity, gas and water, telecommunications, sanitation, sewerage and solid waste disposal); (b) public works (such as dams, irrigation and roads); and (c) other transport subsectors (railways, roads, seaports, airports and urban transport systems). These categories of economic infrastructure are found in two categories of the gross domestic product (GDP) of the national accounts statistics: electricity, gas and water are located in the secondary sector; and transport, storage and communication in the tertiary sector.

Social infrastructure, on the other hand, provides services such as health, education and recreation which have both a direct and an indirect impact on the quality of life. In a direct sense, it supports production and trade; in an indirect sense, it streamlines activities and outcomes such as recreation, education, health and safety. For example, the indirect benefit of improved primary health care is improved productivity which, in its turn, leads to higher real incomes. In addition, social infrastructure facilitates the investment in human capital. This is accomplished by using some of the economy's physical capital stock to raise the productivity of the labour force, resulting in a higher capital to labour ratio which enables a given number of workers to produce more per capita. This impact, therefore, is similar to increasing the supply of capital.

Rietveld and Nijkamp (in Banister and Berechman, 2000:60-61) make the following general observations about infrastructure:

- Infrastructure is a generic term. It needs to be carefully qualified to make it suitable for focused policy analysis. The impact of additional infrastructure differs between regions: it is less pronounced in regions that already have good quality transport systems than in regions where the existing network is sparse or of a poor quality.
- The links between transport and land use need clarification, in particular those pertaining to cause and effect. A large-scale concentration of public/private activities

such as offices or warehouses, for example, may be in response to the existing transport infrastructures. On the other hand, it may be as a result of patterns which would have occurred in any case.

- Infrastructure is subject to decreasing marginal productivity. As a consequence, any addition to the network will have a proportionally reduced impact in cases where a region already has good links. In fact, a high quality network will broaden the location options of industries. This means that location as a decision factor by firms and individuals will be reduced. (This observation is linked to the first observation.)
- On the other hand, significant impacts may result from new types of high quality infrastructure such as the new European high-speed rail network which may revolutionize intra-continental travel, in a similar manner as did the first generation of railways more than 150 years ago.
- An exclusive focus on the improvement of transport infrastructure may not guarantee regional development, as many other factors may also play a role. Also, impacts may be redistributive as well as generative, as the gains in one region may be at the expense of another. This may result in a neutral (or even negative) overall effect.
- The improvement of transport infrastructure will lead to lower transport costs. Regarding this advantage, there are different possibilities: it may be absorbed by entrepreneurs or land owners in the form of profits or rents; it may be absorbed by employees in higher wages; it may be passed on to consumers as lower prices; or any combination thereof. However, there is no method for establishing the most appropriate distribution.
- Infrastructure is a multi-dimensional phenomenon. Although the fact that there may be synergies between various types of infrastructure has been recognized at a theoretical level, not much has been said about the nature of these synergies.
- Infrastructure analysis has focused mainly on firms and not on households, although these two are interrelated. Little attention has been paid to the combined interaction between the location decisions of firms and households.

Banister and Berechman (2000:35-36) describe transport infrastructure as the durable capital of a city, region or country, constituting an indispensable part of the total production costs of goods, and having not only a fixed location but also a spatial dimension as manifested by its

network structure. The spatial dimension of transport infrastructure facilities implies that they are natural monopolies over large territories. Transport infrastructure is furthermore durable, and requires high capital costs (though low running costs) because of its indivisibility, and consequently significant sunk costs once incurred. Transport infrastructure is also likely to generate social and environmental externalities, either through their location or through the services that they produce. Since market exclusion is not feasible for cost, social and legal reasons, transport infrastructure reveals public good characteristics. According to Labuschagne, Naude, Shaw, Schnackenberg and Coovadia (1998:16), roads have the characteristics of both *non-excludability* (since road users cannot be excluded from road usage on the basis of the price of usage (except in the case of toll roads) and *rivalness* (because of traffic congestion, the use of a vehicle interferes with other vehicles' use of road space). With reference to the indivisibilities of social overhead capital, Meier (1995:345) lists four types: "*First*, it is indivisible (irreversible) over time. It must precede other directly productive investments. *Second*, its equipment has high minimum durability. Lesser durability is either technically impossible or much less efficient. For this and other reasons it is very lumpy. *Third*, it has long gestation periods. *Fourth*, an irreducible minimum social overhead capital industry mix is a condition for getting off the dead-end".

Regarding the debate on transport investment and economic development, Banister and Berechman (2000:57-58) contend that major changes that have taken place in society over the last thirty years should be considered. The *first* of these relates to the nature of transport investment: (a) western economies (as opposed to developing economies) already have extensive, high quality networks, and the emphasis now is on maintaining and/or replacing them, as opposed to providing new infrastructure; (b) the traditional role of the public sector in doing this has changed; and (c) a number of other issues have become relevant, such as increasing levels of public expenditure, the notion of transport infrastructure being a public good, and the right to free use of infrastructure at the point of delivery. The *second change* involves developments in the economy itself, in particular the transition from a manufacturing based economy (with a major service sector) to an information based economy. In this regard, Banister and Berechman (2000:57) contend: "Technological change will have a fundamental impact on the rationale for work, the location of workplace, the time available for leisure activities and the way in which people organise their lives. This in turn will affect the structure of cities, the balance between rural and urban areas and the ability of firms and industry to locate wherever they wish. Traditional location constraints have been broken". A

third change involves the greater priority placed on distributional issues (both social and spatial equity) and environmental matters, without jeopardizing economic growth and maintaining (or increasing) competitiveness.

1.2.2 Transport infrastructure and economic development

A discussion of the reciprocal relationship between transport infrastructure and economic development calls for the concepts “economic growth” and “economic development” to be revisited. Gillis, Perkins, Roemer and Snodgrass (1996:7-8) highlight fundamental differences between them: economic growth refers to an increase in the production of goods and services and income per capita. Economic development also implies this but, in addition, involves structural changes to the economy, a more equitable distribution of income and, in general, greater emphasis on the improvement of the quality of life of all members of society. With economic growth, the emphasis is on growth; with economic development, the emphasis is on growth *and* positive socio-economic change. It can be argued that development cannot take place without growth; in fact, that economic growth is a prerequisite for development.

Different views are held on the link between transport infrastructure and economic development; generally, they can be divided into two schools of thought. The *first* school maintains that road infrastructure is a prerequisite for development. This follows from the belief that any region has some development potential waiting to be unlocked – and that the provision of a road will almost automatically result in the development of the region. With the *second* school, less emphasis is placed on roads – they are still regarded as an element of the development initiative, but not necessarily as the most important (DOT, 1993:4-1). Related to these schools of thought is the notion of developmental and rehabilitation social overhead capital. According to Meier (1995:344), a distinction is possible between “the developmental social overhead capital which provides for a hoped for but uncertain future demand and the rehabilitation social overhead capital which caters to an unsatisfied demand of the past. The first with its excess capacity will necessarily have a big sector capital-output ratio (10-15:1); the second, through breaking bottlenecks, has a certain high indirect productivity and a much lower capital-output ratio”.

These two schools of thought, and the concept of developmental and rehabilitation social overhead capital (described above), also tie in with the doctrine of *balanced growth* (supported by economists such as Rosenstein-Rodan and Nurke) and *unbalanced growth*

(supported by Hirschman), as described by Joynt (2004:2-13 to 2-25). The balanced growth doctrine involves the planned, large-scale expansion of economic activities in a region – it is therefore also known as the "big push" or "critical minimum effort" approach. The need for a big push approach is explained by the Massachusetts Institute of Technology (in Meier, 1995:343) as follows: "There is a minimum level of resources that must be devoted to ... a development program if it is to have any chance of success. Launching a country into self-sustaining growth is a little like getting an airplane off the ground. There is a critical ground speed which must be passed before the craft can become airborne ...". Meier (1995:343) continues: "Proceeding "bit by bit" will not add up in its effects to the sum total of the single bits. A minimum quantum of investment is a necessary, though not sufficient, condition of success. This, in a nutshell, is the contention of the theory of the big push". Thirlwall (1999:234) cautions that the term "balanced growth" can be used in different contexts, though the original meaning refers to the scale of investment necessary to overcome the indivisibilities on both the demand and supply side of development. The balanced growth doctrine is not, however, without its critics. Joynt (2004:2-18), for example, concludes that "it is clear that the big push theory tries to change the market system with its investment strategy. This resulted in the approach being severely criticised".

Proponents of the unbalanced growth doctrine, on the other hand, argue that "in the absence of sufficient resources, especially capital, the pursuit of balanced growth may not provide a stimulus to the spontaneous mobilisation of resources or the inducement to invest, and will certainly not economise on decision taking if planning is required" (Joynt, 2004:2-20). In this context, Hirschman (in Thirlwall, 1999) identifies two types of investment choices. *Substitution choices* involve a choice between two projects. This means that if one is selected the other is abandoned. *Postponement choices*, on the other hand, involve a sequence of projects, i.e. their priority for implementation. In this case, both can be selected – the decision merely involves which one should be implemented first. Hirschman favours the postponement option, and maintains that priority should be given to those projects with the greatest potential to induce growth, either through *development via excess capacity*, or *development via shortages*. Although it is also not without its critics, Thirlwall (1999:240) contends that the biggest strength of the unbalanced growth doctrine lies in the fact that it decentralizes decision making, and that it does not interfere with the market mechanism.

The concepts *developmental social overhead capital* and *rehabilitation social overhead capital* (described above) can be expanded further by linking them to alternative views of

selected authors. For example, it can be argued that the first of these (*developmental social overhead capital)* relates to the schematic paradigm presented by Banister and Berechman (2000:39-50), showing the causal relationship between infrastructure investment and economic development. It is maintained that this paradigm resembles a supply-side perspective. This relationship, which can also be viewed as a *process*, implies a number of critical elements (steps) – the absence of any one of which implies a breakdown in the process. These elements, in a temporal (and causal) sequence, are as follows:

- The *investment component.* This is the first element of the process, and required to trigger changes to the economy of the area.
- The *network performance component.* This second element is a consequence of the first and involves improvements to the road network as a result of the investment made.
- The *transport economic component.* This component is a direct consequence of an improved road network, involving location advantages for the region and increased real estate values as the result of a better location.
- The *economic development component.* This involves the positive economic impacts resulting from the initial investment, manifesting in increased economic output and employment facilitated through the multiplier effect of the investment and effected via the second and third elements of the process.

It can also be argued that the notion of *rehabilitation social overhead capital* ties in with the approach suggested by Joynt (2004:5-1 to 5.37), and aimed at determining the likelihood of maximizing economic returns from investments in road infrastructure. Likewise, it is maintained that this approach essentially resembles a demand-side perspective. In terms of this approach, four “markets” are identified which are important in gauging the likelihood of success, and within each, a number of indicators needed for scoring different projects:

- *Urban economic market*, described by the following indicators: attraction for business, agglomeration economies, maturity of the market, and market exposure.
- *Land development market*, described by the following indicators: development stimulus, development applications, development activity, and occurrence of illegal land uses.

- *Real estate market*, described by the following factors: real estate demand, building plans and new building, rental rates, and vacancy rates of buildings.
- *Road and other infrastructure market*, described by the following factors: infrastructure provision, traffic demand, economic leakage versus inflow, and reduction in transport costs.

Finally, and for the purposes of this thesis, it is argued that the notion of (economic) development – which implies a situation characterized by the (total) absence of development – should not be emphasized at the expense of another objective, namely that of *improving* an already existing system. This latter objective is particularly relevant in the case of road authorities in the municipal sphere of government.

1.2.3 Types of intervention

Investment in transport infrastructure can be seen as involving both the improvement of existing infrastructure and the provision of new infrastructure. A different view is presented by Eberts (1999:1-2) in Joynt (2004:1-7), who identifies two basic forms where the distinguishing factor is type of technology:

- *Capital expansion*, using traditional technology for the construction of additional highway segments, rail lines, runways, or additional air, sea, rail or terminal capacity.
- *Capital enhancements*, using new technologies for enhancing the efficiency of the existing system. Applications include intelligent highway systems, congestion pricing, intermodal freight facilities, geographic positioning systems and instrument landing systems.

For the purpose of this study, it is maintained that the distinguishing factor in appraising investment proposals should be project categories which are similar in respect of decision criteria, as is described in later chapters.

1.2.4 Nature of impacts

Impacts, for the purpose of this study, are defined as changes relative to the null alternative (status quo), manifesting themselves over the economic life of the project (i.e. the analysis period) and resulting from investing in the transport system. Impacts may be positive or negative, affecting both travellers and non-travellers (Weisbrod, 1995:1). They may be intentional or unintentional. The Department of Provincial and Local Government (DPLG)

distinguishes between inputs, outputs, outcomes and impacts, and maintains that results can be measured on different levels. These levels and the link between them are described as follows (DPLG, 2000:8):

- *Inputs* are the resources and capacity that are incurred in order to ensure (positive) results.
- *Outputs* are the direct result of the intervention (inputs); e.g. a new link to the road network.
- *Outcomes* are the direct consequences (results) of the output, e.g. a reduction in road user cost.
- *Impacts* are a direct result of the outcomes of the project, e.g. lower transportation costs may attract new businesses, create job opportunities and, in general, may lead to increased economic growth and development.

The *timing* of impacts is also important, as this relates to *type* of impact. Ueda (2001:3) maintains that infrastructure development causes two types of economic impact: the *flow effect* results from the initial investment in infrastructure, which creates a demand for goods and services during the construction phase. The *stock effect* involves the more efficient use of the facility by economic agents during its economic life.

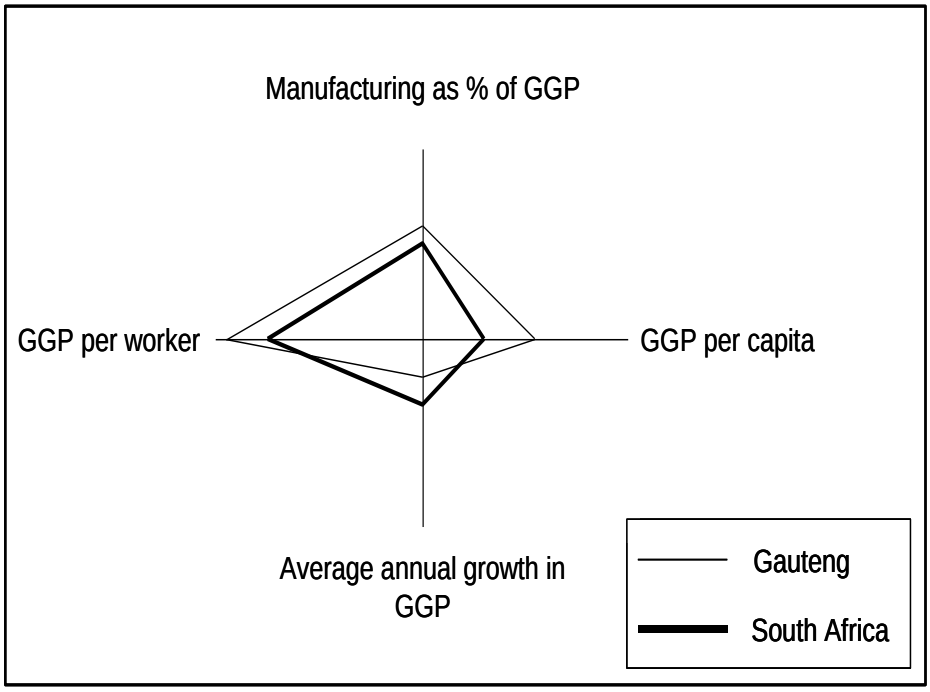
1.2.5 Socio-economic impacts

The need for a specific focus on socio-economic impacts stems from the fact that a project that is found economically feasible will not necessarily impact positively on the plight of lower income groups or poor rural areas. The current emphasis on the achievement of socio-economic goals and objectives, and the improvement of the quality of life for previously disadvantaged groups is evident from, amongst other things, the following extract from a memo from the South African Human Rights Commission (SAHRC) to the City of Tshwane Metropolitan Municipality (CoT): “Section 184 (3) of the Constitution requires the SAHRC to require relevant organs of state each year to provide it with information on the measures they have taken towards the realisation of the socio-economic rights (also known as social and economic rights)”. The SAHRC attempts to fulfil this obligation (of monitoring and assessing the realisation of economic and social rights) by way of an annual questionnaire covering specific aspects such as respondents’ understanding of their constitutional obligations, their performance in terms of these obligations and their future goals. In a sense, this project,

which focuses on socio-economic objectives within a transport infrastructure context, could be viewed as part of the response of the CTMM to this imperative.

Economic and social rights impact on "human well-being" which, according to Huntley, Siegfried and Sunter (in Schutte, 2002:5), is a function of three dynamics, namely economic development, environmental health and quality of life. The latter, according to Möller, quoted in Van der Reis (in Schutte, 2002:5), can be broadly defined as embracing "subjective reaction to one's day-to-day existence and perception of future life circumstances, indicators of mood and morale, and the personal assessment of basic need fulfilment".

"Quality of life" is a condition with many dimensions and with different attributes impacting upon it. A multiple dimensional condition can be portrayed graphically, for example by a "development diamond". In the Development Bank of Southern Africa (DBSA) publication *Guidelines to regional socio-economic analysis*, "development" is defined in terms of four attributes: manufacturing as a percentage of GGP (Gross Geographic Product), GGP per capita, average annual growth in GGP and GGP per worker (Schutte, 2002:5).



Source: Schutte (2002:6).

Figure 1-1: Development diamond

As shown in Figure 1-1, a development diamond is useful for inter-regional comparisons in terms of selected (socio-economic) attributes; in this case, Gauteng versus South Africa.

1.2.6 Modelling project impacts

Two types of modelling tools can be distinguished in the context of transport infrastructure: *transport system models,* typically used by engineers to forecast system behaviour on scores such as trip generation, travel time modal assignment and travel cost, and *economic models*, used by economists. Regarding the latter, van Koesveld and van Santen (1997:1) identify models at different levels of analysis:

- Traditional cost-benefit analysis, comparing savings in road user cost with the amount invested.
- Social cost-benefit analysis, implying an extension to traditional cost-benefit analysis by also including external affects on the environment and social welfare aspects.
- Production and cost functions, which calculate macro-economic productivity gains or losses over the analysis period.
- Macro-economic simulation models, which incorporate multiplier effects and regional interactions.
- Scenario and risk analysis, which adopts a more strategic perspective to evaluation infrastructure investments.

De Brucker, De Winne, Peeters, Verbeke and Winkelmans (1995:262) argue that analytical tools for project appraisal could be used in a complementary fashion: “An SCBA (social CBA) measures the (monetary) welfare economic effects of a project (Pearce and Nash, 1981). An EIS (economic impact study) measures the benefits related to economic development in terms of value added, contribution to employment, etc. (Winkelmans, Peeters and Verbeke, 1993). An EIA (environmental impact assessment) assesses the environmental impact of a project (Wood, 1998). An MCA (multiple criteria analysis) suggests “the most appropriate” or “the optimal” solution to a problem, according to a number of criteria”.

In assessing project impacts, available tools should be used correctly. Weisbrod and Weisbrod (1997:11) refer to the “seven deadly sins” in applying available models and interpreting their results. Of particular importance in the context of this thesis is the risk of double counting and the use of multipliers in cases where they do not apply, as pointed out in subsequent chapters of the thesis.

1.2.7 Definition of selected concepts

The American Association of State Highway and Transportation Officials (AASHTO) defines a number of key concepts in the context of priority programming and project selection. Concepts particularly relevant to this thesis are defined below; the first two underline the importance of goals and objectives.

Planning is “the preparation for action (by) ... examining present conditions, forecasting future conditions; then recommending the objectives and the course of future actions and policies to attain the goals in light of the forecasts” (TRB, 1978:3).

Transportation plan is “an idealistic plan that has general goals, is policy-oriented, and avoids short-term fiscal and other constraints in order to present an uninhibited view of a total transportation system that would provide maximum efficiency in fulfilling all major transportation needs of the comprehensive plan” (TRB, 1978:4).

Project is “a specific, planned unit of proposed construction. The word project may be used initially to describe a large undertaking that is later subdivided into logical sections. If one of these sections becomes independent of the others, it may be listed and programmed as a separate project” (TRB, 1978:4).

Programming is “the matching of available projects with available funds to accomplish the goals of a given period” (TRB, 1978:3).

Prioritizing is “the over-all process of producing a rank order of priority projects and project sections, using technical and nontechnical, quantifiable and non-quantifiable factors as the criteria for ranking” (TRB, 1978:4).

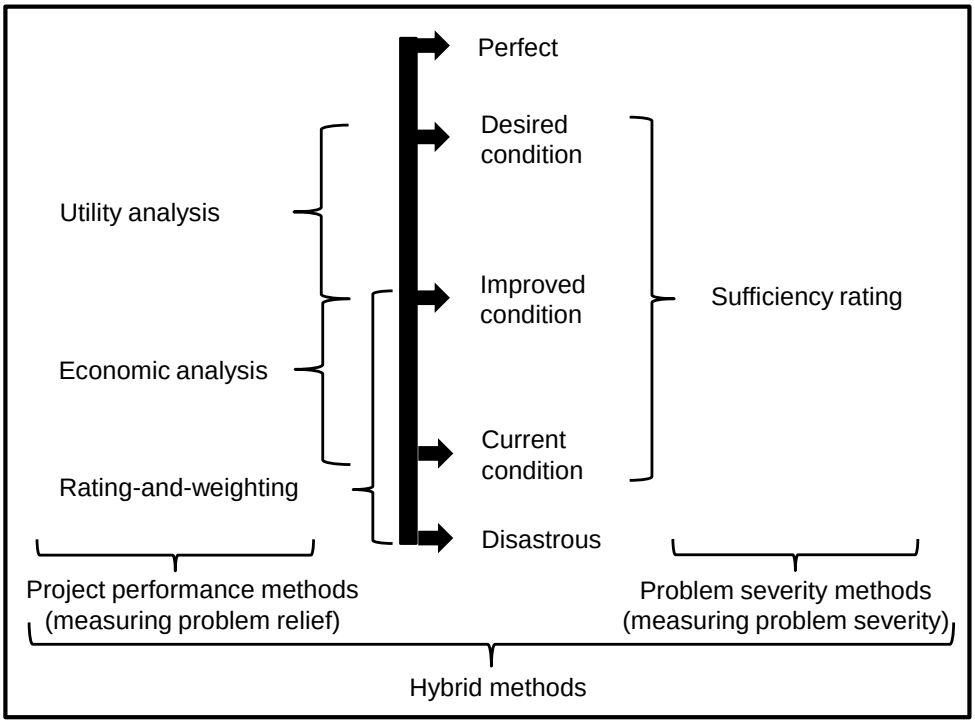
Sufficiency rating is “a numerical procedure that produces a single descriptive value for a location in terms of its existing structure, safety, and service relative to a standard. It usually does not include accident totals, benefit/cost ratios, or social, economic, and environmental factors. Rather, it is a measure of physical sufficiency under existing conditions compared with a given standard. (It might be called deficiency rating)” (TRB, 1978:4).

Priority rating is “a complex rating for evaluating or comparing projects. It usually includes the factors of service, structure, and safety found in a sufficiency rating, but it also includes many other factors, such as a safety rating (accident totals or rates), a capacity rating (volume/capacity), a benefit/cost (or cost-effectiveness) rating, impact ratings (economic,

social, environmental), and such non-quantifiable factors as uncertainty, interrelationships with connecting or competing facilities, and agreements and commitments" (TRB, 1978:4).

1.2.8 Types of prioritization procedure

Simon, Mackie, May and Pearman (1988) (in van Zyl, Wilmot, Morris and Loubser, 1994:3-2) classify prioritization procedures into three categories: (a) *problem severity* procedures, i.e. those measuring the extent of the problem, such as sufficiency ratings which measure the degree of "substandardness", and (b) *problem relief (performance)* procedures, i.e. those measuring the extent to which the project will relieve the need, such as utility analysis; and (c) *hybrid* methods, which measure both. Projects can also be viewed relative to the vertical scale in Figure 1-2, where this scale depicts the level of acceptability of (satisfaction with) a given situation, extending between the two extremes "disastrous" and "ideal", with the following intermediary points: existing (current) condition (i.e. the status quo), the improved condition (i.e. the situation following the introduction of the project), and the desired condition (i.e. the goal set for the project on a particular criterion).



Source: Adapted from van Zyl et al. (1994:2-7).

Figure 1-2: Features of prioritization procedures

Different prioritization procedures use the information in this figure differently. "Sufficiency rating methods (which measure the degree of need existing in the current situation) measure

the difference between the existing condition and the desired condition. Economic analysis methods on the other had (using the null alternative as the basis from which all alternatives are measured) measure the difference between the existing condition and the improved condition Utility analysis measures degree of goal achievement achieved by the project and therefore measures the difference between the improved condition and the desired condition. Rating-and-weighting procedures tend to provide some absolute measurement on the scale and therefore measure the difference between totally unsatisfactory and the current or improved condition, depending on what aspect is being measured" (van Zyl *et al*., 1994:3-6). A sufficiency rating is defined as "a numerical procedure which produces a single composite score for any section of a road network in terms of its condition, safety and service"; it is based on "design standards pertaining to the desirable dimensions and the structural capacity of the physical components of a road" (Smuts, 1981:2).

In terms of measurement methods, the four methods in Figure 1-2 can therefore be classified as follows (van Zyl *et al*., 1994:3-9):

- Absolute rating: Sufficiency rating and rating-and-weighting.
- Relative improvement: Economic analysis.
- Relative goal achievement: Utility analysis.

They continue as follows: "... it is clear that sufficiency rating methods are totally insensitive to the performance of a project in improving the situation. Similarly, utility analysis is insensitive to the extent of need in the existing situation and only looks at how well the proposed project will meet the goals set for it. Economic analysis is almost as restricted; it measures the degree of improvement that can be achieved (per Rand invested – i.e. it measures the efficiency with which improvement can be achieved) without regard for the level of need at which the improvement starts. Rating-and-weighting methods alone appear geared to providing an absolute measurement on the scale. They have also traditionally been the method that attempts to measure both the level of need and the performance of the project in alleviating that need" (van Zyl *et al*., 1994:3-6 to 3-7).

1.2.9 Values, goals, objectives and criteria

A different definition of planning from the one given above is as follows: It is "the process of determining goals and designing courses of action by which these goals may be achieved" (Stopher, Baxa, Ferreira and van Zyl, 1977:1). From this definition, it is clear that setting

goals is basic to this process – "without a clear idea of the goal(s) to be sought, it is not possible for the planner either to specify possible courses of action or to evaluate their desirability and feasibility". This implies that "the first activity of any urban transportation planning study is to set goals for transportation in the metropolitan area, based on values held by the respective communities. Goals are then translated into specific objectives and operational criteria" (Stopher *et al*., 1977:1). These concepts are defined below (Stopher *et al*., 1977:5).

Values: Irreducible qualities upon which individual and group preferences are based; expressions of basic principles or truths held by individuals or groups for whom urban planning is being done.

Goals: Idealized states towards which a plan would be expected to move; the desired eventual end states of a planning process; values interpreted into specific aims of a particular planning process.

Objectives: Specific statements of goals, achievable (without reference to resource or budget constraints), and for which the degree of attainment can be measured through the use of criteria, capable of exhaustive definition by a set of criteria; interpretations of goals into more specific requirements that could be achieved within the period of time for which planning is being done.

Criteria: Operational sets of indices expressing the degree of objective attainment; concrete measures in such detail as to be directly comparable with consequences from alternative courses of action – one particular type of criterion, a standard, is a fixed target, i.e. the lowest (or highest) level of performance or attainment acceptable.

Moving from values to criteria implies a cascade effect; this means that one value produces more than one goal, one goal produces more than one objective, and one objective produces more than one criterion. In addition, "specificity" will increase as one moves from values to criteria (Stopher *et al*., 1977:6).

1.2.10 Transport infrastructure project appraisal

According to *The Heritage Illustrated Dictionary of the English Language (International edition)*, "appraise" means "to estimate the quality, amount, size, and other features of something", and "appraisal" is "the act of appraising". *The Advanced Learner's Dictionary of*

Current English defines “appraise” as follows: “say what something is worth”; and “appraisal” as “valuation”.

Transport infrastructure (TI) *project appraisal*, for the purposes of this study, is defined as the assessment of a project against a required standard (or standards); alternatively, the comparison of project performance (impacts) during its economic life with identified decision criteria, in order to determine if and to what extent the project satisfies required standards. In the case of public sector projects, it can be argued that these criteria should reflect the aspirations, goals and objectives of the communities (constituencies) for whom they are implemented. It also follows that project appraisal is a prerequisite for project ranking and project selection: *project ranking* is defined as the prioritization of feasible (justified) projects in terms of a defined measure of project worth, such as its economic worth (feasibility) (expressed, for example, in terms of its internal rate of return), or total (aggregate) worth (reflecting its performance against the whole spectrum of decision criteria). *Project selection* is defined as the “acceptance” of a feasible project for implementation, given the availability of funds. For the purposes of this study, however, *project appraisal* is deemed to include both *project evaluation* and *project ranking* (prioritization). These definitions are in line with the general philosophy of the CSIR Manual K64 (Schutte, 1983). Furthermore, decision making, for the purposes of this thesis, is defined as encompassing both project appraisal and project selection, as shown in Figure 1-3.

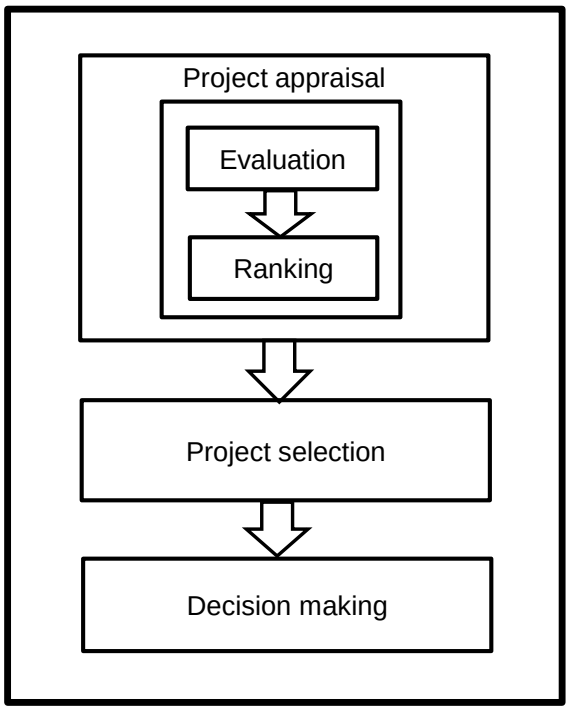


Figure 1-3: Decision making in the case of TI projects

Project appraisal can also be seen as determining project worth in terms of a given criterion or set of criteria; this enables projects to be ranked, and also to be classified as either feasible or not feasible, provided that a value for project worth is specified, below which projects are deemed not feasible.

1.2.11 Transport infrastructure and governance outcomes

Cloete (2003:14-19) discusses a number of key concepts from the public management domain, with a focus on the use of electronic back-office technologies to improve capacity building for good governance outcomes. By definition, they are also relevant to the CoT context. *Good governance* refers to the achievement by a democratic government of its development policy objectives. *Developmental policies* are policies aimed at raising the quality of life of a society's citizens. The *public policy process* involves the interaction of decisions and actions (involving various policy actors such as individuals, interest groups and organizations in the public, voluntary and private sectors). It consists of both a design phase and an implementation phase. *Sustainability*, in addition to the socio-economic and environmental dimensions, includes the political, institutional and managerial dimensions necessary to ensure the functional durability of public policy programmes. Moreover, the change in the analytical focus from *public administration functions* to *governance outcomes*

is important. In the case of an appraisal strategy for CoT, this focus on governance outcomes underlines the need to ensure the alignment of decision criteria used in the appraisal strategy with stated policy objectives in different spheres of government. Finally, both the *outputs* and the *outcomes* of public management are important "objects for evaluation". Output refers to the immediate, tangible "results" of a policy or project, whereas outcome relates to the progress towards goal achievement.

1.2.12 Contexts for project appraisal

Different contexts for project appraisal facing the relevant authority result from the fact that projects can be classified according to their attributes, such as (a) frequency of occurrence (one-off type projects or budget cycle type projects), and (b) scope of their economic impacts (local or external).

Regarding the former, major, one-off projects include "overtly developmental or sustainability-enhancing interventions", as well as major policy intervention initiatives (Naude and Naude, 2005:1), such as:

- "Development corridors and other integrated urban, rural or regional development initiatives that include one or more transport anchor projects (such as a new or upgraded port, a new road connection or a multi-modal transport interchange).
- Specifically targeted, pro-poor transport interventions – such as the promotion of non-motorized transport (NMT) and other affordable means of transport and travel.
- Transport demand management (TDM) strategies aimed at promoting more sustainable travel and land use patterns.
- Interventions such as the phasing out of long-distance transport subsidies, aimed at combating urban sprawl and encouraging more compact and sustainable urban settlement patterns".

They can also be described as follows: "(1) very large projects with complex impacts; and (2) public-private partnerships type projects that require a kind of accounting-based analysis known as financial analysis" (Austroads, 2005a:8). By definition, therefore, these projects are large in terms of scope, impact and cost, will often be of a strategic nature and will occur at irregular intervals only. For the purpose of this study, they fall in the third column in Table 1-1.

At the other end of the spectrum are “day-to-day” (run-of-the-mill) projects, typically of a smaller scale and occurring “all the time”, and thus subject to the annual budget cycle process of the transport authorities – hence termed “budget-cycle projects”. “Major intervention projects” will normally require unique funding arrangements on a “single-project basis”. “Budget-cycle projects”, on the other hand, imply a “ranking problematique”, requiring options to be placed in some form of preference order (Roy, 1996) (in Belton and Stewart, 2002:15), to enable the composition of an optimum investment portfolio of projects under conditions of budget constraints. Characteristics of budget cycle type projects are listed in the second column of Table 1-1.

Table 1-1: Characteristics of budget cycle and one-off type projects

Characteristic	Budget cycle type projects	One off type projects
Number of projects involved in appraisal process	Typically a large number of projects (reflecting identified community needs) – in most cases exceeding available funds	Typically a small number of high profile, high impact projects
Uniqueness of project(s)	Not unique; typically “run-of-the-mill” type of project	Unique in terms of scope and objectives; aimed at bringing about “structural changes”
Magnitude (in terms of cost)	Small, relative to major projects	Large, relative to budget-cycle type of projects
Budget provision	Typically subjected to annual budget process (and constrained by available funds)	Cost/budget is normally dealt with on a project-by-project basis; by definition, they fall outside the annual budgeting process
Frequency of need for decision making (i.e. how often they require	Typically annually, as dictated by administrative budget requirements	From time to time, as the need arises

Characteristic	Budget cycle type projects	One off type projects
a decision to be made)		
Nature and scope of decision criteria	A standardized procedure (set of criteria), applying to all projects, will normally suffice	May require a unique, context-driven and project-specific procedure (set of criteria)
Strategic level of decision criteria	Lower than in case of major projects; often at an operations level, as this normally occurs within a broader framework	Higher than in case of budget-cycle projects; normally at a strategy level
Need for input from technical experts and demands on data for decision making	Availability of in-house experts normally a problem; as a consequence, lack of quality data may also pose a problem	The high profile of major projects often warrants the acquisition of top experts; this may also take care of the "data problem"

Projects also differ in terms of a third dimension, namely the scope of their economic impacts. Impacts could be either local (i.e. "limited" to the area of jurisdiction of the relevant authority) or regional/national (i.e. extending beyond the boundaries of the relevant authority. The latter would apply in the case of "traded" industries, that is industries that sell their products and services to national or international markets, as opposed to "local-serving" industries which essentially serve the needs of local residents. Local industries are (merely) instrumental in circulating and distributing wealth within a region, whereas traded industries serve as "economic pumps", adding wealth within a region (EDRG, 2008:2). Various measures could be used for identifying traded industries, for example: (a) a location quotient which compares a region's share of employment in a particular sector with the national share – a figure greater than one indicates relative concentrations for that industry; and (b) the ratio of regional demand over regional supply, where a ratio in excess of one would also point to a traded industry. This is not always the case, though, and "the difference between local supply and demand (gross exports) does not necessarily equal total (net) exports. Even

products in heavily exported industries may also be imported into a region, reflecting product variation within the industry sector" (EDRG, 2008:4).

Combining this second attribute of projects (scope of impacts) with the first (frequency of occurrence) allows for the classification of projects (and therefore appraisal contexts) as shown in Table 1-2.

Table 1-2: Classification of projects (and appraisal contexts)

Scope of impacts	Frequency of occurrence	
	One-off	**Budget cycle**
Local	Category AA: Not applicable, as one-off projects by definition will have wide (regional and national) impacts.	Category AB: Budget cycle type projects with local economic impacts only (the "typical" case).
External	Category BA: One-off projects which, by definition, have wide economic impacts, extending beyond the study area and across regional borders.	Category BB: Budget cycle type projects with external economic impacts (not the typical case).

1.3 CoT project appraisal context

1.3.1 Key features

An understanding of the key features and characteristics of the CoT as a "typical" authority in the municipal sphere of government in South Africa, serves to provide insights into project appraisal at a practical level. A selected number of aspects are discussed in this section.

The city is described as the administrative capital of South Africa with a population of two million people, housing the headquarters of five of the country's most important activity sectors: education, tourism, automotive, telecommunications and business organizations, and home to the diplomatic community, with over 100 embassies and foreign missions. Tshwane therefore is "the ideal base for international trade and for liaison with political decision-makers from all over the world". The main road network is described as a radial system centred on the CBD of Pretoria, being the dominant economic node. Strong

decentralization trends towards suburban nodes such as the Menlyn Retail Centre have created a demand for concentric roads. “The greatest deficiency in the main road network is the lack of a continuous major ring road around the city, with supporting routes, to serve the suburban nodes” (CTMM, 2007:1). Figure 1-4 depicts the CoT area of jurisdiction, the main road network and municipal electoral wards for CoT.

Source: CoT ITP Figure 3.1 (CTMM, 2007:3-6).

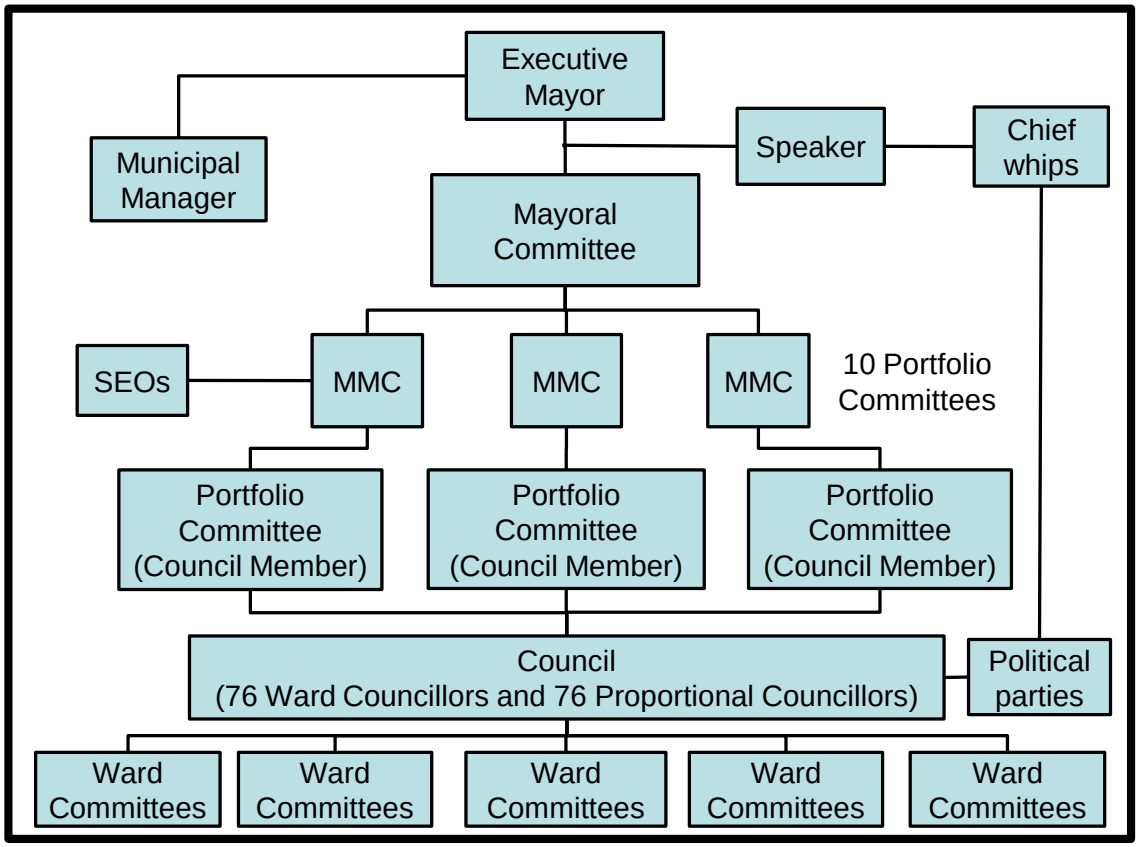
Figure 1-4: CoT area of jurisdiction, major road links and electoral wards

1.3.2 Organization structure

The distinction between political structures, administrative structures and stakeholder participation structures (CTMM, 2007:3-5) is important in order to understand the context within which project appraisal takes place in CoT.

Political structures

The Executive Mayor is the political head of the Tshwane Municipality. In addition to the Executive Mayor, the political structure involves a ten person Mayoral Committee, ten portfolio committees and 76 ward committees (one for each of the 76 wards) (CTMM, 2007:3-5). This is depicted in Figure 1-5 below.



Source: Adapted from CoT ITP Figure 3.2 (CTMM, 2007:3-6).

Figure 1-5: Existing political structures in the CTMM

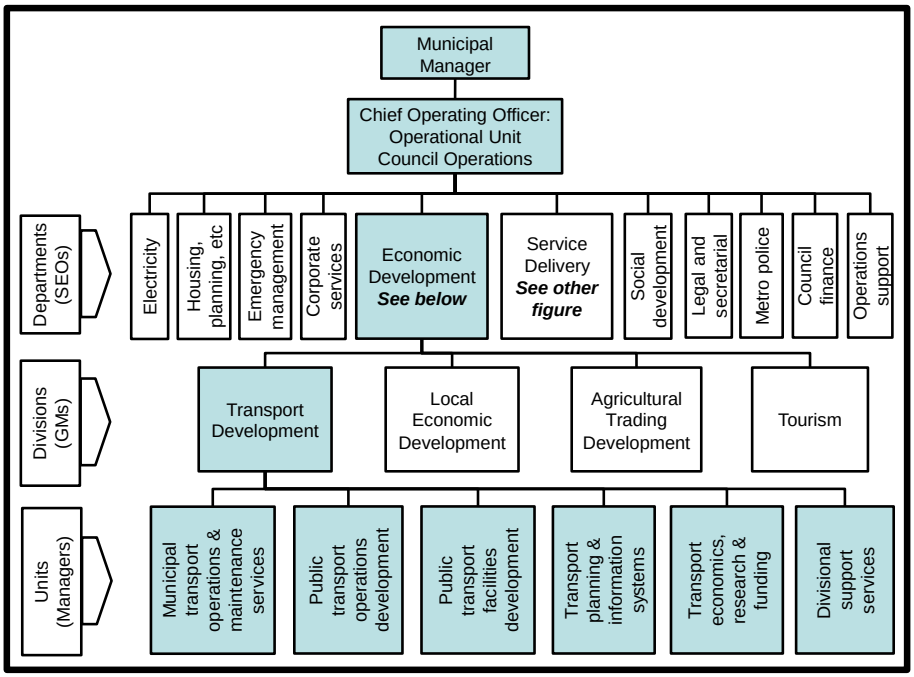
Detail to this figure is provided in the ITP document (CTMM, 2007:3-5): The executive mayor, who has executive powers, takes the overall strategic and political responsibility for the 76 electoral wards in CoT. Horizontally the executive mayor interacts with the municipal administration through the Municipal Manager, and vertically the Executive Mayor presides

over a 10 person Mayoral Committee which functions like a local cabinet. "The Members of the Mayoral Committee (MMCs) are exclusively from the ruling political party and each member is responsible for his own aspects of the municipal government. The purpose of the MMC's is to facilitate the working relationship between the executive mayor on the one hand and the senior management (Strategic Executive Officers) of the Municipal Administration on the other hand" (CTMM, 2007:3-5). Each of the 10 MMCs chairs his own Portfolio Committee (PC), made up proportionally from all political parties. Each PC has mainly two functions: to review reports and to confirm, reject, or amend the contents and recommendations made, and to represent a (final) opportunity for officials to interact at the political level. Given the current administration structure (see the next section), transport reports are submitted to the PC on Roads, Stormwater and Public Transport, and reports on airports to the PC on Economic Development. After serving before the relevant PC, reports are submitted to the Mayoral Committee and then to Council for approval. At the "bottom end" of the political structure, the 76 municipal electoral wards have to constitute ward committees for their areas (wards), chaired by the elected councillor. Ward committees, which are administered by the Office of the Speaker, fulfil an important function by providing important input on community needs.

Administration structures

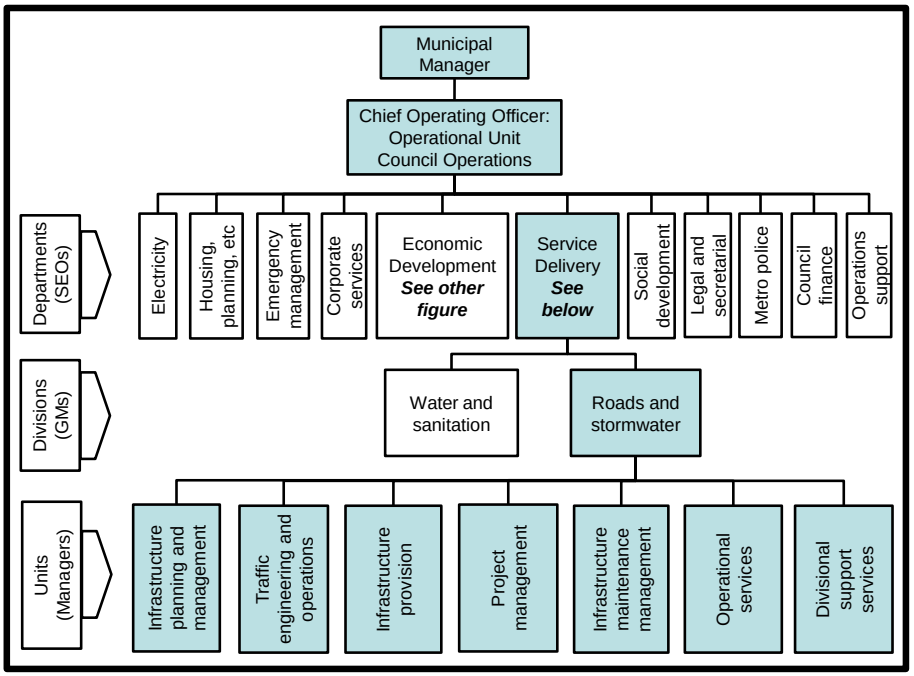
The Municipal Manager, who heads up the administration, provides the link between the political and administrative structures (see Figure 1-5). He is assisted by the Chief Operations Officer and a number of Strategic Executive Officers (SEOs), each heading up a department, and General Managers (GMs), each heading up one of the divisions within a department, in their turn assisted by managers and deputy managers (CTMM, 2007:3-6 to 3-8). CoT consists of 11 departments, as shown in Figures 1-6 and 1-7 (CTMM, 2007:3-7).

These figures also show that there are two "transport-related" divisions within council. This has implications for project appraisal and selection, as argued in Section 5.5.2. "The Transport Development Division (strategic transport planning and public transport) falls under the Department: Economic Development, and Roads and Stormwater under Service Delivery Department. Each has its own General Manager, managers, deputy managers, etc. This transport institutional framework is different to the other departments in the CTMM where the portfolio committees are serviced by one SEO" (CTMM, 2007: 3-8).



Source: Adapted from CoT ITP (CTMM, 2007:3-7 and 3-8).

Figure 1-6: Transport Development Division



Source: Adapted from CoT ITP (CTMM, 2007:3-7 and 3-8).

Figure 1-7: Roads and Stormwater Division

The Department of Economic Development consists of four divisions, focusing on the four areas: transport, local economic development, agriculture and tourism; the division focusing on transport involves both internal transport (internal vehicle fleet) and public transport. Figure 1-7 shows that the Department of Service Delivery consists of two divisions, and that "Roads" and "Stormwater" are grouped together in a single division.

Stakeholder participation structures

Stakeholder participation structures are aimed at facilitating the public consultation process; they are designed for interaction with the community and other role players, and for decision making by CoT (CTMM, 2007:3-9). The ITP lists a number of transport consultative structures (CTMM, 2007:3-9) and explains them in more detail (CTMM, 2007:11-2 to 11-3) as: (a) Tshwane Public Passenger Transport Forum, consisting of representatives of the users of public transport services (taxis, buses and trains); (b) Tshwane Regional Taxi Council, a regional body of taxi operators representing the taxi associations in Tshwane; (c) Tshwane Metered Taxi Council, representing the interests of the metered taxi operators; (d) Taxi Forum, which is a vehicle for addressing taxi related issues; (e) Greater Tshwane Learner Transport Forum, focusing on the needs of learners (they fall under the category of people with special needs); (f) Modal Integration Committee/ Metropolitan Transport Forum, addressing the issue of integrating different modes in a single system; (g) Accessible Transport Committee, catering for the needs of special categories of public transport passengers such as the physically challenged; (h) Tshwane Regional Bus Committee, representing all bus operators in Tshwane; (i) Rail Committee, coordinating the planning and provision of rail services; and (j) various Project Committees, overseeing the development of major inter-modal transport facilities (e.g. the Mabopane Development Forum and the Denneboom Public Transport Interchange Facility Management Board). In addition, the 76 ward committees play an important role. Although they constitute the lowest level of political structure, they have to be consulted by the municipality regarding transport proposals and developments (CTMM, 2007:3-10).

1.3.3 External institutional arrangements

In addition to the CoT, various external authorities share the responsibility for transport in the CoT area of jurisdiction (CTMM, 2007:7); this inevitably has implications for project appraisal and selection. The responsibility for the main road network in CoT is shared between SANRAL (South African National Roads Agency), GDPTRW (Gauteng Department of Public

Transport, Roads and Works), and CoT. It is important to note that the rapid rate of land development, accompanied by a lack of funds to provide additional road infrastructure, has lead to the increased use of national and provincial roads by local urban traffic. "This situation is exacerbated by the negative impact of tolling sections of the existing N1 on urban traffic. The tolling overloads some of the Tshwane roads whilst the Tshwane transport budget cannot cope with the imposed burden. This calls for a more communicative approach between the various spheres of government to the planning, management and funding of roads" (CTMM, 2007:7). Furthermore, GDPTRW is responsible for subsidized bus services, and the national DoT (Department of Transport) for subsidized rail services. The DoT has appointed the SARCC (South African Rail Commuter Corporation) to manage commuter rail assets (such as stations, infrastructure and rolling stock). In its turn, SARCC has contracted Metrorail to operate commuter rail services and to maintain rolling stock and infrastructure.

1.3.4 Funding sources

In addition to internal funding, there are three categories of external funding sources relevant to transport. The *Urban Transport Fund (UTF)* is used for transport research and planning purposes. Financial support for this purpose comes from the GDPTRW and DoT. The *Municipal Infrastructure Grant (MIG)* is aimed at fully subsidizing the capital cost of providing basic services to poor households. *Other sources* of funding (existing and proposed) include the following: engineering services contributions; impact requirements; planning gain; municipal bonds; tax increment financing; special benefit assessment rates; donor funding; private finance initiatives; commercial enterprises; congestion pricing; road taxes; municipal urban tolling; and fuel levies (CTMM, 2007:20).

1.3.5 Nature and scope of ITP

ITP as an element of IDP

The Local Government Municipal Systems Act (Act 32 of 2000) requires local governments to prepare Integrated Development Plans (IDPs). For this purpose, and given the emphasis on a holistic approach to development, the act requires that the various functional plans (of which the Integrated Transport Plan (ITP) is one) be included in the IDP. The Municipal Financial Management Act (Act 56 of 2003) further requires that the municipal budget be based on the projects included in the IDP. This means that the outcome of the IDP process has major implications for the implementation of the ITP (CTMM, 2007:1-4). This is echoed in the following statement: "Although the transport budget (ITP) must be recognized as the

legitimate source of transport development policy and projects, it will remain subject to the IDP process requirements, even if a Transport Authority is established" (CTMM, 2007:22).

The objective and scope of the ITP is described as follows (CTMM, 2007:2): "The Tshwane Integrated Transport Plan (ITP) formulates the vision, mission, policy and objectives for transport, consistent with the National Land Transport Transition Act and the Gauteng Transport Framework Revision Act. It is a statutory plan prepared to guide the development of the transport system and operations in the city. Hence the ITP forms an integral component of the City's most important development policy, namely the Integrated Development Plan (IDP)."

Transport needs assessment

The importance of public (community) consultation is emphasized in both the Constitution of the Republic of South Africa (Act 108 of 1996) and the Municipal Systems Act (Act 32 of 2000) (CTMM, 2007:5-2). Consultation for the purposes of the ITP document took on different forms, such as a household survey of some 7 500 households, consultation at the level of ward committees, and a number of public consultation sessions (CTMM, 2007:5-2). A total of 43 "needs" were identified through public meetings; they are grouped under the following headings (CTMM, 2007:5-3 to 5-4): (a) improving public transport facilities; (b) providing additional public transport services and facilities; (c) improving traffic safety; (d) reducing traffic congestion and providing additional road capacity; (e) "other". A number of needs specifically addressing the transport problems of people with disabilities were also identified (CTMM, 2007:5-4 to 5-5). Needs identified through a household travel survey and ward committees are mostly "area-specific", and grouped under the following headings (CTMM, 2007:5-5 to 5-7): (a) provide additional public transport services; (b) create feeder services to stations; (c) increase frequency of public transport services; (d) improve safety of public transport services; (e) increase punctuality of train and bus services; (f) provide/improve facilities at bus stops; (g) improve overall quality of rail service; (h) improve commuter travel times on public transport services; (i) reduce bus fares; (j) upgrade public transport routes; (k) upgrade major roads; and (l) improve traffic safety.

Proposed TI capital projects

The list of proposed projects constituting the "Roads and Stormwater Division Capital Programme" (summarized in Table 12.2 of the ITP document (CTMM, 2007:12-2)) is given in Annexure A. A similar list for the "Transport Development Division Capital Programme"

(summarized in Table 12.1 of the ITP document (CTMM, 2007:12-2)) is given in Annexure B. However, not all these projects need to be subjected to the appraisal process. Chapter 5 explores which of them do in fact "qualify" for this purpose, as well as the reasons (criteria) for selecting them.

1.4 Problem formulation

1.4.1 Introduction

The problem can be formulated under four headings: (a) the diverse nature and extent of project impacts; (b) the role and limitations of traditional appraisal methods; (c) limitations of current CoT project prioritization procedure; and (d) the emerging use of IT in the public sector. These are discussed below.

1.4.2 Diverse nature and extent of project impacts

Since the consequences of investing in transport infrastructure are wide and varied, TI projects can be subjected to different types of appraisal and "project worth" (project feasibility) be viewed from different angles and expressed in different units. Also, the impacts of TI projects can be classified in different ways. In one such system, impacts are grouped as follows (Schutte, 1983:7-8):

- *Costs involved*, of which the construction cost of the facility is the most obvious, but often relatively small compared with discounted road user cost over the facility's economic life.
- *Convenience*, that is the degree to which the proposed facility will lead to increased convenience for both users of the facility and third parties.
- *Environmental factors*, such as the effect of the project in terms of noise and visual pollution, the demolition of historical buildings.
- *Strategic factors*, such as the importance of the project for national defence and security.
- *Political factors and national prestige*, which may often be of overriding importance.
- The extent to which the project could promote the achievement of *policy goals*. If, for example, the goal is greater utilization of public transport, the construction of an urban freeway could be counter-productive.

- *Income distribution* that is the extent to which a project would lead to a fairer distribution of wealth.

From this classification, it is clear that "project worth" (feasibility) can be observed from different perspectives and can have different meanings, such as economic worth, financial worth, social worth (catalyst for growth and development) and aggregate worth (Schutte, 2004:6). In a similar vein, Adler (1987:3-4) contends that project appraisal involves the following types of analyses:

- "Economic appraisal has to do with the identification and measurement of the economic costs of the project and the size and distribution of benefits.
- Technical appraisal is concerned, for example, with engineering, design, and environmental matters and with estimates of capital and operating costs as they relate to the construction process and the operation of the project after it is completed.
- Institutional appraisal deals with the multitude of management, organizational and staffing problems involved in the construction and operation of the project.
- Financial appraisal is used to determine what funds will be required and whether the enterprise is likely to be financially viable – that is, whether it can meet its financial obligations, produce a reasonable return on the capital invested, and, in appropriate cases, make a contribution from earnings toward the cost of future investments. The financial analysis focuses on the costs and revenues of the enterprise responsible for the project and is usually summarized in the enterprise's income and cash flow statements and balance sheets.
- Commercial appraisal deals with the procurement of goods and services to implement and operate the project and with the marketing arrangement for the sale of its output.
- Social appraisal addresses the social objectives of the project, such as a more equal income distribution or improved nutrition and health, and the social, cultural, and human variable affecting the project, such as involuntary population resettlement or the role of women in development".

"Aggregate or total worth", for the purpose of this study, is defined as a project's performance in terms of *all* relevant decision criteria, encapsulating the whole spectrum of likely impacts emanating from investing in transport infrastructure and expressed in a single quantum.

Impacts from projects in urban areas, involving different modes of transport and/or in the case of TDM (travel demand management) projects, will by their very nature differ from those in rural projects. Litman (2001:9) lists impacts not traditionally addressed by software packages such as HDM-IV (World Bank), and CB-Roads (South African Roads Board), as they were developed with a focus on rural road projects in developing countries:

- *Downstream congestion:* Building a new link or upgrading an existing link can have negative impacts on other links of the network or other modes by increasing traffic levels on such links on modes.
- *Parking costs.* Upgraded road infrastructure may increase the demand for parking space, whereas transit projects or TDM initiatives will lower demand.
- *Roadway impacts:* Large, heavy vehicles may impose high traffic congestion and road wear costs and may require special facilities. This may lead to additional cost.
- *Traffic impacts on non-motorized modes:* Delays, discomfort and increased risk of collisions to cyclists and pedestrians are often ignored.
- *Vehicle ownership and mileage-based depreciation:* An improved road network and/or increased travel options can reduce the number of vehicles per household.
- *Transportation choice:* No consideration is given to options that increase choice and improve access for non-drivers.
- *Environmental costs:* These are often ignored.
- *Land use objectives:* Projects may contribute to urban sprawl. This may be contrary to the community's strategic land use objectives, but may nevertheless not be included in the analysis.

1.4.3 Role and limitations of traditional appraisal methods

In response to the limitations of cost benefit analysis (CBA) as a decision making tool because of its traditional focus on economic efficiency, its scope was broadened and the number of categories of impacts considered in the analysis increased. As a consequence, a distinction became necessary between an "economic CBA" and a "social CBA". According to Brent (1996:5), an economic CBA addresses only the issue of economic efficiency (i.e. the "optimal" allocation of scarce economic resources), whereas a social CBA, in addition, also considers other aspects such as equity effects and externalities. In a similar vein, Dockel,

Mirrilees and Curtayne (1991:3) distinguish between a “narrow” (economic) CBA and a “broad” (social) CBA, and between the “conventional school of thought”, which favours narrow CBA, and the “decision making school of thought” which supports broad CBA. To reflect this thinking, later versions of CBA software packages were modified, for example by allowing for the weighting of benefits to accommodate the notion that beneficiaries in lower income groups are more important than beneficiaries in higher income groups.

The idea of a broad CBA was not, however, without its critics. Dockel *et al*. (1991:8-9), for example, indicate their preference for narrow CBA, arguing that CBA at best is a “soft” technique, and that it will become even softer – and, by implication, less reliable – if it is to be extended to include soft issues such as equity, strategic goals and objectives, and other social considerations. (A “soft” technique, as used here, is defined as a technique where human judgement is required to a greater or lesser extent, as opposed to a “hard” (scientific) technique which is based on hard facts. A “soft” technique therefore can be regarded as subjective to the extent that its outcome depends on human judgement.) This reasoning is also in line with the view expressed earlier by Mishan (1988:209-212).

If, on the other hand, it is argued that the diverse nature of project impacts calls instead for a multi-criteria decision making (MCDM)-type approach, the following comments by Belton and Stewart (2002:4-5) need to be borne in mind: the focus of MCDM is on *aiding* decision making, not on prescribing how decisions should be made. In doing this, it takes into account the existence of multiple, conflicting criteria; it helps to structure the problem; it provides a focus and language for discussion; it helps decision makers learn about the problem situation, their own values and judgements and those of others; and it guides them in identifying a preferred course of action by organizing, synthesizing and presenting information. It also complements and challenges intuition, provides an audit trail for a decision, is conceptually simple and transparent, but nevertheless requires non-trivial skills. Therefore, as noted by Belton and Stewart (2002:2-3), MCDM will not always give the right answer; it does not provide an objective analysis that relieves decision makers of the responsibility of making difficult judgments, and it does not take the pain out of decision making.

In the development of an appraisal framework, it would therefore seem that both CBA and MCDM potentially have a role to play. But in the case of CBA, the issue of narrow versus broad CBA needs to be addressed; in the case of MCDM, it needs to be demonstrated how it can be customized and used in the specific decision making context of the municipal sphere

of government – in particular, which objectives would constitute an appropriate set of decision criteria.

1.4.4 Limitations of current CoT project prioritization procedure

The ITP document cites “constraints relating to the financing of projects” as highlighting the need for proper prioritization. The requirement of the Municipal Finance Administration Act to provide adequately for the maintenance of capital assets exacerbates the situation, placing an additional strain on available funds for capital projects and further underlining the need for proper prioritization procedures (CTMM, 2007:20).

According to the ITP document (CTMM, 2007:20), the prioritization of multi-modal transport proposals is done separately, in the Division of Transport Development (in the Department of Economic Development) – mainly for public transport projects – as well as in the Roads and Stormwater Division (in the Department of Service Delivery) – for all other transport projects. In addition, there are two prioritization processes, namely the ITP (functional or departmental) and IDP (process-related) prioritization process (CTMM, 2007:12-1). These two processes result in different rankings, namely “ITP priorities” and “IDP priorities”. ITP priorities, essentially based on functional/technical considerations, may include return of investment as well as political influence from within the transport sector, whereas IDP priorities reflect “municipal priority areas”. The IDP process carries more weight than the ITP process as budget allocations are based on IDP priorities (CTMM, 2007:12-1). This clearly presents a problem. In the ITP document, for example, the IDP priorities are described as “not mathematically defensible”. Regarding the fact that two sets of priorities are obtained, the following statement is made: “This clearly plays havoc with the logical sequencing of projects” (CTMM, 2007:12-1). In the ITP document, the current undesirable situation is articulated as follows (CTMM, 2007:1-4 to 1-5): “Currently, the IDP process prioritises all project proposals individually by means of a prioritisation mechanism. Although all departments are represented in the annual revision of the IDP, integration between the various projects is not obtained as a result of the individual project prioritisation mechanism. It is of vital importance to re-introduce an issue or programme-based budgeting process. An ITP, as described in the NLTTA and the GTFRA, is a statutory plan which is prepared to guide the development of the transport system in a municipal area. As a statutory plan, it is important that the contents of the ITP be treated as one of the sector plans which are input into the IDP. Thus, from the time that the first ITP is approved by the Metropolitan Council

and the MEC, it should form an addendum to the Integrated Development Plan. The ITP budget should, therefore, form a sector component of the overall IDP budget".

This overview of the current CoT project prioritization situation boils down to the following problem areas:

- What should be the nature of the prioritization/fund allocation process in the ITP and in the IDP, and what mechanics/procedures should be used in each case?
- Who should be involved in each case (technocrats versus politicians)?
- How should the problem of fragmentation (project categories) – such as TI projects and public transport projects – be addressed? At present, this presents itself as transport being in two departments. But if they are housed in the same department, the problem will remain; this time presenting itself as different categories of projects, or projects categories with different focuses.

1.4.5 Emerging use of IT in the public sector

Without the necessary computational tools, developing and applying an appraisal strategy in real-life situations would be no easy task. The information technology (IT) revolution has, however, met this need. In fact, as noted by McGee and Prusak (1993:3) (in Cloete, 2003:25), "information technology has irreversibly changed the business world. The ways organizations perform the operations and market their products have all changed dramatically since the serious introduction of information technology in the mid-1950s". But the IT revolution has not only affected the business world. As noted by Snellen and Van de Donk, (1998:16) (in Cloete, 2003:iii): "informatization is radically changing the 'business processes' of public administration. The automation of implementation processes … is not only blurring organizational boundaries …, it is also changing the organization chart of public administration … In a more fundamental sense it is transforming the bureaucratic structures and processes that have dominated it for ages. The organization of public administration of the next millennium will not be bureaucratic but infocratic". Heeks (1999:18) (in Cloete, 2003:38) lists the main positive impacts of IT on an organisation's output as cheaper results, more results, quicker results, better results and new results. A number of studies have confirmed that IT in management has led to faster decisions, increased productivity, simplified complexity, increased quality outputs and competitive advantages, and helped with cost reductions and overcoming cognitive limits (Finlay, 1994:173, Turban and Aronson,

2001:9-10, 15-16, Bellamy and Taylor, 1998:47,54,59) (in Cloete, 2003:39). The impact of IT on an organization can thus be summarized as follows: it can support existing activities, or replace, change or supplant existing activities and processes, and/or it can create or innovate new activities in the organization (Heeks, 1999:17) (in Cloete, 2003:44). It is envisaged that the implementation of a new appraisal strategy for project appraisal in CoT will involve all these impacts.

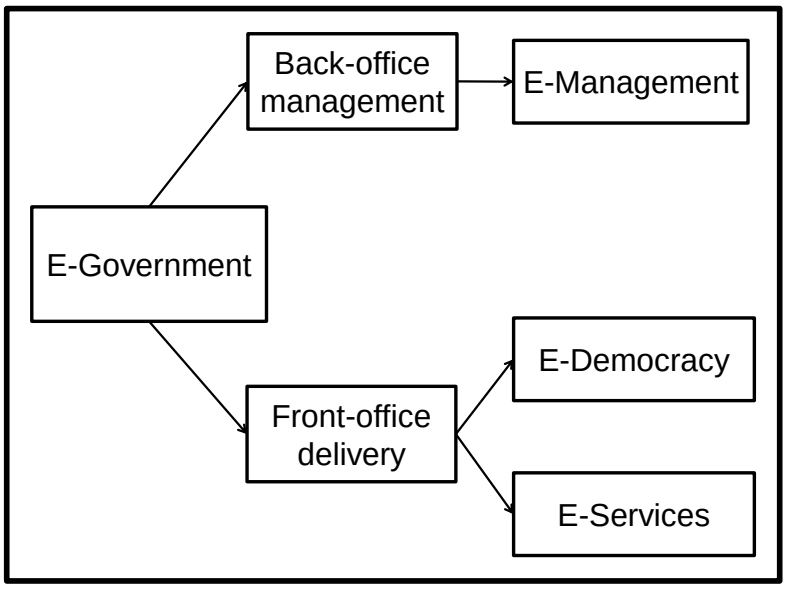
Going the IT route would therefore seem to be "the right thing to do". International research findings highlight positive trends in this regard, such as an increase in the availability of digitized policy-related data, the consequent need for the optimal use and management of such data, and an increased reliance on electronic management information systems (MIS) and decision support (DS) systems, especially in well-developed countries. In developing countries such as South Africa, however, the situation is not satisfactory. Trends regarding public management outputs and outcomes have been described as follows (Cloete, 2003:32):

- Frequent incidences of policy failure resulting from ineffective or bad policy implementation.
- Low capacity for policy implementation and service delivery results.
- Insufficient knowledge of, and experience and skills relating to policy decision making, especially with reference to electronic management information systems which, in its turn, results from a low level of appreciation of the potential of such aids.
- All of this results in "information gaps" and uncertainties which cause a general policy paralysis.

All of this points to the fact that opportunities afforded by current thinking in the MCDM arena and the IT revolution have not yet been fully explored at a "grass-roots" (practical) level in South Africa. As a result, opportunities for better governance outcomes may be missed. Also, there may be obstacles that could impede the application of MCDM and appropriate tools in the public sector, such as technological, financial, political, psychological, organisational and social constraints (Cloete, 2003:41-44). The challenge is to identify these constraints in a South African environment and to come up with appropriate solutions, with the ultimate objective of improved public sector decision making. This can only happen with a grass roots level application of these tools.

E-government and related concepts

The term e-government refers to the new IT-based paradigm in government (as opposed to the traditional paper-based approach). It involves various functions of government based on electronic systems as shown in Figure 1-8, including internal e-government (using back-office support systems) and external e-delivery (front-office delivery); the latter involving both e-demography and e-services (Cloete, 2003:49). Electronic tools for facilitating the CoT appraisal strategy will by definition be of the back-office management type.



Source: Adapted from Cloete (2003:49).

Figure 1-8: Elements of E-Government

Functionalities of electronic tools

Electronic tools also offer a range of functionalities (Cloete, 2003:35-36): (a) They can assist individual decision makers by guiding them through the decision making process on a step-by-step basis. (b) They can also guide groups of decision makers through transparent, standardized processes. (c) They can prompt decision makers to consider variables such as alternative objectives, solutions, costs, benefits risks and priorities. (d) They can model and determine objectives, scenarios, costs, benefits, risks, probabilities and priorities. (e) They can provide pull-down menus or hot links leading to background information and/or templates of standardized formats for information, e.g. on definitions, policy requirements, provisos and documentation (e.g. contracts, forms, legislation). (f) They can draft automatic reports,

tables, budgets, graphs and graphics in a written or visual presentation format that can easily be incorporated into other toolkits.

Uses in public management

Electronic management support tools have various *applications in public management*. They facilitate the different stages of the policy process by setting out in a more systematic manner what should be done, how it should be done, and which variables are to be considered. They therefore apply to: (a) situation analysis, problem identification and structuring; (b) options analysis and assessment; (c) option selection/choice; (d) implementation strategies and tactics; (e) evaluation and impact assessment; (f) process and product analysis, assessment and support; and (g) negotiation support. As mentioned above, electronic tools also offer a range of functionalities, such as assisting decision makers by guiding them through the decision making process on a step-by-step basis (Cloete, 2003:33-34).

Implications for an appraisal framework

The study by Cloete (2003:75-76, 83) lists a number of findings of which the following in particular are deemed relevant to the development of an appraisal framework: (a) the IT revolution is causing a paradigm shift in management theory and practice; (b) outcomes-based governance is only feasible if rooted in a management approach and a system that fully utilizes the potential of IT; (c) the application of back-office technologies may be the only way for developing countries to deliver on their policy objectives and undertakings; and (d) the most important obstacle to the optimal use of technology in government is not limited resources, but a mental obstacle, i.e. the unwillingness to accept the global impact of IT on governance.

Finally, Cloete (2003:vi) notes the following: “The adoption and use of more user-friendly but effective electronic management support systems will not necessarily guarantee policy and service delivery success. It is assumed that these decision aids will, however, maximize the potential for improved or more successful results, if they are applied appropriately and effectively”.

1.5 Research need

Given the four aspects discussed above, the research need is summarized as follows: The annual budget cycle within urban road/transport authorities by implication requires projects to be evaluated, and then ranked in terms of “total worth” (i.e. their performance in terms of all

decision criteria which, in their turn, must be derived from community objectives, in particular those relating to transport infrastructure). This is necessary in order to enable project selection by starting "from the top". This results from the fact that the total "cost" of feasible projects normally exceeds available funds. Owing to the diverse nature of the impacts of TI projects, though, project worth cannot easily be quantified and expressed as a single quantum. For example, "narrow" CBA is not suitable for this purpose as it focuses on economic efficiency only. Attempts to broaden it have been criticized by scholars such as Dockel *et al*. (1991:8-9) and Mishan (1988:209-212). Although the diverse nature of impacts points to a MCA approach, this is considered unscientific in certain quarters; at best, its value at a practical level needs to be demonstrated. If it is argued that an appraisal framework need not imply a mutually exclusive choice between available methods (e.g. CBA versus MCA) but rather a combination of the best elements of each, the challenge is to develop such a framework, customize it to the CoT context and demonstrate its use at a practical level. In the specific case of CoT, problems with project appraisal are evident from the fact that different methods – none of which is defensible – are used, sometimes resulting in rankings that are contradictory (CTMM, 2007:12-1). At the same time, developments in the IT sector have led to the development of decision support tools with functionalities that potentially could improve decision making and lead to better outcomes; but their application in this particular context needs to be demonstrated.

1.6 Study objective

The overall objective is to develop an appraisal framework for TI projects in the municipal sphere of government in South Africa, with reference to the CoT. To this end, three sub-objectives are relevant:

- *Sub-objective 1:* To develop a basic approach that combines the best elements of traditional methods, taking into account the diverse nature and scope of the impacts of TI projects.
- *Sub-objective 2:* To customize this basic approach to the CoT decision making context.
- *Sub-objective 3:* To apply the appraisal framework (i.e. the basic approach, customized to the CoT decision making context) to projects in the CoT environment, in order to demonstrate the application of the framework at a project level and the

implications thereof, as well as the potential of decision support software for improving the quality of decision making and ensuring better governance outcomes.

1.7 Scope of study

This study involves the appraisal of “typical” TI projects in the municipal sphere of government in South Africa, where “typical” is defined as budget cycle type projects with local economic impacts only (see Section 1.2.12). The study scope can further be qualified in terms of capital expenditure as opposed to operating expenditure, in particular capital expenditure on new TI projects, as the expenditure on projects that have already been approved should be considered as committed. It is further important to note that the thesis does not address the issue of how funds (budgets) are allocated to different organizational units in the CoT, as the budgeting process falls outside the scope of the thesis. A given budget is assumed, and the focus is on how best to spend that budget on behalf of the community – in other words, on sound principles and a defendable process.

1.8 Study method

1.8.1 Description

The study method involves three main steps, as shown below. The study method is further evident from the thesis layout, given thereafter.

Overview of methods for project appraisal:

- Traditional methods (Chapter 2).
- Multi-criteria decision making (MCDM) (Chapter 3).

Development of a project appraisal strategy:

- Developing an overall appraisal strategy (Chapter 4).
- Customizing the appraisal strategy for the CoT context (Chapter 5).

Application of appraisal strategy:

- Applying the appraisal strategy (Chapter 6).
- Documenting learning (Chapter 7).

1.8.2 Study type

Mouton (2001:143-180) discusses research designs for 22 study types (18 types of empirical study, and 4 types of non-empirical study). As this study involves assessing traditional approaches to project appraisal and investigating how a new approach could address the identified shortcomings thereof, none of these 22 types of study design fits this study perfectly. At best, a combination of the following two types comes closest:

- Study type no 9: Evaluation research: experimental and quasi-experimental outcome studies" (Mouton, 2001:160-161).
- Study type no 18: Methodological studies (Mouton, 2001:173-175).

1.9 Thesis layout

This thesis comprises seven chapters. The focus and scope of the chapters following this introductory chapter are outlined below.

Chapter 2: Traditional methods of project appraisal

Chapter 2, constituting of a literature review, gives an overview of selected aspects of a number of traditional methods of project appraisal (as defined in Chapter 1). This is done to set the scene for the remainder of this thesis and, more specifically, to justify in later chapters their role (if any) in the proposed appraisal strategy. Traditional methods are discussed under three headings: (a) cost benefit analysis (CBA); (b) general equilibrium analysis; and (c) spatial models.

Chapter 3: Multi-criteria decision making (MCDM)

Chapter 3 gives a synoptic overview of MCDM (i.e. key concepts are highlighted without indulging in technical (mathematical) detail – in other words, key concepts are only touched on in a cursory manner). Reference is made to the CoT case where necessary. This overview is deemed necessary as the nature and impacts of TI projects point to the fact that the appraisal of TI projects essentially takes place in a multiple objective decision making environment, inevitably requiring an "MCDM-type" approach. This chapter examines the general background to and context of MCDM. Attention is then focused on specific aspects of the value function approach, which is deemed most appropriate in the case of road authorities such as CoT.

Chapter 4: Developing the basic approach

Chapter 4 compares two approaches to determining project worth: broad CBA and MCDM, and argues that an overall appraisal strategy should contain elements of both CBA and MCDM. In particular, it argues that an MCDM approach would be most appropriate, but with economic efficiency (determined by undertaking a narrow CBA) as one of the decision criteria (the other criteria to be determined in Chapter 5, after scrutinizing other objectives). Given the important role of efficiency (and therefore narrow CBA) in this strategy, Chapter 4 then examines aspects pertaining to (narrow) CBA, in particular how criticism of CBA should be addressed, focuses on lessons to be learned from ex-post evaluations, and highlights issues not currently addressed by CBA.

Chapter 5: Customizing the basic approach

As the overall appraisal strategy (developed in Chapter 4) involves an MCDM-type approach – specifically the MCDM value measurement model, with economic efficiency as one of the decision criteria – Chapter 5 involves customizing this approach to the CoT which, for the purpose of this thesis, is regarded as a typical road authority in the municipal sphere of government in South Africa. Attention is focused on the following steps of the MCDM approach: (a) identifying alternatives; (b) identifying decision criteria (in addition to economic efficiency); and (c) measuring intra-criterion performance – as it could be argued that the other steps of the approach are normally sufficiently taken care of by the software suggested for this purpose.

To facilitate the identification of decision criteria for CoT, this chapter explores the CoT decision making environment for aspects that could inform the process of identifying decision criteria such as the policy and legislative planning framework in different spheres of government impacting on the CoT planning process, and the vision, mission, goals, objectives, strategies and priorities contained in the IDP and ITP. Decision criteria used in other similar cases are also explored.

Given this appraisal strategy, customized to CoT, the role of traditional methods of project appraisal (as described in Chapter 2) in this strategy is examined. The need for a two-phased approach is also examined, as the appraisal strategy always involves both the evaluation of mutually exclusive alternatives and the ranking of independent projects.

Chapter 6: Applying the appraisal strategy

Based on the outcome of the previous chapters, Chapter 6 demonstrates the application of the appraisal strategy to the CoT environment, using off-the-shelf software available for this type of application. Features of the software are explained as well as the input data used in the application. The results obtained are presented; in particular, how different rankings could be obtained. Based on this application, the strengths and weaknesses of both the appraisal strategy and of "typical" software for this kind of application are also examined.

Chapter 7: Findings, conclusions and recommendations

Based on the study findings in previous chapters, conclusions are drawn and recommendations are made.

2. TRADITIONAL METHODS OF PROJECT APPRAISAL

2.1 Introduction

Chapter 2, which constitutes a literature review, gives an overview of selected aspects of a number of traditional methods of project appraisal (as defined in Section 1.2.10). This is done to set the scene for the remainder of this thesis and, more specifically, to justify, in later chapters, their role (if any) in a proposed appraisal strategy for CoT. Traditional methods are discussed under three headings (a) cost benefit analysis (CBA); (b) general equilibrium analysis; and (c) spatial models.

CBA constitutes the cornerstone of traditional methods. Key aspects are highlighted in order to outline the broad parameters of CBA. The scope of CBA is then considered. Two "opposing" approaches to project appraisal, namely "narrow" and "broad" CBA, are presented, as this distinction is particularly relevant to the context of this thesis. Since it is reasonable to expect the latest software tools for facilitating CBA to encapsulate current thinking on CBA (specifically by operationalizing its basic philosophy, approach and objective), it is apt to examine two internationally used software packages for CBA, namely the HDM-4 (Highway Development and Maintenance) model and the RED (Roads Economic Decision) model. Finally, the *ex post* evaluation of projects constitutes a feedback mechanism necessary for "completing the loop". For this reason, the results of the *ex post* evaluations of a number of major projects from around the globe are presented; they provide valuable insights into the practical application of CBA.

General equilibrium models can be regarded as an extension of and supplement to CBA in the case of large projects under certain conditions. Three general equilibrium approaches are presented, namely Input/Output (I/O) models (including a South African application – the MOTE model), the Social Accounting Matrix (SAM), and Computable General Equilibrium (GCE) models. Other specialized methods are also presented, for example macro-economic impact analysis.

Spatial models by definition focus on the spatial distribution of project impacts – an important objective of project appraisal, especially with reference to the objective of a "fair distribution of positive impacts". Attention is focused on the SASI project (quantifying socio-economic spatial impacts of transport infrastructure investments and transport system improvements in Europe), the CGEurope model (a spatial computable general equilibrium model for Europe),

the IASON project (building on SASI and CGEurope and involving the integrated appraisal of spatial economic and network effects of transport investment and policies), the DELTA model (DELTA being short for Development, Transition, Location, Employment and Area quality), the MEPLAN model (developed by Marcial Echenique and Partners), and the REMI model (developed by Regional Economic Models Inc).

2.2 CBA: Selected aspects

2.2.1 Introduction

This section addresses a number of key aspects of CBA in order to define its broad parameters. The scope and context of CBA are investigated with a focus on the basic philosophy, relevance and limitations of CBA. The distinction between mutually exclusive alternatives and independent projects is highlighted as this distinction is of particular significance regarding the development of an MCDM strategy for CoT. Likewise, the concepts "project evaluation", "ranking" and "selection" constitute elements of a process relevant to the development of an MCDM strategy. Finally, analytical procedures are examined, as they constitute the "operational heart" of CBA.

Examining key aspects of CBA is also relevant because much of the "jargon" in a CBA context also applies to other single-objective appraisal contexts (e.g. when comparing projects from the viewpoint of income distribution or impact on the environment), as well as multiple objective appraisal contexts (as in the case of MCDM). Examples of "universally relevant" concepts are project evaluation, project ranking, null alternative, analysis period, mutually exclusive alternatives, independent projects, and risk and uncertainty.

2.2.2 Context and objective

CBA (also termed SCBA (Social Cost-Benefit Analysis)) evolved "when economists started to link the theory of consumers' surplus with the net gain to communities from government spending projects" (Mullins, Mosaka, Green, Downing and Mapekula, 2007:1). "The idea of measuring the net advantages of a capital investment project in terms of society's net utility gains (welfare economics) originated with Dupuit's well-known work published in 1844 (Dupuit, 1844). He started to develop his definition of what is now called consumers' surplus (i.e. the willingness to pay for a good or service over and above its market price) as a measure of the net welfare gained from a project. This aspect of the definition of net social benefit is fundamental to CBA, and is extended to instances where persons who are not

direct beneficiaries of a project obtain some form of spill-over benefit. Accordingly, the measurement of net social benefits requires the estimation of all the consumers' surpluses to whoever they accrue" (Mullins *et al.*, 2007:7). From this it is clear that CBA is intended to bring into account benefits as represented by willingness to pay, which is derived from consumer surplus, which in turn requires for its derivation a demand curve based on utility of consumption (Mirrilees, 1991:II-3-5).

The next milestone, however, manifested itself only almost a century later: "The link between the surplus theory and the indirect third party losses and gains from capital projects was again revived in the 1930's in the United States with the United States Flood Control Act of 1936" (Mullins *et al*., 2007:1). In the United Kingdom, the first application of CBA was in 1960 in respect of the M1 motorway, and in 1967 the UK government officially directed its nationalized industries to adopt CBA (Mullins *et al*., 2007:1).

CBA has (therefore) been termed "an outgrowth of welfare economics, a branch of economics developed in the early 20th century to gauge the value of economic decisions in terms of their capacity to satisfy the totality of individual wants of all members of society" (Austroads, 2005b:37). It is an economic technique for ensuring that a project contributes towards the goal of economic efficiency, namely the maximization of social welfare (or the collective material wants of individuals) within the constraints imposed by the scarcity of resources (Austroads, 2005b:39). A perfectly efficient economy is defined as one that "leaves no unexploited opportunities to improve everybody's welfare" (Austroads, 2005b:59). In a similar vein, Boardman, Greenberg, Vining and Weimer (1996:28-29) (in Mullins *et al*., 2007:7) view CBA as a protocol for measuring "allocative" efficiency in the economy.

Pareto (1927:354) (in De Brucker and Verbeke, 2007:5) provided the first criterion for economic efficiency in the 1880s. It states that social welfare will increase when a "Pareto improvement" is possible, that is when the utility level of at least one individual is raised without decreasing the utility levels of any other individual – and vice versa, that social welfare will decrease when the utility level of one or more individuals is reduced, without increasing the utility level of any other individual (De Brucker and Verbeke, 2007:5). The Pareto criterion may however be regarded as too strict as projects or policy measures qualifying as a pure Pareto improvement are virtually non-existent. Consequently, a distinction has been made between a *pure* and a *potential* Pareto improvement. Hicks (1939:711) and Kaldor (1939:550) (in De Brucker and Verbeke, 2007:5) introduced the "compensation principle", in terms of which social welfare increases when the "winners"

(individuals whose utility levels have increased) *are able* to compensate the "losers" (individuals whose utility levels have decreased) and still attain a higher utility level than was the case prior to the policy measure or project – *regardless of whether this happens or not*. In other words, winners should win more than losers lose (or stated more fully: the increases in utility levels (the benefits) for those who gain are higher than the decreases in utility levels (the costs) for those who lose). A *"pure Pareto improvement"* would thus result if the compensation indeed takes place; if compensation does *not* take place, the outcome would constitute a *"potential Pareto improvement"* (De Brucker and Verbeke, 2007:5). The latter is also known as the Kaldor/Hicks criterion (Sassone and Schaffer, 1978:9) (in Mullins *et al*., 2007:7).

Determining whether a project will bring about (result in) a Pareto improvement (whether pure or potential) requires benefits and costs to be correctly valued. In CBA, impacts (benefits) should be valued in terms of the willingness-to-pay concept, and inputs (costs) in terms of opportunity costs. The sign of the net benefits (i.e. benefits minus costs) will then indicate if it is possible for winners to compensate losers and still be better off: a positive net benefit indicates this potential for compensation to make the project Pareto efficient, while a negative net benefit indicates the absence of this potential (Mullins *et al*., 2007:7). Also, it follows that CBA – when considered within the potential Pareto improvement context – focuses exclusively on economic efficiency and that equity considerations are not addressed at all (De Brucker and Verbeke, 2007:5). In this regard it should be borne in mind that traditional Pareto principles "use as departure point full employment and equilibrium in all markets at the margin" (Mullins *et al*., 2007:9). In addition to the fact that CBA as defined above does not address income distribution considerations, it could even be argued that CBA has a pro-rich bias. In the case of transport projects, for example, projects benefiting higher income groups will normally be preferred to projects benefiting lower income groups as they will render a higher rate of return when travel time savings are valued as a function of personal income. This underlines the need to address equity separately, for example as one of the decision objectives with an MCDM approach.

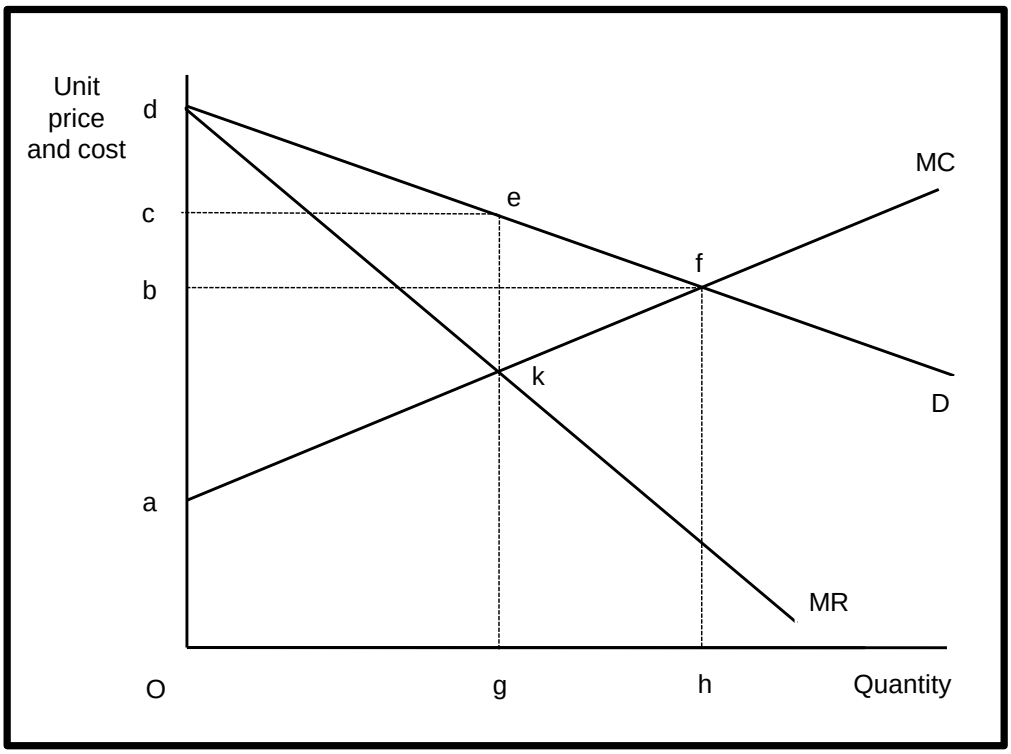
A comparison between CBA (applied in the public sector) and its private sector equivalent (financial analysis) serves to further elucidate key concepts. Firstly, the objective of financial analysis is to maximize shareholder wealth, whereas the objective of CBA is to maximize social welfare. This means that CBA may include impacts that are excluded in a financial analysis because they do not affect profit. Secondly, in terms of scope: a financial analysis

focuses exclusively on the interests of shareholders, whereas a CBA considers the whole community. This means that a CBA omits some impacts that a financial analysis includes, such as certain taxes. Thirdly, in terms of prices: financial analysis is based on market prices (cash inflows and outflows), whereas a CBA is based on shadow prices that reflect the "true cost" of resources to society (Austroads, 2005b:40).

Social welfare (welfare impacts) is a wide concept: "In general, welfare effects include all the consequences that a project has for a human being's social milieu. These effects are related to changing living standards, new opportunities for development and self-improvement and the protection of the environment, but also with population movements and all the negative consequences attached to them, etc. Welfare effects are hard to quantify, but it is important that the analyst should point out any such effect in detail and systematically to the decision maker, even if it is by qualitative means, to enable him/her to attach a subjective weight to it in order to arrive at a more considered decision" (Mullins *et al*., 2007:50).

Regarding the emphasis above on consumers' surplus, it is necessary to note that Ubbels (2005:5) also underlines the importance of producers' surpluses when he states that welfare theory "seeks to maximize the sum of consumers' and producers' surpluses". However, it should be borne in mind that this statement is being made in the context of marginal cost pricing, with the objective of maximizing welfare under monopoly conditions. Examining this process nevertheless serves to highlight important differences between *appraisal* and *pricing*, and provides important insights into project appraisal. Economic efficiency, aimed at maximizing social welfare (Ubbels, 2005:2), "is derived from the theory of welfare economics, and is concerned with the allocation of resources in an economy" (Ubbels, 2005:4). Social surplus is defined as the sum of producers' surplus and consumers' surplus. "Consumers' surplus represents the benefit to consumers, as expressed by their willingness to pay, in excess of the cost of providing a particular quantity or level of output. Producers' surplus represents the revenue in excess of the cost of providing that level of output i.e., profit" Ubbels (2005:4). Figure 2-1 shows that "optimal pricing" is a prerequisite for maximizing social surplus. In this figure, MC denotes the marginal cost curve (or supply function), D the demand curve and MR the marginal revenue curve. It is assumed that marginal costs increase with output (though this may not necessarily be the case in the transport industry faced with large fixed costs). It shows that the output and price of a profit maximising firm depends on the inter of the MC and MR curves – in particular, the firm would produce output *0g* at price *0c,* i.e. where marginal revenues equal marginal cost. Consumers' surplus is

then equal to the area *cde*, and producers' surplus is represented by the area *acek,* resulting in a social surplus equal to the area *adek* (Ubbels, 2005:5). On the other hand, if the firm sets its price equal to marginal cost, output expands to *0h* and price falls to *0b*. In this case, consumers' surplus would be given by area *bdf*, and producers' surplus by the area *abf*, resulting in a social surplus of *adf*. Compared with the previously obtained aggregate (the area *adek*), it is clear that the triangle *kef* makes the difference, and that the sum of the two surpluses is at the maximum when price equals marginal cost. "In other words, social welfare is maximized when price is equated with marginal social cost (Pareto optimum)" (Ubbels, 2005:5).



Source: Adapted from Ubbels (2005:5).

Figure 2-1: Welfare maximization: Marginal cost pricing

Within the context of project appraisal – as opposed to pricing – consumer surplus is regarded as a measure of the net benefit of a project over its economic life, to be compared with the cost of providing and maintaining that facility. In this thesis, it is further argued that the demand curve for a given project is a function of the needs of both producers and consumers. As noted by Austroads (2005b:40), "the purpose of BCA is to maximize social welfare, that is, the sum of consumers' preferences. This is termed the goal of economic efficiency".

2.2.3 Aspects not considered in CBA

Aspects traditionally not included in a CBA (regardless of whether it is done in a narrow or a broad sense) are listed below (Austroads, 2005b:17-19).

Sunk costs: Sunk costs are resources that have already been "sacrificed" in the project and for which there is no alternative use, that is resources for which the opportunity cost is zero.

Transfer payments: Taxes and subsidies are examples of transfer payments. They should be excluded from the analysis to ensure that resources are priced at their real (economic) value and, in so doing, that the optimal allocation of scarce resources is ensured.

Land prices: TI projects may affect the price (value) of land; an increase will result if land is made more accessible; and a decrease if an amenity is reduced. But to include changes in land values in the analysis in addition to changes in total transport costs would amount to double counting.

Impacts relating to the financing decision: The economic evaluation of a project involves its economic feasibility and its financial (financing) analysis addresses its financial feasibility. Impacts relating to the financing decision, such as interest costs, should therefore not be included in CBA. However, CBA does address the time value of money by using a discount rate which is typically a real discount rate as the analysis is done in real terms.

Depreciation: Deprecation can have both an economic and financial meaning. "Accounting depreciation" for example, is a concept that should be limited to financial statements. Its equivalent in CBA is the "using up" of capital items (assets); this should be reflected in the analysis as and when this happens.

Transmitted impacts: This refers to the "ramifications" throughout the economy of the project. They are usually predicted by macro-economic models. Although the ripple effects of projects are real, adding them to the direct benefits of a project as established by the CBA would amount to double-counting.

Regional development: Regional development can be regarded as a special case of transmitted impacts. For the same reasons, its inclusion in CBA would amount to double-counting.

2.2.4 Mutually exclusive alternatives and independent projects

For the purposes of this study, the distinction between mutually exclusive alternatives and independent projects is important. *Mutually exclusive alternatives* are defined as different options for accomplishing a stated objective. If one option is selected, the others will not be required. Assume, for example, that the road between A and B has been identified as sub-optimal from a technical perspective and that two options have been identified to address the problem: the first option is the improvement of the geometric characteristics of the road on the existing alignment, and the other option a road on a new alignment. This situation implies *three* mutually exclusive alternatives: the two options for improving the situation plus the null alternative. In terms of the definition above, it is evident that only *one* alternative can be selected in this case. The transport economic evaluation of these mutually exclusive alternatives therefore involves the selection of the best alternative from an transport economic perspective, and consequently the most cost-effective alternative will be selected, that is the alternative with the lowest present worth of total transport cost. In some cases, this may be the null alternative, meaning that additional investment in the system is not warranted (at least not at this stage). It is however clear that "best" may also be defined from other perspectives, as is argued in Chapter 4 and Chapter 5.

Independent projects relate to different (unrelated) objectives to be accomplished. In the case of CoT, examples of independent projects are: the proposed upgrading of sections of Hans Strijdom Road, (a main arterial in the eastern suburbs of Pretoria), and the construction of a new taxi rank in Mamelodi. From a selection of independent projects, it follows that more than one could be selected – in fact, it would be possible to select *all* independent projects if they were all feasible and if funds were available. The economic evaluation of independent projects therefore involves the ranking of economically justifiable projects in terms of an appropriate "economic" criterion.

2.2.5 Project evaluation, ranking and selection

Project appraisal, as defined for the purpose of this study, includes both the evaluation and the ranking of technically feasible projects. In the case of CBA (being a special case of project appraisal, focusing on a single decision criterion only), project evaluation involves determining if a project is economically justified (i.e. if it meet certain minimum requirements, in other words, the accept/reject concept), and project prioritization involves the ranking of economically feasible projects in terms of this attribute (economic worth). This can also be

described in terms of the "comparison of mutually exclusive alternatives" and the "prioritization of independent projects" which, in turn, will enable the selection of projects.

Comparison of mutually exclusive alternatives

The objective in this case is the identification of the "best" alternative from each set of mutually exclusive alternatives (including the null alternative), where "best" is defined in terms of the agreed criterion or set of criteria. In order to be identified as the best mutually exclusive alternative, the "best" alternative must not only outperform the other alternatives in that set, but must also (at least) exceed the minimum acceptable decision criteria. If, for example, "economic efficiency" were the only criterion, this would mean that the "best" alternative must have a benefit/cost ratio of at least 1 in order to be economically justified. This also means that the null alternative may, in some cases, be indicated the best alternative, and that no additional investment would be required.

Ranking of independent projects

The best option from each set of mutually exclusive alternatives constitutes an "independent project". Project ranking involves prioritizing independent projects in terms of their overall merit (project worth). By definition, all projects on this list will be justified in terms of the relevant decision criteria.

Project selection

There are two requirements for a project to be selected for inclusion in the investment plan for a given year: firstly it must be acceptable in terms of the relevant decision criterion/criteria, and secondly there must be sufficient funds. Under conditions of budget constraints, the benefit of having a list of projects prioritized in terms of their "worth" (however defined), is that a top-down approach could be followed by selecting the best project first, followed by the second best project, and so on, until funds are depleted; in that way ensuring the selection of the optimal portfolio of candidate projects.

2.2.6 Analytical procedures

Background

A project is deemed feasible if discounted benefits over the analysis period exceed discounted costs (or are at least equal to discounted costs). This principle can be formulated in different ways, giving rise to six techniques commonly used in CBA. They are all based on the principle of discounted cash flow analysis (DCFA), allowing for the economic concept of

inter-temporal choice. They can be classified under three headings: (a) least cost approach; (b) maximization of net benefits approach; and (c) investment approach (Schutte, 1983:18-26).

The techniques in the least cost approach differ from the techniques in the other approaches, as they do not involve a *comparison* of investment options, but merely an assessment of the total cost of *each* option. All techniques in the other approaches do involve a comparison between two options, namely the investment option in question and the null alternative; this amounts to a comparison of marginal benefits and costs.

Least cost approach

The Equivalent Uniform Annual Cost (EUAC) technique and the Present Worth of Cost (PWOC) technique fall in this category. They involve a comparison of options in terms of total discounted cost. The option with the lowest cost will be indicated as the preferred option.

Maximization of net benefits approach

This approach involves both the difference between costs and benefits, and the ratio between them.

- *Difference between costs and benefits:* Two techniques fall in this category: the Net Present Value (NPV) technique and the Equivalent Uniform Annual Net Return (EUAR) technique. They calculate the difference between benefits and costs for each investment option, and will indicate the investment option with the highest value for net benefit as the best option, provided this difference has a positive value.
- *Ratio between benefits and costs:* The Benefit/Cost (B/C) ratio expresses benefits as a ratio of costs. It will indicate the investment option with the highest ratio of benefits to costs as the best option, provided this ratio is at least equal to 1 and provided further that, in the case of mutually exclusive alternatives, incremental analysis is used to find the most economic alterative.

Investment approach

The Internal Rate of Return (IRR) technique follows an “investment” approach (as used in the private sector) since it equates the stream of benefits over the analysis period with the return on the investment; the discount rate at which this happens is the internal rate of return (IRR). For an option to be economically acceptable, the IRR must at least be equal to the discount

rate. Also, in the case of mutually exclusive alternatives, an incremental analysis must be conducted to identify “the best” option.

Interest formulae

The interest formulae used in the techniques below underline the fact that the time value of money is considered in the calculation of the economic merit of project proposals. These interest formulae are explained below, where:

i = discount rate p.a. as decimal (in real terms)

n = number of years

t = traffic growth rate as decimal.

(E_tUS, i%, n) = exponential series equivalent uniform series factor

= factor to convert an exponential series growing at t% p.a. for n years to an equivalent uniform series at a discount rate of i% p.a.

= ((((1+t)/(1+i))^(n+1)-1)/((1+t)/(1+i)-1)-1)*((i*(1+i)^n)/((1+i)^n-1))

(E_tPW, i%, n) = exponential series present worth factor

= factor to convert an exponential series growing at t% p.a. for n years to its present worth at a discount rate of i% p.a.

= ((((1+t)/(1+i))^(n+1)-1)/((1+t)/(1+i)-1)-1)

(CR, i%, n) = uniform series capital recovery factor

= factor to convert a present amount to an equivalent uniform series over n years at a discount rate of i% p.a.

= i*(1+i)^n/((1+i)^n-1)

(SPW, i%, n) = uniform series present worth factor

= factor to convert an equivalent uniform annual series for n years to its present worth at a discount rate of i% p.a.

= ((1+i)^n-1)/(i*(1+i)^n)

(PW, i%, n) = single amount present worth factor

= factor to convert a single future (compound) amount to present worth for n years at a discount rate of i% p.a.

= 1/(1+i)^n

Description of techniques

The techniques are described below for the scenario where the traffic volume grows exponentially over the analysis period at a rate of t% per annum. In the equations below, the symbols used have the meanings as explained below.

T = total of recurring cost (i.e. facility maintenance cost, vehicle operating cost, collision cost and travel time cost) at the end of year 1.

C = initial facility construction cost, i.e. investment required to obtain annual benefits over the analysis period.

F = terminal value of facility at the end of the analysis period.

Equivalent Uniform Annual Cost (EUAC) technique

This technique expresses the cost components incidental to each mutually exclusive alternative as an equivalent, uniform annual cost. The alternative with the lowest annual cost is favoured. This technique is therefore based on the principle of cost-effectiveness.

The EUAC of a mutually exclusive alternative is calculated as follows, where the terms have the meanings explained above:

$$EUAC = T\,(E_t US, i\%, n) + (C - F\,(PW, i\%, n))\,(CR, i\%, n)$$

Present Worth of Cost (PWOC) technique

This technique is similar to the EUAC technique, except that the equivalent uniform annual costs are discounted to their present worth. As with the EUAC technique, this technique is based on the premise that the transport facility must be provided at the lowest cost, thus the mutually exclusive alternative with the lowest present worth of cost is favoured. If an

alternative that requires an additional investment in the existing facility is favoured, it means that the additional investment is smaller than the resulting savings.

The PWOC of a mutually exclusive alternative is calculated as follows, where the terms have the meanings explained above:

$$PWOC = EUAC\ (SPW, i\%, n)$$

$$= (T\ (E_tUS, i\%, n) + (C - F\ (PW, i\%, n))\ (CR, i\%, n))\ (SPW, i\%, n)$$

Net Present Value (NPV) technique

This technique calculates the difference between the present worth of the savings resulting from an additional investment in the system and the present worth of the additional investment. The answer is given in absolute monetary terms and must be equal to or greater than 0 for an alternative to be economically justified. The alternative with the highest NPV is favoured.

The NPV is calculated as shown below, where the terms have the meanings as explained above, but with the following qualification:

T_0 = total of recurring costs for the null alternative.

T_n = total of recurring costs for the n^{th} alternative.

$$NPV = (T_0 - T_n)\ (E_tPW, i\%, n) - (C - F\ (PW, i\%, n))$$

Equivalent Uniform Annual Net Return (EUAR) technique

This technique is identical to the NPV technique above, but the net present value is now expressed as the equivalent uniform annual return, by multiplying it by the appropriate capital recovery factor. As with the NPV technique, the alternative with the highest equivalent uniform annual net return is favoured.

The NPV is calculated as shown below, where the terms have the meanings as explained above.

$$EUAR = NPV\ (CR, i\%, n)$$

$$= ((T_0 - T_n)\ (E_tPW, i\%, n) - (C - F\ (PW, i\%, n)))\ (CR, i\%, n)$$

Benefit/Cost (B/C) ratio

This method calculates the ratio of the present worth of benefits to the present worth of costs. A project is economically justified if this ratio is equal to or greater than 1, where a value of 1 indicates that discounted benefits are exactly equal to discounted costs. For mutually exclusive alternatives, when only one alternative from a collection of alternatives can be selected, the best alternative should be determined by using incremental analysis.

The B/C ratio is calculated as shown below, where the terms have the meanings as explained above.

$$B/C = (T_0 - T_n)\,(E_tPW, i\%, n) \,/\, (C - F\,(PW, i\%, n))$$

Internal Rate of Return (IRR) technique

This technique determines the discount rate (or rate of return) that will equalize the present worth of costs and the present worth of benefits. The higher the discount rate, the better the project will be. For a project to be economically justified, it must have a rate of return that is equal to or greater than the required rate of return (i.e. the discount rate prescribed by government for public sector capital projects – this can be interpreted as a "cut-off" rate or the minimum rate of return on investment required by government). However, with mutually exclusive alternatives, incremental analysis must be used to determine the best alternative.

With this technique, the discount rate (or internal rate of return) is actually calculated, whereas the discount rate is used as an input in all previous methods. The IRR of a project is calculated as shown below, where the terms have the meanings as explained above.

$$ROR = j\%\ p.a.$$

so that:

$$(C - F\,(PW, i\%, n)) = (T_0 - T_n)\,(E_tPW, j\%, n)$$

Application of techniques

When *mutually exclusive alternatives* are compared, all six techniques will give the same answer if applied correctly. "Applied correctly" in the case of the B/C ratio and IRR technique means that mutually exclusive alternatives should be compared in an incremental fashion, starting with the least cost option, and eliminating options that do not meet the required

criterion until that option is identified with the highest cost that can still be economically justified. When *independent projects* are compared, only the B/C technique and the IRR techniques (in both cases, expressed relative to the null alternative) can be used, as the other four techniques do not accommodate difference in scale between independent projects.

2.3 CBA applications

2.3.1 Introduction

The distinction between "narrow CBA" and "broad CBA" is particularly important for the purposes of this thesis. This section examines these concepts and highlights important differences. In doing this, though, it is appropriate to first define the following concepts. A *cost* is defined as any utility that is sacrificed to bring about a facility, and a *benefit* is any utility brought about by the use and operation of such a facility (Pienaar, 2005:114). In their turn, Mullins *et al*. (2007:7) distinguish between *impacts* and "all required *inputs*" necessary to bring about these impacts. Elsewhere, reference is made to *inputs* and *outputs* (in particular the need for the prices of inputs and outputs to indicate their economic scarcity value) (Mullins *et al*., 2007:23). Costs are normally associated with inputs into a project and benefits with outputs to be derived from the project (Mullins *et al*., 2007:28). The exception is negative outputs in the form of (unplanned) negative impacts (negative benefits) which have a "cost tag" attached to them.

2.3.2 Narrow and broad CBA

Broad CBA has been termed a variant of CBA; the need for adopting a "broad" approach is explained as follows: "Another variant of BCA was developed in the 1970s to assist international agencies like the World Bank in addressing the requirements of developing countries. Because developing economies often exhibit large price distortions and income inequity, this version of BCA incorporates techniques for deriving and using shadow prices and for quantifying the distributional impact of projects" (Austroads, 2005b:37).

If it is assumed that the distinction between a narrow and a broad CBA (Dockel *et al*., 1991:3) (or an economic and a social CBA in the case of Brent (1996:5)) was made in a general sense, their meaning in the case of TI projects needs to be explored. Regarding CBA in a general sense, examples of "other" objectives (i.e. objectives in addition to economic efficiency) are equity effects and externalities (Brent, 1996:5), equity, strategic

goals and objectives, and other social considerations (Dockel *et al*., 1991:8-9), and objectives (standards) relating to ethics, jurisprudence, politics, distributional justice, or ecology (Campen, 1986:83),

Narrow CBA can be “expanded” in two ways: (a) by “manipulating” the results to also address other objectives, for example by using weights to address equity considerations; and/or (b) by introducing “other” (less tangible) impacts in addressing efficiency considerations, i.e. impacts in addition to total transport cost such as convenience, environmental factors, strategic factors, political factors, and policy considerations.

Differences between narrow and broad CBA can also be articulated differently. In particular: (a) broad CBA also include softer (less tangible) impacts as well; (b) broad CBA broadens the focus from efficiency as the sole objective to also include other objectives such as a fairer distribution of impacts. This is shown in the Figure 2-2 as a move away from hard issues to include soft issues; and also a move away from efficiency objectives to include equity (and other) objectives.

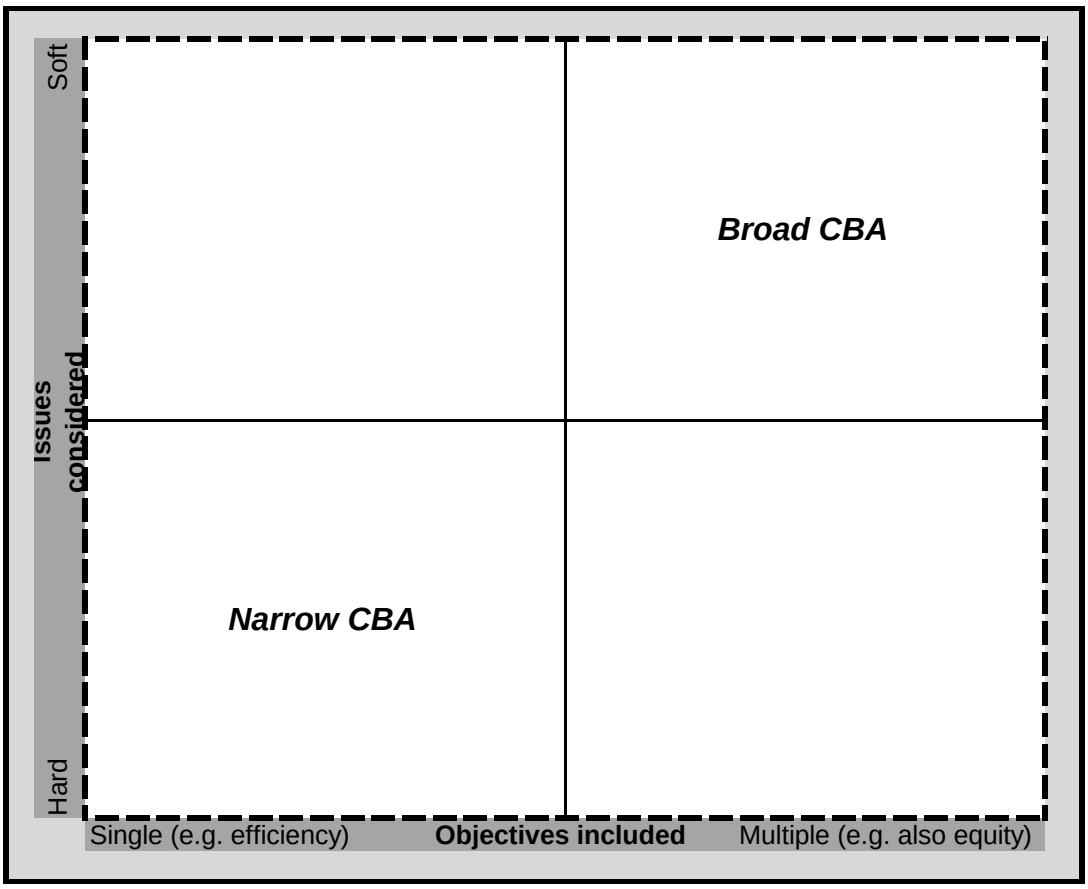


Figure 2-2: Comparison of narrow and broad CBA in respect of selected aspects

By implication, narrow and broad CBA therefore also differ in terms of the valuation techniques used in each case. For example, the willingness to pay (*ex ante*) and human capital (*ex post*) approaches are two established methods for evaluation collision costs, in particular the costs attributable to fatalities, disabilities and injuries. In its turn, the *ex ante* method comprise techniques such as contingent valuation, hedonic pricing, revealed pricing and "standard gamble" (Naude, Evans and Perovic, 2007:17). Approaches that could be used in case of "market failure" can be classified in two groups (Austroads, 2005b:39): (a) "Revealed preference (RP) methods look at 'surrogate markets'; markets that embody an impact as part of a 'bundle' of attributes". Examples are random utility / discrete choice models; averting behaviour models; hedonic pricing; and the travel cost method. (b) "Stated preference (SP) methods use questionnaires to elicit preferences where there may be no surrogate market". They comprise contingent valuation; and contingent ranking / conjoint analysis. Although not a valuation technique in the strict sense of the word, replacement cost can also be used; it normally provides a minimum estimate.

An example of aspects included in a broad CBA in the case of TI projects is given in Table 2-1. In this table, impacts suggested for inclusion in a CBA are classified according to the party affected (Austroads (2005b:14); they include both transport cost and externalities.

Table 2-1: Project impacts classified by the party affected

Affected party	Impact	Main components
Operators	Capital items	New construction Road rehabilitation Land acquisition/disposal Environmental mitigation
	Network operation	Routine maintenance Network management
Users (see note (a))	Vehicle operating cost (VOC) (see note (b))	Fuel and lubricants Repairs and maintenance Economic depreciation (see note (c)) Tyres
	Travel time	Mean walking time Mean waiting time Mean in-vehicle time Variability of trip time
	Crashes	Death, pain and suffering Property damage Emergency services etc.
	Freight performance	Mean delivery time

Affected party	Impact	Main components
		Variability of delivery time Damage in transit
Non-users	Noise	Engine noise Tyre noise
	Air pollution	Small particulates (PM10) Oxides of nitrogen (NOx), ozone (O3) Carbon monoxide (CO) Oxides of sulphur (SOx) Volatile organic compounds etc.
	Nature and landscape	Visual intrusion Loss of flora and fauna
	Severance	Pedestrian walking time
	Climate change	Greenhouse gases (GHGs)
	Culture and heritage	Visual intrusion Loss of built environment

Source: Austroads (2005b:14).

Notes:

(a) Congestion is not separately classified as it manifests itself in terms of other impacts.

(b) Although VOCs normally apply to road vehicles, they have their analogs for other modes: rail (train operation costs), sea (ship operation costs), and air (aircraft operation costs).

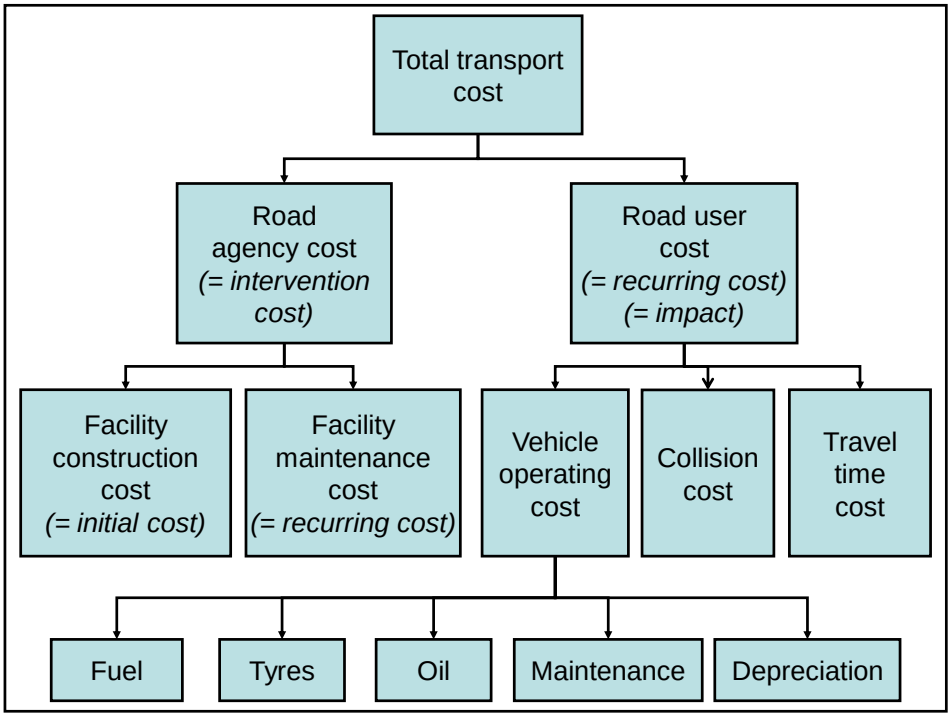
(c) Not to be confused with accounting depreciation, which should be excluded from BCA.

Contrary to this approach, “narrow CBA”, for the purposes of this thesis, is defined as involving (only) *total transport cost*, consisting of the elements shown in Figure 2-3. In other words, impacts affecting non-users are not included. This definition has the important implication that benefits, in the case of TI projects, are interpreted as savings in road user cost relative to the null alternative. The elements of total transport cost depicted in the figure can be disaggregated in three ways, as outlined below and shown in the figure.

Road agency cost and road user cost: Road agency costs are for the account of the road agency, which incurs these costs on behalf of the community it serves. Road user costs accrue to road users.

Initial cost and recurring cost: A distinction between *initial* and *recurring costs is* particularly important in the context of a discounted cash flow analysis (DCFA) where the time value of money has to be considered. By definition, initial cost (in the form of facility construction cost) is incurred at the beginning of the analysis period, whereas recurring costs are incurred throughout the analysis period (the DCFA convention requires that recurring costs be treated as a cost at the end of each year of the analysis period).

Intervention cost and (resulting) impacts: Intervention costs, for the purposes of this study, are defined as all costs necessary to “make a change” (relative to the null alternative). In the case of transport projects, they will consist of facility (road) construction cost (which is an initial cost) plus road maintenance cost (which is a recurring cost). Interventions costs are a prerequisite for impacts to result, where impacts can be either “good” (= benefits) or “bad” (= disbenefits).



Source: Schutte, 1983:9.

Figure 2-3: Elements of total transport cost

2.3.3 Applying CBA to different types of projects

As noted in Section 1.2.12, projects could also differ in terms of the scope (reach) of their economic impacts. The scope could be either local (limited to the area of jurisdiction of the relevant authority) or regional/national (extending beyond the boundaries of the relevant authority), with the latter applying in the case of traded industries (EDRG, 2008:2). This means that CBA applications could be classified in terms of two attributes: (a) definition of benefits; and (b) scope of CBA, as done in Table 2-2.

Table 2-2: Classification of CBA applications

Scope of CBA	**Definition of benefits**	
	Benefits defined in terms of savings in cost	**Benefits defined in terms of increased economic output**
Narrow CBA	Budget cycle type projects where no external economic impacts are	Projects where “external” economic impacts are predicted, as in the case of: (a) one-off projects; (b) some

Scope of CBA	Definition of benefits	
	Benefits defined in terms of savings in cost	**Benefits defined in terms of increased economic output**
	anticipated.	budget cycle type projects.
Broad CBA	As above, but including other objectives (in addition to economic impacts), such as equity.	As above, but including other objectives (in addition to economic impacts) such as equity.

Given the (possible) classification of projects (and appraisal context) in Section 1.2.12, the suggested CBA applications to different categories of projects are summarized in Table 2.3.

Table 2-3: Suggested CBA applications to different categories of projects

Scope of impacts	Project type	
	One-off	**Budget cycle**
Local	Not applicable, as one-off projects by definition will have wide (regional and national) impacts.	Narrow CBA, where benefits are defined as savings in total transport cost.
External	Narrow CBA, where benefits are defined as increased economic output.	Narrow CBA, where benefits are defined as increased economic output.

2.4 Software for facilitating CBA

2.4.1 Introduction

Various software tools and manuals have been developed to facilitate and promote CBA in the roads sector. The World Bank took the lead in the case of rural roads in developing countries, and as a result, HDM-4 and the RED model are currently used world-wide. To meet local conditions and requirements, South Africa had its own quota of manuals and

software tools: the CSIR's Manual K64 was published in 1983 (Schutte, 1983). Other manuals and guideline documents followed, such as the Central Economic Advisory Services (CEAS) manual on CBA (CEAS, 1989), and guidelines for the economic evaluation of urban transport projects, published by the Municipality of Cape Town (CMT-KMV, 1995). The program CB-Roads (software tool for the cost-benefit analysis for roads) was prepared in the late 1980s under the auspices of the South African Department of Transport (DOT, 1989). It can be regarded as the "South African" version of the HDM model (but developed and functioning independently from it) – using default values representative of South African conditions (e.g. South African road construction parameters and vehicle fleet characteristics). In line with international trends, Program CB-Roads has however been discontinued and its function replaced by the HDM model.

Software tools for facilitating CBA are by definition attempts to incorporate current thinking and practice. This section examines how this materializes in the case of HDM-4 and RED. To place them in perspective, the concept of *road infrastructure management*, of which HDM-4 and RED are key elements, is examined first, followed by an overview of other tools that are available for road infrastructure management.

2.4.2 CBA as an element of road infrastructure management

Background

Although CBA can be used as a stand-alone tool, it can also be viewed in the context of road infrastructure management. The term "road infrastructure management" originated from the need for road authorities to manage road networks as a national asset; it became particularly relevant in developing countries as it was required by international funding (donor) agencies as a condition (prerequisite) for providing development aid. Viewing CBA from this perspective also provides valuable insights into CBA vis-à-vis other tools available for this purpose.

Road infrastructure management

In a joint publication by TRL (Transport Research Laboratory) and DFID (Department for International Development) in the UK, *road management* is defined as "(the) process of maintaining and improving the existing road network to enable its continued use by traffic efficiently and safely, normally in a manner that is effective and environmentally sensitive; a process that is attempting to optimise the overall performance of the road network over time" (TRL and DFID, 1998:66). It starts from the premise that any road network is an asset that

needs to be maintained and improved in order to secure the best performance and value-for-money and the maximum service life (TRL and DFID, 1998:5). "The aims of road management are to enable the network to withstand the damage caused by wear and tear, to prevent substandard conditions from developing, and to ensure that traffic can continue to travel, in a manner which is safe, efficient, reliable and which causes the least damage to the environment" (TRL and DFID, 1998:5). Road management involves the four management functions *planning*, *programming*, *preparation* and *operations*, as defined by Kerali (2000:5-6).

Road management system (RMS)

The need to manage the road network under the jurisdiction of a road authority inevitably gave rise to the development of appropriate systems for doing this. A *road management system* is defined as a computer-based system used to assist with road management (TRL and DFID, 1998:66). In a more recent World Bank publication, a road management system is defined as follows: "A RMS (road management system) is defined here as any system that is used to store and process road and/or bridge inventory, condition, traffic and related data, for highway planning and programming. Associated with the RMS are appropriate business processes to use the RMS to execute the business needs of the highway agency" (McPherson and Bennett, 2005:3).

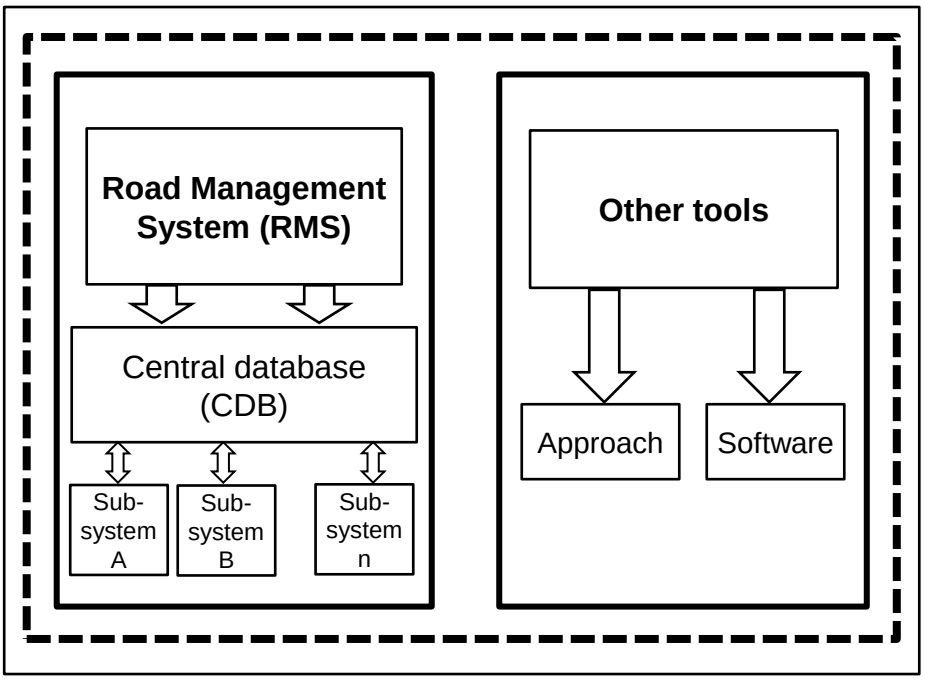
The box below contains a shortened version of a description of typical elements of a RMS, as provided by Pinard for Botswana and documented by Heggie (1995:111).

Elements of the Road Management System (RMS)
The RMS consists of a central database linked to subsystems for data collection, planning, and management: *(1) Central database (CDB) contains validated summary data generated by the other subsystems.* *(2) Pavement management subsystem (PMS) determines the type, optimum timing and level of maintenance required, given prevailing road conditions.* *(3) Maintenance management subsystem (MMS) specifies, for the selected maintenance strategy: (i) performance standards, (ii) budget requirements, (iii) schedule of activities, and (iv) a management information reporting system.*

Elements of the Road Management System (RMS)
(4) Bridge management subsystem (BMS) provides a rational basis for managing the maintenance of bridges. *(5) Traffic subsystem (TSS) provides a variety of statistics on the road network, including traffic volume and loading by vehicle type by road link, total distance travelled, and growth rate by vehicle type by road link.* *(6) Cost accounting subsystem (CASE) provides accurate cost accounting data required for: (i) establishing budgets and standard costs for road maintenance operations, (ii) tracking and accounting for actual costs of operations by activity and cost centre, and (iii) monitoring performance and assessing productivity by cost centre.* *(7) Geographic information subsystem (GIS) allows visual presentation and production of maps of the road network.*

Tools for road infrastructure management

From the extract above it is clear that the RMS is essentially a database consisting of different components, each addressing a particular function of road infrastructure management. The RMS therefore can be viewed as the core (backbone) of road infrastructure management. Further, the RMS is "supplemented" by a number of specific tools (discussed below) for addressing specific aspects of road infrastructure management. A distinction is therefore made between the *RMS* (being a tool itself), and *"other tools"* (e.g. HDM-4), as shown in Figure 2-4. In the case of the RMS, the CDB (central database) constitutes the interface between a number of systems such as the PMS (pavement management system) and the MMS (maintenance management system) (i.e. sub-system A, sub-system B, etc, in Figure 2.4).



Source: Schutte (2008:4).

Figure 2-4: Tools for road infrastructure management

"Other tools" may be either an approach or software, as shown in Figure 2-4. An approach (technique) is defined as a sequence of steps that needs to be followed to ensure that a given principle is adhered to and/or a given objective is reached; for example, "scarce economic resources must be optimally allocated". "Software" is defined as an approach that has been computerized, such as HDM-4.

Classification of tools

Tools for road infrastructure management can be classified in a number of ways. In Table 2-4, 15 tools identified for this purpose are classified in eight categories according to functional similarity (Schutte, 2008:106-108). By definition, tools within a group have a common objective (as indicated by the relevant heading), but may differ in terms of the specific focus of each, that is in how each tool attempts to achieve this objective. A degree of overlap between tools may exist in some cases. This results from the fact that they were developed by different organizations, at different times and in response to different needs/contexts. For example, the tools BAA, SLA and IRAP (and to some extent, PRA) (defined in Table 2-4), all of which focus on basic access, rural roads and poverty alleviation, were developed by different institutions (the World Bank, UK DFID (Department for International Development) and the ILO (International Labour Organization) respectively) in response to unique country

needs and for application in specific contexts. Likewise, both HDM-4 and RED focus on the optimal use of scarce resources. RED, however, was developed later and in response to the need for a tool for unpaved roads that has less stringent data requirements than HDM-4.

Table 2-4: Tools for road infrastructure management

Category	Tool
1. Comprehensive tools for road management	(a) Road Management System (RMS).
2. Tools focusing on accessibility poverty alleviation, community participation	(a) Basic Access Approach (BAA). (b) Integrated Rural Accessibility Planning (IRAP). (c) Participatory Rural Appraisal (PRA). (d) Sustainable Livelihood Approach (SLA).
3. Tools developed in response to stakeholder requirements for feedback/information	(a) Performance Assessment Model (PAM). (b) Rapid Rural Road Appraisal (RRRA). (c) Standard Overall Ultralite Road Care Estimate (SOURCE).
4. Tools aimed at economic efficiency in resource allocation	(a) Highway Development and Management model (HDM). (b) Roads Economic Decision model (RED).
5. Tools suited for multiple criteria decision making	(a) DEcisions on a FINITE set of alternatives (DEFINITE). (b) New Approach to Transport Appraisal (NATA).
6. Tools aimed at road cost recovery	(a) Road User Charges model (RUC).
7. Generic planning tools	(a) Logical Framework Analysis (LFA).
8. Tools aimed at improving organizational efficiency	(a) Balanced Score Card (BSC).

2.4.3 HDM-4

HDM-4 is generally accepted and used as a tool for the CBA of road projects; in total, more than 700 licences have been sold worldwide. This underlines its role as a key tool for economic appraisal, in both developed and developing countries.

Scope and objective

The Highway Design and Maintenance Standards model, developed by the World Bank, combines the technical and economic appraisal of road *projects*, prepares road investment *programmes*, and analyzes road network *strategies*. Based on the International Study of Highway Development and Management (ISOHDM), its scope has been widened and, together with other improvements, this has resulted in the HDM-4 (Highway Development and Management) model. "The scope of HDM-4 has been broadened considerably beyond traditional project appraisals, to provide a powerful system for the analysis of road management and investment alternatives" (Kerali, 2000:1).

HDM-4 has been used in many different countries as a tool for economic analysis and prioritization, capable of undertaking analyses at three levels: strategy, programme and project level. "It utilizes road network inventory and condition data, traffic data, and economic data to feed a series of road deterioration models and cost models, and to formulate candidate work programs for road networks" (McPherson and Bennett, 2005:39). In essence, "(t)he model simulates, for each road , year-by-year, the road condition and resources used for maintenance under each strategy, as well as the vehicle speeds and physical resources consumed by vehicle operation. After physical quantities involved in construction, road works and vehicle operation are estimated, user-specified prices and unit costs are applied to determine financial and economic costs. Relative benefits are then calculated for different alternatives, followed by present value and rate of return computations" (Kerali, 2000:20).

In addition to predicting road deterioration over time and road user effects, it also predicts road user cost and social and environmental effects (Kerali, 2000:10-11). Road user costs comprise vehicle operating cost (fuel, tyres, oil, spare parts consumption, vehicle depreciation and utilization), costs of travel time for both passengers and cargo, and cost of road accidents (loss of life, injury to road users, damage to vehicle and other roadside objects). "The social and environmental effects comprise vehicle emissions, energy consumption, traffic noise and other welfare benefits to the population served by the roads.

Although the social and environmental effects are often difficult to quantify in monetary terms, they can be incorporated within the HDM-4 economic analyses if quantified exogenously" (Kerali, 2000:11).

Historical perspective

In the case of rural roads in developing countries, the World Bank took the lead by producing a "road project appraisal model" in 1968. It involved a "highway design study", the Terms of Reference of which was produced by the World Bank, the Transport and Road Research Laboratory (TRRL) and the Laboratoire Central des Ponts et Chaussées (LCPC). The World Bank commissioned a second study, involving the Massachusetts Institute of Technology (MIT), with the objective of carrying out a literature survey and constructing a model based on available information. This resulted in the Highway Cost Model (HCM). Following this, the TRRL, in collaboration with the World Bank, did a major field study in Kenya to investigate the deterioration of paved and unpaved roads, including factors affecting vehicle operating cost (VOC) in a developing country. This led to the development of the first prototype version of RTIM (Road Transport Investment Model) by TRRL. In the meantime (1976), the World Bank funded further developments of HCM at MIT which led to the first version of the HDM (Highway Design and Maintenance Standards) model. This was followed by a number of further studies:

- The Caribbean study was undertaken by TRRL (1982), focusing on the effects of road geometry on vehicle operating costs.
- The India study was carried out by the Central Road Research Institute (CRRI), addressing operational problems of Indian roads in terms of narrow pavements and the large proportions of non-motorized transport.
- The Brazil study, funded by UNDP, focused on extending the validity of all of the model relationships.

The results of TRRL studies were incorporated in the RTIM2 model, whereas the World Bank consolidated research findings into the HDM-III model. Both these models, originally developed for mainframe computers, were subsequently converted to micro-computer models. RTIM2 was updated to RTIM3 in 1993, providing a user-friendly version of running on a spreadsheet. Regarding HDM-III, two further versions were produced in 1994, namely HDM-Q (incorporating the effects of traffic congestion) and HDM Manager (providing a menu-driven front end to HDM-III).

The current version of HDM (HDM-4, now renamed the Highway Development and Management model) was developed in response to a number of needs (Kerali, 2000:4), including:

- The need for "a fundamental redevelopment of the various models to incorporate a wider range of pavement and conditions of use, and to reflect modern computing practice and expectations" (Kerali, 2000:4).
- The need to update the technical relationships (regarding vehicle operating costs) to reflect the state-of-the-art.
- The need to apply the model in industrialized countries, which requires additional capabilities for modelling aspects such as traffic congestion effects, cold climate effects, a wider range of pavement types and structures, road safety, and environmental effects (e.g. energy consumption, traffic noise and vehicle emissions).

This historical perspective (Kerali, 2000:3-4), clearly shows how the focus of HDM has changed over time to reflect changing needs – for example, from an initial focus on pure "engineering issues" (e.g. road deterioration over time) to softer issues such as safety and environmental effects. This change in focus is also evident from improvements in Version 2 of HDM-4 (discussed below).

Model types in HDM-4

Based on the concept of "road life cycle", HDM-4 uses four sets of models for undertaking technical analysis (Kerali, 2000:20), as shown below. The first three models underline the initial "engineering" focus on road projects (the fourth model was added later):

- *Road deterioration model*, which predicts pavement deterioration for bituminous, concrete and unsealed roads. This is done by considering the consequence of impacts such as traffic loading, environmental weathering and inadequate drainage systems.
- *Road works effects model*, which simulates the impact of road works on pavement condition and determines the corresponding costs.
- *Road user effects model*, which calculates the cost of vehicle operation, road accidents and travel time cost.

- *Socio-economic and environmental effects model*, which determines the effects of vehicle emissions and energy consumption.

Data managers in HDM-4

The three analysis tools in HDM-4 (for analysis at the strategy, programme or project level) operate on data that are defined in one of four data managers (Kerali, 2000:20). *Road Network* defines the physical characteristics of road sections in a network or sub-network to be analysed. *Vehicle Fleet* defines the characteristics of the vehicle fleet operating on the road network to be analysed. *Road Works* defines maintenance and improvement standards, together with the associated unit costs, to be applied to the different road sections to be analysed. *HDM Configuration* defines the default data to be used in the applications.

Improvements in Version 2 of HDM-4

Improvements to HDM-4 Version 2.0 (relative to the previous version 1.3) fall into four areas: (a) new analysis tools; (b) usability; (c) connectivity with external systems; and (d) reporting. Improvements are described below (Kannemeyer, 2006).

New analysis tools

The following four tools have been added:

- *MCA* (key aspects of MCA are described in Chapter 3 of this thesis).
- *Sensitivity analysis* allows the user to investigate the impact of small variations in key parameters on analysis outcomes. Sensitivity factors can be specified for 18 key parameters (including unit costs, traffic levels and growth, vehicle use, and net benefits). Multiple sensitivity scenarios can be defined, each with a particular set of factors for the 18 key parameters.
- *The Budget Scenario Analysis* allows the user to investigate the impact of alternative budget levels and funding periods on network-level/strategic studies
- *Asset valuation* allows the user to estimate the financial and economic value of road assets as a function of the level of investment.

Usability

Usability improvements include the following aspects: calibration sets, complex intervention criteria / editor, traffic redesign, temporary exclusion of sections from study, alternatives interface, post-improvement maintenance standard, configuration, and improvement effects.

Connectivity with external systems

Connectivity with external systems involves the following: import validation, import wizard, import /export files in MS Access format, Rundata in MS Access format, calibration sets, and traffic redesign.

Reporting

Improved reporting involves four aspects: report management facilities, stand-alone report viewer, improved exporting of reports, and additional reports. Additional reports involve the following: energy balance, more input reports, sensitivity analysis, MCA, and budget scenario. The last three of these reports are intended to support the new analysis tools.

HDM-4 applications

HDM-4 facilitates decision making at three levels: strategy, programme and project levels.

Strategy level

Examples of analyses at the strategy level are (Kerali, 2000:13-14):

- *Forecasting:* This includes forecasts of funding requirements for specified target road maintenance standards; alternatively, forecasts of long-term network performance under varying funding levels.
- *Optimal allocation of funds:* This includes the optimal allocation of funds to defined budget heads (e.g. routine maintenance, periodic maintenance, new projects), and the optimal allocation of funds to sub-networks (e.g. functional road class or administrative region).
- *Policy studies:* This could involve aspects such as changes in axle load limit, pavement maintenance standards, energy balance, providing non-motorised transport, sustainable road network size, and pavement design standards.

Programme level

Analysis at the programme level “deals primarily with the prioritisation of a defined long list of candidate road projects into a one-year or multi-year work program under defined budget constraints” (Kerali, 2000:17).

Project level

Analysis at this level deals with the “evaluation of one or more road projects or investment options. The application analyses a road link or section with user-selected treatments, with associated costs and benefits, projected annually over the analysis period. Economic indicators are determined for the different investment options”. Projects may typically include “the maintenance and rehabilitation of existing roads, widening or geometric improvement schemes, pavement upgrading and new construction” (Kerali, 2000:19).

Linkage to road infrastructure management

HDM-4 can contribute to a number of management functions, such as road sector policies formulation, network needs assessment, programming of road expenditures and assessing of road projects (Schutte, 2008:35).

Setting appropriate standards

HDM-4 (at the strategy level) helps to set appropriate performance standards for the road network by determining the funding requirements for a defined network standard and, conversely, by indicating the resulting network standard for a given funding level. The results obtained enable the agency to plan for sufficient funding, or alternatively, to indicate the consequences of insufficient funding.

Asset preservation

HDM-4 (at all levels, in particular at the programme level) assists in preserving the current road network by identifying appropriate actions to maintain and preserve the network, for instance by identifying optimal combinations of road sections to be earmarked for maintenance and improvement, involving one-year or multiple year work programmes under conditions of budget constraints.

Appraisal and ranking of investment options

HDM-4 (at the project level) ensures that an investment in the road network is economically justified, by ensuring that discounted benefits exceed (or are at least equal to) discounted costs over the economic life of the project, and that total transport cost is minimized.

Factors affecting application

HDM-4 uses a wide spectrum of input data at a very detailed/sophisticated level. This very fact may limit its application in certain cases (Schutte, 2008:36). Local data have to be

customized to HDM-4 formats, for example road user data, road and pavement data, traffic data, unit cost data and economic data. Default values in HDM-4 also have to be calibrated for a given country, in particular the Road User Effects model and the Road Deterioration and Maintenance Effects models. Data collection and model calibration are time consuming and costly, constituting limiting factors in the application of HDM-4.

2.4.4 RED

Scope and objective

RED was developed as an economic evaluation tool for low volume rural roads (defined as roads carrying between 50 and 300 vehicles per day). Low volume roads are further characterized by a high degree of uncertainty regarding traffic volumes, road condition, and future maintenance in the case of unpaved roads; periods with disrupted passability; levels of service and corresponding road user costs that are affected not only by road roughness; a high potential to influence economic development; and beneficiaries other than motorized road users (Archondo-Callao, 1999:1). HDM-4 is not suited for this type of road for the following reasons: (a) it is not customized for unpaved roads (low volume roads are often unpaved); (b) it does not capture all the benefits associated with low volume roads; and (c) it requires input data that are impractical to collect for vast networks with low traffic (e.g. surface layers material properties and refined traffic data). For the appraisal of very low volume roads (i.e. lower than 50 vehicles per day), neither HDM-4 nor RED is therefore suitable, and multiple criteria analysis or cost-effectiveness analysis is recommended.

RED uses a consumer surplus approach, measuring benefits as reduced transport cost, as opposed to a producer surplus approach which measures the value added or generated benefits to productive users in the project zone of influence (Archondo-Callao, 2004:1). To accommodate the potential of low volume roads to influence economic development (see above), RED evaluates benefits for four traffic types: normal traffic, generated traffic, diverted traffic and induced traffic (traffic due to local economic development) (Archondo-Callao, 2004:8). Users have the option to include other (“exogenous”) impacts such as those associated with non-motorized traffic, social delivery and the environment.

Linkage to HDM-4

RED constitutes a simplified version of HDM-4. Although it uses the HDM-III Vehicle Operating Costs Module to define the relationship between motorized vehicle operating costs and speeds to road roughness (or the HDM-4 Vehicle Operating Costs Module to define the

same in the case of motorized and non-motorized vehicles), it incorporates the concept of *average levels of service* during the analysis period. This means that the road deterioration equations of the HDM models are not used – a fact deemed reasonable for the following reasons: (a) difficulty in measuring or estimating the current roughness of unpaved roads; (b) seasonal changes in road condition and passability; (c) difficulty in determining the past and/or future grading frequencies; (d) cyclical nature of the road condition under a defined maintenance policy; and (e) convenience of defining levels of service for low-volume roads with parameters other than average annual roughness and gravel thickness (Archondo-Callao, 2004:2-3). As a consequence, RED is able to (Archondo-Callao, 2004:1-2):

- "Reduce the input requirements for low-volume roads.
- Take into account the higher uncertainty related to the input requirements.
- Clearly state the assumptions made, particularly on the road condition assessment and the economic development forecast (induced traffic).
- Compute internally the generated traffic due to decrease in transport costs based on a defined price elasticity of demand.
- Quantify the economic costs associated with the days per year when the passage of vehicles is further disrupted by a highly deteriorated road condition.
- Use alternative parameters to road roughness to define the level of service of low volume roads (vehicle speeds and passability).
- Allow for the consideration in the analysis of road safety improvements.
- Include in the analysis other benefits (or costs) such as those related to non-motorized traffic, social service delivery and environmental impacts.
- Raise questions in non-traditional ways; for example, instead of asking what is the economic return of an investment, one could ask for the maximum economically justified investment for a proposed change in level of service, with additional investments being justified by other social impacts.
- Present the results with sensitivity, switching values and stochastic risk analyses.
- Have the evaluation model on a spreadsheet, such as Excel, in order to capitalize on built-in features and tools such as goal seek, scenarios, solver, data analysis, and additional analytical add-ins".

Software

Software consists of a series of Excel 2000 workbooks for input worksheets, output worksheets and support worksheets. Table 2-5 lists the various Excel 5.0 workbooks that constitute the RED model. As shown, RED can be used for a single road or a network of road sections. It also includes a module for risk analysis.

Table 2-5: Workbooks constituting the RED model

Workbook filename	RED module	Purpose
RED - Main (version 3.2).XLS	Main economic evaluation module	Perform the economic evaluation of one road
RED - HDM-III VOC (version 3.2).XLS	HDM-III vehicle operating cost module	Define the relationship between motorized vehicles' operating costs and speeds to road roughness, for a particular country, using HDM-III relationships
RED - HDM-4 VOC (version 3.2).XLS	HDM-4 vehicle operating cost module	Define the relationship between motorized and non-motorized vehicles' operating costs and speeds to road roughness, for a particular country, using HDM-4 relationships
RED - RISK (version 3.2).XLS	Risk analysis module	Perform risk analysis using triangular distributions for the main inputs
RED - Program (version 3.2).XLS	Programme evaluation module	Perform the economic evaluation of a network of roads sections or road classes

Source: Archondo-Callao (2004:3).

2.5 CBA: Results from *ex-post* evaluations

2.5.1 Background

The importance of *ex post* evaluations is evident from the introduction in Part 1 to the "Austroads Guide to Project Evaluation", where it is stated that the eight parts of the Guide

"offer guidance to practitioners seeking advice for 'beyond the standard benefit-cost analysis (BCA) or multi-criteria analysis (MCA)' evaluations, that is, project risk assessment, the national and regional impacts of projects, distributional (equity) effects of projects, and project post-evaluation analysis" (Austroads, 2005a:1). The post-completion evaluation of projects constitutes an important feedback mechanism. In particular, it provides information regarding the following (Austroads, 2005f:2): (a) how effectively stated objectives were met; (b) how effective the project evaluation methods were; and (c) how efficient the project implementation process was. The learning that takes place from *ex-post* evaluations may therefore help "to reduce the risk of pursuing projects with a low probability of success at significant cost to the community" (Austroads, 2005f:13).

The results of the *ex post* evaluation of a number of major projects from around the globe in the fields of transport, telecommunication and energy networks were documented by Flyvbjerg, Bruzelius and Rothengatter (2003). Based on hard evidence, "project failure" (defined as actual project performance falling short of predicted performance) was shown in most (if not all) cases. As a consequence, Flyvbjerg *et al*. refer to the "megaproject paradox" – the phenomenal increase in these projects around the globe in terms of magnitude, frequency and geographical spread, despite their poor performance. A number of reasons are cited for this. These so-called *symptoms* of project failure present themselves in a number of ways: as (a) cost overruns, (b) over-optimistic demand predictions, (c) the fact that the extent and magnitude of actual environmental impacts are often very different from predicted forecasts, and (d) the fact that regional, national and international development effects often do not materialize or are too diffuse to be detected. Based on the analysis, these authors highlight *causes* of the "megaproject paradox", as well as a number of *cures* to address this. These (*causes* and *cures*) serve as valuable pointers regarding the development and application of an MCDM strategy for CoT.

Flyvbjerg *et al*. (2003:2-3) argue that these multi-billion dollar megaprojects are a global phenomenon; they are built in an attempt to promote a "zero-friction society" in that the focus is on overcoming constraints imposed by distance. The sociologist Zygmunt Bauman concurs, talking of the "great war of independence from space", and describes the new mobility "as the most powerful and most coveted stratifying factor in contemporary society" (Flyvbjerg *et al*., 2003:2). Various authors agree with this view: "Paul Virilio speaks of the 'end of geography' while others talk of the 'death of distance'. Bill Gates …. has dubbed the

phenomenon ‘frictionless capitalism’ and sees it as a novel stage in capitalist evolution” (Flyvbjerg *et al*., 2003:2).

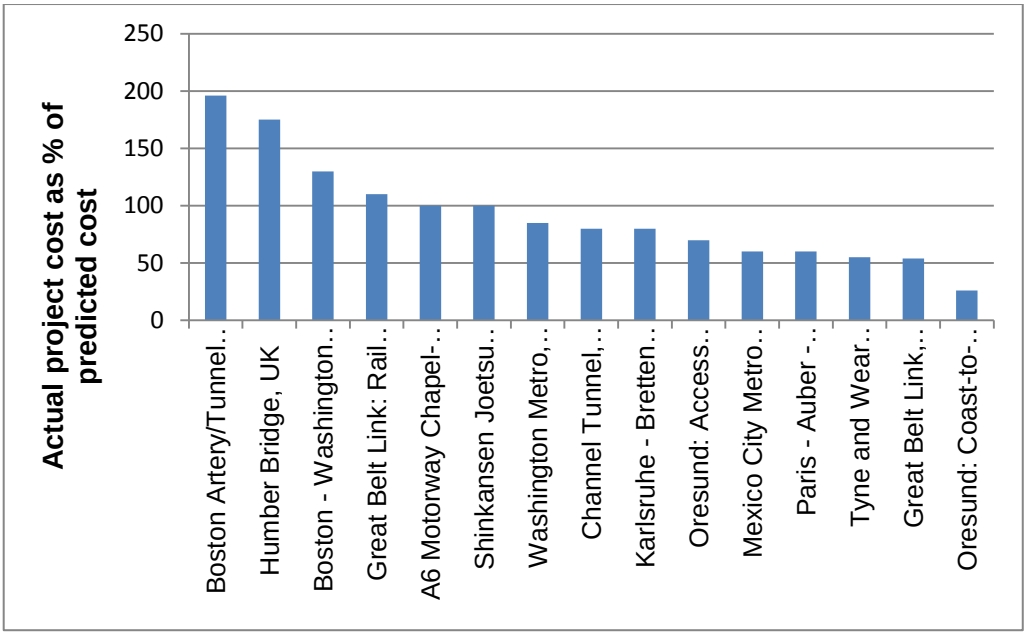
Findings of the *ex-post* evaluations of megaprojects are based on an analysis of a “sample” of projects that had been recently undertaken (Flyvberg *et al*., 2003:8). Links of the so-called Trans-European Transport Network, sponsored by the European Union and national governments, form the core of the analysis. They are:

- The Channel Tunnel (Chunnel) opened in 1994; it links France and the UK and is the longest underwater rail tunnel in Europe.
- The Great Belt Link opened in 1997-98; it connects East Denmark with continental Europe and includes the longest suspension bridge in Europe plus the second longest underwater rail tunnel.
- The Oresund Link between Sweden and Denmark opened in 2000; it connects Scandinavia with continental Europe.

The analysis was supplemented by information from a number of other major projects.

2.5.2 Cost overruns

The underestimation of project cost seems to be a general feature, evidenced in a large number of cases. The results presented for 15 cases are therefore by no means exhaustive. Figure 2-5 shows cost overruns (actual cost relative to predicted cost) for the Trans-European Transport Network megaprojects (with elements of the Great Belt Link and the Oresund Link shown separately) and a number of other projects, ranked from highest (cost overrun of 196 percent) to lowest (cost overrun of 26 percent). In 14 of the 15 cases, cost overrun is more than 50 percent. In almost half the cases cost overruns exceed 100 percent.



Source: Flyvberg et al., 2003:14 (Table II.i).

Figure 2-5: Construction cost overruns in large transport projects

A number of studies specifically involve a comparison of forecast versus actual costs (Flyvbjerg *et al*., 2003:15):

- Study by the Auditor-General of Sweden.
- Study by the US Department of Transportation.
- Study by the Transport and Road Research Laboratory of the UK.
- Study by the Aalborg University in Denmark.

Of these, the fourth study was the most comprehensive. It involved a sample of 258 projects with a total value of approximately USD90 billion (1995 prices) (Flyvberg *et al*., 2003:15). It was the first study of this type which allowed statistically significant conclusions to be made. It involved the whole spectrum of TI projects, namely bridges, tunnels, highways, freeways, high-speed rail, urban rail and conventional (inter-urban) rail, located in 20 countries on five continents, for both developed and developing nations. Projects included in the sample were completed between 1927 and 1998. Older projects were included to determine whether any learning over time has taken place. In the analysis, the 258 projects were grouped according to mode (rail, fixed links and road). Key statistics are given below.

Table 2-6: Analysis of results from the Aalborg study

Type of project	Number of observations	Actual cost as % of predicted cost				
		Average value (Ave)	Minimum value	Maximum value	Standard deviation (SD)	SD/Ave
Rail:	58	45	-50	190	38	0.84
Fixed links:	33	34	-70	290	62	1.82
Road:	167	20	-30	230	39	1.95
Total:	258	NA	-70	290	NA	NA

Source: Flyvberg et al. (2003:15-17).

The results are summarized as follows (Flyvbjerg *et al*., 2003:15-16):

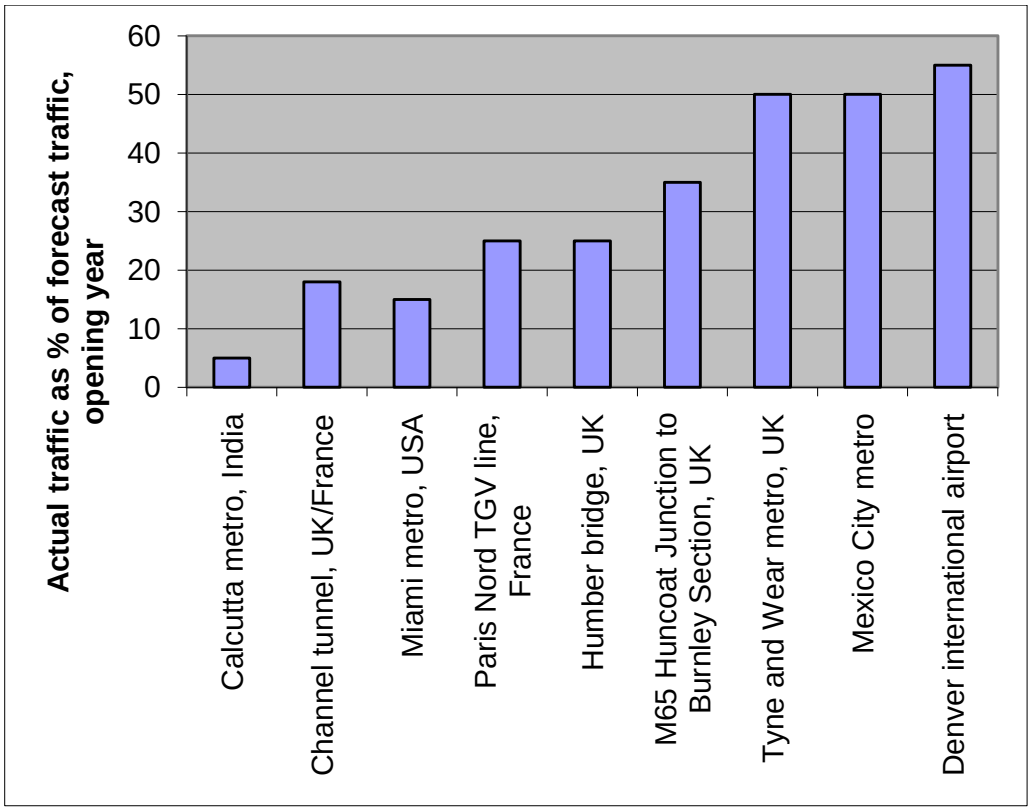
- Infrastructure cost was underestimated in nine out of ten cases.
- Rail projects are most prone to cost overruns (45 percent on average), followed by fixed links (34 percent) and road projects (20 percent). For all projects types, actual cost is 28 percent higher than estimated cost.
- Cost overrun appears to be more pronounced in developing nations than in North America and Europe (data available for rail only).
- Cost underestimation has not decreased over the past seventy years, implying that no learning has taken place.
- The underestimation of cost cannot be explained by error; it seems to be best explained by "strategic misrepresentation", in an attempt to get projects approved.

Flyvbjerg *et al*. (2003:12) therefore cite a *lack of realism* in estimating initial project cost state as the main cause of cost overruns. This opens the door for unplanned cost increases as a result of a number of things that could "go wrong" during the construction phase: unplanned delays, increased contingencies since they were set too low in the first place, changes in project specification and design, exchange rates fluctuations, unforeseen geological

outcomes, quantity and price changes, increased expropriation costs, increased safety and environmental demands, and cost increases due to technological innovation.

2.5.3 Overoptimistic demand forecasts

The accuracy of demand predictions was investigated by analyzing a number of major projects from around the globe as well as a number of specific studies, such as those by the German Federal Ministry for Transport, the UK Department of Transport, UK National Audit Office, US Department of Transportation, UK Transport and Road Research Laboratory, and the Aalborg University in Denmark. Figure 2-6 shows actual traffic as a percentage of predicted traffic in the opening year for a number of projects that experience serious revenue problems.



Source: Table III.i in Flyvberg et al. (2003:25).

Figure 2-6: Over-prediction of demand for projects with revenue problems

Another important finding of the analyses was the differences in prediction failures between market segments, such as road passengers, road freight, rail passengers and rail freight. The Aalborg study (see Table 2-7), for example, based on 210 road and rail projects, confirmed that rail projects are more prone to prediction failures than road projects. On

average, actual traffic was 39 percent lower than forecast traffic for rail. In the case of road projects, actual traffic was 9 percent higher on average than forecast traffic.

Table 2-7: Forecast prediction failures: Summary of results from the Aalborg study

Type of project	Number of observations	Actual demand as % of predicted demand				
		Average value (Ave)	Minimum value	Maximum value	Standard deviation (SD)	SD/Ave
Rail	27	-39	-90	150	52	1.33
Road	183	9	-70	170	44	4.89
Total	210	NA	-90	170	NA	NA

Source: Flyvberg et al. (2003:26-28).

There are various reasons for overoptimistic demand predictions (Flyvbjerg *et al*., 2003:28-31):

Methodology applied: In many cases, the modelling approach *per se* has inherent weaknesses. This is particularly true in the case of freight transport. An example is the rail freight in Europe, where the railways have lost market share for reasons hard to predict or model, such as the inflexibility of railway companies, lack of harmonization in transport markets and the decrease of the relative cost of road transport. The inability to model the dynamics impacting on future demand will inevitably lead to unreliable results, notwithstanding the fact that sophisticated tools are being used for prediction purposes, such as multivariate logit or probit techniques within scenario models.

Poor database: Flyvbjerg *et al*. (2003:29) call this a "more important reason for prediction failures". This is because in many countries there simply is no continuous generation of data, making it difficult, if not impossible, to calibrate demand models. In such cases techniques such as the revealed preference or stated preference analysis may not suffice, given the fact that actual behaviour often deviates from the results of these techniques.

Discontinuous behaviour and the influence of complementary factors: This involves "surprises" such as the fact that the behaviour of people often remains stable in spite of

changes in “influencing factors” such as travel time or cost, but is then changed through the introduction of a number of “complementary factors” that cannot be modelled (e.g. the attractiveness of stations, shopping facilities, user safety).

Unexpected changes in exogenous factors: Many exogenous factors simply cannot be accommodated in modelling and scenario techniques. Examples are the breakdown of the Communist regimes and the change in the East-West relationships in Europe, and the oil crises in 1973 and 1979.

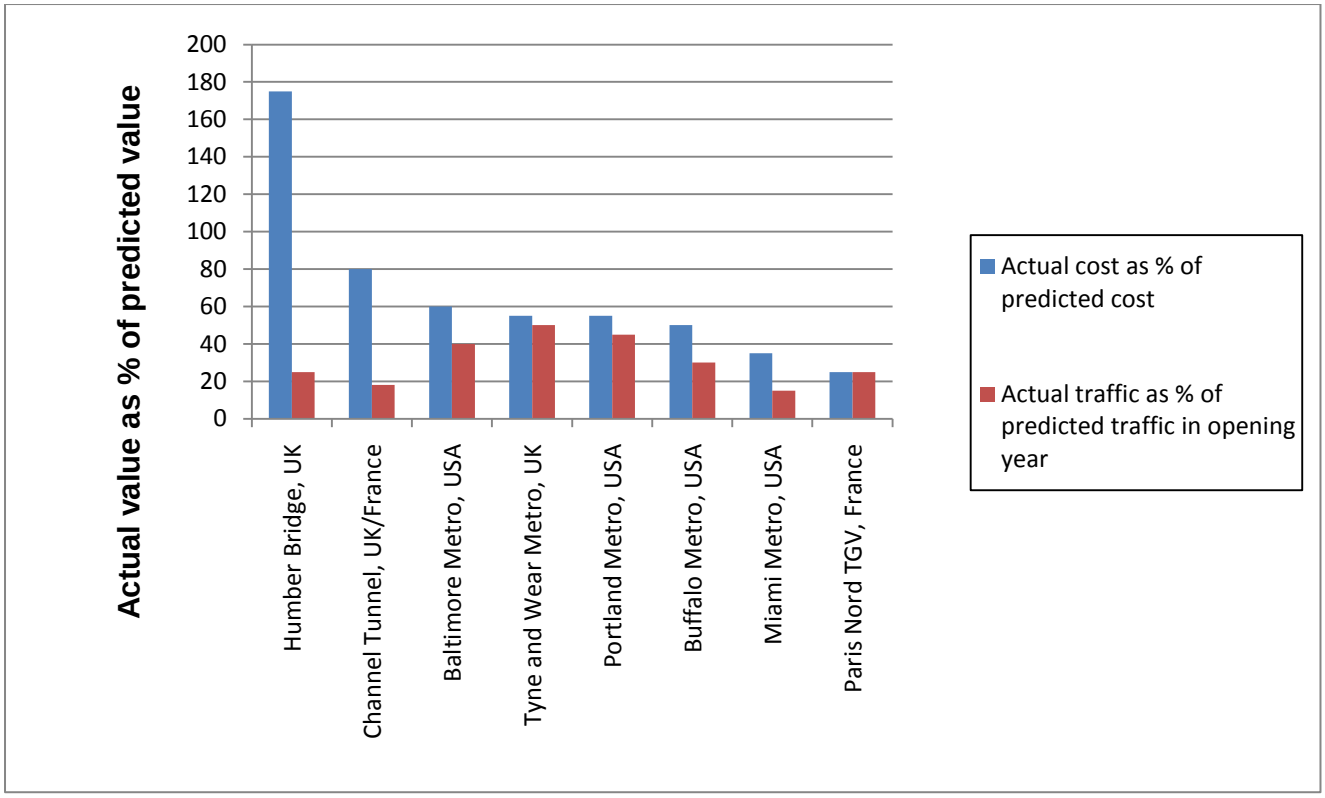
Unexpected political activities or missing realization of complementary policies: This is particularly important in the case of the scenario technique of forecasting, where scenarios are in part determined by political actions. The problem arises when stated political preferences differ from actual political activities, for example taxation policy and regulations. Another example is complementary activities that do not get implemented, such as access roads, urban/spatial development or international agreements.

Implicit appraisal bias of the consultant: This involves the integration by consultants of “political wishes” into their forecasting framework. Although sophisticated prediction models seem objective and hard to manipulate, this can in fact be done relatively easily in order to obtain “plausible” results. It is also possible that problems may arise through the calibration of the models by consultants with inappropriate data, for example data from their home countries that may not necessarily apply to the project case.

Appraisal bias of the project promoter: Since the project promoter has an even more direct interest in the project than the consultant, this may result in a more pronounced bias regarding future traffic demand.

2.5.4 Combined effect of incorrect cost and demand predictions

Project cost and anticipated demand are two critical variables in determining project viability, both from an economic and financial perspective. Figure 2-7 offers examples of projects that “went wrong” in terms of both these variables. The Humber Bridge project was most severely penalized by demonstrating the highest cost overrun and one of the lowest actual demands (as a percentage of predicted demand in the opening year).



Source: Table IV.ii in Flyvberg et al. (2003:42).

Figure 2-7: Combined effect of cost overruns and demand prediction failures

2.5.5 Inaccurate prediction of environmental impacts

Flyvbjerg *et al.* (2003:49) found that environmental impacts are rarely audited on an *ex post* basis. As a result, not much learning has taken place in this area. According to Wood, Dipper and Jones (in Flyvbjerg *et al*., 2003:63), "the main obstacles to learning about actual environmental risks are the absence of mandatory, institutionalised requirements for post-auditing and indifference among authorities, developers and the general public to such audits". This lack of learning has led to the situation that the extent and magnitude of actual environmental impacts are often very different from predicted impacts (Flyvbjerg *et al*., 2003:136). Three reasons are given for the "presumed deficiencies" of environmental impact analysis (Flyvbjerg *et al*., 2003:49): (a) inaccurate predictions; (b) the narrow scope of impact studies and their time horizon; and (c) an "inadequate organization, scheduling and institutional integration of the environmental impact assessment process in the overall decision-making process".

This view is echoed by Buckley, in Flyvbjerg *et al*. (2003:55), who found that "the average accuracy of quantified, critical, testable predictions in environmental impact statements was

only 44 percent". Environmental auditing and management is described as an inexact science without a "single truth" – "what is presented as reality by one set of experts is often a social construct that can be deconstructed and reconstructed by other experts" (Flyvbjerg *et al*., 2003:61). Consequently, "the most pertinent issue regarding environmental impacts may be, not to predict impacts accurately *ex ante*, but to define appropriate environmental goals and then set up the organisation that can effectively adapt and audit the project to achieve the goals" (Flyvbjerg *et al*., 2003:57).

2.5.6 Overoptimistic prediction of development impacts

The over-optimistic prediction of development impacts manifests itself at all levels: regional, national and international. Flyvbjerg *et al.* (2003:65) claim that there has been a "resurgence of interest in the impact of infrastructure on regional development and economic growth" in recent years. Often, therefore, this is heralded as one of the reasons for committing public funds to planned projects. Such claims should be approached with caution: "The substantial regional, national and sometimes international development effects commonly claimed by project promoters typically do not materialise, or they are so diffuse that researchers cannot detect them" (Flyvbjerg *et al*., 2003:136).

According to theory, infrastructure is seen as an input to the production of a transport service which, in its turn, constitutes an input into a final product or service. Hence the generalized cost of transport is reduced, having effects in the short term, the medium term and the long term. In the short term, it will increase the demand of that product and service. This will also increase the profit made by businesses. The medium term effect will be a change in spatial economic interactions. The long term effects (sustained economic growth, relocation and expansion effects in certain areas) will depend on the competitive forces that are generated. In general, however, longer term effects are more difficult to predict. In practice, therefore, it would be difficult for traditional cost-benefit analysis to capture these impacts, although this is possible, at least in theory.

Preliminary evidence from the three European megaprojects (Channel Tunnel, Great Belt Link and the Oresund Link) indicates that economic and regional growth claims may in fact be overstated. Flyvbjerg *et al*. (2003:68) state that "even for a giant investment such as the Channel Tunnel, five years after the tunnel's opening there were very few and very small impacts on the wider economy. The potential impacts on the directly affected regions were found to be mainly negative". Regarding the Oresund Link, it is "currently best seen as a

grand social experiment in cross-national and cross-cultural integration via transport infrastructure development" (Flyvbjerg *et al*., 2003:70).

The main reason for the "failure" of these megaprojects to live up to their expectations in modern economies in respect of economic and regional growth is the fact that transport cost constitutes only a marginal part of the final price of most goods and services. Consequently, substantial positive effects are limited to the following situations (Flyvbjerg *et al*., 2003:72): (a) in cases where there are severe capacity problems in a network; (b) in urban areas when new capacity would result in substantial savings in transport cost; and (c) situations where investments in infrastructure is accompanied by investment in social capital.

For the purposes of this study, it could be argued that, since South Africa is not totally a modern (developed) economy, transport cost constitutes more than merely a marginal part of the final price of most goods and services; also that the three situations sketched in the previous paragraph do indeed present themselves in many cases. This of course also means that investment in transport infrastructure generally has a greater potential for positive development effects in developing economies such as South Africa than in developed economies.

2.6 General equilibrium analysis

2.6.1 Scope and objective

General equilibrium analysis can be viewed as an extension of and supplement to a partial equilibrium analysis (CBA) in the case of large infrastructure projects and policy interventions under certain conditions.

General equilibrium analysis addresses the simultaneous equilibrium in all markets; in doing this, it also explores interactions between them. In contrast, a partial equilibrium analysis focuses on equilibrium in a single market (in an economics context, defined as the state when supply equals demand at a given price). General equilibrium, though, is not a precondition for macro-economic equilibrium. Although general equilibrium in all markets and industries will also automatically ensure macro-economic equilibrium (i.e. the state where total output (GDP) = total income (Y) = total expenditure (C+I+G+(X-Z))), the reverse is not true. In other words, general equilibrium implies macro-economic equilibrium, but the latter does not imply the former (Brink, 2002:8,12-13).

In a project appraisal context, (narrow) CBA focuses on “local” (direct, initial, or first round) impacts – that is, on the efficiency of a project in a *micro-economic sense*. As such, it constitutes a partial equilibrium (PE) analysis, providing a *single measure* of project worth (considering that NPV, B/C ratio, etc are merely variations of the same measure). By this definition, therefore, a broad CBA – as with a narrow CBA – also constitutes a PE type analysis. General equilibrium (GE) analysis, on the other hand, uses economy-wide (e.g. national, provincial, regional) mathematical tools such as Computable General Equilibrium (CGE) models to predict economy-wide impacts, for example the behaviour of industries (producers), consumers and governments in response to the project. Other GE tools include Input/Output (I/O) models, and the Social Accounting Matrix (SAM). MOTE (acronym for **M**odel **O**f **T**ransport and the **E**conomy), constitutes a South African version of the I/O model, but adapted to facilitate the economic analysis of transport projects. GE analysis thus constitutes the evaluation of a project in a *macro-economic sense*. A large infrastructure project in the transport sector, for example, may impact on several other sectors of the economy (e.g. agriculture, construction, manufacturing, mining, and tourism), both within and outside the area of jurisdiction of the model (Austroads, 2005d:2). It thus follows that macro-economic modelling can supplement CBA by providing useful additional information to decision makers by examining broader, economy-wide impacts such as private consumption, investment, exports, imports, inflation, total GDP and GDP on an industry-by-industry basis (Austroads, 2005d:19). For the purposes of this study, it is important to note that by doing this it addresses a number of issues that are important to the decision maker, but does not provide a clear accept/reject rule. Pienaar (2008:2,9-10), for example, distinguishes between a CBA which is concerned with the efficiency of a project in a micro-economic sense and a regional (economic) income analysis (also called regional developmental economic evaluation) focusing on the general economic impacts that a project may have on non-road users, in particular an increase of GDP.

Mullins *et al*. (2007:11) also emphasize the importance of examining welfare indicators: “It is important to remember that CBA is not designed to evaluate macroeconomic performance. As noted earlier where standard assumptions regarding CBA, such as full employment of resources are non-existent, measuring the secondary effects may be admissible as additional welfare indicators. In this regard, projects that have regional development goals in rural areas of developing countries where underemployment may exist may wish to consider the wider economic impacts of the projects. Of course, as the objective of the project – i.e.

regional development – has an inherent distributional objective, models for the evaluation of regional impacts should be considered as a tool in project planning, monitoring and evaluation in any event".

2.6.2 Principles and structure

Economy-wide models can be divided into two groups. *Econometric models* comprise sets of mathematical/statistical relationships to obtain key summary parameters (such as elasticities) which describe the underlying structure of the economy. These parameters and forecasts generated by the econometric models constitute important inputs to I/O type models. *I/O based models* are "simulate-type" models, involving a disaggregation of the national accounts of a country. They model the impacts of projects and policies on the flow of inputs and outputs in the economy, given the inter-sector nature of transport interactions within the economy. The I/O model has led to the development of a number of other economy-wide models, such as the Computable General Equilibrium (CGE) model (Austroads, 2005d:8). They range from static models to dynamic models – the latter modelling how a project will impact on the economy over time – but in both cases modelling the impacts of a project on the economy on a "with and without" basis (Austroads, 2005d:11).

The essence of GE analysis is summarized in the box below (Austroads, 2005d:11).

> At the core of the GE analysis model is a set of equations describing the behaviour of various economic agents (for example industries, consumers and governments) when faced with changes in key economic variables, for example, and most importantly, relative prices. Typically, consumers maximize utility subject to a budget constraint, and industries maximize revenues (or minimize costs) subject to their production functions (technologies). The core behavioural equations are supplemented with market clearing equations that equate supply and demand in all commodity and factor markets. For example market clearing equations ensure that: demand for domestically-produced commodities equals their supply; demand for labour of each type across all industries is satisfied; and demand for capital in each industry is equal to supply (IAC, 1987).
>
> The model is calibrated from a numerical database, the central core of which is a set of input-output (I-O) tables (of national accounts) showing, for a given year, the flows of primary (or intermediate) factors between groups and economic agents.
>
> To obtain a solution to the model, the model's equations are solved simultaneously.

However, GE models have more variables than equations; this means that the user must specify the values of some variables. This set of user-specified exogenous variables is referred to as the model's closure.

Closure plays an important role by creating the economic environment in which the policy scenario is set. In other words, the closure specifies some variables as exogenous to reflect various assumptions regarding the way economic agents behave, for example closure typically reflects assumptions about the government budget deficit, capital formation, wages and foreign currency prices.

I/O models

An I/O table is a summarized version of all transactions that took place between the main economic stakeholders in a particular year. The main feature of an I/O table is that it divides these economic transactions into the main sectors of the economy (agriculture, mining, etc) (Schutte, Masango and Mondlane, 2005:4). An I/O model thus shows the interdependence of sectors within an economy by calculating *multipliers* and *leakages*, with the former showing that the impact of a particular sector on the economy is larger than the value (volume) associated with that sector's output, and the latter indicating where economic impacts (e.g. revenues from a project), leak from one region or economy to another (Mullins *et al.*, 2007:10-11). The structure of an I/O table is shown in Figure 2-8 in terms of four types of transaction that take place in the economy (i.e. the demand (purchase) of intermediate and primary inputs, and the supply of intermediate and final outputs), which result in the four quadrants in this figure (Schutte *et al*., 2005:6-7).

Demand (right) Supply (below)		Intermediate demand (by sector)										Final demand (by type)					Total gross outputs
		Agriculture	Mining	Manufacturing	Electricity	Construction	Wholesale	Transport	Finance	Services	Other	Consumption	Government	Investment	Inventories	Exports	
Intermediate inputs (by sector)	Agriculture	***Quadrant I: Intermediate usage***										***Quandrant II: Final demand***					
	Mining																
	Manufacturing																
	Electricity																
	Construction																
	Wholesale																
	Transport																
	Finance																
	Services																
	Other																
Primary inputs (by type)	Wages	***Quandrant III: Primary inputs to production***										***Quandrant IV: Primary inputs to final demand***					
	Taxes																
	Surplus																
	Imports																
Total gross inputs																	

Source: Schutte et al. (2005:6).

Figure 2-8: Structure of the I-O Table

Quadrant I (the transactions table or transaction matrix) shows intermediate inputs that are intermediate outputs at the same time by economic sector.

Quadrant II shows the final demand for intermediate inputs by type, namely:

- C = final sales to households (i.e. private consumption expenditure).
- G = sales to the government.
- I = gross domestic fixed investment.
- S = changes in the inventories during the period covered by the table. (A negative figure would imply a decrease in total inventories.)
- E = exports.

Quadrant III shows primary inputs by type to production, namely:

- W = remuneration of employees.
- T = indirect tax-payments government (this is normally shown as a net figure, e.g. taxes minus subsidies).

- P = gross operating surplus before direct tax.
- M = intermediate imports.

Quadrant IV shows purchases/inputs by final consumers from primary sources.

MOTE (Model Of Transport and the Economy), developed by the CSIR, comprises an I/O model customized to meet the requirements of the economic analysis of transport projects in the South African environment. It involves the disaggregation of the transport sector (see Figure 2-8) into 11 subsectors along modal lines (Schutte *et al*., 2005:14-15). They are:

- Land transport, distinguishing between (a) freight (namely *rail*, *road*, "*other*" (e.g. pipelines), and (b) passengers (namely public transport *rail*, *bus* and *taxi*, and long distance *rail* and *road*).
- Sea transport.
- Air transport.
- Other.

Examples of the results obtained from an I/O analysis of a South African project (the Kei Mouth access road) are given in Table 2-8 and Table 2-9, in particular impacts on the national and the regional economy.

Table 2-8: Impact on the national economy (1991 rand values)

Item	Direct impact	Indirect impact	Total impact
Gross National Product (GNP)	R6 400 000	R10 236 080	R16 636 080
Balance of Payment (BOP)	Nil	-R3 361 880	-R3 361 880
Exchequer (tax)	R1 742 000	R1 918 350	R3 660 050
Employment (man years)	99	223	322

Source: Jordaan and Floor (1994:8-13).

Table 2-9: Impact on the regional economy (1991 rand values)

Item	Direct impact	Indirect impact	Total impact
Gross National Product (GNP)	R6 400 000	R2 779 700	R9 179 700
Balance of Trade (BOT)	Nil	-R9 270 390	-R9 270 390
Employment (man years)	99	56	155

Source: Jordaan and Floor (1994:8-13).

Limitations of an I/O approach stem from the basic assumptions of I/O analysis: “Input-output analysis proceeds from the theory of general equilibrium and is based on a simplified model of production, which must be derived empirically. The model is concerned only with production and is rigid in the sense that it does not take into account joint production (i.e. each industry produces only one homogeneous product or composite product with fixed proportions) and that all inputs are employed in fixed proportions, irrespective of the size of the output, i.e. the input-output relationships are linear.

This means that the model does not allow economies of scale in production or any choice between labour and capital-intensive production. The restrictions render the results of input-output analysis not really suitable for comparing the effects of road projects, because the comparison may not be valid when large and small projects are compared or the capital-labour ratios of the projects differ. Even if it is assumed that there are not economies of scale as the size of a road project increases, the fact that no substitution of capital for labour or vice versa is allowed, means that comparisons can be made only under rigid conditions” (Jordaan and Floor, 1994:8-14).

As shown in these tables, both positive and negative consequences are shown; this makes it difficult to weigh them up against each other. Linked to this is the fact that impacts are expressed in different units: “Even if those conditions are accepted, the difficulty arises that there is no acceptable method of comparing changes in the Gross National Product, for example, with employment or tax receipts. Some system of weighting is then needed to enable the significance of the results of the analysis to be understood, and it is doubtful whether an unequivocal weighting system can be devised” (Jordaan and Floor, 1994:8-14).

Finally, the risk of double counting should be noted: “For example, the direct benefits of the improvement of a road for users in the form of savings in time and vehicle operating costs will be reflected in increased economic activity, which will result in greater output, higher incomes and more employment. If the value of the savings in time and vehicle operation is taken into account to evaluate the project, it then amounts to double counting if the results of input-output analysis are also ascribed to the project. Thus input output analysis constitutes a substitute for, and not an appendage to, cost-benefit analysis”. The impact on overall or national growth is also important: a road project resulting in cost savings will improve the competitive advantage of the region in which the road is situated – this implies that “any gains in output, income and employment will thus not necessarily contribute to overall or national economic growth”, but merely to relative regional changes in output, income and employment (Jordaan and Floor, 1994:8-15).

Social Accounting Matrix (SAM)

A SAM builds on the I/O table and can be regarded as an extension thereof. “SAMs use a mathematically based matrix presentation to represent the flow of funds linked to demand, production and income within a national or regional economy. SAMs can be designed with a special emphasis on social rather than economic attributes (e.g. low income households) and, thereby, also provide information about equity and distribution issues” (Mullins *et al*., 2007:11).

Computable General Equilibrium (CGE) models

CGE models predict consumer and producer behaviour more realistically than I/O tables and SAMS. This is achieved by modelling their reactions to changes in market conditions such as price. “Yet their detailed breakdown of industries and commodities and regions are usually limited in order to achieve a workable model solution by approximation” (Mullins *et al*., 2007: 11).

Economic impact analysis

An economic impact analysis is defined as a “form of project analysis aimed at establishing the effect that a project will have on the structure of the economy, usually expressed in terms of employment and income broken down by economic sector” (Austroads, 2005b:59). According to De Brucker and Verbeke (2006:2), an economic impact analysis “assesses the direct contribution of projects to the creation of sustainable, new value added or to the non-elimination of existing value added. The project’s contribution to value added is assessed

explicitly, and this also holds for related effects such as sustainable back flow to government and creation of sustainable employment. These effects are calculated on the basis of input-output analysis". It is thus clear that an economic impact analysis constitutes an application (variation) of an economy-wide analysis.

Mullins *et al*. (2007:9) maintain that an "economic impact analysis examines the distribution and many secondary economic impacts and outcomes that traditionally fall outside the scope of CBA. An economic impact analysis does this by studying changes occurring across broadly defined sectors of the economy. The intent is to ascertain who gains and who loses as a result of the project, and by how much". Major categories of potential economic impacts examined in this type of analysis are as follows (Mullins *et al*., 2007:10):

- "Changes in economic growth and productivity: Negative impacts on regional or national productivity and economic growth can result if an investment project creates significant opportunity costs, such as the "crowding out" of investments. Alternatively, new outputs may improve the overall productivity of capital.
- Price impacts: Large projects may create a significant supply of outputs that may in turn stimulate shifts in supply or demand for related goods. During the operational life of a project, for example, irrigation water supplied by a dam may affect markets and prices for substitutes (such as water conservation equipment) and, for example, equipment for higher-value irrigated crops.
- Production and employment impacts: When a project's construction requires significant capital, workers and construction materials, this may create shortages in related markets for labour and other factors of production (i.e. land, capital).
- Changes in government revenues and expenditures: If a project is financed with public funds, this may require large fiscal outlays by the government that may in turn have repercussions on the money supply, inflation, and government indebtedness. Conversely, a project located in a depressed area may boost regional economies (through household and business incomes) and generate higher tax revenues for the government.
- International trade and competitiveness impacts: If a project is large enough to increase productivity and lower the cost of production at a national level, a country's exchange rate, export position, balance of payments, and international competitiveness may improve."

The economic evaluation of the proposed road between Gobabis and Grootfontein in Namibia constitutes an example of an economic impact analysis. In addition to conducting a CBA to determine the efficiency of the project, a "regional income analysis" was performed to determine the increase in GDP. This was accomplished by examining the one-off non-user benefits as represented by the multiplier effect, and the recurring non-user benefits emanating from the economic accelerator effect (Pienaar, 2008:9).

2.7 Spatial models

2.7.1 Context

In addition to *total* project impacts, the geographic distribution of impacts is also important. Two perspectives are relevant in this regard; firstly, the spatial distribution of local impacts (which is the focus of this study), and secondly, the spatial distribution of "external" (regional) impacts. Although the latter are not the focus of this study, important insights for developing an appraisal framework could be obtained from spatial models addressing external impacts.

Spatial economic analysis (modelling), for the purposes of this study, firstly involves the delineation (demarcation) of the (total) geographical area in which project impacts will be manifested. On the assumption that project impacts are not spread out evenly over this area, it further involves establishing how the "intensity" of impacts varies between the zones constituting the total area of impact. Given the likelihood that zones (regions) differ in terms of their socio-economic profiles, spatial analysis therefore allows decision makers to ensure that benefits "reach" identified target groups, such as lower income groups and, by doing that, address equity and distribution considerations and meet set policy objectives and criteria in this regard. This aspect is particularly important because a "pure Pareto" scenario in CBA does not address the objective of a fair distribution of positive project impacts between affected parties (and, by implication, between affected regions). Finally, Ubbels (2005:8) uses the term "spatial or geographical equity", meaning that individuals located in different regions or cities should be treated equally. For the purposes of this thesis, it is argued that this interpretation implies that equity objectives have already been met and that equity does not constitute an issue to be addressed any further. Clearly, this is not the case in the CoT study area.

This section focuses on current thinking in this area as manifested by a number of initiatives and models for doing this, in particular the scope, objective and challenges in each case.

The cases discussed below can be classified according to the dominant discipline involved, although a clear-cut distinction is not always possible: CGEurope, REMI and TREDIS constitute economic models; SASI, IASON (which built on SASI), and MEPLAN can be regarded as spatial planning models; and DELTA can be described as eclectic, building on, amongst others, urban and regional economics, geography, and sociology.

2.7.2 SASI project

Scope and objective

The SASI (short for Socio-economic And Spatial Impacts) project was undertaken for the European Commission between 1996 and 1999. It was coordinated by the Institute of Urban and Regional Research of the Technical University of Vienna (SRF), and carried out by the Institute of Spatial Planning at the University of Dortmund (IRPUD), and the Department of Town and Regional Planning at the University of Sheffield (TRP). SASI focuses exclusively on transport infrastructure (as opposed to, for example, health and education infrastructure), and models the effect of infrastructure investments and system improvements (in particular, system improvements resulting from such aspects as "better" road pricing policies, reduced border waiting times, and alternative toll systems) on socio-economic activities and developments in Europe. It focuses on the Trans-European Transport Networks (TETN), and includes road, rail and air transport. It is described as "a dynamic and recursive simulation model of socio-economic development of 201 regions in Europe" (Naude, Schutte and Maritz, 2003:70).

Model overview

SASI consists of six forecasting sub-models (Naude *et al*., 2003:71-73). The *European developments sub-model* captures a number of assumptions relating to the expected performance of the European economy, immigration and emigration levels across Europe's borders, transfer payments, and policy decisions on trans-European transport networks, the latter being modelled at a detailed level as this constitutes the focal point of the study. The *regional accessibility sub-model* calculates regional accessibility indicators, expressing the "locational" advantage of regions relative to other destinations in terms of travel time, travel cost or both. The *regional GDP sub-model* forecasts GDP by economic sector for each region as determined by its economic structure, labour force, endowment indicators and accessibility (the latter being addressed in the accessibility sub-model). The *regional employment sub-model* calculates employment per region by economic sector. The *regional*

population sub-model predicts population change per region as a result of natural change and migration. The *regional labour force sub-model* forecasts the labour force per region. Finally, a seventh sub-model uses the output of these forecasting sub-modules and calculates regional GDP per capita and regional unemployment (Naude *et al*., 2003:73). The interdependencies between the seven sub-models in SASI are depicted in Figure 2-9.

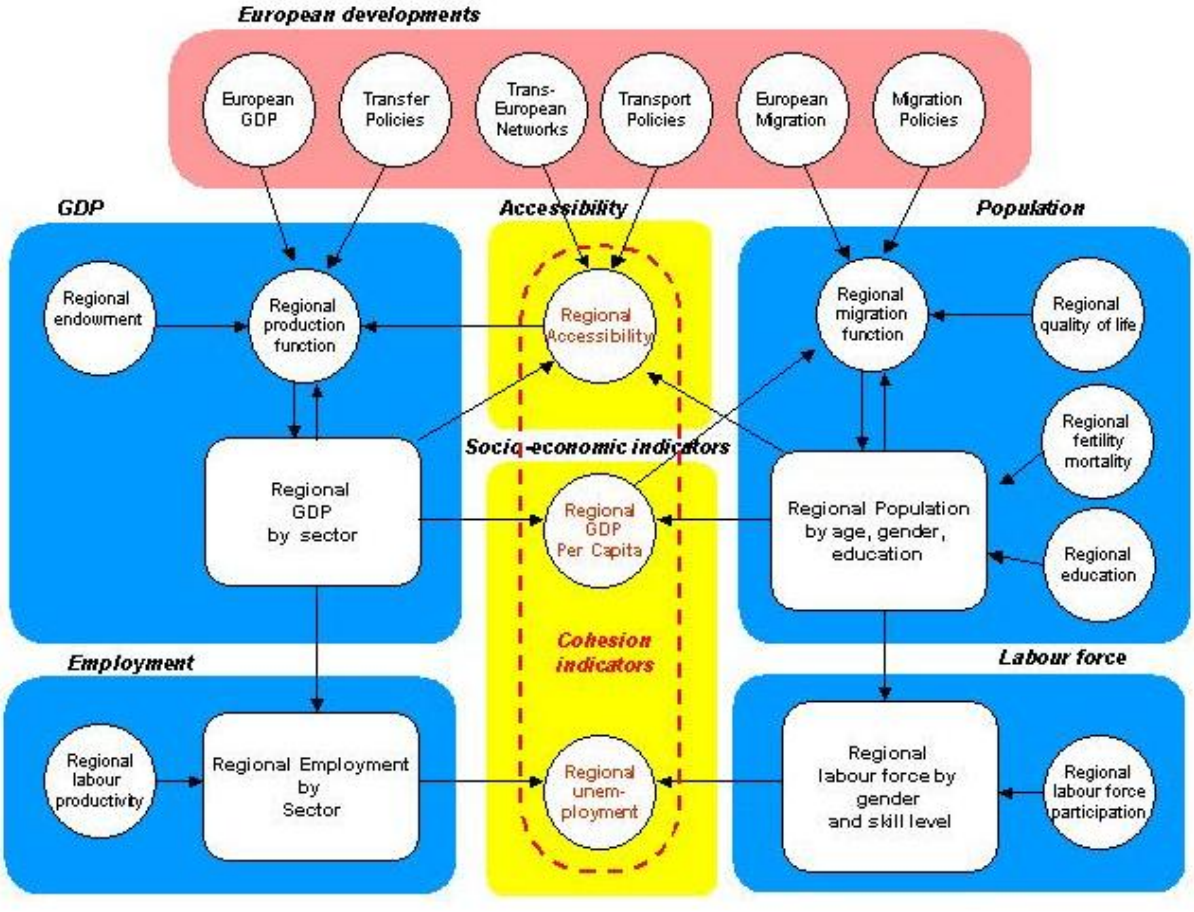


Figure 2-9: Overview of the SASI model structure

Source: Naude et al. (2003:71).

Model output

For each region, the models forecasts, in one-year increments up to the forecasting horizon, the following three parameters as a function of transport infrastructure investments and transport system improvements: relative accessibility, GDP per capita, and rate of unemployment (Naude *et al*., 2003:73-74).

Strengths and weaknesses

"A ... unique feature of the model is the way impacts of transport infrastructure investments and transport system improvements on regional production are modelled. The model uses regional production functions in which transport infrastructure is represented by accessibility. Accessibility is measured by spatially disaggregate accessibility indicators which take into account that accessibility within a region is not homogeneous but rapidly decreases with increasing distance from the nodes of the networks" (Naude *et al*., 2003:77). Weaknesses include extensive data requirements (potentially problematic in a South African context), and the fact that macro-economic multiplier effects of infrastructure investment are not calculated, and that labour productivity is linked to accessibility, but not to other factors in the production function (Naude *et al*., 2003:77-78).

Transferability

SASI was developed especially for application in a European context with its underlying system of regions, and assumptions and formulae. Using SASI in other contexts would require substantial technical assistance from the project team, as this would involve changing the program source code (Naude *et al*., 2003:78).

2.7.3 CGEurope model

Context, scope and objective

CGEurope is a spatial computable general equilibrium model that was developed at the University of Dresden. Its spatial extent, covering Europe and similar to that of the SASI model, is subdivided into 800 regions. Structural models such as CGE use data from different sources, including I/O tables and SAMs. "Transport enters the CGEurope model via the fact that interregional trade in the model is costly, with cost depending on the transport network as well as on international trade impediments to cross-border trade. Transport policies are modelled by varying these transport costs. As a response, prices as well as quantities in each industrial sector react to the cost changes" (Naude *et al*., 2003:78-79).

Special features

The model has a sub-system that incorporates economies of scale and product diversity, based on the latest developments in the discipline of economic geography (Naude *et al*., 2003:79). This is shown in Figure 2-10.

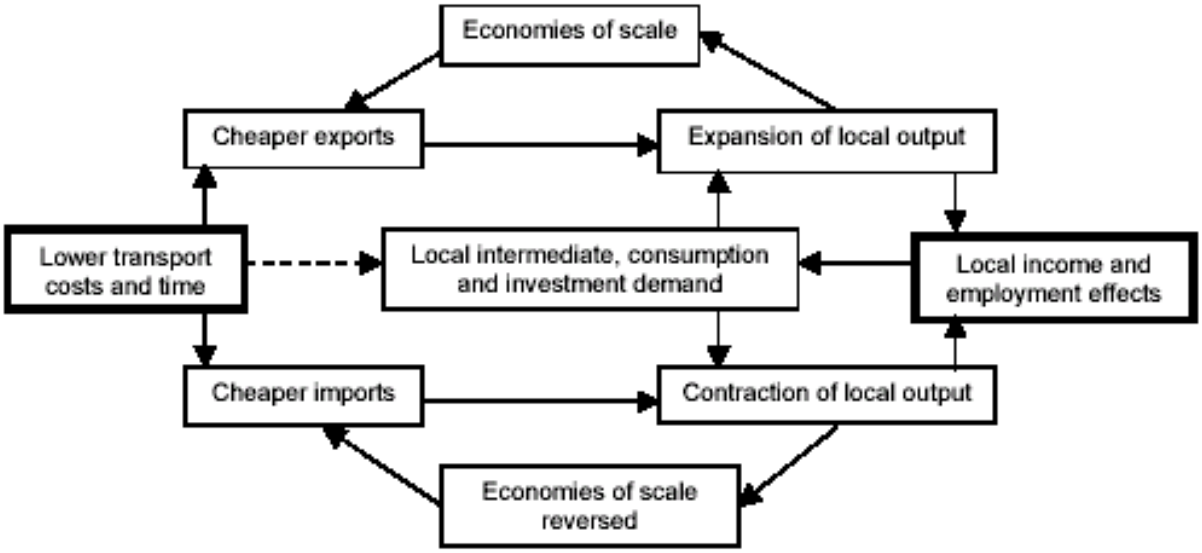


Figure 2-10: Sub-system for indicating changes through cost adjustments

Source: Naude et al. (2003:79).

As impacts are measured in the product and/or labour market, the model can quantify the distribution of welfare gains and losses (measured by the monetary equivalent of variations in household utility): “The focus of the CGEurope model is on evaluating welfare effects in a comparative static equilibrium analysis, which means comparing cases “with” and “without”, leaving everything else unchanged. The approach does not allow for long-term predictions of locational change. It studies welfare gains and losses, taking the spatial distribution of factors of production as a given” (Naude *et al*., 2003:79).

Transferability

Because of almost insurmountable input data problems, multi-regional CGE models are rare. In theory, therefore, the model is transferable but, in practice, it cannot be regarded as an “off-the-shelf” product (Naude *et al*., 2003:80).

2.7.4 IASON model

Context and objective

The IASON project, undertaken by the European Commission, involves the integrated appraisal of spatial economic and network effects (both short and long term) of transport

investment and policies in the European Union. It builds on the SASI project and the CGEurope model and, in fact, involves the refinement thereof. (Naude *et al*., 2003:80-81).

Key challenges

Research challenges can be grouped under two headings. Regarding *spatial economic modelling*, challenges are: (a) showing how the complex network of linkages between the labour, land, product and transport markets can be modelled; (b) reviewing the spatial scale at which models of different styles can be effective; (c) considering the role of dynamics in the modelling process (including reconciling the need to represent leads and lags with the aims of the appraisal); and (d) considering how to represent, at the most strategic level, the external (global) economic competitiveness of European producers as well as regional economic competitiveness within Europe, and the role of transport in all this. Regarding *assessment procedures*, challenges are: (a) demonstrating how models of various styles yield measures of economic efficiency benefits; (b) distinguishing between direct and indirect impacts; (c) considering how best to represent distributive impacts; and (d) recommending appraisal practices and approaches relevant to European transport policy contexts, enabling the broader policy agendas to be integrated more securely within appraisal practice (Naude *et al*., 2003:81).

2.7.5 DELTA model

Context and objective

The DELTA (derived from Development, Transition, Location, Employment and Area quality) model, developed by David Simmons Consultancy, has been applied globally in several instances. The DELTA sub-models incorporate current thinking in disciplines such as urban and regional economics, geography, and sociology. Although DELTA does not provide its own full transport modelling capability, it can be linked to external transport models (e.g. standard packages such as TRIPS or specialist packages such as START). By combining land use and transport models, DELTA enables users to study the effects on land use of both land use and transport policies. DELTA therefore claims to constitute a land-use/transport interaction (LUTI) model. The complete DELTA model also includes elements of demographic modelling, property market modelling, residential and employment location modelling, and labour market modelling (Naude *et al*., 2003:84).

Model overview

By combining a transport model and a land use model, DELTA predicts *changes in land use* in "increments" of time, as shown in Figure 2-11. "DELTA calculates all the information about households, population, employment and floor space, which the transport model requires to generate travel. DELTA thus replaces what is otherwise a process of preparing exogenous "planning data" input" (Naude *et al*., 2003:84-85).

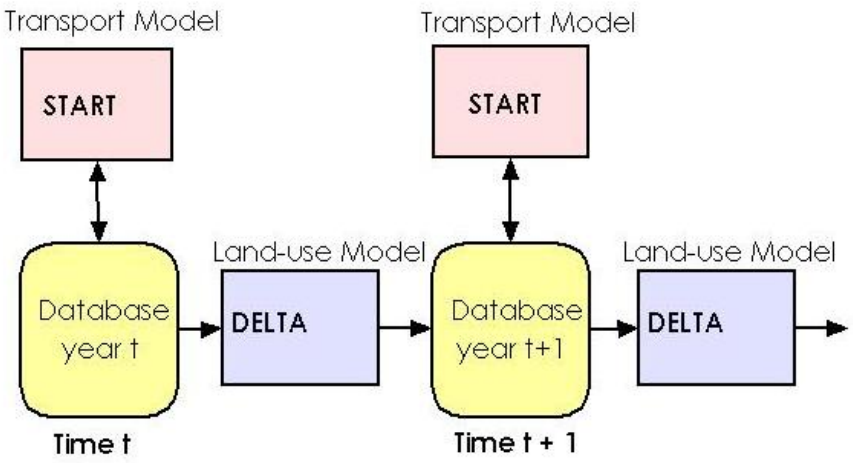


Figure 2-11: DELTA model sequence

Source: Naude et al. (2003:85).

DELTA operates on two spatial levels (either separately or interactively). The upper (regional) level models the economy and migration. The lower (urban) level models aspects such as location of households and employment, and the physical development of cities (Naude *et al*., 2003:91). DELTA has six urban and three regional sub-models, the configuration of which is shown in Figure 2-12.

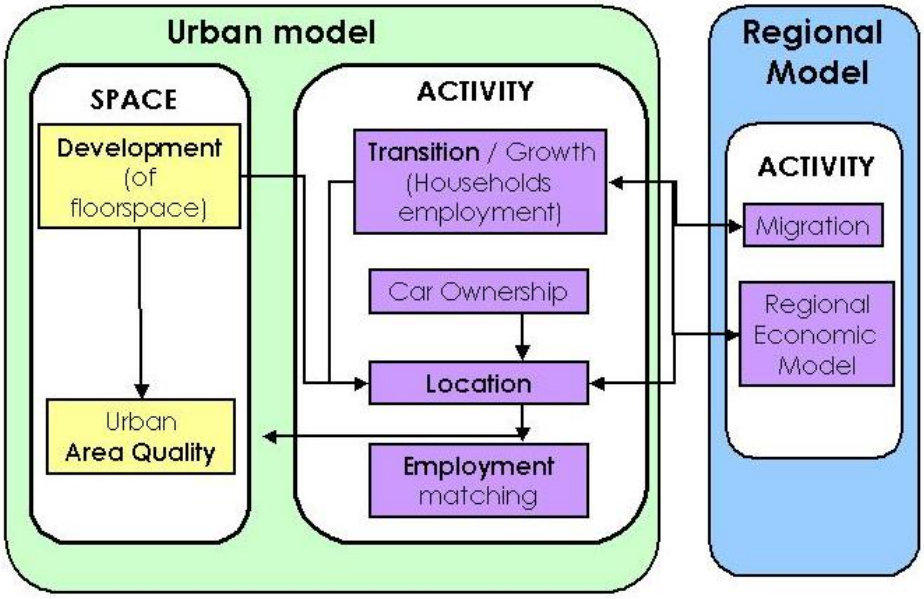


Figure 2-12: Urban and regional sub-models

Source: Naude et al. (2003:86).

The *urban sub-models* involves the following: (a) the development of buildings on land; (b) demographic change and economic growth (growth rates are either exogenously entered, or predicted in the regional sub-models); (c) changes in car ownership; (d) location and relocation of households and jobs; (e) employment and status changes; and (f) changes in the quality of urban areas. The *regional sub-model* involves the following: (a) migration between different labour market areas; (b) investment in the regional economy (affecting the future location of employment); and (c) production and trade in the regional economy (Naude *et al*., 2003:85-89).

2.7.6 MEPLAN

Context

MEPLAN, developed by Marcel Echenique and Partners, is described as a stochastic computer model for the analysis and evaluation of land use and transport policies in cities (or parts thereof), regions, and larger areas, by predicting the impacts of planning decisions (Naude *et al*., 2003:92).

Overview

A key feature of MEPLAN is it recognition of the interaction between land use and transport at different levels, as depicted in Figure 2-13.

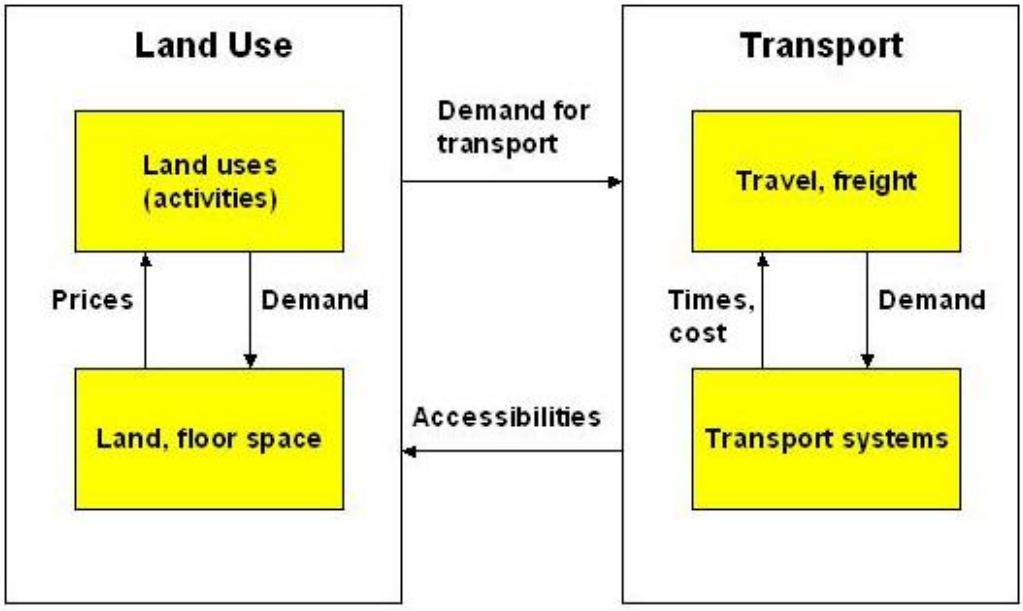


Figure 2-13: Land use / transportation interaction

Source: Naude et al. (2003:92).

On the one hand, the spatial pattern of land use and economic activity creates the demand for transport (moving people and goods between origin and destination). In its turn, the supply of transport (availability, price and efficiency, level of service) affects the location of different land use types (industry, commercial, residential, recreational, etc) and economic activity. "On the land-use side, activities such as industry, retailing, and residence create demands for industrial land, retail floor space, and housing. The relationship of supply to demand influences prices for space in each location, and the pattern of prices influences where people choose to live and work. Such decisions are also influenced by the state of the transport system for travel: from home to work, from home to shop, from factory to purchaser, and so on. This depends on the supply of and demand for transport. The demand for travel depends on the distribution of activities and how they are linked. The supply of transport is the road and rail network, the ownership of cars and the availability of public transport" (Naude *et al*., 2003:93).

MEPLAN model outputs are obtained by first calibrating the model to reflect the base case, presenting the current pattern of land use, trips, congestion, and the like. To examine the effect of a policy change, it is then re-run with the appropriate changes in the input information. By comparing the results obtained, the effects of a given policy change can be observed (Naude *et al*., 2003:93).

Strengths and weaknesses

MEPLAN is based on sound economic theory and makes use of concepts/models such as behaviour logit models, and utility maximizing functions of household consumption. It also incorporates spatial input/output modelling meaning that, for example, “households are "generated" by the demand for labour wherever the economy happens to require them” (Naude *et al*., 2003:91). It further uses a sophisticated transport model. The versatility of MEPLAN allows for the evaluation of different types of measure such as investment projects, control and regulation policies, and subsidy or taxation policies, thus obviating the need for different types of tools. Weaknesses result from its dependency on sophisticated markets and short-run equilibrium, and its segregation into an equilibrium model and an incremental model (Naude et al, 2003:93-94).

2.7.7 REMI models

Context

The REMI models (developed by Regional Economic Models, Inc.) deal with questions of the "what if?" type. It predicts the economic and demographic effects of alternative economic development programmes, transport infrastructure investments and other policy initiatives in the case of a given region. The methodology used in the socio-economic modelling system was developed by the University of Massachusetts (Dr George Treyz), involving regions of varying sizes in the United States, the European Union, and Canada. “The standard REMI model is called the REMI EDFS 53 model. This is a model with 53 industrial sectors and 606 age, gender and racial categories. REMI also has EDFS 14 and 172 models that include 14 and 172 sectors respectively” (Naude *et al*., 2003:94).

Model overview and application

REMI integrates three types of economic models, namely Input/Output (I/O) models, Computer-Generated Equilibrium (CGE) models, and econometric models. It incorporates economic notions such as the utility-maximizing nature of households and the profit-maximizing nature of producers. It is both a *dynamic* model (meaning that changes to the economy and adjustments to those changes are forecast on a year-to-year basis), and a *structural* model (meaning that it includes cause-and-effect relationships) (Naude *et al*., 2003:95).

Model forecasts are based on the interaction between the five blocks shown in Figure 2-14. In addition to including all the inter-industry relationships found in the input/output model in the Output block, it goes beyond the input/output model by including key relationships in other blocks, developed from large datasets and based on extensive research (Naude *et al*., 2003:96).

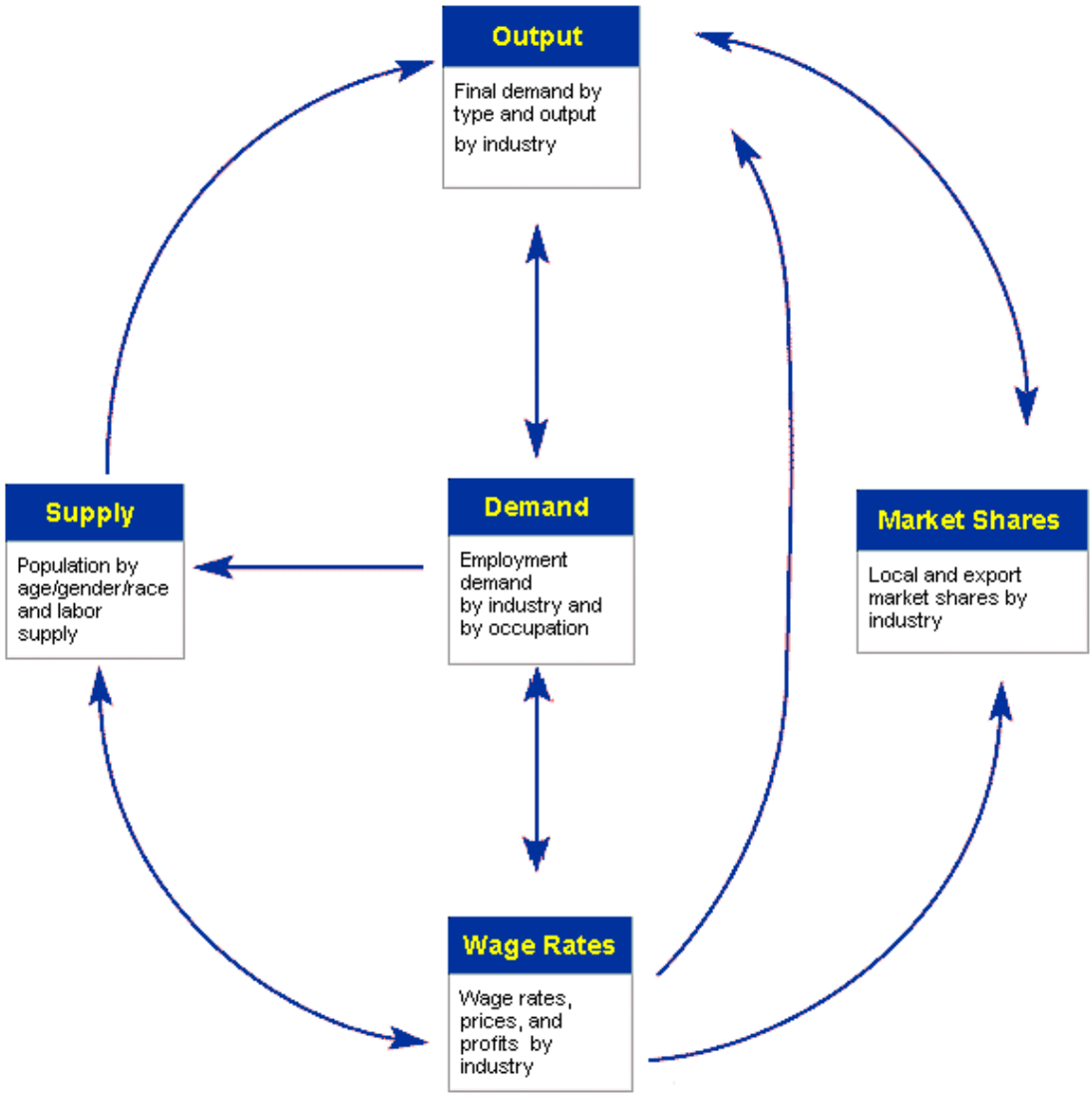


Figure 2-14: Basic components (modules) of the REMI model

Source: Naude et al. (2003:96).

"The Output block shows a factory that sells to all the sectors of final demand, as well as to other industries. The Labour and Capital Demand block shows how labour and capital

requirements depend both on output and their relative costs. Population and Labour Supply are shown as contributing to demand and to wage determination in the product and labour market. The feedback from this market shows that economic migrants respond to labour market conditions. Demand and supply interact in the Wage, Price and Profit block. Once prices and profits are established, they determine market shares, which, along with components of demand, determine output" (Naude *et al*., 2003:95).

The application of the model is depicted in Figure 2-15.

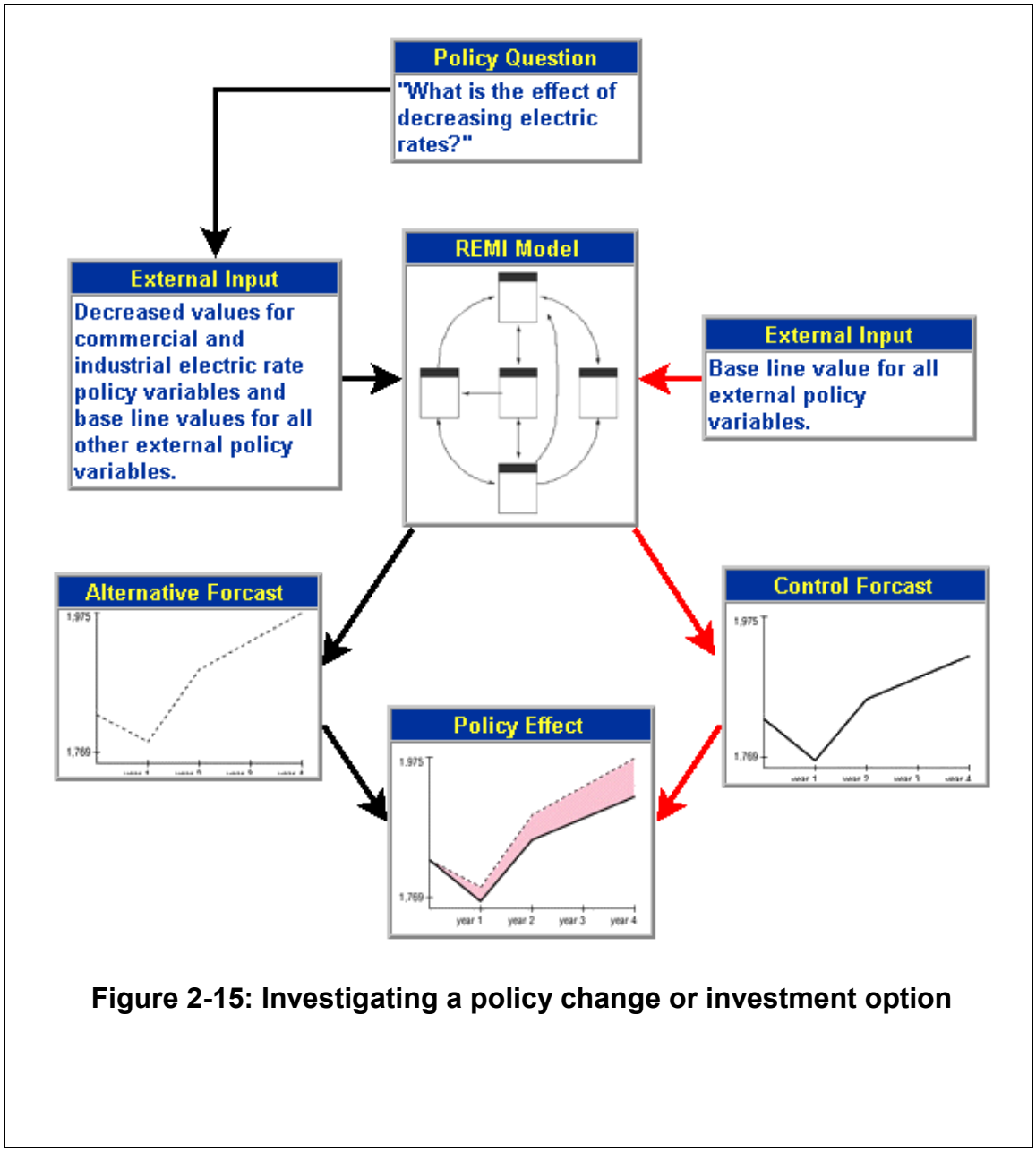


Figure 2-15: Investigating a policy change or investment option

Source: Naude et al. (2003:97).

The process starts by posing a policy question. A baseline forecast, using baseline assumptions about external policy variables, is then selected. Alternative forecasts, using an external variable set that includes changes in external values as effected by the policy to be introduced, are generated. The difference between the baseline and alternative forecasts (see bottom graph in the diagram) represents the resulting effects of a policy change (Naude *et al*., 2003:97).

Strengths and weaknesses

The REMI model is capable of producing integrated forecasts of population/demography, enabling projected population growth and economic growth consistency. Its top-down approach ensures that projections for sub-elements of the region are consistent with projections for the region itself – for example, projections for states (provinces) are consistent with national growth patterns. It also uses sound economic theory and operates at an acceptable level of detail. It is further flexible in terms of the specification of exogenous variables. Regarding weaknesses: the top-down approach means that forecasts typically will be most reliable at the national level, and successively less reliable at the regional (sub-regional) level. Another weakness is the fact that projections are based on historical relationships, meaning that events and trends foreseen by local experts are ignored. Finally, it uses a large number of variables which, together with the complex linkages between them, mean that accuracy and reliability are difficult to determine (Naude *et al*., 2003:98).

2.7.8 TREDIS

A common feature of economic model systems is the distinction between “transportation drivers” and “economic outcomes”. In the “traditional” form of regional economic models (e.g. REMI), though, the emphasis is on cost competitiveness, whereas “economic development models” recognize a broader set of market access and system connectivity factors impacting on freight movement, business attraction and retention (EDRG, 2008:22).. Examples of this latter type of model are (a) LEAP (Local Economic Assessment Package), funded by the Appalachian Regional Commission; (b) CDSS (Congestion Decision Support System), funded by the National Cooperative Highway Research Program; (c) University of Maryland econometric model, funded by the Maryland DOT; (d) HEAT (Highway Economic Analysis Tool), funded by Montana DOT and developed by Cambridge Systematics; and (e) TREDIS, which is described below in more detail (EDRG, 2008:22-23).

With the latter type of model, the emphasis on access and connectivity is evident from the distinction between “transportation input measures” and “economic outcome measures”; that is between “drivers of economic impact” and “ultimate impacts on the economy”; and in particular from the elements of “drivers of economic impact” (EDRG, 2008:24):

Drivers of economic impact:

- Access to global markets or gateways.
- Access to (or connectivity with) airports and rail intermodal terminals.
- Connectivity with larger national highway networks.
- Connection to, or adjacency to, business activity clusters.
- Freight shipping cost or cost-competitiveness.

Ultimate impact on the economy:

- Jobs.
- Income.
- Business output or GDP.

TREDIS is explored below in more detail as it supports the logic of focusing on the identification of key market segments (and thus specific types of users dependent on specific types of transportation facilities), and then developing a “logical process for understanding the implications of transportation system changes for those groups” (EDRG, 2008:31). TREDIS (acronym for Transportation Economic Development Impact System), developed by the EDR Group, is described as “the first truly multi-modal economic analysis system for local, regional and state planning” (Weisbrod, 2008 in EDRG, 2008:23). It forecasts how improvements to the transport system will affect business growth and attraction over time, where transportation system changes – relating to both freight and passenger movement on different modes – include the following (EDRG, 2008:23-24):

- “Cost of commuting (by industry and by mode).
- Cost of freight movement (by industry and by mode).
- Breadth of market for same-day delivery markets (2 hour time access ring).
- Breadth of market for workforce (45 minute time access ring).

- Level of passenger service at closest commercial airport (passengers).
- Access drive time to closest airport with scheduled service.
- Access drive time to closest marine port with scheduled service.
- Access drive time to closest intermodal (highway-rail) terminal.
- Access time to international trade gateways.
- Constraints on particular classes of vehicles, trips or freight (such as weight or size restrictions)".

TREDIS comprises four modules that combine to determine the full economic impact of transportation projects (although any single module or combination of modules may be used independently). These modules are listed below (EDRG, 2008:32); their interrelationship is explained in Figure 2-16.

Travel Cost Module (TC), translating changes in traffic volumes, travel times and accidents into direct cost savings that accrue to various categories of households and businesses.

Market Access Module (MA), translating changes in regional accessibility and intermodal connectivity into effects on productivity and business relocation (for various elements of the economy).

Economic Adjustment Module (EA), incorporating a dynamic regional economic impact model to estimate total impacts on growth of the study area economy over time. The REMI model, CRIO-IMPLAN model system or the Global Insight model could be used for this purpose.

Benefit-Cost Module (BC), calculating the net present value of benefits and costs from different perspectives (federal, state and local agencies).

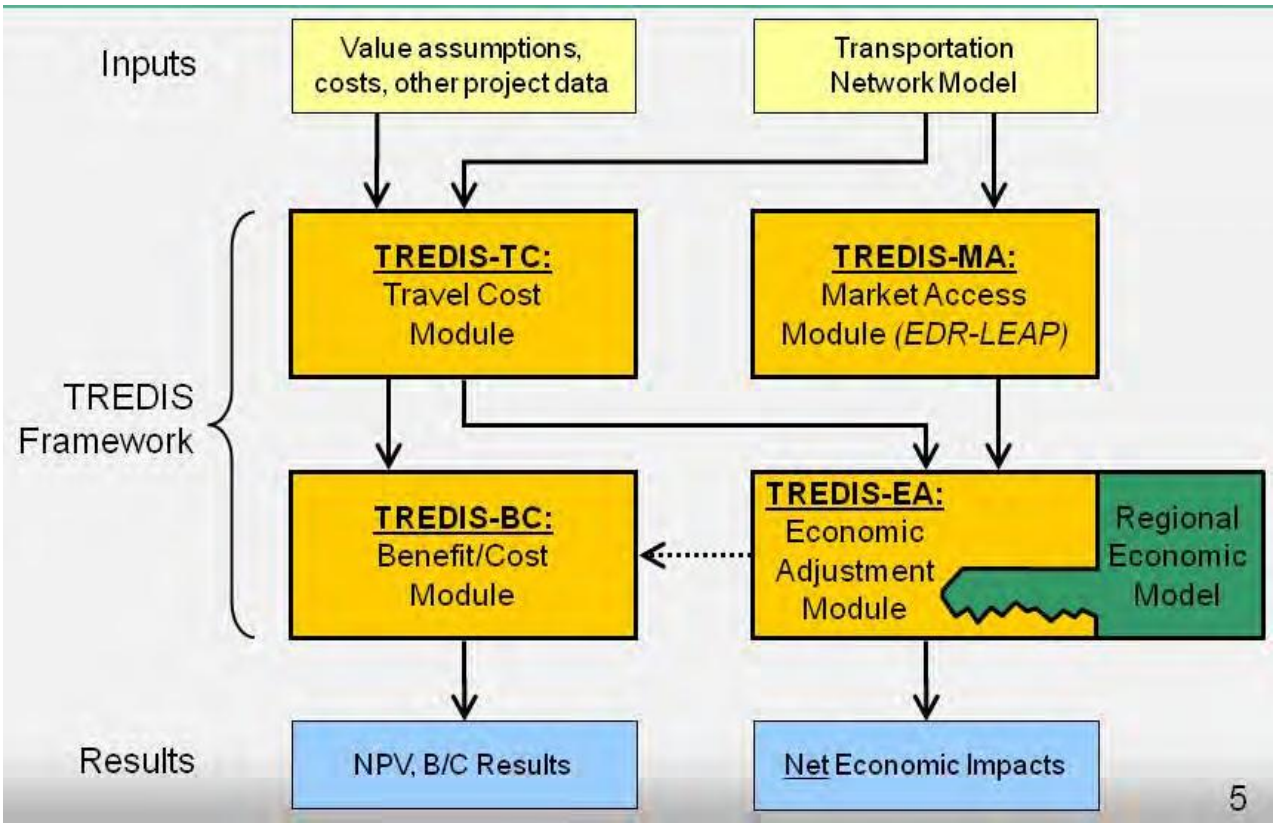


Figure 2-16: Relationship of economic analysis modules

Source: EDRG, 2008:32.

The types of input factor that can be used are shown in the box below (EDRG, 2008:33).

Definition of TREDIS Economic Analysis Input Factors

Travel benefit factors

- Freight value of time savings and reliability; by mode & vehicle type (truck/rail concentration), industry/commodity type and time of day (reflecting peak and off-peak differences).
- Passenger value of time savings and reliability; by mode, trip purpose and time of day (reflecting peak and off-peak differences).
- Vehicle operating cost; by mode and vehicle type (truck, car, train, plane, ship), based on VMT (vehicle-miles of travel), VHT (vehicle-hours of travel), average speed and peak period delay.
- Accident cost; by mode and vehicle type.

Definition of TREDIS Economic Analysis Input Factors
Connectivity factors • Airport connectivity: Average travel time from population centre of the study area to closest available commercial airport. • Marine port connectivity: Average travel time from population centre of the study area to closest available commercial river or sea port. • Rail freight connectivity: Average travel time from population centre of the study area to closest available TOFC/COFC intermodal terminal. • Highway connectivity: Average travel time from population centre of the study area to closest available interstate highway. • International border connectivity: Average travel time from population centre of the study area to closest available Mexico or US border station with truck or rail freight processing. • Overseas air gateway connectivity: Average travel time from population centre to closest available international airport with scheduled overseas airline flights. • Overseas sea gateway connectivity: Average travel time from population centre of the study area to closest available marine port with scheduled commercial ship calls to overseas destinations. **Market size (access)** • Local markets size (shopper & labour markets): Population reachable within 40 minutes' drive time. • Same-day delivery market: Employment reachable within 180 minutes' drive time. • Airport service: Number of destinations served at closest commercial airport. • Marine port service market: Number of destinations served at closest commercial river or sea port. • Freight rail service market: Number of destinations served at closest TOFC/COFC terminal. **Market level of service/activity**

Definition of TREDIS Economic Analysis Input Factors
• Airport market service: Frequency of service (average daily scheduled trips) for closest commercial airport. • Marine port market service: Frequency of service (average daily scheduled trips) for closest commercial river or sea port. • Freight rail market service: Frequency of service (average daily scheduled trips) for closest TOFC/COFC intermodal terminal.

2.7.9 Comparison of spatial models

The spatial models considered in this section are similar in as far as they all attempt to predict (socio-economic) changes (on a spatial basis) resulting from interventions in transport infrastructure and systems, and they all adopt a before and after (with and without) stance by comparing results to the base case. But there are also differences as shown in Table 2-10 where models are compared in terms of the parameters *output* and *methodology*. This constitutes an *intra*-category comparison of models in terms of selected parameters, as opposed to an *inter*-category comparison of traditional methods for project appraisal in terms of the appraisal requirements of CoT projects.

Table 2-10: Comparison of spatial models in terms of output and methodology

Model	Output (What does the model do?)	Methodology (By doing what?)
SASI	For each region, changes in economic efficiency are predicted as manifested by the following parameters: GDP per capita by economic sector. Unemployment.	By considering changes in regional accessibility (expressing locational advantage of each region i.r.o. relevant destinations as a function of travel time and travel cost (or both) for road, rail and air transport).

Model	Output (What does the model do?)	Methodology (By doing what?)
CGEurope	For each region, changes in output, income and welfare (the latter being expressed as the monetary equivalent of variations in household utility), are predicted.	In the SCGE (spatial computable general equilibrium) model, inter-regional trade is calculated as a function of, amongst other things, transport cost which, in its turn, is a function of both the transport network and international trade impediments to cross-border trade.
IASON	As IASON builds on SASI and CGEurope, its output is similar but with some improvements, such as integrating the network, regional and macro economic impacts of transport projects and policies, and creating datasets for use by both SASI and CGEurope.	By refining the methodologies of SASI and CGEurope, with a particular focus on improved spatial economic modelling and assessment procedures.
DELTA	Changes in land use over time are predicted as a function of alternative land use and transport policies.	By analyzing dynamics at both the urban level (development of buildings on land, demographic change and economic growth, changes in car ownership, location of households and jobs, employment and status changes, changes in the quality of urban areas) and the regional level (migration between different labour market areas, investment in the regional economy, production and trade in the regional economy).
MEPLAN	Patterns of land use, trips,	By modelling the interaction between

Model	Output (What does the model do?)	Methodology (By doing what?)
	congestion, etc, are predicted as a function of a given set of land use and transport policies.	transport and land use (the notion that the spatial pattern of land use and economic activity creates the demand for transport, and conversely, that the supply of transport affects the location of different types of land use and economic activity), and by basing the model on sound economic theory and using concepts/models such as behaviour logit models, utility maximizing functions of household consumption, spatial input/output modelling and a sophisticated transport model.
REMI	Estimation on a year-to-year basis of the economic and demographic effects of economic development programmes, transport infrastructure investments and other policy initiatives.	By integrating key aspects of three types of economic models, namely: Input/Output models, CGE (computer-generated equilibrium) models, and econometric models.
TREDIS	Predictions of impacts on the economy (jobs, income, business output (GDP)) of “drivers of economic impact”, namely improvements in access, connectivity and cost-effectiveness.	By focusing on the identification of key market segments (and thus specific types of users dependent on specific types of transportation facilities), and then developing a “logical process for understanding the implications of transportation system changes for those groups”.

2.8 Summary

Chapter 2, constituting a literature review, examines key aspects of traditional methods for project appraisal (as defined in Chapter 1) considered relevant to this study. This is done to set the scene for the remainder of this thesis and, more specifically, to justify (in later chapters) their role (if at all) in a proposed MCDM strategy for CoT. Traditional methods involve the following: (a) CBA; (b) general equilibrium analysis; and (c) spatial models.

Context and objective of CBA

CBA (also termed SCBA (Social Cost-Benefit Analysis)) originated when the concept of consumers' surplus was linked to the net gain to communities from government projects. CBA is therefore rooted in welfare economic theory, and aimed at ensuring that a project contributes towards the goal of economic efficiency (defined as the maximization of social welfare (or the collective material wants of individuals) within the constraints imposed by the scarcity of resources). The distinction between a "pure" and a "potential" Pareto improvement is important; in practice, however, the latter mostly applies – this means that equity considerations are excluded from the analysis. To determine if a project will bring about a Pareto improvement (whether pure or potential) requires benefits and costs to be correctly valued; benefits should be valued in terms of the willingness-to-pay concept, and inputs (costs) in terms of opportunity costs. A comparison between CBA (applied in the public sector) and its private sector equivalent (financial analysis) highlights important differences, such as the fact that social welfare (welfare impacts) includes all the consequences that a project has for the social milieu of a human being.

Aspects not included in CBA

The following aspects are traditionally excluded from CBA: (a) sunk costs; (b) transfer payments; (c) land prices; (d) impacts relating to the financing decision; (e) depreciation; (f) transmitted impacts; and (g) regional development.

CBA: Mutually exclusive alternatives and independent projects

Mutually exclusive alternatives are defined as alternative options for accomplishing a stated objective. Independent projects relate to different (unrelated) objectives to be accomplished.

CBA: Project evaluation, ranking and selection

Project appraisal includes both the evaluation and the ranking of technically feasible projects. The former involves the comparison of mutually exclusive alternatives, and the latter the

ranking of independent projects. The completion of both is a prerequisite for project selection.

CBA: Analytical procedures

A project is deemed feasible if discounted benefits over the analysis period exceed discounted costs (or are at least equal to discounted costs). Six techniques are commonly used to establish this; they are all based on the principle of discounted cash flow analysis (DCFA), meaning that the time value of money is taken into account. These techniques can be classified under three headings. The *least cost approach* makes use of the Equivalent Uniform Annual Cost (EUAC) technique and the Present Worth of Cost (PWOC) technique. The *maximization of net benefits approach* can be split into two parts: (a) difference between costs and benefits, involving the Net Present Value (NPV) technique and the Equivalent Uniform Annual Net Return (EUAR) technique, and (b) the ratio between benefits and costs, involving the Benefit/Cost (B/C) ratio. The *investment approach* involves the Internal Rate of Return (IRR) technique. When mutually exclusive alternatives are compared, all six techniques will give the same answer if applied correctly. When independent projects are compared, only the B/C technique and the IRR technique can be used, as the other four techniques do not accommodate difference in scale between projects.

Narrow and broad CBA

Narrow CBA and variations thereof: Impacts of TI projects can be classified in different ways, for example according to affected party, distinguishing between: (a) the operator (transport authority); (b) users of the facility; and (c) non-users. Contrary to this approach, narrow CBA is defined as involving only tangible impacts which, in the case of TI projects, translate into total transport cost, consisting of road agency costs (comprising the cost of constructing and maintaining road infrastructure) and road user costs (comprising vehicle operating cost, collision cost and travel time cost). Total transport cost can also be disaggregated into initial cost and recurring cost; or intervention cost and (resulting) impacts.

Broad CBA: Narrow CBA can be broadened in two ways: by including in the analysis (a) less tangible impacts; and/or (b) objectives other than efficiency (e.g. equity, through the use of weights). Regarding the role of decision makers, the “conventional” school of thought favours narrow CBA, viewing CBA as just one input into the decision making process, whereas the “decision making” school of thought supports broad CBA, viewing it as encapsulating most if not the complete process.

Application of CBA

Project impacts may be local or external. This means that CBA applications could be classified in terms of two attributes: (a) definition of benefits; and (b) scope of CBA. These CBA applications can also be related to the different projects categories (and appraisal contexts) that were suggested in Section 1.2.12.

Software for facilitating CBA

CBA and road infrastructure management

In addition to using CBA as a stand-alone tool, one can also view it in the context of "road infrastructure management", which is aimed at managing the entire road network as a national asset. A road management system (RMS), defined as a computer-based system for facilitating road management, can be instrumental in accomplishing this, but needs to be supplement by other tools to address specific objectives. HDM-4 and the RED model are examples of such tools. They can be classified into eight groups: (a) comprehensive tools for road management; (b) tools focusing on accessibility, poverty alleviation and community participation; (c) tools developed in response to stakeholder requirements for feedback/information; (d) tools aimed at economic efficiency in resource allocation; (e) tools suited for multiple criteria decision making; (f) tools aimed at road cost recovery; (g) generic planning tools; and (h) tools aimed at improving organizational efficiency.

HDM-4

HDM was initiated by the World Bank in 1968 with a focus on the analysis of design specifications and maintenance options. It is a world-wide tool for application at different levels: (a) the technical and economic appraisal of road *projects*; (b) the preparation of road investment *programmes*; and (c) the analysis of road network *strategies*. In addition to predicting road deterioration over time and road user effects, it also predicts road user cost, and social and environmental effects. Social and environmental effects comprise vehicle emissions, energy consumption, traffic noise and other welfare impacts on the population served by the roads. Improvements to HDM-4 Version 2.0 (relative to the previous version 1.3) fall into four areas: (a) new analysis tools; (b) usability; (c) connectivity with external systems; and (d) reporting. New analysis tools include MCA, sensitivity analysis, budget scenario analysis and asset valuation.

RED

RED was developed by the World Bank in the late 1990s, in response to the need for a tool for economic analyses in the case of low volume roads. Requirements for such a tool were that it should be less "data-intensive" than HDM-4, and be able to consider "other" costs and benefits such as those associated with non-motorized traffic, social delivery and the environment.

CBA: Results from ex-post evaluations

The post-completion evaluation of projects is important because it provides information on: (a) how effectively stated objectives were met; (b) how effective the project evaluation methods were; and (c) how efficient the project implementation process was. A recent study involving a number of major infrastructure projects from around the globe focused on the "megaproject paradox" (i.e. the increase in these projects in terms of magnitude, frequency and geographical spread, in spite of their poor performance), and identified reasons for project failure.

Four reasons for project failure were indicated: (a) cost overruns, (b) over-optimistic demand predictions, (c) the fact that the extent and magnitude of actual environmental impacts are often very different from predicted forecasts, and (d) the fact that regional, national and international development effects often do not materialize or are too diffuse to be detected.

General equilibrium models

General equilibrium (GE) models constitute an extension of and supplement to CBA in the case of large projects under certain conditions. CBA focuses on "local" (first round) impacts, addressing projects in a micro-economic sense, constituting a partial equilibrium (PE) analysis, and providing a single measure of project worth (e.g. B/C ratio and variations thereof). In contrast, GE analysis focuses on economy-wide impacts, addressing a project in a macro-economic sense, and providing a number of "indicators" such as impact on private consumption, investment, exports, imports, inflation, total GDP and GDP on an industry-by-industry basis. While CBA does provide a clear "accept/reject" rule; GE analysis does not do this directly. GE analysis involves a number of models and approaches, as listed below.

I/O models: An I/O table is a summarized version of all transactions that took place between the main economic stakeholders in a particular year, breaking them down by the main sectors of the economy, thus showing the interdependence of sectors within an economy by calculating the relevant multipliers and leakages

Social Accounting Matrix (SAM): A SAM builds on the I/O table and can be regarded as an extension thereof. It can be designed with a special emphasis on social rather than economic attributes. In doing this, it also provides information about equity and distribution issues.

Computable General Equilibrium (CGE) models: CGE models predict consumer and producer behaviour more realistically than I/O tables and SAMS. This is achieved by modelling their reactions to changes in market conditions such as price.

Economic impact analysis: An economic impact analysis examines the nature and distribution of secondary economic impacts and outcomes that traditionally fall outside the scope of CBA. This is done by studying changes occurring across broadly defined sectors of the economy, with the intention of ascertaining who gains and who loses as a result of the project, and by how much.

Spatial models

In addition to considering total project impact, it is also important to analyze impacts from a spatial perspective (i.e. their geographical distribution). There are two reasons for this: (a) project impacts are not normally "spread out" evenly over the study area, and (b) zones (regions) differ in terms of their socio-economic profiles. Spatial analysis allows decision makers to ensure that benefits "reach" identified target groups, such as lower income groups and, in so doing, meet policy objectives and criteria in this regard. This is particularly important as a "pure Pareto" scenario does not address the objective of a fair distribution of positive project impacts between affected parties (and, by implication, between affected regions).

The seven models/approaches examined can be classified into three groups, according to the dominant discipline involved (although a clear-cut distinction is not always possible): (a) CGEurope, REMI and TREDIS can be termed economic models; (b) SASI, IASON (which builds on SASI) and MEPLAN can be termed spatial planning models; and (c) DELTA can be described as eclectic, building on, amongst others, urban and regional economics, geography, and sociology.

3. MULTI-CRITERIA DECISION MAKING

3.1 Introduction

Chapter 3 gives a synoptic overview of multi-criteria decision making (MCDM) by highlighting key concepts without indulging in technical (mathematical) detail. Reference is made to the CoT case where necessary. This overview is deemed necessary because the nature and impacts of TI projects mean that their appraisal takes place in a multi-objective decision making environment, arguably requiring an "MCDM-type" approach. The general background to and context of MCDM are explored first. Attention is also focused on specific aspects of the value function approach, which is deemed most appropriate in the case of CoT.

3.2 Context

3.2.1 Basic notion

Decision making is difficult for a number of reasons (Clemen, 1986:2) (in Engelbrecht, 2007:1-4). *Firstly*, when various stakeholders are involved, decision making is complicated by the fact that the interests and expectations of all stakeholders (which may vary from one another) have to be accommodated. *Secondly*, the fact that impacts cannot, by definition, be predicted with absolute certainty gives rise to risk and uncertainty. Uncertainty becomes particularly problematic when a sequence of decisions needs to be taken, where a given decision depends on the outcome of the previous decision. *Thirdly*, decision makers are often confronted with multiple decision objectives which, in addition, are often conflicting and so require trade-offs to be made. *Fourthly*, the perspectives of different role players in decision making may differ (e.g. regarding the outcomes to be achieved or the methods to be employed to achieve these), and this may influence decision making at all levels. An optimist, for example, may have more of an appetite for difficulties than a pessimist, and may require a higher "pay-off" than a pessimist.

The "typical" MCDM context involves a decision to be made regarding a number of alternatives, based on a number of criteria. For example, a decision maker must decide between five alternatives: the set of alternatives $A = \{a_1, a_2, a_3, a_4, a_5\}$, basing the decision on four criteria: the set of decision criteria $C = \{c_1, c_2, c_3, c_4\}$. This can be depicted as the matrix below where the evaluations (scores) correspond to alternatives on the rows and the criteria

on the columns, and where the score of 100, for example, relates to the performance of alternative 1 in terms of the first criterion, and the score of 180 to the performance of alternative 2 in terms of the second criterion (Clemen, 1986:2, in Engelbrecht, 2007:4-5):

	c_1	c_2	c_3	c_4
a_1	100	180	120	90
a_2	90	120	170	110
a_3	110	90	120	80
a_4	110	50	80	120
a_5	70	130	150	170

3.2.2 Defining MCDM

Stewart, Joubert, Scott and Low (1997:5) define MCDM as "the process of decision making in contexts in which substantial conflict between goals or criteria exist". In its turn, Multi-Criteria Decision *Aid* (or *Analysis*) (MCDA) is defined as "the field of management science concerned with providing decision support in contexts in which substantial conflict between goals or criteria exist". The following definition adds value by including qualitative aspects (in addition to quantitative aspects): "Multi-Criteria Analysis is a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process" (Mendoza, Macoun, Prabhu, Sukadri, Purnomo and Hartanto, 1999:15). De Brucker and Verbeke (2006:3) emphasize the importance of (and the tendency towards) a mathematical approach: MCDA "compares a number of actions or alternatives (e.g., projects or policy measures) in terms of specific criteria. These criteria represent an "operationalization" of the objectives and sub-objectives of decision makers and stakeholders participating in the decision-making process". "Operationalized", for the purposes of this thesis, is defined as "having been expressed in measurable terms".

In developing an appraisal strategy, it is important to note that MCDA applies to both the *mutually exclusive alternatives* context and the *independent projects* context, where the former refers to situations requiring only one option to be selected, and the latter to situations where one or more options could be selected (as discussed in Section 2.2.4). According to Engelbrecht (2007:4), for example, "Multi-criteria Decision Analysis aims at providing the decision maker with a ranking of alternative choices or alternatives according to a set of associated properties, attributes or criteria that will enable the decision maker to make an optimal decision on instrumentally rational grounds". MCDM is also described as "a variety of methods or techniques that can be employed in ranking a set of alternatives according to a

set of associated criteria" (Engelbrecht, 2007:5). This qualification is important, as it might be deduced from examples in the literature that MCDM mainly involves mutually exclusive alternatives (i.e. the so-called "discrete choice problem"). A case in point is the example by Engelbrecht (2007:117), involving a family relocating to another town and adopting a "scientific approach" in finding a new house that complies with a number of criteria. "Discrete choice problems" in fact constitute only one of several types of MCDM application, as is evident from Section 3.2.3.

MCDM has developed rapidly over the last quarter of a century; in this process, a number of divergent schools of thought have developed (Belton and Stewart, 2002:xvii). Belton and Steward therefore view MCDM as an umbrella term "to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter" (2002:2). The latter ("decisions that matter") are relevant "when the level of conflict between criteria, or of conflict between different stakeholders regarding what criteria are relevant and the importance of the different criteria, assumes such proportions that intuitive "gut-feel" decision making is not longer satisfactory" (Belton and Stewart, 2002:2). It also follows that MCDM is relevant to both *individuals* (in making personal decisions) and *groups* (e.g. in the case of corporate decision making or when multiple stakeholders are involved – and thus also in the case of CoT where decisions are taken by council).

3.2.3 MCDA applications

Belton and Stewart (2002:16-31) list five types of problem contexts for which an MCDM approach would be desirable. This highlights not only the wide spectrum of potential MCDM applications, but also the fact that a given MCDM approach may be better suited to one problem type than to another, with the consequent imperative to match methodology with problem context. This description of MCDA applications also serves to clarify the nature and characteristics of the context of the development of an appraisal strategy for CoT.

1. Discrete choice problems: These can be regarded as the "classical context" within which MCDM can be viewed, i.e. problems involving the selection of a single best choice from a given set of discrete options. Nevertheless, Belton and Stewart (2002:16) point out that, even with this "classical application" of MCDM, it would be "far from the truth" to assume that "the alternatives and the criteria against which they are judged are more-or-less self-evident, and that the difficult problem is to identify the solution which best satisfies the associated

decision making goals". Instead, MCDM should be seen as a process aimed at gaining a better understanding of the underlying issues; "problem structuring" therefore constitutes a critical element of the MCDM process, as argued in subsequent sections of this chapter. To emphasize this point, Belton and Stewart (2002:16) cite examples of multi-criteria discrete choice problems that required a considerable degree of evaluation and analysis. These cover a wide range and show that MCDM is a generic tool not limited to transport projects only: they include the choice of locations for power stations; the evaluation of tenders and selection of a contractor to develop an information system; the selection of metro stations in Paris for renovation, selection of a haulage contractor, relocation decisions, selection of an architecture for a defence communication system, the evaluation of public transport options, and the selection of a textbook for a course.

2. Multi-objective design problems: In this case, alternatives are defined implicitly and not explicitly as with discrete choice problems (see above). According to Belton and Stewart (2002:19), this happens "in terms of a variety of components or features which may need to be selected and combined, but where the possible or allowable combinations are subject to a number of feasibility constraints". Financial investment options, for example, can be constructed from a variety of "instruments" (asset types) such as shares and derivatives, bonds, property and cash, subject to the availability of funds (and perhaps legal constraints). This implies an infinite range of possibilities. Belton and Stewart (2002:19) call this a "'design problem'", in the sense that we are assembling a particular course of action from more fundamental elements". Examples of this type of problem as described in the literature are: power generation planning, selection of rootstock in citrus agriculture, plant layout for manufacturing flexibility, and reservoir operation planning (Belton and Stewart, 2002:20).

3. Mixed design and evaluation problems: This type of problem is characterized by the existence of an infinite list of possibilities, requiring a design phase to precede the evaluation phase, with the objective of developing a suitable shortlist of options which could then be subjected to detailed analysis, similar to the discrete choice problem (Belton and Stewart, 2002:22). Examples of this approach include river basin planning, and nuclear waste management (Belton and Stewart, 2002:22).

4. Project evaluation, prioritization and selection: The objective in this case is to find the best way of allocating available funds, for example for research and development projects. From this it would appear that this type of MCDM application comes closest to the objective of this thesis, namely developing an appraisal strategy for CoT. In a sense, this category is the

inverse of the previous category, as the process begins "with the 'evaluation' of individual projects before moving on to the 'design' of a preferred portfolio, once again illustrating the need for an integrated understanding of methods and processes" (Belton and Stewart, 2002:28). Regarding practical applications, the following are cited (Belton and Stewart, 2002:24-25): the approach adopted by a company in the chemical industry to monitor research and development expenditure on drug compounds; a decision support system developed for the engineering investigations division of a large electricity supply company; the process adopted to help the Social Services Department of a UK County Council in prioritizing new initiatives (such as improved care packages or new information systems); and resource allocation in local government. Regarding two case studies cited (Belton and Stewart, 2002:25-29), a number of generic questions can be posed which serve to clarify key features of this typology – these questions are also particularly relevant to the proposed appraisal strategy for CoT: Who are the *real* decision makers? What is the profile and role of the different stakeholders in the process? How should projects of different magnitude be compared? Are projects independent? Are there portfolio considerations, such as balancing allocated funds across different disciplines or organizational units? Are there budget constraints, which imply that not all proposals can be accepted? Regarding the process to be followed, Belton and Stewart (2002:26) list the following questions: "will they first evaluate the projects individually and then come together to discuss their assessments? Are they aiming to arrive at a consensus view of which projects should be funded or do they intend to work from individually prioritized lists (for example funding each person's 5 preferred projects)? How much time are they able to spend together? How will they communicate at other times?"

5. Classification of alternatives: The objective here is to classify alternatives into different categories (e.g. a two-way system consisting of acceptable-unacceptable, or a system with more categories). This is a fundamental difference from the cases above, where the objective was to identify a preferred alternative. This category of problems thus involves the *sorting problematique*, and the focus is on developing a rating system that can accommodate all factors to be taken into account in the classification process. Examples include the evaluation of a number of universities in terms of their research and teaching quality, and the classification of estuaries or river basins into conservation types (Belton and Stewart, 2002:30). In as far as this application of MCDM allows for projects to be classified into "feasible" and "not feasible", it also applies to the CoT case as an appraisal strategy must

inevitably encompass the evaluation of projects (i.e. classifying them into “feasible” and “not feasible”) – which also then allows the ranking of feasible projects.

3.2.4 Typologies and classification of MCDM contexts

Different types of problem context requiring an MCDM approach were described in the previous section. Roy (1996) (in Belton and Stewart, 2002:15) offers a different perspective and groups MCDM applications according to the particular “problematique” to be addressed, resulting in four typologies. The *choice problematique* involves making a simple choice from a set of alternatives. The *sorting problematique* involves classifying actions (options) into categories such as “definitely acceptable”, “possibly acceptable but need more information” and “definitely unacceptable”. The *ranking problematique* involves placing options in some form of preference order. The *description problematique* involves describing actions and their consequences in a formalized and systematic manner – as such, it can also be termed a *learning problematique,* aimed at providing clarity of what is (and what is not) achievable. To these, Belton and Stewart (2002:15-16) add two more: The *design problematique* involves the identification of new options for meeting goals and objectives that were revealed in the MCDM process. The *portfolio problematique* involves selecting a subset of options from a larger set of options, considering interactions between them as well as positive and negative synergies.

Whereas these typologies are essentially a function of the *objective* of the analysis, MCDM problem contexts can also be classified in terms of their *characteristics*. Belton and Stewart (2002:31-33) list six characteristics that enable such a classification:

1. One-off versus repeated problems: One-off decisions (e.g. location of a proposed airport) often tend to be more of a strategic nature. Repeated decisions recur at regular time intervals, e.g. monthly or annually. In the case of budget decisions of funding agencies, the same issues will tend to be considered every time. Other decisions of a repetitive nature may be unique (e.g. the routing of a new highway), requiring a fresh look each time.

2. Number of stakeholders: “The ‘decision maker’ may be a single individual, a small group of individuals with more-or-less common goals, or a corporate executive or political decision maker acting on behalf of a large group of interested and affected persons with divergent interests” (Belton and Stewart, 2002:32).

3. Status and influence of the client: There are three possibilities: The client may, in some cases, also be the final decision maker. Alternatively, the client may be a group tasked with

making recommendations to the decision maker (e.g. a government department making recommendations to a board or council). Thirdly, the client may be a stakeholder (interest) group requiring assistance with preparing submissions to the decision maker.

4. The "problematique": MCDM problems may differ according to the different problematiques (as discussed above). In its turn, the problematique in a given case may be a function of the number of stakeholders involved and/or the status and influence of the client.

5. Range of available alternatives: At the one end of the spectrum, the number of alternatives will be relatively small and identified explicitly. The number of alternatives may however also be large or infinite, defined only in terms of constraints as in the case of the investment problem discussed above. In such cases, a two-phased approach may be feasible, focusing firstly on the selection of the shortlist, and subsequently on the evaluation of alternatives on the shortlist.

6. Facilitated versus "do-it yourself" analysis: In the case of an individual or small homogeneous group, the choice may be to adopt a do-it-yourself mode. In the case of (large) groups, the analysis will normally involve a facilitator to guide the process and the decision makers to find a solution that best satisfies their needs.

At this juncture, it is opportune to consider the CoT case from the perspective of both typology and classification, as explained above. In terms of the former, it could be argued that the CoT case involves not only one, but a combination of three "problematiques", for the reasons given:

- Sorting problematique, as there is a need to distinguish between feasible and non-feasible alternatives. Feasibility could, for example, be viewed from both a technical and economic perspective. It could also be argued that alternatives should further comply with certain minimum standards regarding other objectives such as equity and sustainability (i.e. impact on the environment).
- Ranking problematique, as projects proven feasible should be ranked in terms of their worth (or desirability), to enable their selection for implementation, starting from the top (best) of the list and proceeding down the list until funds are depleted.
- Portfolio problematique, as interactions between alternatives as well as positive and negative synergies should be examined.

Linked to the ranking and portfolio problematiques, the complicating factor of project size needs to be borne in mind: “It is sometimes difficult to compare evaluation performance measures of projects that vary greatly in size, e.g. implementation of a number of low cost improvements versus the construction of a new rail link” (CMT-KMV, 1995:6).

Regarding *characteristics* in the case of CoT, the situation can be summarized as follows:

- *One-off versus repeated problems:* As explained in Section 1.7, this study focuses on the budget-type of CoT projects which, by definition, can be described as “repeated problems”.
- *Number of stakeholders:* For the purposes of this study, focusing on CoT, (at least) three groups of stakeholders are involved, namely the technocrats, the (political) decision makers, and the public at large. Within each group, there may be divergent views and interests. The last (and certainly most important) group, namely “the public”, may, in its turn, consist of widely differing sub-groups (e.g. groups in different income groups, previously disadvantaged groups).
- *Status and influence of the client:* The client (i.e. the institution requesting the analysis) in the CoT case would be the Council, the final decision maker. The client may, however, also be the (relevant) department if that department is expected to make recommendations to the final decision maker.
- *Range of available alternatives:* In the CoT case, Council will be confronted by a finite, relatively large number of alternatives – typically, projects will exceed funds, indicative of an “unlimited needs, limited resources” scenario.
- *Facilitated versus “do-it yourself” analysis:* Given the context and objective of this thesis, it could be argued that the analysis should be conducted by external consultants with a proven track record.

3.2.5 The role of MCDA in decision making

Belton and Stewart (2002:4-5) emphasize the fact that MCDM focuses on *aiding* decision making, not on prescribing how decisions should be made. Diakoulaki and Grafakos (2004:3-4) concur with this view and list five advantages of MCDA: (a) It directly involves the stakeholders; their preferences and values are therefore better detected and their concerns and priorities better reflected in decision making. (b) It acts as an interactive learning process, by motivating/forcing stakeholders to consider conflicts by taking into account other

points of view and opposing arguments. (c) It is a multi-disciplinary approach "amenable to capturing the complexity of natural systems, the plurality of values associated with environmental goods and varying perceptions of sustainable development" (Toman, 1998) (in Diakoulaki and Grafakos (2004:4). (d) It can consider a large variety of data, both quantitative and qualitative, and independent from the measurement scale. (e) It is less prone to biases and distributional problems than WTP (willingness to pay) or WTA (willingness to accept) estimates as it could be argued that individuals are more comfortable with expressing their preferences in the form of importance weights and deciding on the necessary trade-offs when not restricted by their ability to pay (Joubert, Leiman, de Klerk, Katua and Aggenbach, 1997) (in Diakoulaki and Grafakos, 2004:4).

MCDM should not be viewed in isolation, but be informed and supported by the theory, method and experience from the wider fields of Management Science and related disciplines (Belton and Stewart, 2002:293). These fields can be grouped under four headings (Belton and Stewart, 2002:294):

- Analytical methods of operations research and management science, as well as statistics that have strong parallels with MCDA. Examples are Game Theory and associated methods, Data Envelopment Analysis (DEA) and methods of multivariate statistical analysis.
- Management science approaches, for example problem structuring methods such as cognitive/cause mapping and aspects of Soft Systems Methodology (SSM) and Strategic Choice, as well as discrete event simulation, system dynamics, scenario analysis (planning) and conflict analysis.
- Management science and other managerial methods such as the Kepner Tregoe method, value engineering, Kaplan and Norton's Balanced Scorecard, Quality Function Deployment and the European Federation for Quality Control (EFQM) Excellence model, all have a strong multi-criteria component.
- Application areas with a naturally strong multi-criteria element, such as Environmental Impact Analysis, portfolio analysis, risk analysis, and quality assurance could be relevant.

Three myths regarding MCDM should be noted (Belton and Stewart, 2002:2-3): (a) It will give the right answer; (b) it provides an objective analysis that relieves decision makers of the responsibility of making difficult judgments; (c) it takes the pain out of decision making.

Instead, MCDM should be seen as an aid to decision making and a process aimed at integrating objective measurement and value judgement, and of making explicit and managing subjectivity (Belton and Stewart, 2002:3). This view is shared by a number of prominent thinkers (Belton and Stewart, 2002:4-7):

“Simply stated, the major role of formal analysis is to promote good decision making. Formal analysis is meant to serve as an aid to the decision maker, not as a substitute for him. As a process, it is intended to force hard thinking about the problem area: generation of alternatives, anticipation of future contingencies, examination of dynamic secondary effects and so forth. Furthermore, a good analysis should illuminate controversy – to find out where basic differences exist in values and uncertainties, to facilitate compromise, to increase the level of debate and to undercut rhetoric – in short ‘to promote good decision making’” (Keeney and Raiffa, 1972:65–66).

“… decision analysis (has been) berated because it supposedly applies simplistic ideas to complex problems, usurping decision makers and prescribing choice!

“Yet I believe that it does nothing of the sort. I believe that decision analysis is a very delicate, subtle tool that helps decision makers explore and come to understand their beliefs and preferences in the context of a particular problem that faces them. Moreover, the language and formalism of decision analysis facilitates communication between decision makers. Through their greater understanding of the problem and of each other’s view of the problem, the decision makers are able to make a better informed choice. There is no prescription: only the provision of a framework in which to think and communicate” (French, 1989:1).

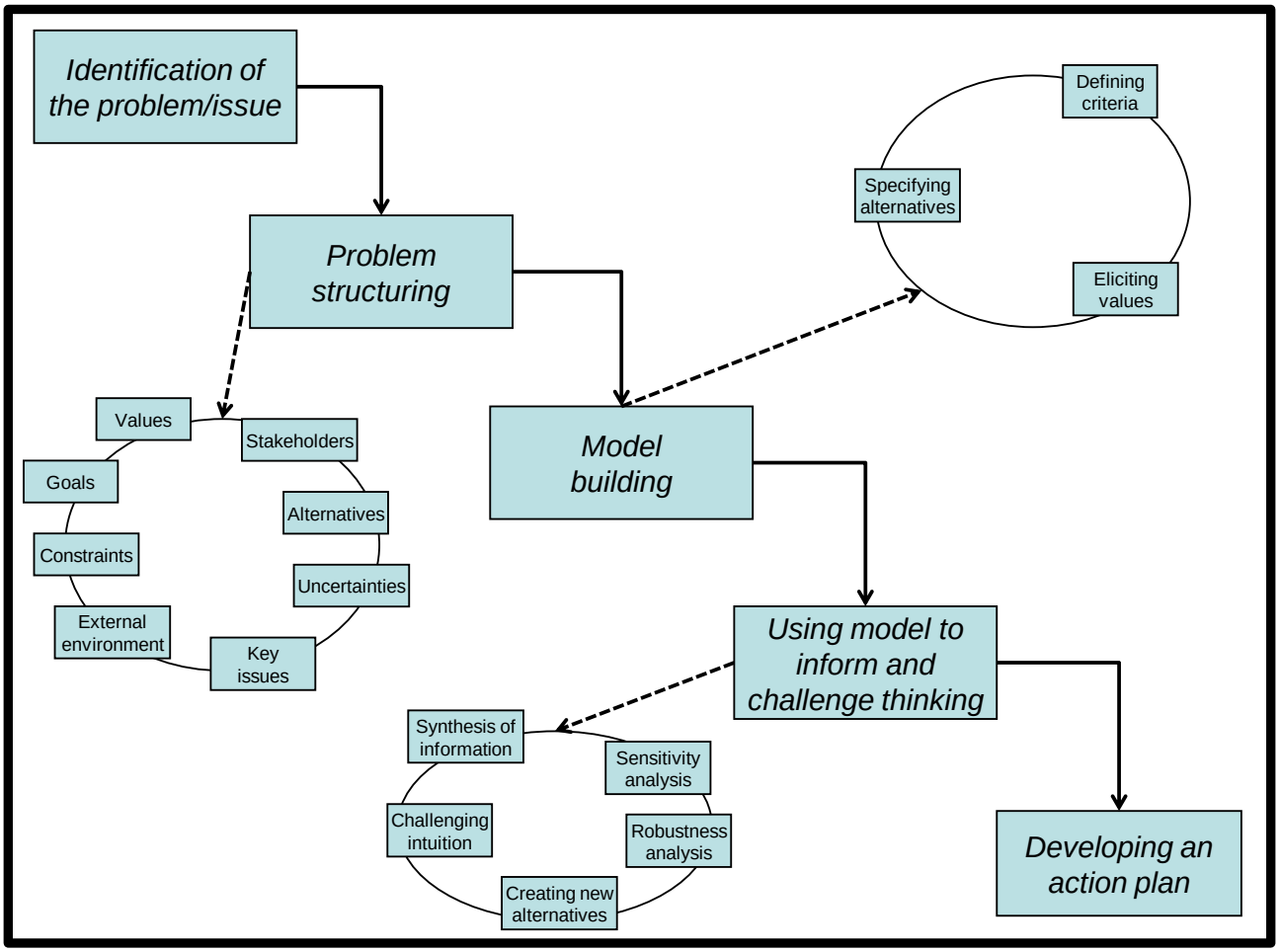
“We wish to emphasize that decision making is only remotely related to a ‘search for the truth.’ … the theories, methodologies, and models that the analyst may call upon … are designed to help think through the possible changes that a decision process may facilitate so as to make it more consistent with the objectives and value system of the one for whom, or in the name of whom, the decision aiding is being practiced. These theories, methodologies, and models are meant to guide actions in complex systems, especially when there are conflicting viewpoints” (Roy, 1996:11).

“The decision unfolds through a process of learning, understanding, information processing, assessing and defining the problem and its circumstances. The emphasis must be on the process, not on the act or the outcome of making a decision“ (Zeleny, 1982).

"… decision analysis helps to provide a structure to thinking, a language for expressing concerns of the group and a way of combing different perspectives" (Phillips, 1990:150).

3.2.6 MCDM process

"Much of the literature on MCDA can be criticized for adopting a stance of "given the problem" – i.e. taking as a starting point a well defined set of alternatives and criteria, and focusing on evaluation" (Belton and Stewart, 2002:5-5). They note that, instead, "the MCDA process will be embedded in a wider process of problem structuring and resolution ". This process is depicted in Figure 3-1 "which is deliberately messy in order to convey the nature of MCDA in practice …" (Belton and Stewart, 2002:5); it does, however, also indicate its objective, namely "through complexity to simplicity" (Belton and Stewart, 2002:6). The figure shows the five main stages of the process: (a) the identification of a problem or issue; (b) problem structuring; (c) model building; (d) using the model to inform and challenge thinking; and (e) determining an action plan. These stages can be grouped into three key phases (Belton and Stewart, 2002:14). The *problem identification and structuring phase* is aimed at a common understanding of the problem, the decisions to be made, and the criteria in terms of which decisions are to be made. The *model building and use phase* involves the development of formal models of decision maker preferences. The *development of action plan phase* involves translating the results of the analysis into specific plans of action.



Source: Based on Fig 1.1 in Belton and Stewart (2002:6).

Figure 3-1: The MCDM process

3.2.7 Stakeholders in the MCDM process

A distinction must be made between *types* and *roles* of stakeholders. This distinction is critical with regard to an appraisal strategy for CoT and its practical application; potential problems in this regard in the CoT context and possible solutions are explored in subsequent chapters.

According to Belton and Stewart (2002:7), "(t)here are many actors central to the process; these include decision makers, clients, sponsors, other stakeholders, including potential saboteurs, and the facilitators or analysts". The roles of critical stakeholders are defined as follows (Belton and Stewart, 2002:7-8; 14-15): The *decision maker* has the responsibility for the decision to be made. The *facilitator* guides and assists the decision maker by managing group processes. The *analyst* works independently and gathers information required by the

process and captures expertise that adds value to it. Facilitators and analysts may be external consultants on in-house experts. The *client* contracting the facilitator/analyst may not always be the final decision maker, but a person or group given the responsibility of exploring the issue and making recommendations. Alternatively, the client may be one of several stakeholder groups.

The majority of cases reported in the literature are supported by one of more analysts or facilitators – either in-house or external (Belton and Stewart, 2002:7-8). The role of the facilitator is particularly important when features of the stakeholder group are considered (Belton and Stewart, 2002:262). At one end of the spectrum, this may be a small, homogeneous group with common goals and objectives. At the other end, it may be "highly diverse interest groups with very different agendas".

3.2.8 Ordinal and cardinal importance, ranking and rating

A number of concepts are fundamental to MCDM and thus also to the development and application of an appraisal strategy for CoT. *Ordinal importance* refers to the order of importance of decision elements (which comes first, which second, etc.) *Cardinal importance* refers to the difference in magnitude between the importance of any two decision elements, for example "one element is three times more important than another" (Mendoza *et al*., 1999:39).

Likewise, the distinction between ranking and rating is important. *Ranking* refers to the process of assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made; this enables decision elements to be ordered according to their rank (first, second etc.). *Rating* is similar to ranking, but here decision elements are assigned "scores" between 0 and 100, with the requirement that the scores for all elements must add up to 100. This means that when one element is allocated a high score, another element must be allocated a lower score (Mendoza *et al*., 1999:16). In the case of ranking, a distinction is made between regular ranking and ordinal ranking (Mendoza *et al*., 1999:36-38). With *regular ranking*, each decision element is assigned a "rank", depending on its perceived importance. For example, ranks could be assigned according to a nine-point scale, as shown below:

1	3	5	7	9
Weakly important	Less important	Moderately important	More important	Extremely important

With *ordinal ranking*, decision elements are placed in order (hierarchy) of importance. This means that each element will have a unique place (position) in the hierarchy, unlike regular ranking where different decision elements can be given the same ranking, as shown above. Both ordinal and regular ranking have advantages and disadvantages. Regular ranking offers the following advantages: it allows for the possibility of "ties", and the decision maker can specify the "grades" of importance, using the table (scale) above. But it may not be sufficiently discriminating, as decision makers may "opt out" by giving equal assessments. Ordinal ranking offers two advantages: there can be no ambiguity regarding the order of importance, and it discriminates in terms of the *degree* of importance. But it does not allow for "ties", as no two elements can have the same order of importance. Also, it does not allow for "grades of importance", as on the nine-point scale of regular rating (see the scale above). Ranking therefore involves the ordinal importance of decision elements. Rating, on the other hand, provides both an ordinal and cardinal measure of importance (Mendoza *et al*., 1999:39).

3.2.9 Instrumentally rational behaviour

The notion of "instrumentally rational behaviour" holds a central position in almost all decision making techniques; for most mathematical models, it is a prerequisite (Engelbrecht, 2007:7). In the context of choices to be made, a person is deemed instrumentally rational if he or she has preferences that satisfy four axioms relating to reflexivity, completeness, transitivity and continuity (Heap and Varoufakis, 1995:6) (in Engelbrecht, 2007:7-9). For the purposes of this thesis, it is assumed that these axioms also hold in the case of a group of decision makers, as in the case of CoT. These axioms are listed below for the scenario where a person has to choose between (select the best of) alternatives $x_1, x_2, \ldots, x_n$, and where $x_i \leq x_j$ denotes that he either prefers x_j to x_i or is indifferent in his preference between x_j and x_i, and where $x_m = x_n$ denotes that he is indifferent in his preference between x_m and x_n:

Reflexivity: For any x_i, $x_i \leq x_i$. In other words, a person who compares something with itself, should be indifferent in his or her choice.

Completeness: For any x_i, x_j, either $x_i \leq x_j$ or $x_i \geq x_j$. In other words, when faced with any two options, a person will prefer one to the other or he will be indifferent in his preference between the two.

Transitivity: For any x_i, x_j, x_k, if $x_i \leq x_j$ and $x_j \leq x_k$, then $x_i \leq x_k$. In other words, a rational person will always prefer the option that allows him or her the greatest utility. This transitivity axiom is the essence of utility theory.

Continuity: For any x_i, x_j, x_k, if $x_i \geq x_j \geq x_k$, then there must exist some "composite" of x_i and x_k, say y, which gives the same amount of utility as x_j, that is $y = x_j$ and the person is indifferent in his preference between them.

When the first three of these axioms hold, then a person has a well-defined preference ordering. If the continuity axiom also holds, the preference ordering can be represented by a utility function (Engelbrecht, 2007:8). The theory of instrumentally rational choice (or expected utility theory) has, however, been challenged, as people often are not capable of "neatly ordering their priorities or preferences" and sometimes are "incapable of making rational choices". Criticisms against this theory can be grouped under three headings: (a) the Allais Paradox; (b) the Weltanschauung of Immanuel Kant; and (c) the source of beliefs in the social world (Engelbrecht, 2007:9-11).

3.2.10 Models for representing preferences

The outcome of the problem structuring phase of the MCDM process (described above) will be (more) clarity and consensus on a number of key issues such as the objective of the analysis, nature of the decision to be made, the set of alternatives to be considered (this could be either a discrete list of alternatives, or alternatives defined implicitly by constraints), and the set of decision criteria applicable to the context in question (Belton and Stewart, 2002:79). The problem structuring phase is therefore a prerequisite for the model building phase.

Several models have been developed to represent (model) preferences in the context of multi-criteria problems. These preference models all contain two primary components: (a) preferences in terms of each criterion (i.e. intra-criterion comparisons); and (b) an aggregation model (i.e. inter-criteria comparisons, which combine preferences across criteria) (Belton and Stewart, 2002:79). Diakoulaki and Grafakos (2004:8) classify preference models into two groups, namely Multi-Attribute Value Theory methods (MAVT) (i.e. value measurement methods) and outranking methods – based on the theoretical

background and the key assumptions adopted in modelling aspects with regard to (a) elicitation of preferences and (b) aggregation. Belton and Stewart (2002:9, 84) add a third group, namely satisficing models, and contend that the choice of the most appropriate method in a given case will be a function of the specific context, underlining the need for adopting a "horses for courses" approach (2002:338). A comparative overview of these models (schools of thought) is given below; this enables the choice of the most appropriate one in the case of CoT.

Value function models

With value function models (also known as value measurement models, Multi-Attribute Value Theory methods (MAVT) (Diakoulaki and Grafakos, 2004:8), the "weighted sums method (Engelbrecht, 2007:12-20), or additive value function model (Belton and Stewart, 2002:115), a single, unique numerical score representing "project worth" is constructed for each alternative, to represent the degree to which any one alternative is preferred to another. Scores are developed initially for each criterion and then aggregated over all criteria (Belton and Stewart, 2002:9). Diakoulaki and Grafakos (2004:8) capture key aspects of value functions as follows: "Multi-Attribute Value Theory methods (MAVT) aim to associate a unique number ('value') representing the overall strength of each alternative, taking all criteria into account. If there is substantial uncertainty about the performances of alternatives, the term 'utility' is used to denote that the preferences of stakeholders against risk are formally included in the analytical procedure. To begin, partial value (or utility) functions are defined for each criterion for reducing performances, in the [0-1] interval. Partial values are then aggregated for deriving total values and for pre-ordering examined alternatives. The transition from partial to global value functions (taking into account the whole set of criteria) implies the use of an aggregation formula together with the inter-criteria preferences provided by the decision maker".

Value measurement models are discussed in more detail in Section 3.3. The Analytic Hierarchy Process (AHP) and SMART (Simple Multi-Attribute Rating Technique) (including its improvements) fall in the ambit of value measure models, and are also described in Section 3.3.

Outranking models

Outranking as an approach to MCDA arose largely in Europe, and France in particular (Stewart *et al*., 1997:5). With the outranking approach (or "school of partial aggregation" (De

Brucker, Verbeke and Macharis, 2004:6), as opposed to “complete aggregation” methods as with value function models), a pairwise comparison of alternative courses of action (alternatives) is conducted, first done in terms of each criterion in order to determine the extent to which “a preference for one over the other can be asserted. In aggregating such preference information across all relevant criteria, the model seeks to establish the strength of evidence favouring selection of one alternative over another” (Belton and Stewart, 2002:9). Outranking methods are applied directly to partial preference functions (assumedly) defined for each criterion on a cardinal, ordinal or ordered categorical scale, and the underlying principle is “a generalization of the concept of dominance” (Belton and Stewart, 2002:106). Important concepts are the “concordance” principle (i.e. evidence in favour of *a* outranking *b*), and the “discordance” principle (evidence against *a* outranking *b*), which means that discordance can be understood in terms of a “veto” (Belton and Stewart, 2002:109-110). Outranking methods therefore differ from value function methods in that there is not underlying aggregative value function; the output of the analysis therefore is not a value for each alternative, but an outranking relation on the set of alternatives (Belton and Stewart, 2002:233). Outranking is generally applied to discrete choice problems (Belton and Stewart, 2002:234) where a simple (single) choice has to be made from a set of alternatives – it therefore addresses the choice problematique described above. On the other hand, as previously noted, the CoT case involves the selection of a number of projects, subject to a number of conditions, one of which involves budget constraints.

Diakoulaki and Grafakos (2004:9) note that weights in outranking methods have a different meaning from those in value function methods: “In outranking methods, they do not represent trade-offs between criteria scores, since they are used to combine preference relations rather than scores of alternatives. They are measures of the degree to which each criterion influences a final statement of whether or not ‘alternative a is equal or preferred to b’. If this statement is valid for the most important criteria, this supports the validity of the assertion overall”. Vincke (1989:143) (in De Brucker and Verbeke, 2007:10) adds that, with outranking methods, “the weight of a criterion is to be compared to the number of votes in an election procedure”.

Outranking approaches include the Electre family of methods (Electre I to Electre IV and Electre TRI), as well as Promethee (Belton and Stewart, 2002:233-252). Stewart *et al*. (1997:4) define Electre as “a method of decision analysis based on “outranking”; the approach incorporates concepts of voting (the weighted number of criteria favouring a

particular course of action) and vetoes (in which a course of action can only "outrank" another if there is no criterion which very strongly prefers the latter)".

Satisficing models

Satisficing models (also known as goal programming and reference point methods) firstly attempt to establish desirable or satisfactory levels of achievement for each of the criteria, and then "seek(s) to discover options which are in some sense closest to achieving these desirable goals or aspirations" (Belton and Stewart, 2002:9). Generalized goal programming models, developed within the context of linear programming models, are important building blocks in respect of satisficing models (Belton and Stewart, 2002:220). Goal programming essentially is "a simple operational implementation of the satisficing heuristic. The satisficing levels are generally assumed to be specified *a priori* as "goals", after which a mathematical programming algorithm is used to approach these goals as closely as possible" (Belton and Stewart, 2002:105).

3.3 Value function models

3.3.1 Introduction

From the discussion above of different models for representing preference, it is evident that value function models are most appropriate in the case of CoT: they allow a numerical indicator of (total) project worth to be established that enables projects to be evaluated and ranked, facilitating project selection. This section therefore examines value function models in more detail, in particular the terminology and basic principles of this type of model. This is done with reference to the process (steps) to be followed in order to arrive at a single indicator of project worth. To this end, an overview of the process is provided first, followed by a more detailed examination of each step.

3.3.2 Overview of the process

The overall MCDA process, described above in terms of its five main stages and/or three key phases, can also be broken down into a number of operational steps. Although there appears to be a general consensus on the essence and objective of this process, it can be disaggregated in a number of ways. Three views are presented here; assuming that they reflect different contexts for application which, in turn, may have required differences in emphasis and detail. De Brucke and Verbeke (2006:4), for example, suggest the following

"process-related steps in multi-criteria analysis", based on Nijkamp, Rietveld and Voogd (1990:13), but add that Steps 2 and 3 could be reversed – if Step 3 is kept in the second position, this would indicate focus on "alternative-focused thinking"; if criteria are developed first and actions (alternatives) thereafter, this would indicate "value-focused thinking" (Keeney, 1996:47ff) (in De Brucke and Verbeke (2006:4):

Process-related steps in multi-criteria analysis

Source: De Brucke and Verbeke (2006:4) *(based on Nijkamp et al., 1990:13).*

1 Problem definition.

2 Generation of alternatives.

3 Generation of a set of criteria.

4 Completion of the evaluation matrix.

5 Overall evaluation of alternatives.

6 Integration of the evaluation in the decision making process.

In terms of the SMART method (described below), these "process-related steps" are broken down in more detail, resulting in eight steps (Goodwin and Wright, 2004:30–48 in Engelbrecht, 2007:116), as shown below.

Steps in terms of SMART

Source: Goodwin and Wright (2004:30–48) (in Engelbrecht, 2007:116).

1 Identify the decision to be made and the relevant decision maker.

2 Identify the alternatives.

3 Identify the criteria which are relevant to the choice of alternative.

4 Determine the importance or weights of the criteria.

5 Measure the performance of all the alternatives in terms of the identified criteria.

6 Calculate the weighted value of each alternative.

7 Choose the alternative with the highest weighted value.

8 Perform a sensitivity analysis to determine the robustness of the decision.

Considering the structural elements of MCDA as captured by checklists such as CAUSE (Criteria, Alternatives, Stakeholders, Uncertainty, Environment) (Belton and Stewart, 2002:45-46), Diakoulaki and Grafakos (2004:6-8) suggest five "procedural steps" of the MCDA approach as shown in the box below; these steps are "interconnected in that backtracking and loops are often necessary before arriving at the final decision". They also note that all stakeholders are or should be actively involved in all these steps.

"Procedural steps" of an MCDA approach

Source: Diakoulaki and Grafakos (2004:6-8).

1 Problem identification

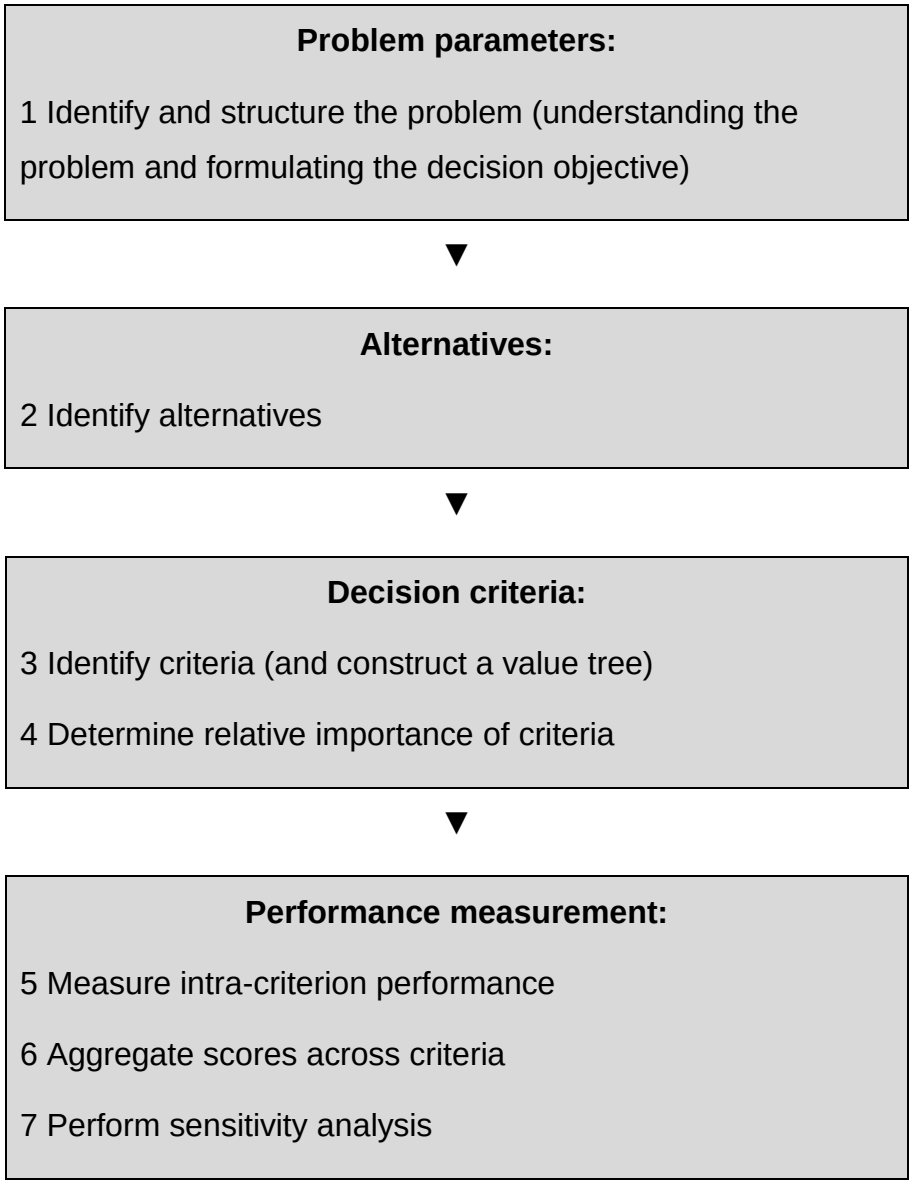
2 Problem structuring.

3 Preference modelling (including analysis of both intra- and inter-criteria preferences).

4 Aggregation and analysis of results.

5 Negotiation and consensus.

In order to examine the terminology and basic principles of value measurement models in the context of CoT, it is maintained that these steps should be broken down further. The diagrams below show the seven steps of the MCDM process deemed most logical in the case of CoT, grouped under four headings: (a) problem parameters, (b) alternatives; (c) decision criteria, and (d) performance measurement. These steps are discussed in more detail in the ensuing sections.



3.3.3 Identifying and structuring the problem

As noted in Section 3.2.7, the *problem identification and structuring phase* is aimed at ensuring a common understanding of the problem, the decisions to be made, and of the criteria in terms of which decisions are to be made (Belton and Stewart, 2002:14). This is necessary because MCDA problems do not present themselves in a structured form; a structure is therefore needed which by nature is a human construct, based on a shared understanding of the problem – with the inevitable conclusion that there will be no single right structure (Belton and Stewart, 2002:77). Engelbrecht (2007:35-45) also distinguishes between *defining the problem* and *formulating the decision objective*, and emphasizes that a correct definition of the problem is critically important because otherwise decision makers

may solve symptoms and not address the root cause of the problem. Formulating the decision objective is equally important: the decision objective is the crux of the decision to be made and it should therefore be stated "singularly, positively, clearly and concisely" (Engelbrecht, 2007:44).

3.3.4 Identifying alternatives

From the definitions in Section 2.2.4 it follows that the evaluation of mutually exclusive alternatives should always precede the ranking of independent projects. By definition therefore, the list of independent projects in the case of CBA is the collection of the best (feasible) option from each set of mutually exclusive alternatives, provided "the best" is not the null alternative. If the null alternative is indicated as the best alternative, it means that the status quo is acceptable from a transport economics perspective, and that any additional investment in transport infrastructure would amount to a wasteful allocation of scarce economic resources, since benefits would not exceed costs. In this regard, the distinction between budget cycle type projects and one off type projects (see Section 1.2.12) is important: In the case of repetitive projects, it is unlikely that the null alternative will, as a rule, be indicated the best alternative, as they normally are of a reactive nature – that is, addressing identified problems in the existing situation (infrastructure) – as opposed to one-off projects, which normally are of a proactive nature.

For the purpose of this study, it is argued that this "sequence of events" holds good not only for CBA (i.e. efficiency), but for decision objectives (criteria) in general. Consequently, it is essential to ensure that all mutually exclusive alternatives have been identified. In this regard, Belton and Stewart (2002:53) argue that "although the rationale for MCDA may appear to be the evaluation of given alternatives, equal emphasis should be given to the potential for creating good alternatives" – with the implication that alternatives are not given, but that they evolve. This underlines the importance of "value-focused thinking" in generating alternatives, a concept to which two chapters are devoted in a work by Keeney (1992) (in Belton and Stewart, 2002:53). Diakoulaki and Grafakos (2004:5) concur with this view: "alternatives may result from the systematic exploration of the objectives pursued in the decision situation considered". They also highlight the importance of value-focused thinking, by "generating alternatives through creative thinking focused on the values of the people concerned".

There are a number of methods for generating alternatives, such as brainstorming and the Delphi technique (Engelbrecht, 2007:46-47). Other methods are free association, forced relationship, attribute listing, creative leap and strategizing (Engelbrecht, 2007:54-55). He also gives the "basic rule" for identifying alternatives, namely that infeasible alternatives should not be included in the set of alternatives (2007:117).

In identifying a "complete" set of mutually exclusive alternatives, problem scoping is important, as incorrect scoping may result in the problem being addressed at an incorrect level. "Scoping requires that the problem be defined in such a way that all potential solutions are considered, so that it is possible to test objectively whether the problem has been solved or not. Its purpose is to help the analyst define a set of options, all of which demonstrably solve the problem and which include the global optimum" (Austroads, 2005b:2). In the case of a congested road, for example, the "problem" could be defined in a number of ways, with probable solutions at different (global) levels (Austroads, 2005b:2):

- As a narrow engineering issue, in which case the solution would involve widening or re-engineering the road.
- As a wider engineering issue, in which case building a bypass will be required.
- As an urban planning issue, in which case changing land-uses in the vicinity will be required.
- As a local pricing issue, in which case tolling will be required.
- As a network pricing issue, in which case the introduction of general road pricing will be required.

These examples serve to demonstrate the range of options considered in each case; an incorrect scoping may result in an incorrect range of options. "In general, the wider the scope of the problem, the more options there are to analyse, but the more likely that one will be globally optimal" (Austroads, 2005b:2).

By definition, the null alternative will always form part of this set of mutually exclusive projects and therefore needs to be correctly defined: "It is meaningless to ask the value of an option without first defining a reference point against which to measure it. This means that every project is represented by at least two options, one of which is the option against which all the others are compared" (Austroads, 2005b:3). An incorrect definition of the null alternative (base case) will not alter the choice of the best mutually exclusive alternative, but

will change the ranking of independent projects: “This will not change the ranking of other options, as all are affected equally, hence the same optimal option will be identified. But it will alter the apparent performance of the project relative to other projects, which leads to misallocation of resources” (Austroads, 2005b:3).

Regarding the distinction between mutually exclusive alternatives and independent projects, Austroads (2005b:4) adds value by disaggregating independent projects into three groups: “Consider two projects that, in isolation from each other, are valued at A and B respectively. Now consider their value in combination, C.

Independence. If both projects have no effect on each other, their combined value is the sum of their values in isolation: C = A + B. This is the case with most projects.

Synergy. If both projects reinforce each other in some way, their combined value is greater than the sum of their values in isolation: C > A + B. This is the case with projects that share joint costs (for instance, pedestrianization and the construction of new road or rail links), or whose benefits are complementary (for instance, road safety enforcement and road safety publicity).

Negative synergy. If both projects interfere with each other in some way, their combined value is less than the sum of their values in isolation: C < A + B. This is the case with safety projects that target the same traffic, since a life saved by one project cannot be saved again by another”.

For the purpose of this study, it is argued that the concept “synergy” be expanded and interpreted as “synergy for the right reasons”, that is being in line with strategic objectives. This substantiates the argument for an additional decision criterion in the case of CoT, namely compatibility with strategic planning objectives.

3.3.5 Identifying decision criteria

A (decision) criterion is defined as “a particular point of view or interest according to which policy or decision alternatives may be compared” (Stewart *et al*., 1997:4). Several techniques are available for finding criteria of “superior quality”, such as brainstorming and the Delphi technique (Engelbrecht, 2007:45-46). In order to be “operationally logical/correct”, any given set of criteria has to comply with a number of minimum requirements; these apply to all MCDM applications (i.e. not only to TI projects). Belton and Stewart (2002:55-59) list eight requirements for identifying a set of criteria, Roy (1985:312) (in De Brucker *et al*.,

1995:264) mentions four, and Diakoulaki and Grafakos (2004:5) list five characteristics of a coherent set of criteria. Requirements from these three sources are combined in the list below in order to serve as a "check" for identifying decision criteria in the case of CoT. The last of these requirements refers to situations warranting the use of a value tree:

(1) *Value reference* means criteria should be linked to the fundamental goals of stakeholders, enabling them to specify preferences.

(2) *Understandability* means that decision makers must have a shared understanding of key concepts used in the analysis, in other words, the concept behind each criterion is clear; and there is a common view about the preferred direction of alternatives' performance.

(3) *Measurability* implies that the performance of alternatives against the specified criteria must be measurable, and that it can be expressed on either a quantitative or qualitative measurement scale.

(4) *Non-redundancy* means the avoidance of duplication in measuring performance (in other words, two criteria measuring the same aspect) – double counting is avoided when no criterion reflects the same concept as another.

(5) *Judgmental independence* means that the preferences with respect to a given criterion do not depend on the level of another.

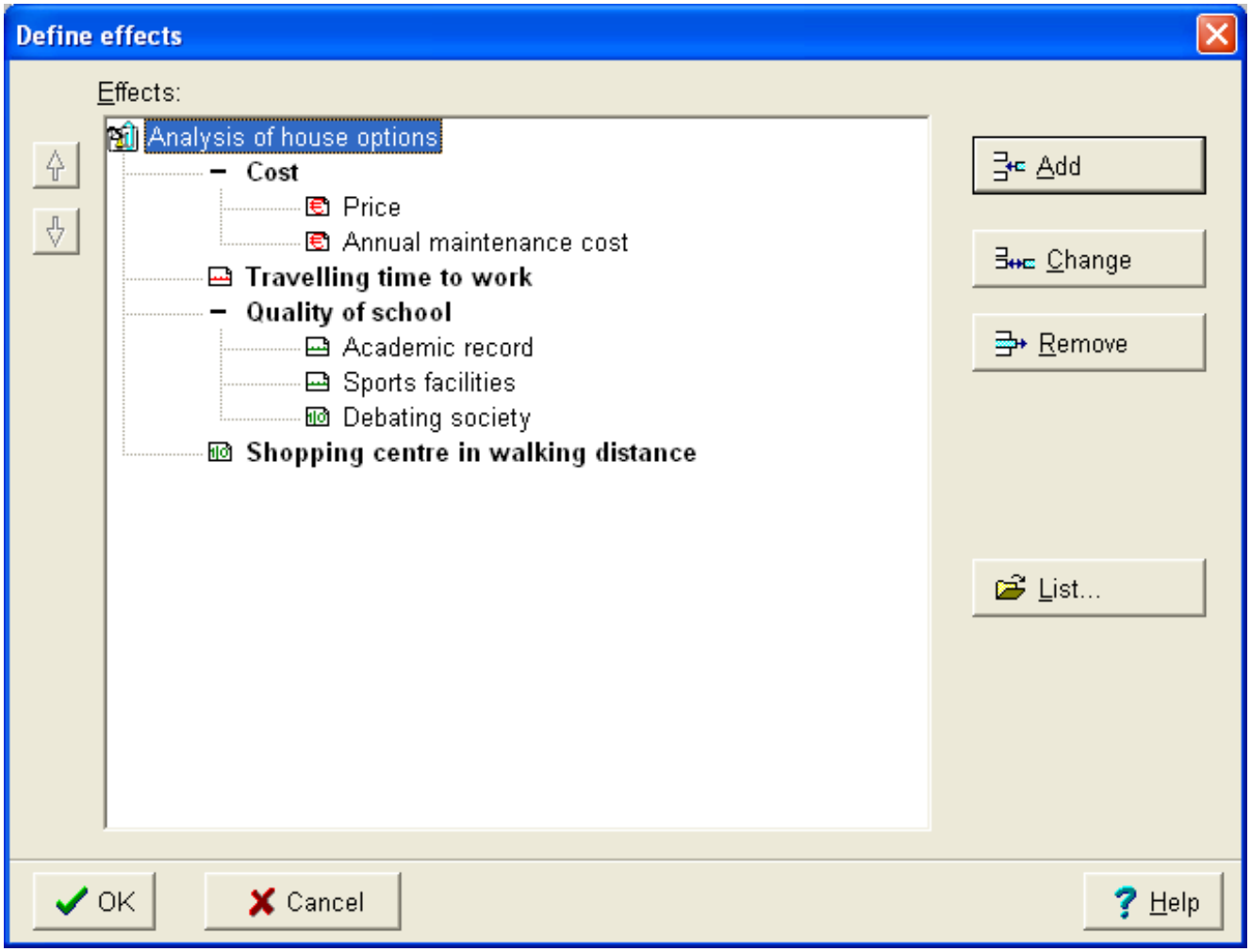
(6) *Operationality* means that the information demanded by the model must not place excessive demands on the decision makers. This means that there must be a balance between the importance of information needed and time constraints; this impacts on the initial specification of the model.

(7) *Simplicity versus complexity* refers to real-life situations where it is often found that the initial representation of the problem (value tree) is more detailed than necessary or operationally desirable, and where the actual use of the model leads to its refinement. This means that the requirements of *completeness and conciseness* must be balanced; that the value tree applicable to a given situation must be both complete (i.e. the set of criteria must cover all important aspects of the problem considered) and concise.

It is possible, in some cases even likely, that criteria are constructed hierarchically as a value tree (also called decision hierarchy (Engelbrecht, 2007:20-26), or ranked tree (Engelbrecht, 2007:22-24)), where broad, general interests (e.g. social and economic objectives) are presented at the top of the tree, and more specific criteria at the lowest level of the tree, on

the assumption that these lowest level criteria are defined in such a way that “unambiguous ordering of the alternatives can be stated in terms of each criterion” (Belton and Stewart, 2002:80). Engelbrecht (2007:50) talks of “operationalizing the criteria”, i.e. decomposing the criteria (and sub-criteria) a number of times before (until) their associated attributes (i.e. their measurable and discernable characteristics) become apparent.

Figure 3-2 depicts a value tree used in an example by Engelbrecht (2007:116-126), and involving the ranking of a number of residential dwellings in a given location according to a set of decision criteria in order to select the “best” one. The decision software DEFINITE – described in Section 6.4.3 and Section 6.4.4 – was used to prepare this figure. The figure indicates four “main” criteria, with two of the main criteria having sub-criteria.



Source: Adapted from Engelbrecht (2007:116-126).

Figure 3-2: Example of value tree

Moving from values to goals, then to objectives, then to criteria, therefore implies a cascading effect, meaning that one value produces more than one goal, one goal produces

more than one objective, and one objective produces more than one criterion (Stopher *et al*., 1977:6). The following example illustrates this cascading effect (Stopher *et al.*, 1977:6-8): a number of goals could be derived from the value "equity", such as: (a) every person must have the same opportunity to travel, regardless of income, age or infirmity; (b) every person must bear equal generalized costs relative to income for their work trips, regardless of distance to work; and (c) all persons must experience an equal incidence of disbenefits of transport location (e.g. acquisition of land and property, air pollution and noise levels. Each of these goals will generate a number of *objectives*. Examples of objectives to be generated from the first goal are: (a) the provision of a uniform level of public transport service to all parts of the study area; (b) the provision of the same total transport capacity to each community group relative to the size of the group; (c) increased accessibility of public transport for those handicapped by age or infirmity; and (d) the provision of a transport pricing system requiring each person to pay in proportion to his or her ability to pay. Likewise, a number of *criteria* can be defined for each objective; in the case of the first objective these may include the following: (a) the frequency of public transport service should not be less than one vehicle per hour in all areas; (b) walking distances should not exceed 300 m between residences and public transport access points; (c) walking distances should not exceed 200 m between stops and main business concentrations; (d) the total duration of work trips from all areas should not exceed 35 minutes; (e) the maximum waiting time for a mode change in main mode intersections in all areas should be 10 minutes; (f) adherence to the time schedule should be within +- 5 minutes; (g) time schedules and route layouts must at all times be available at all stations and stops of public transport; (h) no trip from residence to the CBD should require more than one transfer, and (i) no trip from any one suburb to another should require more than two transfers. Stopher *et al*. (1977:8) conclude that even these nine criteria may not provide an exhaustive definition of the first objective, but on the other hand warn against the danger of specifying too many goals (Stopher *et al*., 1977:4).

Developing a value tree can happen in both a *top-down* and a *bottom-up* manner. With a top-down approach (i.e. disaggregating criteria), one general objective (focus) is subdivided into different sub-objectives, with each of which criteria could be associated. With a bottom-up approach (i.e. aggregating criteria), criteria are developed on the basis of the relevant impacts (strengths and weaknesses) of an action (alternative), and then grouped in broader categories. These approaches could be used in parallel as they are complementary; in fact, this is likely to ensure a complete array of decision criteria (De Brucker *et al*., 2004:2).

Regarding the choice between a top-down and a bottom-up approach, Belton and Stewart (2002:59) concur with this view and conclude that there is no single right way; in practice, one perspective should inform the other. A top-down approach implies "value-focused thinking", and the bottom-up approach "alternative-focused thinking" (Diakoulaki and Grafakos, 2004:5) (see also Section 3.3.2). In the CoT case, therefore, adopting a parallel approach would add value by ensuring that the value tree is optimal. Also, for the purposes of this thesis, it is argued that another "layer" should be added at the bottom of the hierarchy, and that a bottom-up approach instead should be based on anticipated *impacts* – this will ensure that the value tree is complete. Combining this with the hierarchy of values, goals, etc (from Section 1.2.9) would translate into the extended value tree illustrated in Figure 3-3.

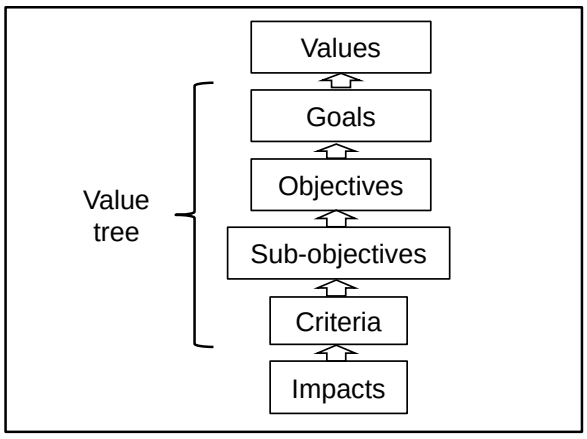


Figure 3-3: Extended value tree

Keeney and Raiffa (1976) (in Engelbrecht, 2007:126-130) list five criteria for determining whether a ranked tree is of "sufficient quality". To some extent, these criteria overlap with the requirements for identifying decision criteria (see above); however, some relate exclusively to ranked trees. *Completeness* means that all criteria relevant to the decision maker should be included. *Operationality* means that the attributes at the lowest level (at the end of the branches) must be operational (measurable). *Decomposability* means that decision maker must be able to consider a criterion without reference to other criteria. *Absence of redundancy* means that two or more criteria should not relate to the same objective. *Minimum size* means that the value tree should be as small as possible (in terms of the number of levels) without losing important information, as a meaningful analysis may become difficult if the value tree is too large; this means that no value will be added after some optimal level of disaggregation is exceeded.

3.3.6 Determining inter-criteria preferences

Preference modelling is applicable to (and needed for) both *intra-criterion preferences* (examined in the next section) and *inter-criteria preferences* (i.e. judgements referring to the relative importance attached to the information associated with each single criterion (Diakoulaki and Grafakos, 2004:7-8). The issue of the relative importance to be attached to each of the (conflicting) criteria is fundamental to the analysis of all MCDM problems, and the notion of "numerical weight parameters" applies to all MCDM preference methods: value measurement methods, outranking, as well as goal programming (although weight parameters are not always made explicit with the latter) (Belton and Stewart, 2002:114). With reference to the example by Engelbrecht (presented in Section 3.3), determining the relative importance of decision criteria involves completing the following weight vector:

$$w = \begin{bmatrix} v_1 v_{11} \\ v_1 v_{12} \\ v_2 \\ v_3 v_{31} \\ v_3 v_{32} \\ v_3 v_{33} \\ v_4 \end{bmatrix}$$

where the weights refer to the lowest order criteria, that is:

$v_1 v_{11}$ = weight of the sub-criterion "Cost: Price" i.e. initial purchase price of the house);

$v_1 v_{12}$ = weight of the sub-criterion "Cost: Maintenance" (i.e. maintenance cost of the house);

v_2 = weight of the criterion "Travelling time to work";

$v_3 v_{31}$ = weight of the sub-criterion "Quality of school: Academic record";

$v_3 v_{32}$ = weight of the sub-criterion "Quality of school: Sports facilities";

$v_3 v_{33}$ = weight of the sub-criterion "Quality of school: Debating society";

v_4 = weight of the criterion "Shopping centre in walking distance".

With value measurement models, regarded as most appropriate in the case of CoT, a criterion weight essentially constitutes a *scaling factor*, relating scores on that criterion to scores on all other criteria; this means that it would be incorrect to assume that weights are

independent of the measurement scales used (Belton and Stewart, 2002:135). Therefore, if scales are changed, weights should be changed accordingly (Belton and Stewart, 2002:289). These authors continue: "(t)he assessment and interpretation of importance weights has often been a matter of heated controversy, which regretfully often misses the point that the meaning of the numerical weight parameter will differ according to the particular preference model being used, and often also according to the range of alternative under consideration" (Belton and Stewart, 2002:114). Also complicating the issue is the fact that it becomes increasingly more difficult to simultaneously discriminate between a large number of criteria in terms of utility. A rule of thumb is that for cases involving more than seven criteria, methods such as pairwise comparisons (discussed below) should be used (Engelbrecht, 2007:19).

Given the three methods for representing preferences (value measurement, outranking, and goal programming), different authors use different classification systems. De Brucker *et al*. (2004:4-5), for example, list nine weighting methods: (a) trade-off method, (b) swing method, (c) rating method, (d) ranking method, (e) verbal statements method, (f) pairwise method, (g) scenario method, (h) method based on previous choices, and (i) method to determine weights on the basis of a ranking of a limited number of actions. Diakoulaki and Grafakos (2004:11-13), on the other hand, divide weighting methods into two categories: compensatory and non-compensatory, and list the five most widely used compensatory weighting methods as follows: (a) trade-off method (Keeney and Raiffa, 1976); (b) swing method (Von Winterfeldt and Edwards, 1986); (c) resistance to change (Rogers and Bruen, 1998); (d) MACBETH (derived from "Measuring Attractiveness by a Categorical Based Evaluation Technique") (Bana e Costa and Vansnick, 1997); and (e) conjoint or holistic approach. They also assess weighting methods according to four properties that "may significantly influence their capacity to translate human preferences into numerical values" (Diakoulaki and Grafakos, 2004:13). This assessment is reproduced in Table 3-1.

Table 3-1: Assessment of weighting methods

Property	Assessment
Simplicity and transparency	The trade-off and MACBETH methods are the most complicated, and the holistic approach the simplest. The latter method, however, follows a less transparent procedure, and the obtained weights are not reliable.

Property	Assessment
	The swing and resistance to change methods are considered both simple and transparent.
Degree of inconsistencies in the articulation of preferences	There are more inconsistencies with the trade-off, MACBETH and the holistic approach. Also, their resolution may be intricate and confusing. With the swing and resistance to change methods, inconsistencies are normally avoided.
Ability to handle small or large number of criteria	The trade-off and the MACBETH methods are the most difficult to apply in problems with a large number of criteria. This results from the increased number of pairwise comparisons that are needed. The holistic approach is prone to inconsistencies if the number of criteria increases. In problems with a small number of criteria, the resistance to change method is not appropriate as the least important criterion could be assigned a zero weight. The swing method is least sensitive to the number of criteria.
Sensitivity to impact range	"The more a preference elicitation procedure involves cross-attribute comparisons of impact range, the more sensitive will be the elicited weights to the range of attributes, and thus the more reliable for use as scaling factors." The trade-off and MACBETH methods are the most sensitive to impact range, and the holistic approach the least. Both the swing and resistance to change methods present an intermediate sensitivity to impact range.

Source: Diakoulaki and Grafakos (2004:13).

Based on this assessment, it follows that the swing and trade-off methods offer the most advantages: the swing method is simpler, more transparent, better capable of avoiding inconsistencies, and has no limitation with regard to the number of decision criteria. The trade-off method, in its turn, is more sensitive to variations of impact range. The swing method appears to be preferred by most users "because of the much simpler way of eliciting the stakeholders' preferences", and "because of the reluctance of certain stakeholders to

directly define trade-offs including ethical values (e.g. human health vs. cost)" (Diakoulaki and Grafakos, 2004:13-14).

For the purposes of this study (which focuses on value measurement models for the purpose of developing a strategy for CoT), a brief description is given below of a number of methods for establishing the relative importance of criteria.

Intuitive methods: Two "intuitive methods" are described here which will both result in a discrete utility function (Engelbrecht, 2007:14). Firstly, criteria are simply ranked according to preference (or importance, significance). The normalized weight for the *i* th criterion is then given by

$$W_i = ((n + 1) - p_i) / \sum p_j$$

where p_i is the rank of the *i* th criterion, and n = the number of criteria. In the case of four criteria, for example, the normalized weights, written as a weight vector, will be

$$\boldsymbol{w} = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix}$$

$$= \begin{bmatrix} 0{,}4 \\ 0{,}3 \\ 0{,}2 \\ 0{,}1 \end{bmatrix}$$

The weight vector *w* in this case displays a "multiple of the smallest rank" property, that is the utility of the successive alternatives differ by the same fixed amount. This very fact may preclude its use in cases where it may be necessary to discriminate with more precision between the utility of various criteria.

A second "intuitive method" to find more precise values for the utility of criteria involves asking the decision maker to divide (say) 100 points between criteria according to their preference (importance). Assuming four criteria, this may result in a weight vector such as

$$\boldsymbol{w} = \begin{bmatrix} 55 \\ 30 \\ 10 \\ 5 \end{bmatrix}$$

In this case, it is unlikely that a set of utility values would be obtained with a *multiple of the smallest rank* property.

The revised Churchman-Ackhoff technique: This technique "is based on the strong theoretical assumptions of additivity of the criteria or the existence of an additive utility function" (Engelbrecht, 2007:14-17). It comprises six steps, namely the ranking of criteria, the evaluation of criteria according to a cardinal scale, the comparison of criteria in a systematic manner, verifying coherence, modifying non-coherent cardinal values by means of a given algorithm, and writing down the weight vector by normalizing the values obtained from the previous step.

Zeleny's entropy method: This method "is considered to be an objective method as it allows for the determination of criterion weights without the intervention of the decision maker. Criterion weights are determined from the values, e_{ij}, in the decision matrix. The relative importance of criterion c_j as measured by its weight w_j is assumed to be an immediate function of the amount of information contributed by the $_j$ th criterion on the set of alternatives" (Engelbrecht, 2007:17). With this method, therefore, the importance of a criterion is assumed to be a function of its dispersion (using Shannon's measure of entropy), on the basis that it will have the most discriminating influence between alternatives. As a consequence, this method is useful in cases where criteria weights cannot be readily determined, and the impact of the dispersion of the evaluations of a given criterion is likely to be important. "However, a valid criticism of the method is applicable in cases where criteria with evaluations of larger dispersion are clearly of lesser importance. In such cases, Zeleny's entropy method may yield inferior results for decision making" (Engelbrecht, 2007:19).

Swing weighting: This method (used in SMART) attempts to address the "problem" with methods basing preference on the importance (ranking) of criteria only (namely that the *range* between the most preferred and the least preferred alternatives in terms of a given criterion may not be considered.) It involves a number of steps: (a) determining the set of criteria, (b) ranking the criteria, (c) assigning an arbitrary value to the first ranked criteria, (d) finding swing weights for all other criteria, and (e) normalizing criteria weights. Finding swing weights for all other criteria is described as follows: "The analysis continues when the decision maker is asked to indicate how important he or she would rate c_2 in relation to c_1 given the swing from worst to best case for profitability history and the swing from worst to best for management quality. Suppose the decision maker indicates that he or she rates the swing in c_2 at 75% of the swing in c_1, then the swing value for the comparison:

100 (0.75) = 75.

By determining swing values for the remaining criteria in relation to c_1 values for v_1, v_2, v_3 and v_4 are determined by normalising the various swing values" (Engelbrecht, 2007:137). Stewart *et al*. (1997:124,126) note that software such as VISA (Visual Interactive Sensitivity Analysis) and SDAW (a simpler alternative to VISA) will not only serve to do the necessary calculations automatically, but will also assist in carrying out sensitivity analyses to determine the impact of the precise relative weight attributed to each criterion. With SMARTER (short for SMART Exploiting Ranks, and building on SMART), a *rank order centroid weight method* is used to allocate weights to criteria (Engelbrecht, 2007:140).

Analytical Hierarchy Process (AHP): AHP uses pairwise comparisons, considering only two entities at a time, for both evaluating (scoring) alternatives and weighting criteria (Engelbrecht, 2007:147). Belton and Stewart (2002:114) refer to the use of "semantic scales for purposes of expressing relative importance". In particular, decision makers are asked to make intuitive statements (verbal descriptions) of relative importance using terms such as "moderate", "strongly" or "absolutely" more important – which are then converted into assumed ratios. However: "It is by no means evident ... that intuitive importance ratios expressed in this way correspond even approximately to the meaning of the weight parameter in a specific preference model. Even if the intuitive weights are appropriate to one decision model, they cannot apply equally to all decision models, since ... the meanings weights differ between models. The readiness of people to express importance ratios intuitively and in the absence of context may thus well be a hindrance rather than a help to the implementation of MCDA" (Belton and Stewart, 2002:114-115). Also, the fact that people do not normally adjust direct assessment of relative importance in the light of changed ranges of outcomes (which lead to a re-scaling of the partial value functions), means that "directly assessed importance ratios are almost certainly inappropriate for use in a value function model", indicating a preference for the concept of swing weights (Belton and Stewart (2002:289).

3.3.7 Measuring intra-criterion performance

Intra-criterion performance measurement, for the purpose of this study, is defined as including both (a) scoring alternatives and (b) standardizing the scores. This is necessary in order to populate the evaluation matrix,

$$E = \begin{bmatrix} e_{11} & e_{12} & \dots & e_{1n} \\ e_{21} & e_{22} & \dots & e_{2n} \\ . & . & . & . \\ . & . & . & . \\ e_{m1} & e_{m2} & \dots & e_{mn} \end{bmatrix}$$

which refers to a decision making context with a finite set of m alternatives denoted by $A = \{a_1,...,a_m\}$, and a finite set of n criteria denoted by $C = \{c_1,...,c_n\}$. Also, e_{ij} refers to the evaluation of the i th alternative on the j th criterion (Engelbrecht, 2007:12-13).

Table 3-2 contains scores for the alternatives in the example by Engelbrecht (2007:116-126) (referred to in the previous section). The evaluation matrix following the table contains scores after having been standardized, using procedures such as those examined in this section, and from which it will be clear that *standardizing scores* cannot be done independently from *scoring projects* – implying that scores should be known before they can be standardized.

Table 3-2: Scores for alternatives

Alternatives	Scores						
	c_1	c_2	c_3	c_4	c_5	c_6	c_7
	$ mil	**$ '000**	**minutes**	**proportion**	**number**	**NA**	**NA**
a_1	0.7	15	28	0.02	1	No	No
a_2	1.2	10	44	0.04	2	Yes	Yes
a_3	0.9	8	50	0.03	1	No	Yes
a_4	1.8	5	6	0.10	3	Yes	Yes
a_5	1.0	11	22	0.06	4	No	No

$$E = \begin{bmatrix} 0.99 & 0.333 & 0.533 & 0.2 & 0.25 & 0 & 0 \\ 0.92 & 0.667 & 0.267 & 0.4 & 0.50 & 1 & 1 \\ 0.97 & 0.800 & 0.167 & 0.3 & 0.25 & 0 & 1 \\ 0.45 & 1.000 & 0.900 & 1.0 & 0.75 & 1 & 1 \\ 0.96 & 0.600 & 0.633 & 0.6 & 1.00 & 0 & 0 \end{bmatrix}$$

Scoring is defined as "the process of assessing the value derived by the decision maker from the performance of alternatives against the relevant criteria. That is, the assessment of the partial value functions, $v_i(a)$ in the above model" (Belton and Stewart, 2002:121), where "above model" refers to the additive model that is the most widely used form of the value function (2002:120). In this regard, Belton and Stewart (2002:85) continue: "Within the value measurement approach, the first component of preference modelling (measuring the relative importance of achieving different performance levels for each identified criterion) is achieved by constructing "marginal" (or "partial") value functions, say $v_i(a)$, for each criterion". Partial preference (value) functions are based on multi-attribute value theory (MAVT); value measurement models have, however, been extended to include the notion of "utility theory" for dealing with uncertainties in MCDA, leading to the development of multi-attribute utility theory (MAUT) (Belton and Stewart, 2002:7,84). Utility theory "represents the only formalized theory for explicit modelling of uncertainty in MCDA" (Belton and Stewart, 2002:84).

Value function methods "synthesize assessment of the performance of alternatives against individual criteria, together with inter-criteria information reflecting the relative importance of the different criteria, to give an overall evaluation of each alternative indicative of the decision makers' preferences" (Belton and Stewart, 2002:119). They continue (2002:123): "The first step in defining a value function is to identify a measurable attribute scale which is closely related to the decision makers' values". In other words, performance must be assessed on an interval scale of measurement, defined as a scale on which the difference between points is the important factor. Two reference points (maximum and minimum) need to be assigned to this scale, and they can be defined in a number of ways: a *local scale* is defined by the set of alternatives under consideration, whereas a *global scale* is defined by reference to a wider set of possibilities (Belton and Stewart, 2002:121). This matter (selecting the appropriate scale) is explored further in Chapter 6 with reference to the CoT case, **us**ing appropriate software for applying the appraisal strategy.

The next step involves determining how other scores (i.e. scores other than these reference points) are to be assessed. Belton and Stewart (2002:123-132) describe three ways in which this can be done: (a) definition of a partial value function; (b) construction of a qualitative value scale; or (c) direct rating of alternatives.

Definition of a partial value function: A distinction is made between the *direct* and the *indirect* assessment of a value function. With the former, the decision maker determines if the value function is monotonically increasing or decreasing against the natural scale, or whether it is non-monotonic. With indirect assessment models, which assume that the value function is monotonically increasing or decreasing, both the bisection and the difference methods could be used.

Construction of a qualitative value scale: This applies when it is not possible to find a measurable attribute that captures a criterion; an example in this regard is the Beaufort scale for measuring the strength of wind (Belton and Stewart, 2002:128). A qualitative scale should have a number of characteristics: they should be operational, reliable, value relevant and justifiable.

Direct rating of the alternatives: This can be viewed as the construction of a value tree, but defining only the end points of the scale (minimum and maximum). "All other alternatives are positioned directly on the scale to reflect their performance relative to the two reference points" (Belton and Stewart, 2002:131). Direct rating would apply for example in the case of the criterion "ease of set up and operations" where the decision objective is to find the best location for a new office (Belton and Stewart, 2002:131).

It is important to note that the value functions for all criteria should be in the same interval (e.g. [0,1], [0,100]), in order to avoid inadvertent changes to the criterion weights. In the case of alternatives that have no intrinsic value with regard to a given criterion, the intervals should be of the form [0,η], where η is the maximum score that can be achieved (Engelbrecht, 2007:131). Also important is the fact that preferences can be expressed not only on a cardinal scale, but also in ordinal terms (involving comparative statements, e.g. one criterion is more important than another) and categorical terms (where the latter is an extension of ordinal statements into categories of importance) (Engelbrecht, 2007:164). It should further be noted that determining the performance of alternatives against the relevant criteria is a prerequisite for establishing partial value (preference) functions, as the output from the former serves as input for the latter. In particular, values on the performance of alternatives

on a given criterion are needed to determine the minimum and maximum reference points on the measurement scale referred to above.

A number of standard value functions have been developed for SMART, namely the bi method, linear functions, step functions, and Boolean functions (Engelbrecht, 2007:131-135). With the latter, only two options are possible, for instance Yes (which = 1) and No (which = 0).

Under conditions where simpler methods will suffice, SMARTER may be used (Engelbrecht, 2007:138). In an attempt to reduce the interaction between decision makers and the analyst, SMARTER allows only linear functions (except for yes/no evaluations), of the following form:

$$e_{ij} = b_0 + b_{1x}$$

where e_{ij} is the evaluation of the i th alternative against the j th criterion, b_0 is the starting point on the e_{ij} axis, b_1 is the slope of the function and x is the actual value measured for the alternative (Engelbrecht, 2007:138-140). The SMARTER strategy of "heroic approximation" "is based on the idea that although a simplified decision model may only approximate the decision problem, the likelihood of introducing errors in the values elicited from the decision maker will be greatly reduced when the judgements to be made are less complex. This would be true of both the evaluation of alternatives and the allocation of weights to criteria" (Engelbrecht, 2007:138-139). In answer to Von Winterveld and Edwards' plea (in Belton and Stewart, 2002:124) that all value functions should be linear or close to linear, Belton and Stewart (2002:124) argue as follows: "Whilst we agree that an extremely non-linear value function, in particular a non-monotonic function, may indicate a need to revisit the definition of criteria, we caution against over-simplification of the problem by inappropriate use of linear value functions". This view is substantiated by the results of experimental simulations that suggest that the result of the analysis may be sensitive to such assumptions, and the "default assumption of linearity" may generate misleading answers (Belton and Stewart, 2002:124).

With reference to a scenario-based policy planning procedures, Stewart *et al*. (1997:119-124) describe the thermometer scale approach for scoring different scenarios on each criterion, where a thermometer scale is defined as "a method of directly associating relative scores with a set of policy scenarios or courses of action" (Stewart *et al*., 1997:5).

De Brucker *et al*. (2004:3-4) use the concept of "normalization of the scores". They argue that the "partial evaluations" are normally expressed in different units, using different evaluation scales. To (eventually) allow for comparisons between criteria, performance

measurements therefore have to be “normalized”. They list a number of “normalization procedures”, but note that each method has its strengths and weaknesses, and that normalization methods and MCA methods are related. It is also noted that “the specific normalization procedure used may affect the results of the final aggregation procedure” (De Brucker *et al*., 2004:3). They list four normalization methods (2004:3-4): (a) vector normalization; (b) normalization by dividing each score by the column maximum; (c) normalization by dividing each score by the column total; and (d) interval normalization. (These methods are explored further in Chapter 6 where the application of the appraisal strategy for CoT is demonstrated, using software selected for this purpose.) In addition, they distinguish between a “benefit criterion” and a “cost criterion”: “A benefit criterion is a criterion to be maximized, because the higher the score, the better it is. A cost criterion should be minimized because the lower the score, the better it is. In view of the aggregation of the criteria, the criteria should all share the same ‘direction’ (higher scores are always preferable or lower scores are always preferable). This can be achieved by converting all scores into benefit criteria, for instance by subtracting the cost-related scores from 1 or by multiplying them by -1” (De Brucker *et al*., 2004:4).

3.3.8 Aggregating scores across criteria

This step involves calculating a single numerical score representing “project worth” for each alternative, to represent the degree to which any one alternative is preferred to another. This can only be effected after (a) the relative importance of criteria has been determined (i.e. the weight vector has been computed), and (b) the evaluation (decision) matrix has been determined. With value function models, the simplest and most widely used form of value function for value measurement models is the additive model given below (Belton and Stewart, 2002:120):

$$V(a) = \sum w_i v_i(a)$$

where:

$V(a)$ is the overall value of alternative a;

v_i is the value score reflecting the performance of alternative *a* on criterion *i*; and

w_i is the weight assigned to reflect the importance of criterion i.

Stated differently, this step involves the calculation of the solution vector, *s*, which is the product of the evaluation (decision) matrix and the weight vector:

$$s = Ew$$

where *E* is the decision (evaluation) vector and *w* the weight vector. This can be rewritten as follows (Engelbrecht, 2007:19-20:

$$s = \begin{bmatrix} e_{11} & e_{12} & \dots & e_{1n} \\ e_{21} & e_{22} & \dots & e_{2n} \\ . & . & . & . \\ . & . & . & . \\ e_{m1} & e_{m2} & \dots & e_{mn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ w_n \end{bmatrix}$$

The evaluation matrix for the example presented by Engelbrecht (2007:116-126) was given in a previous section. The corresponding weight vector was given as follows (2007:120):

$$w = \begin{bmatrix} v_1 v_{11} \\ v_1 v_{12} \\ v_2 \\ v_3 v_{31} \\ v_3 v_{32} \\ v_3 v_{33} \\ v_4 \end{bmatrix}$$

Assuming the following weights for the *main criteria* (Engelbrecht, 2007:120): (a) Cost: 0,50; (b) Travelling time to work: 0,20; (c) Quality of school: 0,25; and (d) Shopping centre in walking distance: 0,05; and the following weights for the *sub-criteria* under Cost: (a) Price: 0,6; (b) Annual maintenance cost: 0,4; and for the *sub-criteria* under Quality of school: (a) Academic record: 0,6; (b) Sports facilities: 0,2; (c) Debating society: 0,20; the weight vector can be calculated as follows:

$$w = \begin{bmatrix} (0.5)(0.6) \\ (0.5)(0.4) \\ 0.2 \\ (0.25)(0.6) \\ (0.25)(0.2) \\ (0.5)(0.2) \\ 0.05 \end{bmatrix} = \begin{bmatrix} 0.3 \\ 0.2 \\ 0.2 \\ 0.15 \\ 0.05 \\ 0.05 \\ 0.05 \end{bmatrix}$$

and the solution vector, *s*, can now be rewritten as follows (Engelbrecht, 2007:120):

$$s = \begin{bmatrix} 0.99 & 0.333 & 0.533 & 0.2 & 0.25 & 0 & 0 \\ 0.92 & 0.667 & 0.267 & 0.4 & 0.50 & 1 & 1 \\ 0.97 & 0.800 & 0.167 & 0.3 & 0.25 & 0 & 1 \\ 0.45 & 1.000 & 0.900 & 1.0 & 0.75 & 1 & 1 \\ 0.96 & 0.600 & 0.633 & 0.6 & 1.00 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.3 \\ 0.2 \\ 0.2 \\ 0.15 \\ 0.05 \\ 0.05 \\ 0.05 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5127 \\ 0.6478 \\ 0.5919 \\ 0.8025 \\ 0.6746 \end{bmatrix}$$

This means that the alternatives can be arranged from most preferable to least preferable in the following sequence:

$$a_4 \rightarrow a_5 \rightarrow a_2 \rightarrow a_3 \rightarrow a_1$$

This means that alternative a_4 is most preferred and alternative a_1 least preferred (Engelbrecht, 2007:124).

3.3.9 Examining sensitivity of results

The preliminary results of the analysis (i.e. the overall values of alternatives and their ranking; see the previous section) do not signal the end of the analysis. Instead, establishing the preliminary results merely constitutes "another step in furthering understanding and promoting discussion about the problem" (Belton and Stewart, 2002:143). Sensitivity analysis is important in this regard; its objective is to examine if the results are robust, or if they are sensitive to changes in certain aspects of the model. In addition to the overall ranking of alternatives, therefore, the profiles of alternatives should be examined, as well as the "make-up" of the overall value of an alternative, whether it is a good "all rounder", and whether it has certain strengths and weaknesses. The notion of dominance is important in this regard, as alternatives with similar overall (total) scores may have very different profiles. For example, it may be possible that a given alternative emerges as best in terms of overall value (score) without scoring highest on any single criterion. In such cases, the underlying reasons and the implications thereof should be investigated and understood and, most importantly, accepted by all involved in the decision making process (Belton and Stewart, 2002:145).

Sensitivity analysis can be viewed from three perspectives (Belton and Stewart, 2002:148). The *technical perspective* involves an objective examination of the relationship between input parameters (namely value functions, scores and weights) and model output (namely the overall evaluation of alternatives); in particular, the effect on output of changes in input parameters. It aims at determining which (if any) input parameters have a critical impact on model output (i.e. where a small change in input parameters has a substantial effect on overall preference order). The *individual perspective* is aimed at providing a sounding board to individuals for testing their intuition and understanding of the problem, to ensure that they are comfortable with the results of the model. The *group perspective* is aimed at allowing the exploration of alternative perspectives on the problem, for example by including representatives from other disciplines such as economists, environmentalists or industry representatives – this may lead to a different set of criteria weights to be used in the analysis.

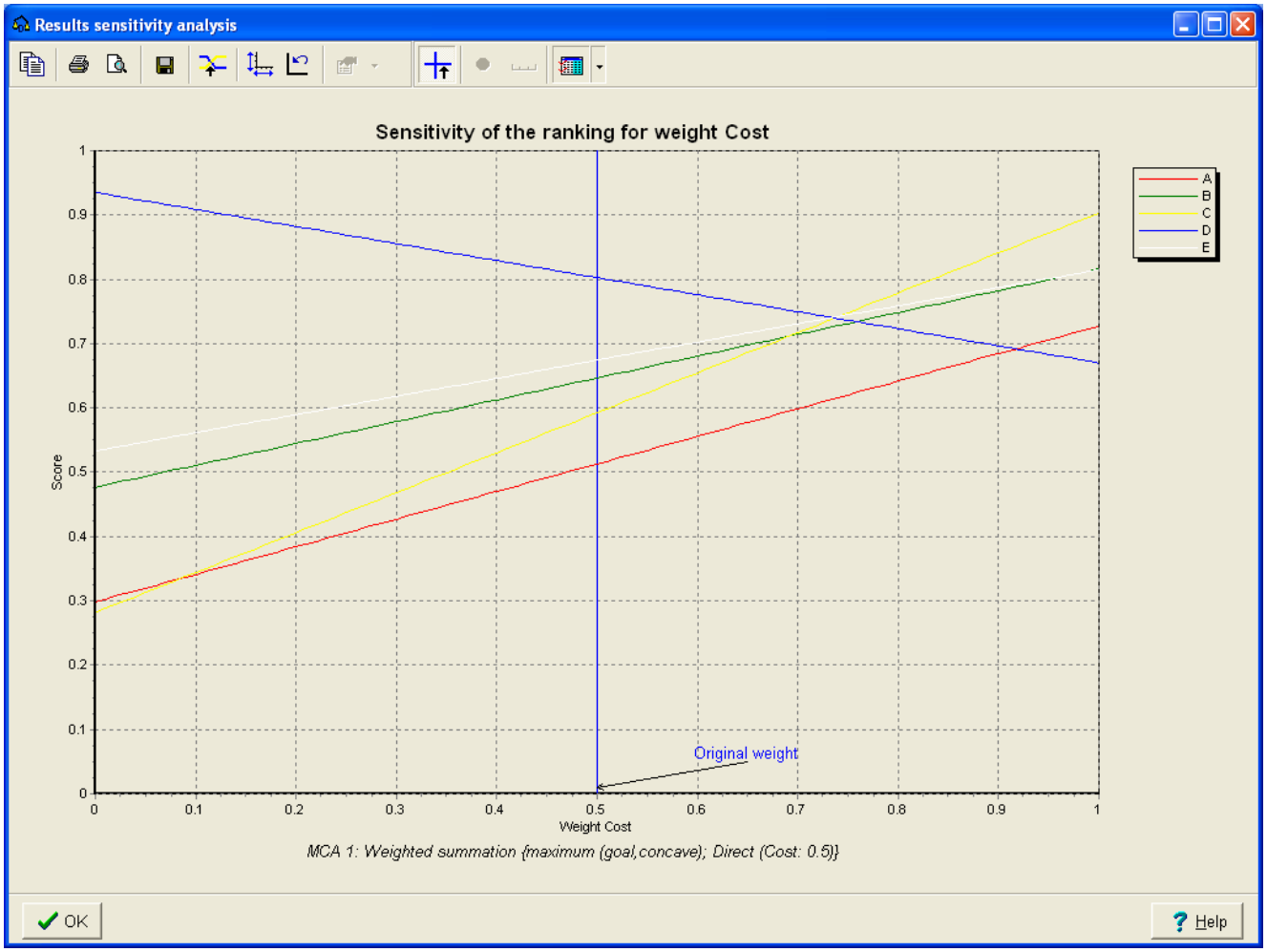
DEFINITE, the decision support software selected for the purpose of this thesis (explained in subsequent sections) allows a sensitivity analysis of a selected score as well as a selected weight. Weight sensitivity is explained below with reference to the example used by Engelbrecht and presented in previous sections, where the preliminary ranking was indicated as follows:

$$a_4 \rightarrow a_5 \rightarrow a_2 \rightarrow a_3 \rightarrow a_1$$

which, for the purpose of the example below, could be rewritten as:

$$D \rightarrow E \rightarrow B \rightarrow C \rightarrow A$$

and where a_4 (i.e. alternative D) emerged as best. As pointed out by Engelbrecht (2007:124-126), the objective of a weight sensitivity analysis is to determine how large errors in the criteria weights could become before a different ranking is obtained and another alternative is indicated as best: “If the error margins are large, then the decision maker should be comfortable with the decision. However, if the error margins are small, the decision maker may decide to revisit the criteria weight in order to assure himself or herself that the decision was the right one” (Engelbrecht, 2007:124). In the example, the criterion Cost(Price) was allocated the biggest weight (= 0,3); it therefore is most influential. Figure 3-4 involves the analysis of the sensitivity of this criterion; this is done by plotting solution values (total scores) (*y*-axis) as a function of a range of values for the relative importance (weight) of the criterion Cost(Price) (on the *x*-axis).



Source: Adapted from example by Engelbrecht, and produced by DEFINITE.

Figure 3-4: Sensitivity of ranking for criterion weight Cost: Price

The graph shows that alternative a_4 (Alternative D) is dominant over other alternatives for Cost (Price) weight in the interval [0, 0,74]; that is, a 148 percent change in the weight for the criterion Cost (Price) is allowed before the ranking changes and a different alternative (Alternative C) emerges as the best alternative. This means that the chosen criterion weight for Cost (Price) can be considered robust. To dispel any reservations regarding the allocation of criteria weights, however, it is necessary to conduct sensitivity analysis for all criteria.

3.3.10 SMART and AHP

Both SMART (Simple Multi-Attribute Rating Technique) and AHP (Analytic Hierarchy Process) are relevant in the context of value function models. The software tool used in

Chapter 6 in a CoT context also facilitates their application. They are therefore briefly explored below.

SMART

SMART, first described by Von Winterfeldt and Edwards (1986), is a collection of techniques rather than a single process, with the main commonality between techniques being their reliance on direct numerical estimation methods (Engelbrecht, 2007:113). It is a multi-criteria decision analysis tool for evaluation of a finite number of decision alternatives (*n*) under a finite number of performance criteria (*m*) (Engelbrecht, 2003:77). It is an implementation of MAUT (Multi-Attribute Utility Theory) "which is the core of the thermometer scale and swing weighting assessments of scenario planning" (Stewart *et al*., 1997:5). Belton and Stewart (2002:7) describe SMART as "a simplified multi-attribute rating approach which now underpins much practical analysis". "The general idea is to quantify the expected values or utilities associated with the vertices of the ranked tree or decision hierarchy … by the use of a set of attributes that is relatively simple to evaluate. SMART relies on simple additive models, numerical estimation techniques for eliciting single-attribute values and ratio estimation of weights" (Engelbrecht, 2007:113). Although SMART was initially justified by its simplicity, later studies proved the robustness of additive multi-attribute models. Later it was given theoretical support because of the inclusion of difference measurement (Engelbrecht, 2007:113). Also, the use of more sophisticated swing weights and single-attribute curve-drawing procedures is becoming common (Lootsma, Mensch and Vos, 1990:293–305 in Engelbrecht, 2007:113).

In addition to the four axioms in the case of instrumentally rational behaviour (relating to reflexivity, completeness, transitivity and continuity; discussed above), Goodwin and Wright (2004) (in Engelbrecht, 2007:114) added four axioms regarding SMART, namely (a) decidability axiom, (b) summation axiom, (c) solvability axiom, and (d) axiom regarding finite upper and lower bounds for value. Recent improvements to SMART include the development of standard value functions (such as the bi method, linear functions, step functions and Boolean functions) (Engelbrecht, 2007:131-135), and the development and refinement of the swing weight method for weighting criteria (Engelbrecht, 2007:135-138). More recently, SMARTER (SMART Exploiting Ranks) was developed later in an attempt to reduce the amount of interaction between decision makers and the analyst (Engelbrecht, 2007:138-142).

AHP

AHP is a method of MCDA or MCDM developed by Saaty (in 1980); it is based on the pairwise comparisons of criteria and of alternatives (Stewart *et al*., 1997:4). "The AHP method reduces complex decisions into a series of simple comparisons, called Pairwise Comparisons, between elements of the decision hierarchy. By synthesizing the results of these comparisons, AHP can help you arrive at the best decision and provide a clear rational for the choice you made" (Mendoza *et al*., 1999:77). The need for AHP therefore arose from the fact that MCDM problems may become very complex, and also that a person's attention span reduces rapidly as the level of complexity increases. To address this, AHP uses pairwise comparisons, considering only two entities at a time, for both evaluating (scoring) alternatives and weighting criteria. Engelbrecht (2007:147) continues: "The main difference between the Analytical Hierarchy Process (AHP) and other MCDA techniques is that the AHP uses ratio comparisons whereas the other methods use scale comparisons. For example, within AHP, the analyst will determine that alternative a1 is twice as preferable as alternative a2 whilst a scale comparison would suggest that for alternative a1, for example, U(a1) = 0.6 and for alternative a2, U(a2) = 0.3. Certain mathematical concepts allow for the evaluation and weighting of activities by using ratio comparisons (Saaty 1980)" (in Engelbrecht, 2007:148). Engelbrecht (2007:148-163) cites these mathematical concepts such as determinants, eigenvectors, and eigenvalues, as well as other "AHP jargon" such as pairwise comparisons, measure of consistency, and consistent and inconsistent matrices.

Criticism of AHP is summarized under four headings: (a) no axiomatic foundations for AHP are provided; (b) the questions that are asked may be ambiguous; (c) the ratio scale that is used to measure the preference intensities is questionable; and (d) rank reversal may take place under certain conditions when a new alternative is added to the problem (Harker and Vargas, 1987:1383-1403) (in Engelbrecht, 2003:81). Strengths of AHP are four-fold: (a) it provides a formal structure to problems; (b) pairwise comparisons focus the decision maker on each small part of the problem; (c) the redundancy inherent to AHP is employed usefully to check the consistency of the evaluations; and (d) it is a versatile technique, allowing for judgements on the likelihood of events, in addition to judgements on preference, importance and contribution (Engelbrecht, 2007:174-175).

According to Belton and Stewart (2002:152), "the major factors which differentiate the AHP from the MAVF approach from a practical viewpoint are the use of pairwise comparisons in comparing alternatives with respect to criteria (scoring) and criteria within families

(weighting), and the use of ratio scales for all judgements". They list four points of concern and debate regarding AHP: (a) interpretation of criteria weights; (b) the assumption of a ratio scale of preference; (c) the numerical interpretation of the semantic scale; and (d) the eigenvector method of estimation (Belton and Stewart, 2002:157-159). As pointed out above, the software used in Chapter 7 to demonstrate the application of the proposed CoT appraisal strategy, allows the user the choice of "going the AHP route".

3.3.11 Dealing with uncertainty

Uncertainty (and therefore risk) is, to some extent, inherent in most decision making situations. It may arise for different reasons and takes on different forms. It can be managed, but not eliminated. Friend (1989) (in Belton and Stewart (2002:61), as part of the Strategic Choice methodology, classifies uncertainty in terms of values, related decision areas, and the environment. French (1995) (in Belton and Stewart (2002:61) identifies ten sources of uncertainty which could be classified into three groups: uncertainty (a) in the modelling process, (b) in the use of models for exploring trends and options, and (c) in interpreting results.

In an MCDA context, Belton and Stewart (2002:61-62) distinguish between *internal* uncertainty and *external* uncertainty. Internal uncertainty refers to the structure of the model adopted and the judgemental inputs required by the model. External uncertainty involves both uncertainty about related decision areas (in the case of transport, a competing mode, for example), and uncertainty about the "external" environment (concerning issues outside the control of the decision maker). This distinction is important, as the most appropriate response to uncertainty is a function of the type of uncertainty. Belton and Stewart (2002:63-64) list three options within MCDA for addressing uncertainty about the environment. With (a) *scenario planning*, the emphasis is on defining good strategies that are robust over a range of possible futures. (b) *Decision theory* uses *probability* to predict the likelihood of certain events, and *utility* to model a person's attitude to risk, distinguishing between risk averse, risk neutral and risk seeking behaviour. Multi-attribute utility theory (MAUT) models decision maker preferences in situations that require that attention be given to both multiple objectives and environmental uncertainty (Belton and Stewart, 2002:63). Stewart *et al*. (1997:4) define MAUT as follows: It is "a method for MCDA or MCDM based on the construction of value functions consistent with a number of axioms of rational decision making; this is a fundamental basis for the assessment phase of scenario based policy

planning". Utility theory can be seen as an extension of value measurement, using probabilities and expectations (expected values) to deal with uncertainty (Belton and Stewart, 2002:95). MAUT "represents the only formalized theory for explicit modelling of uncertainty in MCDA" (Belton and Stewart, 2002:84). (c) *Risk as a criterion* involves including the level of risk as one of the decision criteria. For example, the level of risk could be represented by the probability of success or failure in achieving certain objectives.

The software used for demonstrating the application of the suggested appraisal strategy for CoT has a complete section on uncertainty and sensitivity analysis; how this applies to CoT is explored further in Chapter 6.

3.4 Summary

Chapter 3 gives a synoptic overview of MCDM by exploring key concepts without indulging in technical (mathematical) detail. Reference is made to the CoT case where necessary. This overview is necessary because the nature and impacts of TI projects mean that their appraisal essentially takes place in a multiple objective decision making environment, requiring an "MCDM-type" approach to be adopted.

MCDM context

Basic notion: Decision making is difficult for a number of reasons: (a) the interests and expectations of decision makers may differ; (b) uncertainty may prevail; (c) decision makers may be confronted with multiple, conflicting objectives; and (d) stakeholders may have different perspectives.

Defining MCDM: MCDM can be defined in different ways, for example the process of decision making in contexts where a substantial conflict between objectives exists. It can also be seen as an umbrella term, including a number of divergent schools of thought that have developed over time. Although mostly presented in the context of mutually exclusive alternatives, MCDM applies to both mutually exclusive alternatives and independent projects.

MCDM applications: MCDM has (at least) five applications: (a) discrete choice problems; (b) multi-objective design problems; (c) mixed design and evaluation problems; (d) project evaluation, prioritization and selection; (e) classification of alternatives. The last two of these applications are particularly relevant in the CoT case.

Typologies and classification of MCDM contexts: MCDM applications could be grouped according to seven *"problematiques"* (problem contexts), namely: (a) the choice; (b) the

sorting; (c) the ranking; (d) the description (or learning); (e) the design; and (f) the portfolio problematique. MCDM problem contexts can also be classified according to their *characteristics*: (a) one-off versus repeated problems; (b) number of stakeholders involved; (c) status and influence of the client; (d) the relevant "problematique"; (e) the range of available alternatives; (f) facilitated versus "do-it yourself" analysis. The "CoT case" involves three problematiques: the sorting, ranking and portfolio problematiques; and it is characterized by the following: (a) problems are constantly repeated; (b) it has a large number of stakeholders consisting of three main groups; (c) Council is the final decision maker; (d) Council is typically confronted with a finite, relatively large number of alternatives which, in total, exceed available funds; and (e) MCDM should preferably be conducted by external consultants with a proven track record.

The role of MCDA in decision making: MCDM can facilitate decision making in a number of ways: by accommodating multiple, conflicting data; by structuring the problem; by providing a focus and language for discussion; by helping decision makers learn about the problem situation, their own values and those of others; by guiding them in identifying a preferred course of action; by complementing and challenging intuition; and by providing an audit trail of a decision. However, three incorrect assumptions regarding MCA should be borne in mind: (a) it will give the right answer; (b) it provides an objective analysis that relieves decision makers of the responsibility of making difficult judgments; and (c) it takes the pain out of decision making.

The MCDM process: MCDM typically does not present itself as a well-defined set of alternatives and criteria, leaving the decision maker to merely focus on the evaluation of alternatives. Although it is not a structured process, it nevertheless involves the following stages: (a) identifying a problem or issue; (b) problem structuring; (c) model building; (d) using the model to inform and challenge thinking; and (e) determining an action plan. These stages can be grouped into three key phases: (a) the problem identification and structuring phase; (b) the model building and use phase; and (c) the development of action plan phase.

Stakeholders in the MCDM process: Stakeholders differ in terms of type and role: The *decision maker* has the responsibility for the decision to be made. The *facilitator* guides and assists the decision maker by managing group processes. The *analyst* works independently and gathers information required by the process and captures expertise that adds value to it. The *client* contracting the facilitator/analyst may or may not be the final decision maker, but

could also be a person or group given the responsibility of exploring the issue and making recommendations; alternatively, the client may be one of several stakeholder groups.

Ranking and rating: Ordinal importance refers to the order of importance of decision elements (e.g. first, second). *Cardinal importance* refers to the difference in magnitude between the importance of any two decision elements (e.g. one element is three times more important than another). *Ranking* refers to the process of assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made. With r*ating,* decision elements are assigned "scores" between 0 and 100. In the case of ranking, a distinction is also made between *regular* and *ordinal* ranking; both have advantages and disadvantages. Ranking provides a measure of the ordinal importance of decision elements; rating provides a measure of both ordinal and cardinal importance.

Instrumentally rational behaviour: The notion of "instrumentally rational behaviour" holds a central position in almost all decision making techniques. In making choices, a person (or group of decision makers, as would be the case for CoT) is deemed instrumentally rational if he has (they have) preferences that satisfy four axioms relating to reflexivity, completeness, transitivity and continuity. When the first three of these axioms hold, a person has a well-defined preference ordering. If the continuity axiom also holds, the preference ordering can be represented by a utility function.

Models for representing preferences: All models contain two primary elements: (a) preferences in terms of each criterion (i.e. intra-criterion comparisons), and (b) an aggregation model (i.e. inter-criteria comparisons). With *value function models* (also known by various other names), a single, unique numerical score representing "project worth" is constructed for each alternative, to represent the degree to which any one alternative is preferred to another. With the *outranking approach*, generally applied to discrete choice problems, a pairwise comparison of alternative courses of action (alternatives) is conducted in terms of each criterion first, in order to determine the extent to which a preference for one over the other can be asserted. *Satisficing models* (also known as goal programming and reference point methods) attempt to establish desirable or satisfactory levels of achievement for each of the criteria, and then to discover options which are in some sense closest to achieving identified desirable goals or aspirations.

Value function models

This type of model is deemed most appropriate to the CoT context as it allows the ranking of projects. It can be described in terms of seven steps. AHP and SMART are important n the context of value function tools, as is the treatment of uncertainty.

Step 1: Identifying and structuring the problem: This is aimed at ensuring a common understanding of the problem, the decision to be made, and the relevant decision criteria.

Step 2: Identifying alternatives: In order to ensure that opportunities are not missed out, *all* alternatives must be included in the analysis. As the evaluation of mutually exclusive alternatives precedes the ranking of independent projects, the set of mutually exclusive projects (including the null alternative) must be a *complete* set, containing *all* options for addressing an identified problem/need. *Value-focused thinking* is important in identifying *good* alternatives, as is the correct *scoping of the problem*. Regarding independent projects, there are three possibilities: they may be completely independent; or any two or more may have positive or negative synergy.

Step 3: Identifying decision criteria: A (decision) criterion is a particular point of view or interest according to which alternatives are compared. Decision criteria have to comply with eight requirements: (a) value reference; (b); understandability; (c) measurability; (d) non-redundancy; (e) judgmental independence; (f) balancing completeness and conciseness; (g) operationality; and (h) simplicity versus complexity. A value tree (or decision tree or ranked tree) is a hierarchical presentation of decision criteria. It may be desirable in some cases, and can be developed in a *top-down* and/or a *bottom-up* manner. Criteria for developing a value tree are: (a) completeness; (b) operationality; (c) decomposability; (d) absence of redundancy; and (e) minimum size.

Step 4: Determining inter-criteria preferences: This involves establishing the relative importance to be attached to each decision criterion. A number of methods could be used for this purpose, such as: (a) intuitive methods; (b) revised Churchman-Ackhoff technique; (c) Zeleny's entropy method; (d) swing weighting; and (e) the Analytical Hierarchy Process (AHP).

Step 5: Measuring intra-criterion performance: This step involves defining partial (or utility) functions for each criterion to reduce performances in the [0-1] interval. It involves both *scoring* alternatives and *standardizing* scores. In scoring alternatives, an appropriate scale

for each criterion must be selected, and two reference points (maximum and minimum) must be assigned to this scale, using for example a local scale or a global scale.

Step 6: Aggregating scores across criteria: This step involves calculating a single numerical score representing “project worth” for each alternative, to represent the degree to which any one alternative is preferred to another.

Step 7: Examining sensitivity of the results: Sensitivity analysis aims to establish if the preliminary results of the analysis are robust, or if they are sensitive to changes in certain aspects of the model, such as score(s) and/or weight(s). Sensitivity analysis can be viewed from three perspectives: (a) the technical perspective; (b) the individual perspective; and (c) the group perspective

SMART and AHP: These are important in the context of value function models. SMART (first described by Von Winterfeldt and Edwards in1986) is a collection of techniques rather than a single process, with the main commonality between techniques being their reliance on direct numerical estimation methods. AHP is a method of MCDA (or MCDM) developed by Saaty in 1980, based on the pairwise comparison of criteria and of alternatives.

Dealing with uncertainty: Uncertainty is, to a lesser of greater extent, inherent in most decision making situations. It can arise for different reasons and can take on different forms. It can be managed, but not eliminated. Both internal and external uncertainty are important. Options for addressing uncertainty include: (a) scenario planning; (b) decision theory; and (c) treating risk as a decision criterion.

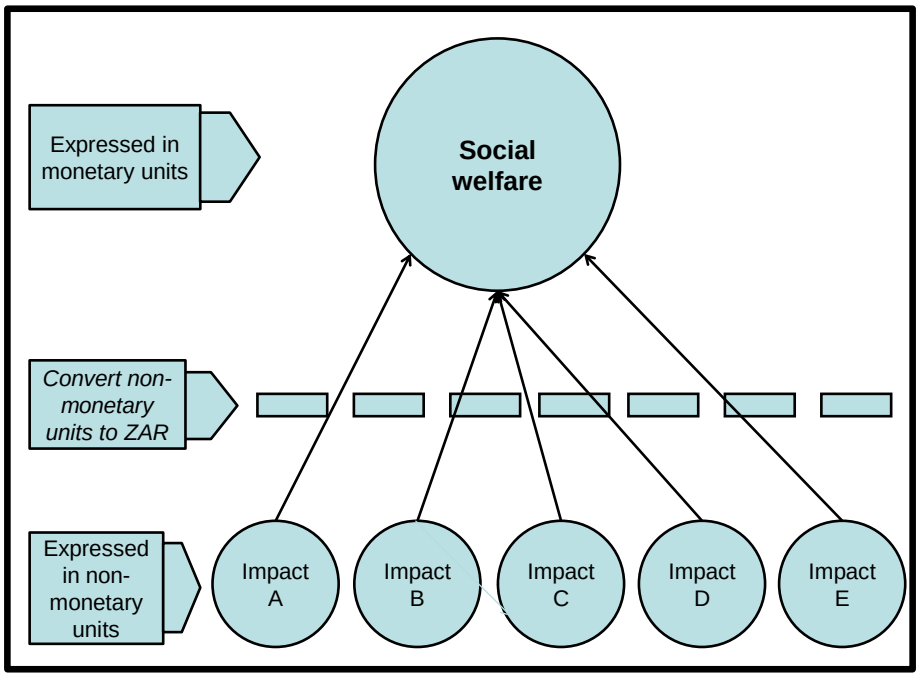
4. DEVELOPING THE BASIC APPROACH

4.1 Introduction

As noted in Section 1.5, project selection in the case of the local impact, budget-type context in road authorities requires feasible projects to be ranked in terms of total worth (relative value). Two opposing and fundamentally different methods were presented for this purpose, namely broad CBA (in Chapter 2) and MCDM (in Chapter 3). This chapter explores their role (if any) in the suggested appraisal framework. To this end, likely impacts of TI projects in the municipal sphere of government are examined in detail in order to derive a set of appropriate decision criteria for use in an appraisal framework. Quantifying these impacts inevitably brings to the fore the choice between a partial equilibrium and a general equilibrium type of analysis, and their suitability in this context is therefore examined. Given the importance of economic efficiency (and thus narrow CBA) in the basic approach, this section also examines how criticism of CBA should be handled; highlights issues not dealt with in CBA; and focuses on lessons from *ex post* evaluations.

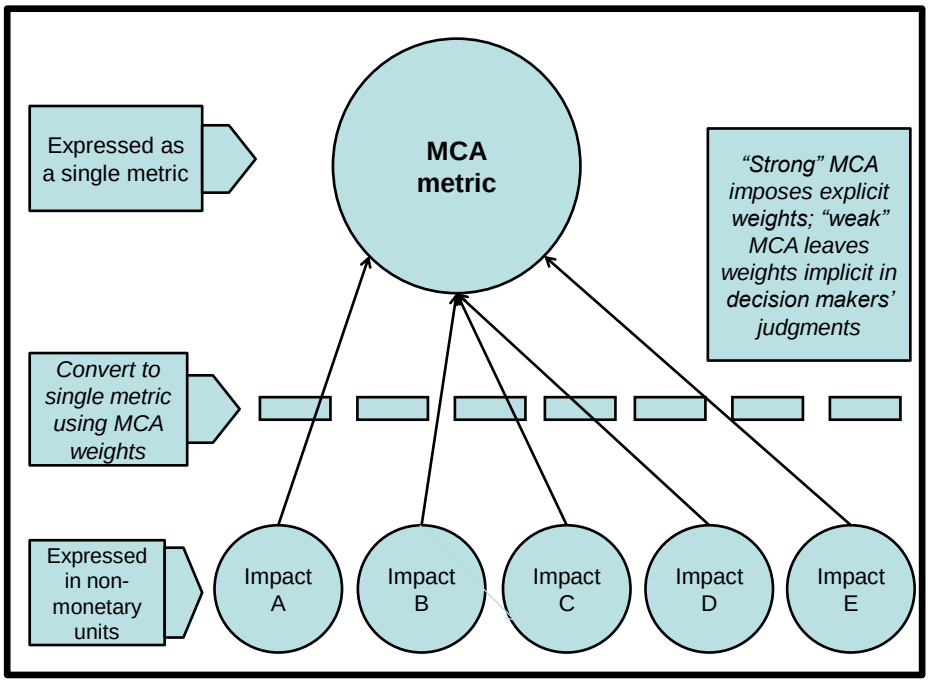
4.2 Features of broad CBA and MCA

To set the scene for the ensuing discussion, key differences between the two methods for determining project worth are revisited in Figures 4-1 and 4-2. With broad CBA, project worth is obtained by converting impacts to monetary units and expressing them as "social welfare", using indicators such as B/C ratio, IRR or NPV, as noted in Section 2.2.6. With MCA (Figure 4-2), project impacts, expressed in either monetary or non-monetary units, are converted to a single MCA metric representing project worth.



Source: Adapted from Austroads (2005b:23).

Figure 4-1: Broad CBA



Source: Adapted from Austroads (2005b:23).

Figure 4-2: MCA

4.3 Examining project impacts

4.3.1 Introduction

Examining the probable impacts of municipal projects is necessary for two reasons: to determine the correct approach to treating economic impacts in the proposed appraisal framework (in particular the choice between a partial equilibrium and a general equilibrium approach), and to explore the whole spectrum of impacts for further consideration in Chapter 5 and Chapter 6. In fact, as indicated in Section 3.3.5, identifying (unpacking) impacts is the first step of the bottom-up approach to building a decision (value) tree. As noted in that chapter, a bottom-up approach involves developing decision criteria on the basis of the relevant impacts (strengths and weaknesses) of an action (alternative); in particular, it involves the consecutive grouping of impacts into broader categories. As also mentioned in Section 3.3.5, both a top-down approach (where one general objective (focus) is subdivided into different sub-objectives, to each of which criteria could be associated) and a bottom-up approach are useful; in fact, they should be used in parallel since they are complementary. According to De Brucker *et al*. (2004:2), using them in parallel is likely to ensure a complete array of decision criteria; Belton and Stewart (2002:59) concur with this and note that one perspective should inform the other. The bottom-up approach adopted in this chapter (implying "alternative-focused thinking") will therefore be supplemented in Chapter 5 with the top-down approach (implying "value-focused thinking") (Diakoulaki and Grafakos, 2004:5).

4.3.2 Examining impacts

Examining ("unpacking") project impacts will not only reveal the whole spectrum of impacts to be considered, but also problems that may arise in quantifying them for the purpose of determining project worth. Regarding the quantification of impacts, the following dimensions should be noted (Schutte, 2004:5): (a) *temporal (time) dimension,* which is the timing (duration) of impacts, bearing in mind that the analysis period should coincide with the economic life of the facility; (b) the *spatial distribution of impacts,* which is the specific area within the area of jurisdiction of the authority that will be impacted on, bearing in mind that different sub-areas within the municipal area have different socio-economic attributes and different socio-economic development objectives and priorities; and (c) *affected parties,* for example the age and income groups that will be affected – there is typically a correlation between "spatial distribution of impacts" and "affected parties".

In examining the impacts listed below, a number of problems may arise in quantifying impacts (and determining project worth) and therefore in developing an appraisal framework. Problems may result for the following reasons (Schutte, 2004:5): (a) Impacts may be contradictory. For example, efficiency considerations would normally direct investment to densely populated, affluent urban areas, whereas "equity" considerations would direct investment to lesser-developed (semi-rural) areas, benefiting lower income groups. (b) Impacts may be overlapping: Job creation and income levels are examples of overlapping impacts (criteria), as an improvement in the one is normally associated with a corresponding improvement in the other. In such cases, double counting can easily occur. (c) Impacts may be expressed in different units. "Economic efficiency" is typically expressed as a ratio (B/C ratio) or percentage (IRR). "Job creation", however, is likely to be expressed as "number of jobs additional to the base case". (d) It may not be possible to quantify impacts that can only be expressed in qualitative terms. This would typically apply to "softer" issues such as comfort and reliability, which would require an ordinal scale, allowing projects to be *ranked* in terms of their performance relative to a given impact.

This nature and extent of impacts of projects in urban (municipal) areas (both intended and unintended) are examined below under appropriate headings (Schutte, 2004:54-60).

Vehicle operating cost. Savings in vehicle operating cost (VOC) can be considered a primary objective (and consequence) of investing in transport infrastructure and improving the quality of the road network. In semi-urban areas this normally stems from a reduction in travel distance, higher geometric standards and improved road surfaces. In downtown urban areas, this may stem from lowering congestion levels and thus reducing congestion cost by providing additional capacity, where congestion cost is defined as VOC on the congested network (or congested operating conditions) *over and above* VOC under uncongested network (or "normal" operating conditions).

Collision cost. The same factors as in the case of VOC can lead to a reduction in road collision cost. The cost to the economy of road collisions not only involves damage to property (in particular vehicles), legal and medical costs, but also loss of output which, in the case of fatal and serious injury collisions, is by far the biggest element.

Travel time cost. Travel time cost is defined as the duration of the trip (or journey in the case of public transport), valued at the opportunity cost of time, as travelling implies a disutility and the time spent travelling could have been spent on more meaningful activities such as work

or recreation. In urban areas, travel time cost savings are typically obtained through shorter routes and/or higher speeds, the latter especially resulting from added capacity, leading to a reduction of congestion.

User cost. This is the total of vehicle operating cost, collision cost and travel time cost. As with infrastructure maintenance cost, it is of a recurring nature, as it is incurred throughout the analysis period (i.e. the economic life of the facility), as opposed to facility construction cost, which is a one-off cost incurred at the beginning of the analysis period. The components of total road user cost do not, however, always "work in the same direction". For example, for travel speeds higher than the optimum travel speed, an increase in speed will result in reduced travel time cost but increased vehicle operating cost. Also, with narrow CBA, the elements of total road user cost by definition are deemed of equal importance (i.e. having equal weight); from the perspective of the decision maker, this may constitute a problem, as a given policy objective may be deemed of overriding importance, for example increased safety or the removal of "black" spots. (In such cases, considering such initiatives as a separate category may be a solution.)

Total transport cost. Reduced total transport cost probably constitutes the "most desired" impact of a project. As its elements (infrastructure cost – consisting of facility construction cost and facility maintenance cost – and road user cost) are incurred at different "points in time" during the analysis period, the time value of money is taken into account in calculating it by using interest formulae. If total transport cost is reduced relative to the base case (null alternative), a project is deemed economically justified; if not, the null alternative should not be abandoned as, by definition, it then constitutes the best ("most economical") option from the set of mutually exclusive alternatives. This formulation of total transport cost also implies that a project will only be economically justified if (discounted) marginal savings in user cost exceed (discounted) marginal infrastructure cost.

Economic growth. A reduction in total transport cost resulting from the implementation of a project will benefit the economy by reducing one of the inputs to total production cost and, in so doing, stimulating economic activity by creating an environment conducive to economic growth. However, given the fact that transport cost constitutes but one component of total production cost (and thus one of the factors determining an efficient economic system), the need for a balanced approach is clear. Other, more critical or obvious deterrents to economic growth and development may prevail and may need to be addressed first. In the case of inter-regional transport, for example, improved institutional arrangements at border

posts may be preferable to infrastructure improvements, while in the case of urban transport, TDM measures (such as signalized traffic lights) may be preferable to expensive network improvements. This notion of a balanced approach must not, however, be confused with the *doctrine of balanced growth* (Joynt (2004:2-13 to 2-25), as described in Section 1.2.2). Economic growth is a blanket term and can manifest itself in a number of interrelated ways. They are listed below separately, as decision makers, in terms of policy objectives, may consider some more important than others.

Economic output. An increase in economic output will be reflected in an increase in total GDP (or increase in GDP per capita); this constitutes the most obvious parameter of economic growth. Under conditions of macro-economic equilibrium, total output will be equal to total expenditure, i.e. GDP = C+I+G+(X-Z) where C = private consumption; I = gross investment; G = government spending, X = total exports; and Y = total imports (Brink, 2002:8). These components of GDP are considered below.

Employment. Job creation, an important policy objective of government, goes hand in hand with economic growth. Jobs will not only be created as a result of increased economic activity on completion of the project, but also during the construction phase of the project (by the construction activity itself). Regarding the latter, a continued strong focus on investment will result in sustained job creation.

Income levels. Increased economic activity (for the reasons given under “Economic Growth” above) and higher levels of employment will lead to increased income levels per capita (and per household) and increased private consumption.

Investment. An efficient transport infrastructure system may attract new entrepreneurs and induce existing entrepreneurs to increased investment in the form of factories and retail centres.

Fiscal arrangements. Increased levels of economic activity will normally lead to a broader tax base, which will allow for increased government spending. This may apply to the whole spectrum of taxes. Government’s income from personal income taxes, for example, will increase as personal income levels increase. Likewise, property taxes may increase as property values (which could be considered as the discounted (present) value of the future income streams generated by the property) increase. Whereas the first type of fiscal impact mainly benefits central government, the latter impact will benefit mainly the local metropolitan authority.

Land and property values. Increased economic activity will have positive spin-off effects on land and property values. The focus here however is on *access*: it could be argued that good access will increase land and property values and poor access will reduce values. In the case of retail centres, for example, good access will increase the potential of the property to generate future income streams, resulting in increased property values. Good access is also important for residential property. But in this case a distinction between access at the macro and micro level is important: at a micro level, a major arterial through a residential area will adversely affect the value of residential property and/or will lead to eventual changes in land use. In CoT, an example of this is Lynnwood and Duncan streets, where, assumedly, increased traffic levels have led to the conversion of residential homes to offices and retail centres.

Economic development. A project may (or may not) have positive development impacts. The distinction between economic growth and development is important: the former involves increased economic activity, whereas the latter, in addition, involves a more equitable distribution of the fruits of economic growth between members of society. Economic growth, resulting from a project, may benefit only some members of society (say higher income groups) and spin-offs may not trickle down to other members (say lower income groups). Also, the link between economic growth and development is important for the purpose of an appraisal strategy: Economic growth is a prerequisite for economic development, and without growth, there cannot be development. Given this link, a balance needs to be sought between projects with positive growth impacts and projects with positive development impacts. As with economic growth, economic development is a blanket term and it can be manifested in a number of ways, as listed below. In all cases, though, this can only happen if projects are targeted at the "right" sections of society and/or areas.

Mobility and accessibility. The essence of increased mobility and accessibility is an increase in transport options and lower transport costs. This constitutes a primary objective of investment in transport infrastructure and is the direct result of a more efficient transport system. "Mobility" refers to the users of the transport system becoming more mobile, and "accessibility" refers to the improved proximity to economic and social opportunities and services. Access to business and retail centres may be regarded as a special case of increased mobility and accessibility. As indicated above, good access is important in the case of, in particular, regional business and retail centres. The impact of investment in transport infrastructure on access to business and property values should therefore be

carefully monitored. A case in point is the Platinum Toll Road project, of which it was maintained that tolling would affect traffic patterns so much that patronage of certain retail centres would be negatively affected and that these centres might not be viable any more. Mobility and accessibility (relative to place of residence) are also important in respect of places and worship, education and training, employment, and the like.

Economic empowerment. Economic empowerment involves increased opportunities and options for economic advancement. This could, for example, be brought about by increased mobility and accessibility resulting from an improved transport infrastructure.

Skills transfer. This involves acquiring new skills that would open up new horizons to beneficiaries and which therefore would amount to economic empowerment. This could be the direct result of increased mobility and accessibility, brought about by improved transport infrastructure.

Income distribution. A more equitable and just income distribution constitutes an important policy objective of government, and transport infrastructure may be an important tool for accomplishing this.

Poverty alleviation. This can be considered a special case of income distribution, as a more equitable income distribution will impact positively on poverty alleviation.

Crime. Transport infrastructure can affect the nature and level of crime by creating crime-friendly or crime-unfriendly environments. This is particularly important in the case of public transport systems and interchanges. Another manifestation is lighting, which also affects urban road networks.

Health. Transport infrastructure can lead to improved health conditions, for example by reducing dust levels in the case of surfaced roads and providing protection from the elements in the case of increased public transport interchange facilities.

Environmental cost. Environmental cost refers to the externalities of transport related to the environment. An externality is a cost inflicted on third parties; a cost that is not borne by the recipient of the product or service. In the context of transport infrastructure, air and noise pollution associated with (or caused by) the use of the infrastructure are examples of environmental cost. At a macro level, environmental cost is affected by mode type: rail transport implies lower environmental cost than road transport. In addition, environmental impacts also refer to impacts on the bio-physical environment and impacts on our cultural heritage, such as buildings of architectural merit.

Traffic levels and composition. An investment in transport infrastructure will typically affect traffic levels (i.e. number of vehicles using a link of the network) and/or traffic composition (i.e. the mix of different vehicle types, namely cars, trucks, minibuses, etc.). This impact may be varied; a new or improved road may initially alleviate traffic congestion but, as the improved network attracts economic activity, it may over time become congested again. Where an investment in transport infrastructure involves expanding users' choice of modes, it may lead to reduced traffic levels for one mode and an increase for the other. A case in point is the proposed Gautrain, which (it is maintained) will attract commuters currently using the road network. In addition to impacts on traffic levels and composition *on completion of the project*, these will also be affected *during the construction period*. This is particularly important in urban areas which suffer from congestion on their main arterials under normal circumstances, without the added constraint of construction and maintenance activities.

Responsibilities of relevant authorities. This goes hand in hand with the impact of the investment on traffic levels and composition (see "Traffic levels and composition" above). A case in point is the Platinum Toll Road, especially the N1 section between the Proefplaas and Zambesi interchanges where (it is maintained) traffic will be "tolled off" the N1 to the urban network. Increased traffic levels on the urban (suburban) network mean increased expenditure for maintaining the affected network. This means that the actions of one road authority (the South African National Road Agency in this case) may have serious implications for the responsibilities of another (the City of Tshwane Metropolitan Municipality).

Travel demand management (TDM) schemes. TDM measures aim at managing the demand for travel on selected links of the network or in selected areas, in particular the "uncontrolled" demand for private transport. TDM involves many aspects, ranging from "optimum" land use planning to "getting people out of their cars into buses". One feature of TDM therefore is dedicated lanes for high-occupancy vehicles (HOVs). The rationale for this is that, on congested links of the (urban) network, commuters will be enticed to move to HOVs because dedicated lanes for HOVs will imply higher travel speeds than on the congested lanes used by low-occupancy cars. For this reason, "undesirable" investments in transport infrastructure (such as increasing the supply of road space) may therefore counter the objectives of TDM schemes in a particular area.

Modal split and patronage of public transport systems. The Moving South African Action Agenda and various other policy documents advocate the 80/20 principle. This means that

government want to attain an 80/20 split in favour of public transport by the year 2020. Investment in road infrastructure serves to make private (car) transport more attractive vis-à-vis public transport and may counter the achievement of this policy objective.

Affordability of other "necessary" projects. This is a logical consequence of and especially relevant to major projects consuming large amounts of funds that could have been used for other worthy projects. As noted in Section 3.2.4 in the discussion of typologies and classification of MCDM contexts, "it is sometimes difficult to compare evaluation performance measures of projects that vary greatly in size, such as the implementation of a number of low cost improvements versus the construction of a new rail link" (CMT-KMV, 1995:6). This dilemma arguably is normally solved through the economic feasibility selection process; however, in many cases the motive for a project is not an economic one.

Policies, strategies and priorities. Investment in transport projects often may have impacts that are not aligned to government policy, strategy and priorities. Greater use of public transport, as spelt out above, is but one example. Another is urban densification, where continued investment in road infrastructure may promote urban sprawl and render the successful introduction of public transport systems less likely. Examples of policies, strategies and priorities that should be considered are listed below:

- Integrated Development Plan (IDP), National Spatial Development Framework (NSDF) and Provincial Land Transport Framework.
- Metropolitan transport strategies and priorities.
- Local land use and development policies.
- Local Economic Development (LED) strategies and other key economic development projects.

Other initiatives and projects. It is important to note that different projects and initiatives of a given sphere of government should be aligned. Similarly, projects and initiatives at different spheres of government should also be aligned. For example, the road network cannot be expanded without taking cognizance of planned areas of high-density residential development, and vice versa. Likewise, the planned investment in public transport cannot be considered without taking into account planned future improvements of main urban arterials, as the one may counter the objectives of the other. A case in point is the Gauteng Superhighways and the Gautrain project.

Land use and urban form. Transport infrastructure is a critical determinant of urban land use and form. It is, for example, maintained that urban sprawl and the low density of South Africa cities can be ascribed to the private car. The impact of a project (and the accumulated impacts of all other projects) on land use and urban form should therefore be carefully considered against stated policy objectives and future visions for the ideal city.

User-friendly transport environment. Impacts in this regard refer to changes in the attributes of the transport environment, for example improved storm-water drainage, better pavements, reduced dust levels, improved lighting, and protection from weather.

Protection of capital assets. This illustrates the adage "a stitch in time saves nine". It is critically important that funds be expended in time to allow for the proper maintenance of existing infrastructure, in order to obviate the need for increased maintenance later on. In macro-economic terms, this impact is the result of "replacement investment", which refers to the investment required to counteract the effect of wear and tear on capital items and to maintain capital stock, and which, together with "net investment" (which refers to the accumulation of new capital assets) amounts to "gross investment" (Brink, 2002:24-25).

4.3.3 Aggregating impacts

Aggregating "bottom-level" impacts (with the ultimate aim of linking impacts to decision criteria) constitutes the next step of the bottom-up approach. For the purpose of the framework, the impacts listed above are aggregated into the following categories:

- Impacts relating to a better transport system.
- Impacts relating to a more efficient macro-economic environment (economic impacts resulting from a better transport system).
- Impacts relating to equity.
- Impacts relating to the physical environment.
- Other impacts (not listed above).

In the boxes below, each of these broad categories is reconfigured as shown. As noted above, the risk of double-counting in some cases is evident; this needs to be borne in mind when "linking" impacts to criteria.

Impacts relating to a better transport system

Manifesting in a reduction in total transport cost, consisting of:

Infrastructure cost, consisting of:
- Construction cost
- Maintenance cost

Road user cost, consisting of:
- Vehicle operating cost
- Collision cost
- Travel time cost

Macro-economic impacts resulting from a better transport system

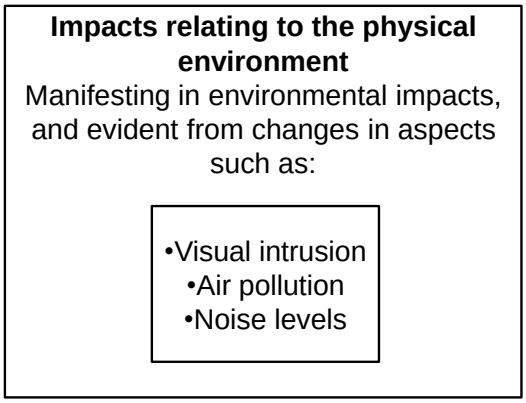
Manifesting in economic growth, and evident from positive changes in aspects such as:

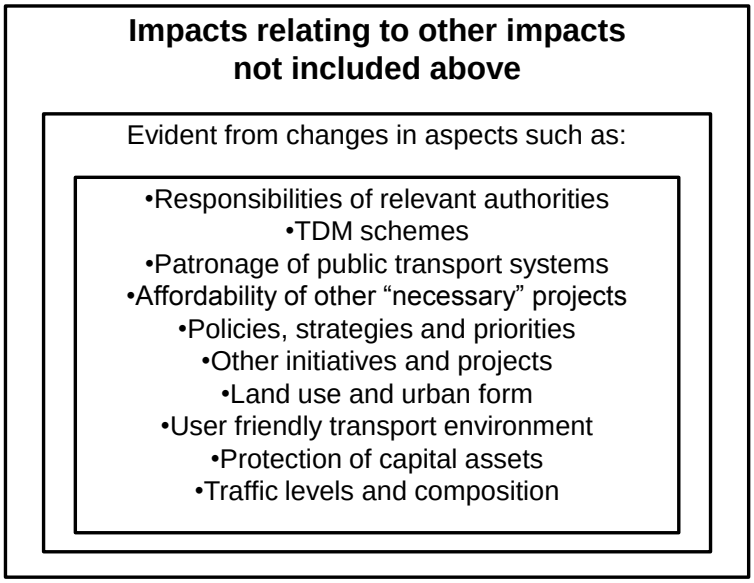
- Output (GDP)
- Employment
- Income
- Investment
- Fiscal environment
- Land and property values

Impacts relating to equity

Manifesting in economic development, and evident from changes in aspects such as:

- Mobility and accessibility
- Economic empowerment
- Skills transfer
- Income distribution
- Poverty alleviation
- Crime levels
- Health





4.3.4 The case for a partial equilibrium type approach

This section focuses on the cause and effect relationship between the first two categories of impacts listed above; as shown in Figure 4-3. In quantifying impacts, this implies a choice between first round and second round impacts (or direct and indirect impacts) and thus a choice between a partial equilibrium type approach and a general equilibrium type approach, in order to avoid double-counting, as argued in this section.

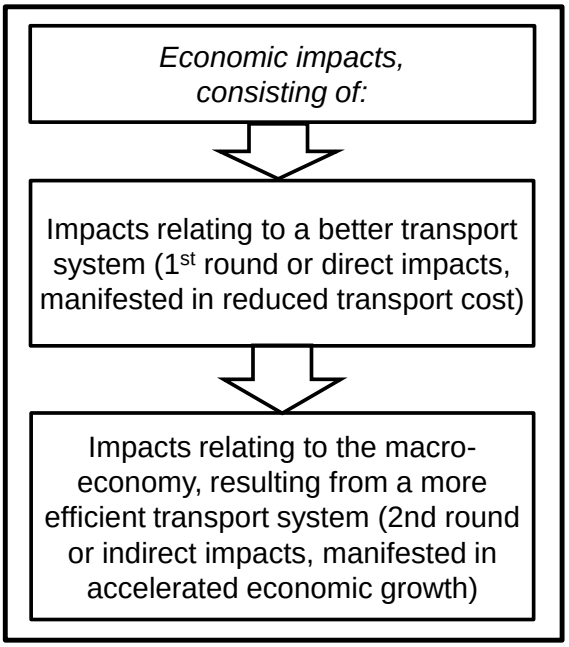


Figure 4-3: Nature of economic impacts

In a similar vein, Pienaar (2008:2,9-10) distinguishes between a CBA which is concerned with the efficiency of a project in a micro-economic sense and a regional (economic) income analysis (also called regional developmental economic evaluation), which focuses on the general economic impacts that a project may have on non-road users, in particular an increase of GDP. This distinction was applied in the case of the economic evaluation (and an economic impacts analysis) of the proposed road between Gobabis and Grootfontein in Namibia. In addition to a CBA to determine the efficiency of the project, a "regional income analysis" was undertaken to determine the increase in GDP. To accomplish this, the one-off non-user benefits as represented by the multiplier effect, and the recurring non-user benefits emanating from the economic accelerator effect, were examined (Pienaar, 2008:9). In conclusion, the following was noted: "In addition to being justified from a micro-economic perspective, the project's good once-off income-multiplier effect and significant recurring non-user benefits will support the macro-economic objectives of (i) full employment, (ii) economic growth, (iii) price stability, and (iv) equitable distribution of income. In general the proposed Gobabis-Grootfontein road project will make a significant contribution to the primary macro-economic goal of improving the wealth of Namibia" (Pienaar, 2008:17).

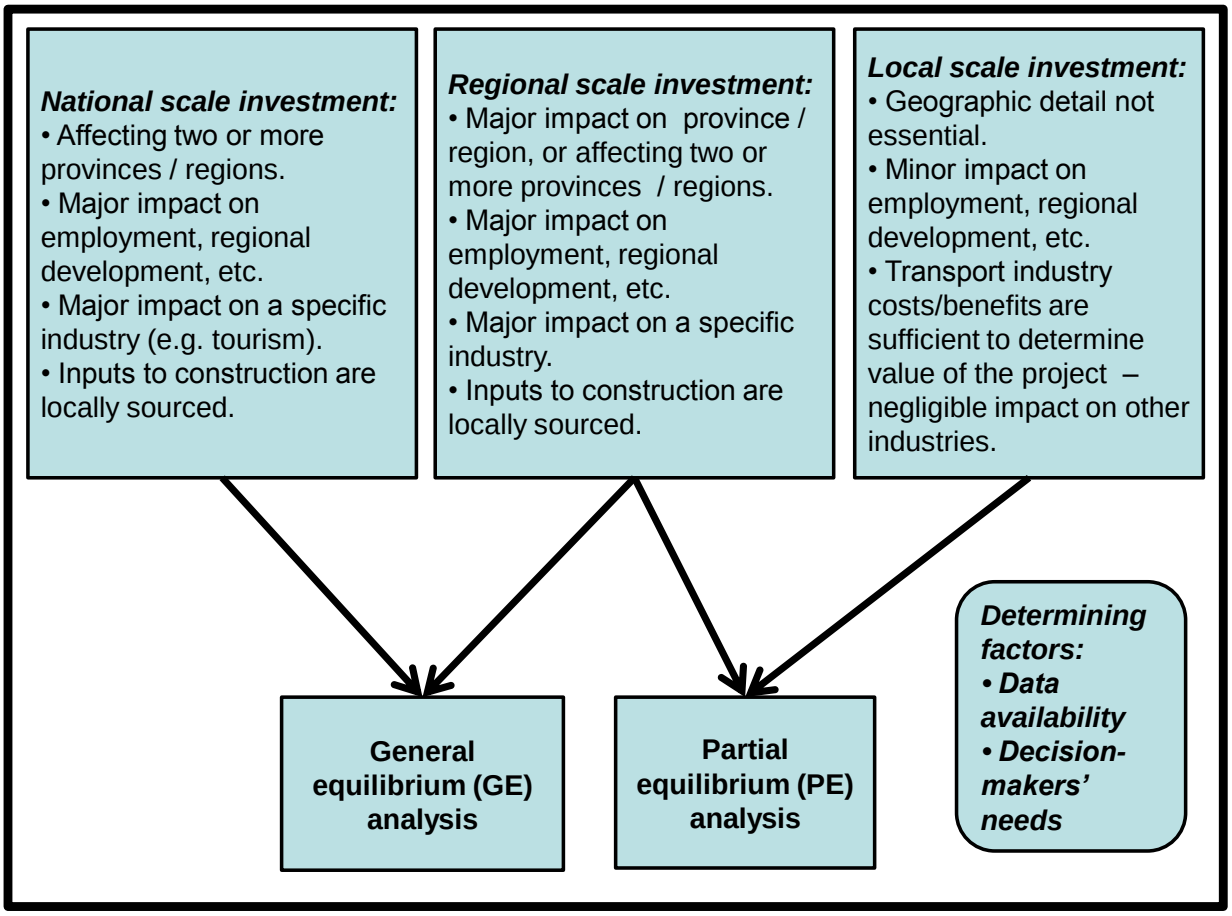
For the purposes of project appraisal, it could be argued that both types of analysis are justified and useful, as they provide different perspectives on the problem. But it could also be argued that the two types of results merely reflect two sides of the same coin and that

therefore project performance should not be based on both sets of results as this would amount to double counting. If so, the question then arises as to which set of results (type of analysis) would constitute the better choice for the purpose of project appraisal.

It has been argued that CBA should suffice as a decision making tool in most cases "as many of the assumptions in transport BCA will entail only minor loss of realism" (Austroads, 2005d:3). This source adds the following view regarding GE models: "Economy-wide modelling is conceptually attractive but often difficult and relatively expensive in practice. It is complex and requires detailed data which may not always be available; and it is often difficult to model all the dynamics involved with confidence. Economy-wide modelling is also not the most appropriate tool for road agencies to use when undertaking portfolio wide project prioritization". It has therefore been suggested that economy-wide models be limited to the following cases (Austroads, 2005d:3):

- "Projects that will have a major regional impact on land use or transport distribution patterns (e.g., a metropolitan ring road).
- Projects which are likely to yield special benefits to traded goods sectors. For example, upgrading of road or rail infrastructure may benefit primary industries through lower transport costs for commodity exports and machinery imports.
- Projects that facilitate regional and national development, for example providing or upgrading a key transport link to a developing regional or rural area.
- Projects that provide benefits which rely on geographic connections between regions.
- Projects for which inputs to construction are sourced locally, for example, local sourcing of labour and materials".

Figure 4-4 suggests the complementary roles of partial equilibrium (PE) and general equilibrium (GE) type analysis in project appraisal.



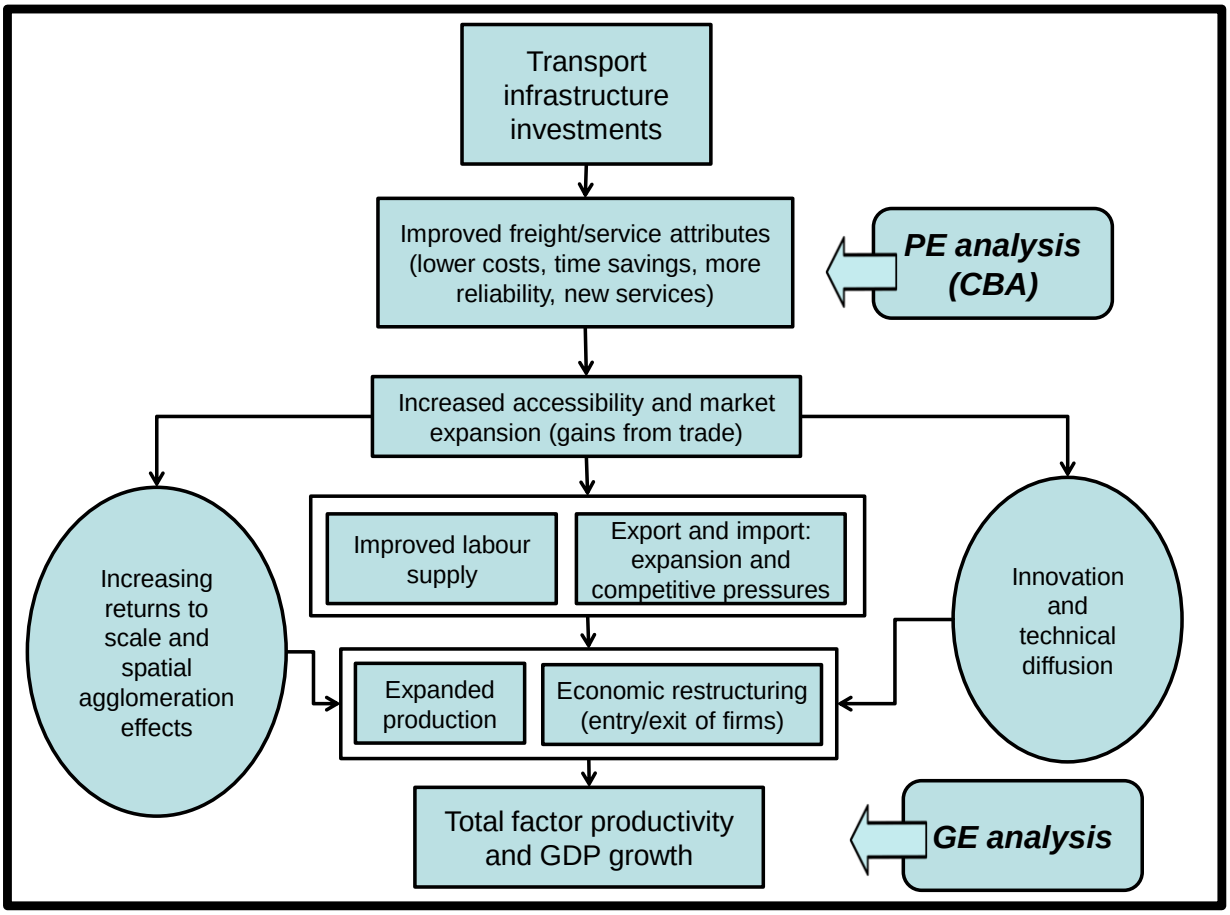
Source: Adapted from Austroads (2005d:18).

Figure 4-4: Suggested role of GE and PE models in project appraisal

In the case of large-scale infrastructure projects, economy-wide modelling can serve to supplement (extend) CBA by providing *additional* (and perhaps "better") information to decision makers. For example, the fact that a project will generate 200 new jobs arguably will have more appeal than its having a B/C ratio of 1,6. The transport sector in the case of one-off projects is a good candidate for economy-wide analyses, given its impact on various other sectors, in particular construction, agriculture, mining, manufacturing and tourism (Austroads, 2005d:5).

Figure 4-5 shows where in the process a PE and GE type analysis are applied. Whereas "outputs" in the case of CBA are indicators such as the B/C ratio and the IRR, outputs in the case of a GE analysis are (for example) positive changes in GDP and total factor productivity. The latter measures the productivity of all inputs necessary for the production of services, taking into account the interaction between inputs (Brits, 2010:4). By definition, total factor productivity could be expected to improve as a result of reduced transport cost

(resulting, in its turn, from the implementation of "economically sound" projects). In an application to an airline industry, Brits (2010:6) distinguishes between two approaches to measuring (changes in) total factor productivity, namely an index approach and an econometric (production function) approach. The econometric approach, based on the development of a cost function relative to a production function, is ideal for observing changes in total factor productivity as well as the reasons for these changes. But it requires sufficient comparable data to determine the statistical significance of the coefficients to be estimated, and such data may not always be available (Brits, 2010:19-20). As the availability of data will be a deciding factor in choosing between these approaches, the index approach may be more appropriate in the case of TI projects.



Source: Adapted from Austroads (2005d:6).

Figure 4-5: Role of PE and GE analysis

Although a GE type analysis may not be the best tool for road agencies to undertake a portfolio-wide prioritization, this does not preclude its use in the case of assessing several large projects at the same time to obtain additional measures of project worth that may be

more useful to decision makers. It is further important to note that, for the majority of projects, a GE type of analysis may not be necessary, as a CGE analysis requires estimates of costs (e.g. construction cost) and benefits (cost savings in the case of transport projects) as a starting point (Austroads, 2005d:17). This means that a CBA has to be undertaken in any case, and to the extent that macro-economic benefits are a function of the costs and benefits measured by a CBA, it can be argued that adding the benefits of the macro-economic analysis to that of the micro-economic analysis amounts to double counting (Austroads, 2005d:16).

Also, GDP (in particular, increases thereof) does not constitute an appropriate measure of welfare (Austroads, 2005b:48): "Both approaches should produce the same result. But analyses of transport projects using a GE approach commonly show an increase in GDP in excess of the benefits under a PE approach. If this change in GDP is interpreted as a net benefit, the conclusion is that a PE approach understates benefits. However, GDP is an inappropriate measure of welfare as it includes returns-to-capital, which are either compensation for past domestic savings (and hence lower domestic consumption) or interest on debt or dividends paid to foreigners; and it excludes non-market welfare effects such as life and limb, and many environmental goods". In the context of assessing the benefits and costs of inbound tourism, Dwyer and Forsyth (1993:753) note that changes in GDP are poor measures of net benefits. Instead, "effects, to a considerable extent, show up as a change in the composition of the economy, rather than as a net addition to output (Adams and Parmenter, 1991) (in Dywer and Forsyth, 1993:754).

De Brucker and Verbeke (2006:3) also caution against the risk of double-counting: "Although the effects measured through the REIS (regional economic impact study) may be relevant in specific circumstances, double counting of effects, inter alia resulting from the crowding-out phenomenon, is obviously methodologically unacceptable. A careful examination of these effects is therefore necessary before integrating them into the decision-making process".

If it is argued that a PE and a GE type of analysis address two sides of the same coin and that considering both types of benefits in appraising projects would amount to double counting, a choice between these types of analysis seem inevitable. Given the ability of a CBA-type of analysis to provide a measure in terms of which feasible projects can be ranked according to the objective of "economic efficiency" – and, in so doing, addressing the "ranking problematique" described in Section 3.2.4 – it is clear that the CBA type approach is preferred to the economy wide approach for the purpose of an appraisal framework.

Economy wide models do not allow projects to be ranked, i.e. they do not address the relative performance of projects.

In conclusion, therefore, it is argued that economy-wide type of models should be limited to large projects, and used only when needed. In most cases a CBA will suffice. Generally, the attractiveness of GE type models lies in format of their outputs – for example, it could be argued that a performance indicator such as "the project will create 200 new jobs" will have more appeal to decision makers than "the project has a B/C ratio of 1,6". However, when the benefits of a CBA are added to those of a GE analysis, this will amount to double counting. In addition, GE models do not comply with the CoT type requirements – for example, they are expensive and require specialized and experienced professionals. As a consequence, the following can be stated:

- GE type models are not necessary in the context of an appraisal framework; CBA will suffice for this purpose.
- In cases where GE type models are "appropriate", there is the danger of double-counting
- GE type models are not operational in the sense that they allow projects to be appraised (evaluated (accepted/rejected) and ranked).

4.3.5 Concluding comments

This examination of probable project impacts confirms the diverse nature thereof and the consequent need for an appropriate method to quantify them. Equally important is the fact that economic efficiency, regardless of the method of quantifying project worth, constitutes an important objective.

4.4 Developing the approach

4.4.1 The case for narrow CBA

As noted before, narrow CBA addresses only the objective of economic efficiency, which involves the optimal allocation of resources (Raux and Souche, 2004:194). These authors further note that efficiency relates to both optimum pricing and optimum investment. Regarding optimum pricing, the "rule of short run marginal cost pricing" (expressed in a congestion cost context) states that "road users should pay a toll that pays for congestion, environmental and accident externalities". Regarding optimum investment, the "rule of

optimum investment" states that "investment should be continued to the point where the discounted sum of marginal congestion cost savings is equal to the marginal cost of extending the infrastructure" (Raux and Souche, 2004:194).

Broad CBA, in addition, also involves other (community) objectives such as equity (in general, relating to a more equitable distribution of resources/income) and externalities, by quantifying all impacts in monetary terms and expressing "project worth" in a single monetary quantum such as B/C ratio. The scope of narrow and broad CBA is shown below.

Objective	**Scope of narrow CBA**	**Scope of broad CBA**
Economic efficiency	Yes	Yes
Equity	No	Yes
Environmental externalities	No	Yes
Other	?	?

Regarding arguments in favour of conventional (i.e. narrow) CBA as opposed to broad CBA, Mishan (1988:209-212) in Dockel *et al*. (1991:4-5) states the following*:* "It cannot be too often stressed that cost-benefit analysis as traditionally practised is no more than a useful technique in the service of social decisions ...

"Attempts to work more into the technique of cost-benefit analysis, to endow it with greater self-sufficiency for policy purposes by recourse to distributional weights or national parameters formulated by reference to political decisions or, at any rate, by reference to non-economic considerations … entail the following disadvantages:

- If the weights are to be chosen by the economist, they are arbitrary. They will vary with the political climate and are likely to cause squabbles among economists themselves, and between economists and the public. Since some projects will be accepted on one set of weights and rejected on another, one may anticipate continued political in-fighting over the weights to be adopted. To the extent

economists did not reject the principle of employing such weights but participated in the struggle to establish one set of weights rather than another, cost-benefits analysis as a technique could become discredited.

- If the weights are chosen through the political process, they will also vary from year to year, and from one country to another, according to the composition of legislatures, political fashions, and the exigencies of bureaucrats. These variations could be such as, again, to bring the methods of cost-benefit analysis into disrepute.

- Once political valuations are believed pertinent for some items, there is no clear case for limiting the extent of political intervention for that purpose. If decision-makers can attach weights to merit goods, why not to ordinary goods also on the argument that, as among ordinary goods, some have smaller social merit than others? If they can attach a valuation to accidents or loss of life, why not also to a wide range of spillover effects? And if so much can be justified, there seems to be no logical reason against going further and having political decision override all market prices and subjective valuations. Indeed, there is no reason why each and every investment project should not be approved or rejected directly by the political process, democratic or otherwise…

- Even if it were conceivably possible to secure permanent agreement within one country on the set of distributional weights to be attached to the benefits and losses of different income groups, it could not, as already indicated, be counted on to prevent the introduction of projects having markedly regressive distributional effects. Projects that would meet a weighted cost-benefit criterion could be such as to make the rich richer and the poor poorer if the beneficiaries were rich and many and the losers were poor and few. This possibility can be avoided only by a separation of these distributional effects from the Pareto effects of the traditional cost-benefit analysis.

- Last but not least is the question of consistency. Methods of project evaluation that can claim no virtue other than “marshalling data systematically, putting them in quantitative terms, and rendering them commensurable” have nothing to commend them if, in the process, fundamentally different criteria are used in producing a single figure…”.

In this regard, Dockel *et al*. (1991:9-10) argue as follows: “because CBA is suitable to provide only one of the inputs required in an overall resource allocation decision making process, this technique should not be permitted to play a dominant role in the macro level allocation of funds between different functional categories of expenditure. CBA is thus not suitable, for example, for the allocation of funds between State departments, as was envisaged by the State President’s Capital Expenditure Priorities Committee”.

Finally, Dockel *et al*. (1991:9) conclude that CBA should not involve value judgments but should instead focus on objective facts and information: “the CBA technique is well-suited to deal with efficiency considerations, despite its softness even in this more modest context. It does not, however, have any particular merits when equity, strategic or other social issues are to be considered and when, a result, value judgments predominate in the decision making process”.

As explained by Campen (1986:83), therefore: “CBA is merely one input in the outcome-determination process. The role of CBA is to provide better information to decision makers, to encourage systematic thought about alternatives, consequences, and values, and to increase the explicitness of the evaluative process and the accountability of those who actually make decisions. Decision makers must still use their judgment to combine the economic efficiency result of CBA with the results of evaluations according to other relevant standards – whether these standards are concerned with ethics, jurisprudence, politics, distributional justice, or ecology. Quantitative information provided by CBA constitutes a highly useful input into the process of balancing, or trading-off, among different objectives – a necessary process whenever there is no dominant alternative that is best with respect to each individual standard”.

According to Dockel *et al*. (1991:3), an important distinction between broad and narrow CBA lies in the role to be played by decision makers: “The ‘conventional’ school of thought, which favours narrow CBA, maintains that this technique should be based only on objective (market) data and generally accepted principles of economic efficiency. Here the terms cost and benefit are defined more specifically than in general English usage, while the procedures for measuring and comparing them rest on principles drawn from economic theory. The output of a narrow CBA is a single quantitative measure of net benefits expressed in monetary terms. In contrast to this, the ‘decision making’ school of thought, which supports broad CBA, holds that decision makers’ more subjective beliefs concerning, for example,

weights of benefits, social attitudes and the values of non-economic variables, should be included as part of CBA".

It is though important to note that the importance of subjective factors in the decision making process is acknowledged by both schools of thought. "The crux of the matter, therefore, is that the conventional approach favours narrow CBA being viewed as just one input into this process, while advocates of the decision making school see broad CBA as encapsulating most or all of the process" (Dockel *et al*., 1991:3-4).

4.4.2 The case for MCA

A number of key differences between cost-benefit analysis (CBA) and MCDA are highlighted in the manual on cost-benefit analysis prepared for the Water Research Commission (WRC) (Mullins *et al.*, 2007:11-12). Of note is the following: "MCDA aims to take into account multiple criteria to arrive at a scientific conclusion on the impact of the proposed project or programme on various aspects of society. MCDA allows for the application of both quantitative and qualitative criteria. Consequently, the types of key issue that are to be considered at a project or programme level are not restricted by requiring monetary values.

As touched upon in the theoretical section above, the theoretical origin of CBA is based on neo-classical economic theory. Criticism of this theory and the method of determining the welfare impacts of a project is directed mainly at the fact that CBA attempts to achieve efficiency by mimicking a perfectly competitive market. Maximising efficiency does not necessarily promote equity and sustainability. By introducing the use of income distribution weights in CBA, the issue is addressed to some extent.

On the other hand, MCDA does not limit the number and nature of objectives and criteria. According to a WRC report on MCDA (Stewart *et al*.), trade-offs between different stakeholders and criteria are a focus of attention. In contrast to CBA, the gains to one group of stakeholders are not assumed to compensate for the losses to other stakeholder groups.

The World Commission on Dams (WCD) also advocates the use of MCDA as an alternative approach to a decision-support system exclusively based on CBA (World Commission on Dams, 2000:182). In this regard, the WCD 'recognises that projects often have multiple objectives and not simply economic welfare maximisation'. Experience to date with these multiple criteria methods suggests that, while economic criteria remain important, these decision frameworks have the benefit of allowing disaggregated information on social and environmental impacts to enter directly into the decision analysis".

It is important to note, though, that there are widely differing views on the role of MCA. For example, “Multi-criteria analysis (MCA) is neither an alternative to BCA, nor an extension of it but is best regarded as an adjunct to BCA. Specifically, it is a means of coping with a partial BCA – one that fails to monetize significant impacts. Although BCA requires that every impact be monetized …, this is often impossible. Sometimes the non-monetizable impacts may be safely ignored; but if not, decision-makers may have to trade-off the incommensurable monetary and non-monetary impacts. Formal mechanisms for doing so, such as the Goals Achievement Matrix (GAM) are collectively known as MCA ...” (Austroads, 2005b:22).

The roles of CBA and MCA envisaged in the overall approach are argued in Section 4.4.3 below.

4.4.3 Suggested overall approach

Arguments in favour of the suggested overall approach are revisited below.

Traditionally, the focus in project appraisal has been on economic impacts. This is evident from the fact that the first attempts at project appraisal involved a CBA (i.e. a PE-type analysis) with the focus on economic efficiency, and with the aim of ensuring the optimal allocation of scarce resources in the context of transport infrastructure expenditure. This was also revealed by the bottom-up approach (in building a decision tree) adopted above. It can therefore be maintained that economic efficiency constitutes an important objective of society (community) in expending social funds on transport infrastructure, and that “economic worth” therefore constitutes one of the decision criteria in project appraisal.

But there are also second round (indirect) economic impacts. The bottom-up analysis of impacts also revealed the importance of indirect economic impacts, which manifest themselves in various indicators of economic growth – made possible by a more efficient transport system – and quantified by means of a GE type analysis.

Including both direct and indirect economic impacts in determining economic worth would amount to double counting. It was argued that direct and indirect impacts are two sides of the same coin; that indirect impacts are a consequence of direct impacts and that direct impacts (benefits) therefore are a prerequisite for indirect impacts (benefits) to materialize.

This means that a choice between direct and indirect economic benefits is inevitable. And taking this further, a choice between a PE type analysis and a GE type analysis needs to be made, as project worth cannot be based on both direct benefits and indirect benefits.

But the ability to rank projects is a requirement for the purposes of this thesis. As argued, the ability to rank projects in terms of (total) project worth to enable project selection is a requirement in the case of budget type projects.

The GE type analysis does not allow ranking. Although it is true that the results of a GE type analysis (e.g. “a project will generate 750 new jobs”) may have more “public relations appeal” than the results of a PE type analysis (e.g. “the project has a B/C cost ratio of 1,25”), the results of the former type of analysis are not “operational” as they do not allow projects to be ranked in terms of their economic worth – as is indeed possible in the case of a PE type analysis by rendering values for both benefits and costs.

A PE type analysis is therefore preferred to a GE type analysis. This preference follows from the reasoning above; it also means that direct impacts are preferred to indirect impacts in the economic appraisal of projects.

But there are also other types of impacts. The bottom-up analysis revealed other categories of impacts that by definition will be excluded from a traditional (narrow of economic) CBA which focuses on economic efficiency only.

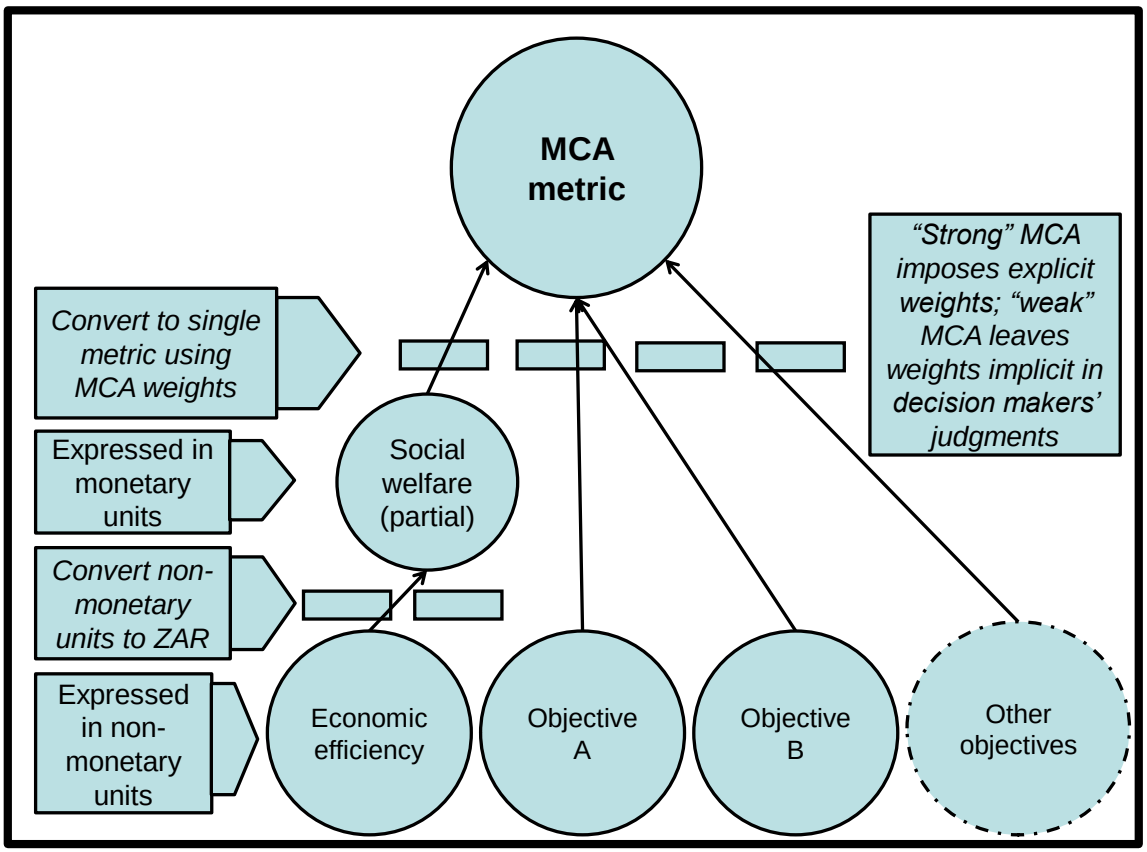
Broad or social CBA tries to address this problem by including other objectives as well in the analysis. Examples of such “other” objectives (in addition to efficiency) are equity and environmental externalities.

But, as argued, broad CBA has flaws that render it not suitable for the purpose of this thesis. This means that a narrow CBA is preferred to a broad CBA, but also leaves the decision maker with a problem as “other” objectives will still not be included in project appraisal.

All this necessitates adopting a “new” approach. Given the fact that economic efficiency remains an important objective in project appraisal (as stated above), in conjunction with the fact that there is a need to include other relevant objectives (decision criteria) in order to make the appraisal complete, the obvious choice is a combination of MCA and CBA – in particular, that a basic (overall) MCA approach should be adopted, but with economic efficiency (determined by a narrow CBA, pointing to the need for a PE type analysis) constituting one of the decision criteria.

All this can be summarized as follows: Economic efficiency (which requires a partial equilibrium type analysis) constitutes an important and essential decision criterion. And, as was also argued, narrow CBA is preferred to broad CBA. This implies that MCA is preferred to broad CBA as a basic option for quantifying project worth, as it was argued that broad CBA is essentially flawed. But, given the diverse nature of project impacts, this means that a number of "other" objectives (decision criteria) need to be taken into account in a different manner.

The suggested basic approach resulting from this is depicted in Figure 4-6. The identification of the remaining decision criteria (indicated by Objective A, B, etc, in the diagram) will be done in Chapter 5. This formulation of the set of decision criteria highlights the argument that CBA (in particular narrow CBA) is considered essential for project appraisal, but not sufficient.



Source: Adapted from Austroads (2005b:23).

Figure 4-6: Suggested overall approach

4.5 Dealing with criticism of CBA

Given that narrow CBA is important in the suggested CoT project appraisal approach, it now remains to explain how criticism of CBA is to be taken care of in this approach.

Quantification of benefits and costs: Benefits and costs cannot always be easily quantified. To address this problem, various approaches have been developed. Regarding benefits, the "willingness-to-pay" approach "introduces serious difficulties of quantification" (Baxa and van Zyl, 1977:9) (role of Stated Preference and Revealed Preference techniques). Likewise, costs are difficult to quantify, especially in respect of shadow prices and surrogate prices. Also, quantification of "social discount rate" has caused much debate. The combined effect of all these puts a question mark over the correctness of the results obtained.

Non-monetary costs and benefits: By definition, non-monetary costs and benefits are not included in the analysis. As CBA is a money-based technique, the implication is that only those positive and negative impacts (benefits and costs) that can be expressed as monetary values can be considered in the analysis. This in itself constitutes a "built-in restriction" (conceptual limitation) of CBA as not all impacts can possibly be expressed in monetary terms – and inevitably this means that some impacts will not be included in the analysis, which renders the answers obtained from the analysis inconclusive in these cases. This applies, for example, to air and noise pollution, improvement in accessibility and mobility, neighbourhood cohesion and aesthetic appeal (Baxa and van Zyl, 1977:10). This implies a limitation on the usefulness of CBA as, by definition, these impacts are not included in the analysis, which renders the answers obtained unrepresentative and unreliable.

Bias towards certain income groups: Typically, rich people tend to be favoured. By its very nature, the willingness-to-pay approach (used to value benefits) tends to give greater weight to the preferences of richer people. According to Baxa and van Zyl (1977:9), "cost-benefit analysis, like the market itself, tends to identify as "efficient" those projects whose benefits accrue largely to those who are already privileged".

Compensation to "losers": Losers are not generally compensated. "Theoretically, any undesirable redistributive effects which result from this tendency can be offset by requiring the high-income "gainers" to compensate the low-income "losers" in cash for their losses. In practice, there is obviously no guarantee that such a requirement will be imposed" (Baxa and van Zyl, 1977:9).

Secondary economic impacts: By "secondary economic impacts" is meant impacts outside the immediate sphere of influence of the project, such as the consequences of the project for the balance of payments and employment creation. These impacts are not addressed in CBA and should be evaluated independently.

Equity and sustainability: CBA does not address the socio-economic objectives of equity and sustainability. "Criticism against this theory and method of determining the welfare impacts of a project is mainly directed at the fact that CBA attempts to achieve efficiency by mimicking a perfectly competitive market. Maximizing efficiency does not necessarily promote equity and sustainability. By introducing the use of income distribution weights in CBA, the issue is addressed to some extent" (Mullins *et al*., 2007:11). Raux and Souche (2004:195) distinguish between three types of equity applicable in the context of transport *pricing*, namely spatial (geographical) equity, horizontal equity, vertical equity. The relevance of these types of equity in an appraisal framework is explored further in Chapter 5.

4.6 Other issues

Given the importance of narrow CBA in the overall appraisal framework, it is opportune to consider issues not currently dealt with in CBA, and which should be flagged for future research effort. A number of issues were identified as relevant in an Australian context (Naude *et al*., 2007:24); they have been customized below for a South African context.

Vehicle occupancy and utilization. Traffic models traditionally focus only on the movement of vehicles as opposed to the movement of people and freight. HDM-4, for example, does not allow for the availability of public transport and/or alternative modes regarding the movement of people. Regarding freight, models do not take into account the poor utilization of road space due to surplus carrying capacity often applicable in the case of urban delivery vehicles.

Changing freight and logistics task. The size and nature of freight logistics are changing internationally. This inevitably will impact on the number of commercial vehicles on the road network; the implications of this for traffic projections for the purpose of CBA need to be understood.

CBA in the case of infrastructure maintenance initiatives versus new projects. The argument here is that CBA is used mainly for new projects, assuming an expanding network. However,

its role is not clear in the case of “mature”, static networks that are not expanding, but now need substantial maintenance as they are nearing the end of its design (economic) life.

Traditional application of CBA to road projects. Given the focus of CBA on road projects, there is a need to demonstrate its application in the case of non-road projects, such as those involving demand management, public transport, and walking and cycling, so that they can be evaluated and ranked in the same way as road projects.

Frequency of updates. An important issue is the time intervals between updates. This relates to VOC models: the unit prices used in calculating VOC and road roughness relationships.

Higher level policy issues such as carbon tax. Given the likelihood of an increased emphasis on environmental externalities, it needs to be determined how possible measures such as a carbon tax will impact on transport cost and the demand for transport, and traffic growth rates used in CBA.

In addition to issues not currently dealt with in CBA, there are a number of “continuing” issues and methodological challenges (Naude *et al.*, 2007:25). Satisfactory answers to these have not been forthcoming and/or consensus regarding their treatment has not been reached. Examples are given below.

Travel time. There are a number of issues relating to travel time, such as the valuation of small time savings which remains the topic of debate amongst scholars. The valuation of travel time in the case of other (public) modes of transfer also needs to be addressed. In addition to the valuation of travel time, the issue of the reliability of travel (journey) times in the case of both passenger and freight transport is becoming increasingly relevant, especially in an urban context.

VOC models. Substantial progress has been made over time in this regard since the development of the original “Brazil relationships”. In the South African context, it is important that, when international packages such as HDM-4 are used, VOC models are calibrated to reflect local conditions, taking into account the characteristics and composition of local vehicle fleets. To ensure uniformity between different road authorities in the municipal sphere of government, it is important that standardized decision support software be used, and that reliable input data (such as the unit prices for fuel, vehicles, and travel time, reflecting the real economic cost thereof), provided by a reputable national source, are used in such models.

Collision cost. The two internationally accepted methods for determining collision cost, namely the human capital approach (gross and net output approach) and the willingness-to-pay approach, render substantial differences in collision cost estimates, and can thus result in different outcomes in a CBA. The most appropriate method for a South African context needs to be identified and applied in an uniform manner. There is also a need for a continued focus on the potential of collision reduction factors.

Externalities. As the matter of environmental externalities is becoming increasing important globally, this issue needs to be addressed sufficiently in the appraisal of TI projects. This is especially important in the case of projects involving different modes. This requires the calculation of environmental externality values that more accurately represent the South African situation.

4.7 Lessons from ex post evaluations

4.7.1 Causes of project failure

Flyvbjerg *et al*. (2003:46) describe the motives of stakeholders involved in the decision-making process as follows: “Politicians may have a ‘monument complex’, engineers like to build things and local officials sometimes have the mentality of empire-builders”. More important however, are those stakeholders that stand to gain directly from the project under consideration: “contractors and other project promoters who stand to gain from the mere construction of projects, and who are often powerful movers in the early stages of project development, may have a self-serving interest” (Flyvbjerg *et al*., 2003:137). This leads to “rent-seeking behaviour” and the associated “appraisal optimism”. Contributing to this is the long construction periods (often of several years), “relegating the concerns of operations to a distant future” (Flyvbjerg *et al*., 2003:137).

These factors all point to a situation of *risk-negligence* and *lack of accountability*. In this regard, the conventional approach to project development and appraisal does not offer much of a solution, as it has its own inherent shortcomings. Flyvbjerg *et al*. (2003:86-88) describe the characteristics of (and problems with) the *conventional approach* to project development and appraisal as follows:

1 A pre-feasibility analysis is not undertaken: A pre-feasibility analysis is often not undertaken (as it is not considered an essential part of the project cycle) before a full-scale

investigation takes place, resulting in the unnecessary over-commitment of resources and political prestige at an early stage.

2 The focus is on technical solutions: Project development and appraisal are seen as a technical exercise, focusing on technical solutions, as opposed to a discussion of policy objectives to be achieved by the project.

3 Externalities are not addressed timeously: This may result in costly changes to the project in later phases of the project when the scope for changes is limited, as well as time delays due to public hearings and the need for formal approval by authorities.

4 Stakeholders are not optimally involved: This involves both negatively affected stakeholder groups and the "general public". When input from these groups (e.g. in setting performance standards) is limited or only effected at a late stage, they may feel "left out", resulting in public dissatisfaction with the project.

5 Risk analysis is neglected: Risk analysis (involving the identification and quantification of the nature and extent of risk, responsible parties and options for mitigating risk) constitutes an important element of project appraisal. When this fact is ignored, the appraisal is incomplete.

6 Institutional, organizational and accountability issues are not adequately addressed: These issues apply to the implementation and operations of and the regulatory regime for the proposed project. They should be in place to ensure that project cost and risk are properly addressed, in the appraisal and decision-making process as well.

4.7.2 Options for dealing with project failure

Four inter-related "cures" are suggested for project failure (Flyvbjerg *et al*., 2003:138-141): *Firstly*, risk and accountability should be more centrally based in decision-making. This may require the necessary institutional arrangements to provide the necessary checks and balances.

Secondly, a rearrangement of public and private responsibilities may be required, as there may be a conflict of interest within government – it cannot be both the promoter of megaprojects *and* the guardian of public interests such as the protection of the environment at the same time.

Thirdly, four basic instruments of accountability are suggested, namely transparency, performance specification, regulatory regime, and the involvement of risk capital. They are discussed in Section 4.7.3.

Fourthly, two alternative models for accountable decision-making are proposed: the state-owned enterprise (SOE) approach and the build-operate-transfer (BOT) approach. It is maintained that, if the four instruments of accountability (see Section 4.7.3) are in place, either of these models could be selected, as both as both are suitable for this purpose.

4.7.3 Instruments of accountability

Four "instruments of accountability" (listed above) are suggested to facilitate the *process* and *institutional set-up* needed for developing major infrastructure projects (Flyvbjerg *et al*., 2003:139-141):

Transparency: The role of government in project development and appraisal is to represent and protect the public interest. To ensure that this happens, transparency and public scrutiny are critical, as they constitute the main means of enforcing accountability in the public sector (Flyvbjerg *et al*., 2003:139). Government can best perform its role (of representing and protecting the public interest) if it is subjected to public scrutiny. This implies the involvement of stakeholder groups and civil society throughout the appraisal and decision making process. It also calls for peer review.

Performance specifications: The use of performance specifications implies a *goal*-driven approach to project development and appraisal as opposed to the conventional approach which is a *solution*-driven approach. Ideally, performance specifications should be derived from policy objectives at national, provincial and municipal level as well as public interest requirements. When this is done, all relevant requirements with respect to a project will be decided first, before various technical options for accomplishing this are evaluated.

Regulatory regime: It is important that the regulatory regime should be set up front. It is equally important that the regulatory regime does not only include the set of economic rules that regulate the construction and operation of the project, but also other rules having a bearing on the financial and economic performance of the project, and rules for complementary investments that may be required, for example collection and distribution systems in the case of the Gautrain project.

Involvement of risk capital: This involves the participation of financiers, developers and other stakeholders from the private sector in the project without any sovereign guarantee. Their involvement would ensure a proper risk assessment of the project under consideration.

4.8 Summary

As noted in Section 1.5, project selection in the case of the local impact, budget-type context in road authorities requires feasible projects to be ranked in terms of total worth. Two opposing and fundamentally different methods were presented for this purpose, namely broad CBA (in Chapter 2) and MCDM (in Chapter 3). This chapter explores their role (if any) in the suggested appraisal framework. To this end, likely impacts of TI projects in the municipal sphere of government are examined in detail in order to derive a set of appropriate decision criteria for use in an appraisal framework. Quantifying these impacts inevitably brings to the fore the choice between a partial equilibrium and a general equilibrium type of analysis, and their suitability in this context is therefore examined. Given the importance of economic efficiency (and thus narrow CBA) in the basic approach, this chapter also examines how criticism of CBA should be handled, highlights issues not dealt with in CBA, and focuses on lessons from *ex post* evaluations.

Broad CBA versus MCA

Given the two methods for determining total worth, (broad CBA and MCA), key differences between them are highlighted. With broad CBA, all impacts are expressed in monetary units and project worth is expressed as “social welfare”. With MCA, project worth is expressed as a single MCA metric, and weights are used to reflect the relative importance of impacts.

Examining project impacts

This step is important in order to ensure the correct approach to considering economic impacts in the proposed appraisal framework (in particular the choice between a CBA approach and a general equilibrium type approach), and also to explore the whole spectrum of impacts for further consideration in Chapter 5. It also constitutes the first step of a “bottom-up” approach to building a decision (value) tree as opposed to a top-down approach. Is has been argued that these approaches should be used in parallel since they are complementary and inform each other, thus ensuring a complete array of decision criteria.

Examining impacts of municipal projects

In quantifying impacts, cognisance needs to be taken of the *temporal (time) dimension of impacts and their spatial distribution,* as well as the characteristics of affected parties. A number of problems may also be encountered: Impacts may be contradictory; they may be overlapping; they may be expressed in different units; and/or they may be able to be expressed in qualitative terms only. The probable impacts of urban projects that were listed (in excess of 30) were grouped under the following headings:

- Impacts relating to a better transport system.
- Impacts relating to a more efficient macro-economic environment.
- Impacts relating to equity.
- Impacts relating to the environment.
- Impacts relating to other aspects not included above.

The case for a partial equilibrium type approach

Impacts in the first category (also known as direct or first round impacts) require a partial equilibrium analysis which focuses on project efficiency in a micro-economic sense. Impacts in the second category (also known as indirect or second round impacts) require a general equilibrium analysis which focuses on projects in a macro-economic sense. For the purposes of an appraisal framework, it is argued that including them both in project appraisal would amount to double counting. Given the requirement of *ranking* for the purpose of an appraisal framework, it argued that a partial equilibrium type of analysis (i.e. CBA) constitutes the preferred choice.

Developing the framework

The case for narrow CBA

Narrow and broad CBA differ in various ways, in for instance the role to be played by decision makers. The conventional school of thought, favouring narrow (economic) CBA, argues that CBA provides only one of the inputs in the decision making process. The decision making school of thought, favouring broad CBA, argues that decision makers' more subjective beliefs should be included as part of CBA. For the purpose of an appraisal framework, narrow CBA is preferred, as the view is supported that even narrow CBA already constitutes a soft approach.

The case for MCA

The strength of the argument for adopting an MCA type approach is directly proportional to the diverse nature of the impacts of TI projects.

Suggested framework

This involves an MCA type approach, with economic efficiency as one of the decision criteria. This means that a narrow CBA should always be conducted.

Other aspects

This chapter dealt firstly with criticism of CBA, then considered issues not currently addressed in CBA, as well as a number of "continuing" issues and methodological challenges on which scholars have not yet reached consensus.

Lessons from ex post evaluations

Causes of project failure

Projects often fail because of risk-negligence and lack of accountability. Problems with the conventional approach to appraisal includes: (a) a pre-feasibility analysis is not undertaken; (b) the focus is on technical solutions; (c) externalities are not addressed timeously; (d) stakeholders are not optimally involved; (e) risk analysis is neglected; and (f) institutional, organizational and accountability issues are not adequately addressed.

Suggested cures

Four inter-related solutions are suggested for project failure: (a) risk and accountability should be more centrally based in decision-making; (b) a rearrangement of public and private responsibilities may be required; (c) four basic instruments of accountability are suggested; (d) two alternative models for accountable decision-making are proposed: the state-owned enterprise (SOE) approach and the build-operate-transfer (BOT) approach.

Instruments of accountability

These four instruments are: (a) transparency; (b) performance specifications; (c) regulatory regime; and (d) involvement of risk capital.

5. CUSTOMIZING THE BASIC APPROACH

5.1 Introduction

The basic approach developed in Chapter 4 involves an MCDM-type approach – using the MCDM value measurement model – with economic efficiency as one of the decision criteria. From Section 3.3.2, applying this model requires the following steps:

- Identify and structure the problem.
- Identify alternatives.
- Identify decision criteria.
- Determine relative importance of criteria.
- Measure intra-criterion performance.
- Aggregate scores across criteria.
- Perform sensitivity analysis.

This chapter focuses on customizing this approach to the CoT context. To this end, attention is focused on the second, third and fifth steps – identifying decision criteria (in addition to economic efficiency that was identified in Section 4.4.3), identifying alternatives and measuring intra-criterion performance. Identifying decision criteria involves both an analysis of the CoT decision making environment and an analysis of the approach adopted by a selected number of external institutions or suggested by independent sources. Regarding the remaining four steps of the model not dealt with in this chapter, it is argued that they are sufficiently taken care of by the software suggested for this purpose. A number of additional aspects relating to customizing the framework are also explored, such as the need for a two-phased approach which results from the distinction between mutually exclusive alternatives and independent projects and which directly impacts on intra-criterion performance measurement, in particular the choice of performance measurement units.

5.2 Decision criteria from the CoT planning environment

5.2.1 Introduction

Given the definition of “appraisal” (in Section 1.2.10) as “matching” (comparing) project impacts with decision criteria which, in their turn, are arguably to be derived from community

objectives, and assuming that community objectives are embodied in policy documents such as the ITP and IDP, a logical starting point for identifying decision criteria would seem to be to scrutinize all relevant documents with a view to revealing these objectives. This chapter examines the South African project planning environment and explores literature on the subject. It examines policy and legislation frameworks for the different spheres of government (national, provincial and municipal), with special reference to the requirement of "integrated planning", and planning documents emanating from this process such as the IDP (Integrated Development Planning) and ITP (Integrated Transport Planning) frameworks. These in their turn, provide information on aspects such as the vision and mission statements, goals, objectives, strategies and priorities.

In essence, therefore, it is argued that the "corporate vision", "city strategy", "transport vision and mission", "transport goals" and "transport objectives" (as defined in the IDP and ITP documents) collectively constitute a hierarchical framework against which organization performance could be measured and which guides planned actions in the organization, including the selection and implementation of projects. Each element of this hierarchy is "informed" by the element at the preceding (higher) level, and each subsequent element implies the "unpacking" of its predecessor. Moreover, these elements become more "operational" (defined here as doable, practical and measurable) as one moves from the top to the bottom of the hierarchy, with the "Corporate Vision" (top level) being more "value-laden" (philosophical), and "objectives" (bottom level) being more operational (measurable). In theory, therefore, it could be argued that these objectives should constitute the decision criteria against which proposed projects are to be evaluated. The extent to which this is true is examined in this section.

5.2.2 Statutory environment and spatial development framework

Laws and statutes

A number of laws and statutes impact on land use and transport development in South Africa and thus on CoT and, in so doing, also on the development of an appraisal strategy for CoT.

The *National Land Transport Transition Act (NLTTA) (Act 22 of 2000)* states that land transport planning must be integrated with the land development process; in particular, that the Integrated Transport Plan (ITP) of a municipality constitutes the transport component of the Integrated Development Plan (IDP) of a municipality (CTMM, 2007:4-1).

The *Development Facilitation Act (Act 67 of 1995)* is aimed at introducing extraordinary measures to facilitate the implementation of reconstruction and development programmes and projects impacting on land and land use (CTMM, 2007:4-1).

The *Gauteng Planning and Development Act (GPDA) (Act 3 of 2003)* "provides for a single system of development, planning and land management in the Province" (CTMM, 2007:4.2).

The *Local Government Municipal Systems Act (Act 32 of 2000)* provides the core principles, mechanisms and processes necessary for enabling municipalities to become developmental institutions. "Development", involving the upliftment of communities by improving the quality of life of citizens, is defined here in a holistic sense, involving the integration of the social, environmental, spatial, infrastructure, institutional, organizational and human resources dimension (CTMM, 2007:4-2).

Spatial development frameworks

The *Gauteng Spatial Development Framework (SDF)* guides land development and transport in the province and therefore also affects CoT. The guiding principles influencing the urban development strategy in this framework are those in the Development Facilitation Act (see above) (CTMM, 2007:4-4). A total of 11 provincial Spatial Development Initiatives (SDIs) have been identified, of which four impact on CoT: Gautrain, Gauteng Automotive Cluster, the Innovation Hub, and Dinokeng (a biosphere-type nature reserve, aimed at business tourists) (CTMM, 2007:4-2).

The *Metropolitan Spatial Development Framework (MSDF)* for CoT "establishes a geographic context to the development framework process regarding the form, structure and location of future development" (CTMM, 2007:4-11). Current (regional) development initiatives listed in the ITP document are the "Blue IQ projects" (namely the Innovation Hub, Gauteng automotive cluster, Gautrain, and Dinokeng, mentioned above under the Gauteng SDF), the Freedom Park project, the Maputo – Walvis Bay corridor (Platinum Toll Highway), and the Mabopane – Centurion Development Corridor (CTMM, 2007:4-14).

5.2.3 Policy imperatives

National and provincial level

In preparing the IDP document for CoT, a number of "policy imperatives" at national and provincial level were taken into consideration (CTMM, 2009:11-14). These imperatives are

equally important for developing an appraisal strategy for CoT, by informing the process of identifying decision alternatives relevant to this strategy.

The *National 2014 Vision*, prepared as part of South Africa's celebration of 10 years of democracy, formulates national government's vision for the 10-year period to 2014, namely "to build a society that is truly united, non-racial, non-sexist and democratic. Central to this is a single and integrated economy that benefits all" (CTMM, 2007:11). This translates into a number of *targets and objectives*, relating to aspects such as reducing unemployment, reducing poverty, providing skills, empowering all citizens in terms of their constitutional rights, compassionate government service, reducing health risks, reducing crime, and positioning South Africa strategically as a global force. Vision 2014 also translates into a number of *practical steps*, with a number of specific implications for CoT, namely a growing economy, sustainable livelihoods, access to services, comprehensive social security, visible policing to combat crime and corruption, and improving the interaction between government and the people (CTMM, 2007:11-12).

The *Accelerated and Shared Growth Initiative – South Africa (ASGISA)* "focuses on growing the economy and creating jobs, and states that growth should be government-led" (CTMM, 2007:12). Six *levers for economic growth* are listed, namely macro-economic intervention, infrastructure development, skills development, strengthening public institutions, sectoral investments, and intervention in the second economy. *Strategies for growth and development* "include investment in transport infrastructure, support to SMME's and labour intensive projects, prioritizing social and economic infrastructure and building partnerships" (CTMM, 2007:12). *Targets* are also set with reference to poverty reduction, unemployment reduction, economic growth and government's contribution to total spending on infrastructure.

The *ANC Manifesto* "emphasizes growing the economy, fighting poverty, creating jobs, building roads, rail networks and dams, building better quality houses closer to economic opportunities, providing skills required by the economy, being a compassionate government to the people, improving services for a better national health profile, and reducing preventable causes of death (violent crime and road accidents)" (CTMM, 2007:12).

The *National Spatial Development Perspective (NSDP)* was formulated to ensure that infrastructure investment and development programmes are channelled towards the objectives of government such as those listed above (e.g. economic growth, employment

creation, sustainable service delivery). Its *vision* therefore is that "South Africa will become a nation in which investment in infrastructure and development programmes support government's growth and development objectives". This is to be achieved in the following manner (CTMM, 2007:12): "by focusing economic growth and employment creation in areas where this is most effective and sustainable; by supporting restructuring where feasible to ensure greater competitiveness; by fostering development on the basis of local potential; and by ensuring that development institutions are able to provide basic needs throughout the country". A number of *normative principles* are given to guide government in all spheres when deciding on infrastructure investment and development spending. They are: (a) economic growth is a prerequisite for achieving other policy objectives; (b) government spending on fixed investment should be focused on localities of economic growth; (c) in addressing social inequalities, efforts should be focused on people and not places; (d) in attempting to address spatial distortions of apartheid, future settlement and economic development opportunities "should be channelled into activity corridors and nodes that are adjacent to or link the main growth centres. Infrastructure investment and development spending should primarily support localities that will become major growth nodes in South Africa and the Southern African Development community region to create regional gateways to the global economy" (CTMM, 2007:13). By emphasizing the role of economic growth as a prerequisite for achieving socio-economic objectives, these principles therefore not only serve to inform the identification of decision criteria in a proposed appraisal strategy for CoT, but also the relative importance to be attached to them in appraising projects.

Government's *Medium Term Strategic Framework* focuses on its financial strategy. It also expresses the view that the IDP (developed for local government level" constitutes the local expression of national development plans (CTMM, 2007:13).

The *National Apex Priorities,* announced by President Mbeki in his State of the Nation Address in February 2009, listed 24 priority projects as part of the "Business Unusual: All hands on deck to speed up change" initiative. They cover a wide spectrum; those most relevant to developing an appraisal strategy for CoT are the Industrial Policy Action Plan and the programme aimed at speeding up community infrastructure (CTMM, 2007:13).

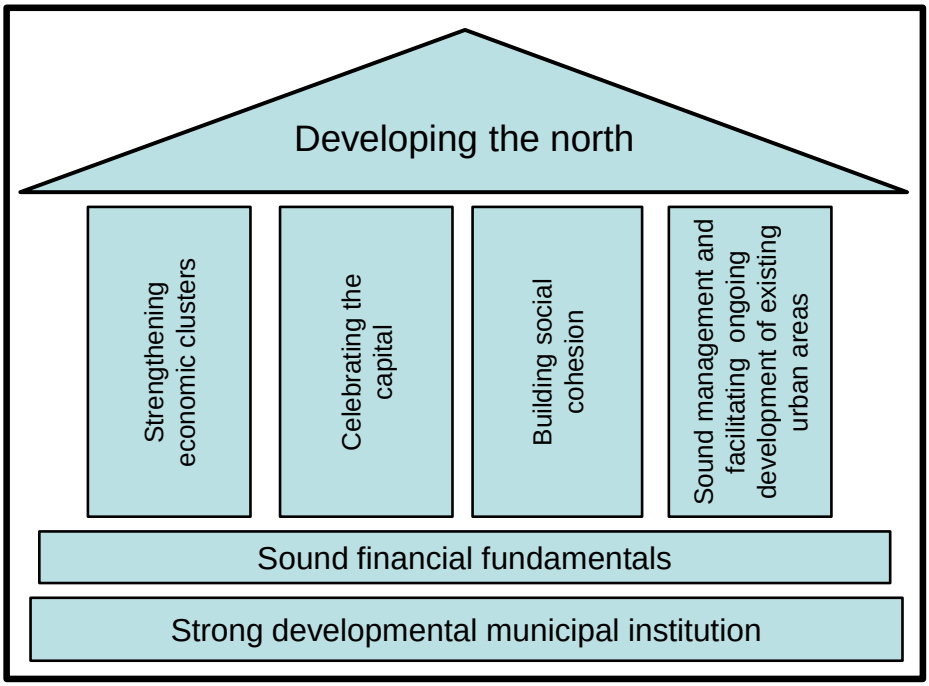
The *Gauteng Growth and Development Strategy (GDS)* in essence involves all the socio-economic objectives and strategies listed in the national initiatives outlined above, but with a specific (provincial) focus on Gauteng. A number of *strategic levers* are proposed to enact the Gauteng GDS. Of relevance to developing an appraisal strategy for CoT are the

provision of an optimal public transport system and the Gautrain project (CTMM, 2007:13-14).

CoT corporate vision and strategy

In terms of the corporate vision for Tshwane, the city is envisaged as "the leading international African Capital City of Excellence that empowers the community to prosper in a safe and healthy environment" (CTMM, 2007:2-2). The City Development Strategy (CDS) and the Integrated Development Plan (IDP) are the two key processes for materializing this vision. The CDS, with its 20-year horizon, gives a broad direction to the development of the city and, in so doing, informs the objectives, programmes and outputs of the IDP which has a 5-year horizon. The alignment of the IDP, the CS, CTMM priorities, national budget priorities, provincial budget priorities and the national key performance indicators is regarded as requiring special effort (CTMM, 2007:2-2).

The *City Development Strategy (CDS)* is aimed at influencing city development over the next 20-30 years. "It proposes a substantial programme of public-led investment to re-structure current patterns of settlement, activity and access to resources in the City towards greater equity and enhanced opportunity. The CDS specifically targets future development opportunity in traditional dormitory settlements to the north, east and west of the CBD. It is the umbrella strategy that provides direction to the City's Integrated Development Plan, associated sectoral plans and strategies, and the allocation of resources of the City and other service delivery partners" (CTMM, 2009:15). Policy shifts and emphases involve six aspects, of which the following are deemed the most relevant for the purpose of developing an appraisal strategy for CoT: a move away from unfocused, low impact expenditure to focused, high impact investment; from unsustainable patterns of infrastructure investment to an approach that balances growth and maintenance; from "unproductive" investments to investments with a multiplier effect, and from being a development facilitator to directing development. These policy shifts have been translated into seven strategic focus areas (CTMM, 2009:15-16), as depicted in Figure 5-1.



Source: Adapted from ITP Fig 2.1 (CTMM, 2007:2-3).

Figure 5-1: Tshwane City Strategy

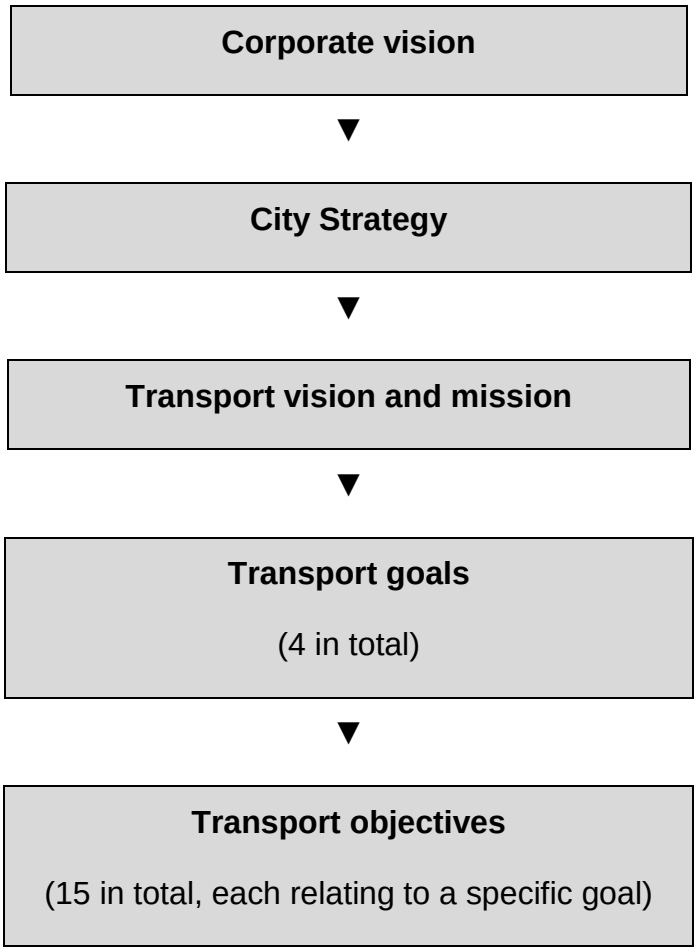
The *CDS Implementation Agenda* outlines a number of "lead programmes" – each with a number of sub-programmes and projects – aimed at fast-tracking implementation of the CDS, namely: (a) Re Kgabisa Tshwane (revitalizing the inner city); (b) building of a new municipal head quarters; (c) Tshwane Kopanong (building an iconic square and monumental land-mark to celebrate Tshwane as the capital city); (d) city living initiative and "West Capital Urban Renewal"; (e) urban arts and culture initiative (exploring Africaness); (f) Tsosoloso (quality public spaces) programme; (g) smart city digital hub programme (connecting Tshwane to the knowledge economy); (h) development of the zone of choice; (i) building an international logistics cluster and freight airport; and (j) working infrastructure programme. In addition, two others are of particular relevance to developing an appraisal strategy for CoT: the "moving Tshwane initiative" and "completing the metropolitan mobility ring and building a Tshwane Western Bypass". The former includes establishing the Tshwane Transport Authority, introducing a Bus Rapid Transit system and transforming the bus service, building connectivity routes, and improving accessibility to the northern parts of Tshwane (CTMM, 2009:16-17).

Whereas the City Development Strategy (CDS) constitutes the overarching (spatial) development strategy for CoT, the *Tshwane Growth and Development Strategy (TGDS)*

complements and facilitates it by adopting a sector approach – in particular, by identifying sectors and industries that should be leveraged to develop (CTMM, 2007:17).

5.2.4 CoT vision, mission, goals and objectives for transport

According to the ITP document, the policy framework for transport, as set out in Chapter 2 of the ITP document (CTMM, 2007), involves all elements of land transport, including public transport (CTMM, 2007:2-5). Specific goals, objectives and strategies public transport are nevertheless summarized separately in Chapter 7.3 of the ITP document (CTMM, 2007). The overall policy framework involves a vision and mission statement for transport, as well as goals, objectives and strategies, all of which are aligned with the corporate vision and city development strategy. This implies a hierarchy with corporate vision and city strategy at the top, and cascading down to lower levels, as depicted below.



Vision and mission

The vision and mission for land transport are given below.

Vision:
A safe and integrated transport system that empowers the community to prosper in the leading African Capital City of Excellence (CTMM, 2007:2-3)

Mission:
To make best use of the existing infrastructure and services, eliminate the backlog thereof, and achieve one integrated transport system that capitalizes on strengths of each mode (CTMM, 2007:2-4)

Goals

The transport goals describe "the idealized end-state of the transport system and the desired direction for the evolution of the system towards which planners and engineers strive" (CTMM, 2007:2-4). The four goals are the following (CTMM, 2007:2-4):

"1. *Improve accessibility and mobility provided by the transport system:* To improve the overall accessibility and mobility of the transport system, especially for communities situated in the north and special categories of passengers, to have appropriate transport choices and affordable access to the transport system.

2. *Develop a transport system that drives economic growth:* To influence the development, maintenance and use of transport system to deliver improved logistics, environmental and social outcomes that contributes to the economic growth of the region.

3. *Improve the safety and security of the transport system:* To ensure a high level of safety and security for all users of the transport system.

4. *Develop a transport system that reflects the image of the city:* To facilitate effective industry, community and government participation in the development and use of the

transport system and design the system in such a manner that it reflects the image of the city."

Objectives and strategies

A total of 15 objectives were identified, each addressing one of the four goals listed above (CTMM, 2007:2-4 to 2-5). In addition, the ITP document also lists key strategies for achieving objectives, as well units for measuring success in each case (CTMM, 2007:2-6 to 2-6). These are presented in Table 5-1.

Table 5-1: Transport goals, objectives and key strategies

Objectives	Key strategy	Measurement
Goal 1: Improving accessibility and mobility provided by the transport system		
i To reduce *transport infrastructure backlogs*	Build new roads that impact on the backlogs focused on in the City Strategy "Zone of Choice"	Km new roads built (total backlog = 2214 km)
ii To reduce *public transport service backlogs*	Determine need for public transport service Improve efficiency by eliminating duplication Expand service capacity	% Capacity utilization Subsidy spending per capita
iii To maintain the transport system in a *cost effective and serviceable condition*	Blade and re-gravel gravel roads Maintain existing surfaced roads Repaint road markings Replace traffic signs Repair traffic signals Repair dangerous potholes Maintain public transport facilities	Length of gravel roads Length of surfaced roads Length of road markings Number of traffic signs Number of traffic signals Number of potholes Number of facilities with maintenance contracts
iv To safeguard and improve the utilisation of the existing and future *transport resources*	Implement freight overloading project Prepare and implement OLS and	% Completion Average % utilisation of bus fleet

Objectives	Key strategy	Measurement
	Ratplan (see Note 1) Prepare public transport charter Implement concept of rank managers at public transport facilities	Average % utilisation of taxi fleet Completion date Number of managers
v To promote, plan and develop the expansion of the transport system to eliminate infrastructure *disparities*, public transport service *disparities*, improve *mobility* and *access* and regenerate the inner city	Promote the development of the western bypass to improve mobility (Utilize) Gautrain to regenerate the inner city Provide infrastructure to the north to eliminate infrastructure disparities	Expand western bypass Complete the Gautrain Extent of infrastructure provision
Objectives addressing Goal 2: Developing a transport system that drives economic growth		
vi To create *job opportunities* through the development of the transport system	Build new roads that make use of labour intensive practices	Km new roads built
viiTo increase trade and development at the *Wonderboom airport*	Obtain international status Revamp office buildings and hangars Lengthen runway strip Blade and re-gravel gravel roads	Monitor completion of activities
viiiTo make the transport system easily accessible for *tourists and visitors* to the city	Upgrade signage in and around city Transport tourist information kiosks Adequate services availability system	Conduct surveys on user friendliness of the transport
ix To promote *BEE and SMME* development in the planning, maintenance and upgrading of the transport system	BEE and SMME involvement in planning, design and operation	Statistics on the number/extent of BEEs and SMMEs involvement and ownership in the transport system

Objectives	Key strategy	Measurement
x To support the development of the *"Zone of Choice"* north of the Magaliesberg in line with the CS.	Develop Rainbow Junction inter-modal facility and road network system	Complete construction
Objectives addressing Goal 3: Improving the safety and security of the transport system		
xi To reduce *injuries and fatalities* on all modes of transport.	Campaigns on safe road usage Effective law enforcement Develop appropriate design standards	Statistics on fatalities
xii To improve *personal security* on the public transport system	Deploy more security personnel at facilities and on the system	Statistics on crime incidents
xiii In conjunction with other service sectors, develop *contingency plans* for possible transportation emergencies	Develop a contingency plan	Statistics
Objectives addressing Goal 4: Developing a transport system that reflects the image of the city		
xiv To make transport planning and decision-making processes *user based*	Host public participation sessions and rallies Successful branding	Number of suggestions received Surveys conducted Attendance of open days
xv To plan and develop a unitary *branding system* for the public transport system that reflects the image of the city	Creation of minimum performance standards Universally recognised transport system Meeting the needs of commuters	Statistics and commuters' feedback

Source: Table 2.1 of ITP (ITP, 2007:2-6 to 2-7) (edited/adapted).

Note 1: OLS = Operating License Strategy and Ratplan = Rationalization Plan; both these terms pertain to public transport.

5.2.5 Suitability of CoT goals and objectives

This section involves a critical analysis of the objectives (and, by implication, the strategies for achieving them and measurements of the degree of success) derived from stated goals in order to determine the following:

- Whether the objectives listed in the ITP constitute a complete set of operational decision criteria necessary to evaluate and prioritize new TI projects.
- If not, then (at least) the extent to which they inform the process of selecting decision criteria.
- Alternatively (worst case scenario), whether they are contradictory to the decision criteria suggested for CoT.

This is done below by unpacking each of the 15 objectives listed in Table 5-1 above and establishing (a) if it specifically relates to new TI projects (or to another project type, which (usually) may warrant a different set of decision criteria), and (b) if it facilitates the evaluation and prioritization of new TI projects (by providing a means of evaluating and prioritizing a proposed new TI project).

i To reduce transport infrastructure backlogs: This objective involves welfare (equity) considerations as these backlogs refer to backlogs in the City Strategy "Zone of Choice".

ii To reduce public transport service backlogs: This objective involves equity considerations. However, it relates to public transport projects which, by definition, constitute a separate list (i.e. it should not appear on the TI list of projects).

iii To maintain the transport system in a cost effective and serviceable condition: This relates to maintenance projects (as opposed to new construction projects) which, for the same reasons as public transport projects, constitute a separate list of projects.

iv To safeguard and improve the utilisation of the existing and future transport resources: From the key strategies suggested in Table 5-1, it is clear that this objective refers to both public transport projects and transport infrastructure. Regarding the latter, it is further clear that it does not refer to new TI projects.

v To promote, plan and develop the expansion of the transport system to eliminate infrastructure disparities, public transport service disparities, improve mobility and access and regenerate the inner city: This objective is very broad, comprising a mixture of objectives and strategic initiatives. Projects involving public transport services should appear

on a separate project list and be subjected to its own decision criteria. In as far as this objective refers to transport infrastructure, it (again) emphasizes the importance of equity considerations. Further, it is maintained that to "regenerate the inner city" (last part of the objective) constitutes a project ("strategic" initiative) and not an objective.

vi To create job opportunities through the development of the transport system: The strategy suggested for this objective further qualifies it: "Build new roads that make use of labour intensive practices". In other words, this objective relates to *how* a project should be implemented, not *if* it should be implemented. By definition, therefore, it does not constitute a decision criterion. It nevertheless points to a preference for equity considerations. (On the issue of labour intensive practices, it is the author's view that this is allowable, as long as it does not add to project cost.)

vii To increase trade and development at the Wonderboom Airport: The Wonderboom airport and all aspects thereof should be considered a project on itself – in the CoT jargon, a strategic initiative – and therefore it does not qualify as an objective. Being a project in its own right, it is further maintained, for the purpose of this study, that strategic initiatives (special projects) should appear on a separate project list.

viii To make the transport system easily accessible for tourists and visitors to the city: To the extent that this objective adds additional cost (relative to making it accessible to "normal" users), this constitutes a special project (strategic initiative) in it own right (as in the case of the Wonderboom Airport), which warrants inclusion on the list of "special initiatives".

ix To promote BEE and SMME development in the planning, maintenance and upgrading of the transport system: As with objective vi (involving labour intensive practices), this objective relates to *how* a project should be done and not *if* it should be done. Also, as with objective viii, and at least in theory, this constitutes a strategic initiative to the extent that it involves additional cost (additional to not promoting BEE and SMME development), which should be added to a separate list (list for strategic initiatives). A complicating factor here is the fact that this objective is required by government as part of national policy.

x To support the development of the "Zone of Choice" north of the Magaliesberg in line with the CS: This involves a spatial (geographic) preference for new projects: To the extent that this "Zone of choice" involves lower income groups, it points to equity considerations. To the extent that it does not, but is merely a spatial preference (town

planning objective), it involves a strategic initiative which should be treated like other strategic initiatives (e.g., it should appear on a separate list).

xi To reduce injuries and fatalities on all modes of transport: This is a justified objective which is (already) included in any transport CBA.

xii To improve personal security on the public transport system: This is a valid objective, and it could be argued that "personal security" should be incorporated in the engineering (technical) feasibility analysis.

xiii In conjunction with other service sectors, develop contingency plans for possible transportation emergencies: This does not relate to new TI projects. It can be argued that this constitutes a strategic initiative and that it should be contained on that list.

xiv To make transport planning and decision-making processes user based: Whilst this objective is valid, it refers to how planning and decision making should be done, and not whether a project should be selected.

xv To plan and develop a unitary branding system for the public transport system that reflects the image of the city: This involves a different category of projects and not TI projects at all – it therefore does help to determine whether a new TI project should be selected.

Summary of findings

From this critical analysis of the objectives (above), the following emerges:

- Some of the objectives are in fact themselves proposed projects (or strategic initiatives) and, by definition, can therefore not serve as decision criteria.
- Of the remaining objectives, many relate to non-new TI projects, and therefore are not useful for new TI projects.
- Of those objectives that do relate to new TI projects, some objectives relate to (a) *how* a project should be executed and not *if*;, or (b) engineering (technical) feasibility (for the purpose of this study, it is maintained that technical feasibility is a prerequisite for any project to be listed in the ITP).
- Regarding the remaining objectives, particular emphasis is placed (only) on *equity* and *safety*.

In Table 5-2, these objectives are classified into five categories, based on (and for the reasons given in) the discussion above. Only the first category involves objectives that constitute valid decision criteria for the purpose of this study. As shown in Table 5-2, this amounts to only four out of the 15 objectives listed in Table 5-1. These four objectives are therefore reflected in the list of "generic decision criteria" – all remaining objectives are, by definition, not.

Table 5-2: Classification of CoT objectives

Category	Objective
Objectives constituting valid decision criteria	*The following objectives emphasize the importance of equity considerations:* Objective i: To reduce transport infrastructure backlogs: Objective v: To promote, plan and develop the expansion of the transport system to eliminate infrastructure disparities, public transport service disparities, improve mobility and access and regenerate the inner city. Objective x: To support the development of the "Zone of Choice" north of the Magaliesberg in line with the CS. *The following objectives emphasize the importance of safety considerations:* Objective xi: To reduce injuries and fatalities on all modes of transport.
Objectives focusing on *how* a project should be implemented, and not *if* it should be constructed	Objective vi: To create job opportunities through the development of the transport system. Objective ix: To promote BEE and SMME development in the planning, maintenance and upgrading of the transport system. Objective xiv: To make transport planning and decision-making processes user based.
Objectives that are	*All objectives referring to strategic initiatives fall in this category, viz:*

Category	Objective
projects in their own right	Objective vii: To increase trade and development at the Wonderboom Airport. Objective viii: To make the transport system easily accessible for tourists and visitors to the city. Objective x: To support the development of the “Zone of Choice” north of the Magaliesberg in line with the CS (in so far as this involves a spatial (geographic) preference for new projects.
Objectives involving other (non-new TI) projects	*Involving public transport projects:* Objective ii: To reduce public transport service backlogs. Objective iii: To maintain the transport system in a cost effective and serviceable condition. Objective iv: To safeguard and improve the utilisation of the existing and future transport resources. Objective v: To promote, plan and develop the expansion of the transport system to eliminate infrastructure disparities, public transport service disparities, improve mobility and access and regenerate the inner city. Objective xv: To plan and develop a unitary branding system for the public transport system that reflects the image of the city. *Involving maintenance of TI:* Objective iii: To maintain the transport system in a cost effective and serviceable condition. *Involving other TI-related aspects:* Objective iv: To safeguard and improve the utilisation of the existing and future transport resources. Objective xiii: In conjunction with other service sectors, develop contingency plans for possible transportation emergencies.

Category	Objective
Objectives relating to engineering (technical) feasibility	Objective xii: To improve personal security on the public transport system.

5.2.6 Conclusions

The main findings of the analysis of the CoT decision making environment are the following:

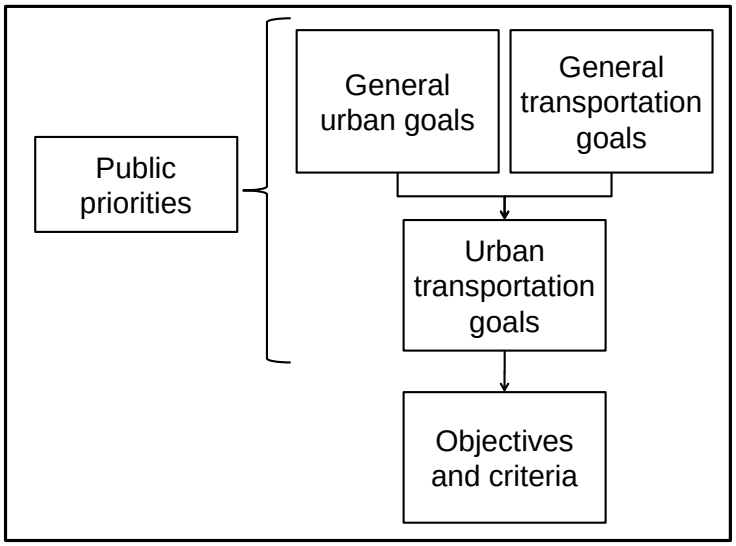
- In general, the relevant CoT planning documents, in particular the ITP and the IDP documents, are not very helpful for the purpose of identifying a list of decision criteria.
- Regarding those objectives that do qualify as decision criteria, they are not operational (i.e. they are incomplete) because no performance (measurement) scale is suggested (e.g. for equity and safety) which would enable the identification of a cut-off point (required minimum) in order to define feasibility, as well as the ranking of projects in terms of this measurement scale. A case in point is Objective 1 ("to reduce transport infrastructure backlogs"), for which the following "measurement" is suggested: "Km new roads built (total backlog = 2214 km)".

5.3 Decision criteria from other contexts

To supplement the top-down approach adopted above (i.e. the analysis of CoT goals and objectives in order to derive a set of decision criteria), this section explores decision criteria suggested by a selected number of "other" institutions and researchers – both local and abroad – by focusing on the context, objective and method in each case. A total of ten sources were consulted; they can be classified into five groups as follows: (a) views on decision criteria from independent researchers (Stopher and De Brucker); (b) criteria suggested by (or for) road/transport authorities abroad (NATA, Austroads, HDM-4); (c) criteria used by a selected number of road/transport authorities in the USA; (d) criteria suggested by the South African Department of Transport; and (e) criteria suggested for a number of South African urban municipalities (or regional authorities) (Cape Town, East Rand and Port Elizabeth).

5.3.1 Stopher and others

In setting goals for urban transportation (from which criteria can be derived), it should be borne in mind that the urban transportation system is a subsystem common to two main separate systems, i.e. the general urban system and the general transportation system. Stopher *et al*. (1977:1) argue that planning goals should be derived from both these larger systems; in addition, goals should be consistent with overall goals of the national economy. Regarding general urban goals, the provision of adequate and equal options and opportunities for all residents is cited as the most essential. Another would be "to increase the aggregate quality of life which includes social, economic and environmental considerations" (Stopher *et al*., 1977:2-3). Regarding general transportation goals, the primary goal is cited as providing maximum mobility of people and goods; another goal is that transportation should be used as a tool for enhancing national economic development (Stopher *et al*., 1977:3). Finally, the set of urban transportation goals must reflect and satisfy these general goals and the needs of the community at a given time and under specific local conditions, which calls for this set of goals and their relative importance to be developed with the participation of all community groups (Stopher *et al*., 1977:3). This reasoning is depicted in Figure 5-2.



Source: Adapted from Stopher et al. (1977:2).

Figure 5-2: Deriving objectives and criteria from public priorities

According to Stopher *et al*. (1977:3), the five goals stated in the Report on Urban Transport Facilities in the Republic (also known as the Driessen Report) – economy, safety, mobility,

efficiency and minimum side-effects – are too broad and vague, and can serve only as a basis for more specific goals. Instead, they provide the following *"guiding list of possible transportation goals"* (Stopher *et al*., 1977:Appendix):

1. "To meet anticipated transportation needs most satisfactorily.
2. To provide improved mobility to metropolitan area residents.
3. To improve the mobility of the transport disadvantaged (e.g. the carless, the young, the old, the infirm, the handicapped, etc.).
4. To provide improved or additional facilities at the journey ends, in terms of parking, modal interchange, and accessibility to vehicular travel modes.
5. To provide all metropolitan area residents with a choice of travel means and destinations.
6. To minimize the total cost of metropolitan area travel.
7. To provide for the efficient movement of people and goods by private and public transport.
8. To provide fast transportation for people and goods in the metropolitan area.
9. To improve the productivity of all forms of metropolitan transport of people and goods.
10. To provide for the safe movement of people and goods by private and public transport.
11. To improve transportation facilities that contribute to more effective national defence.
12. To minimize the disruption resulting from new construction, and to preserve residential and neighbourhood character and location.
13. To protect and improve the environment in the metropolitan area (air quality, noise, water quality).
14. To provide transportation facilities that will promote a desired pattern of regional development.
15. To provide transportation facilities that meet contemporary standards of aesthetic design.
16. To preserve and enhance natural and historic landmarks, areas of natural beauty and conservation areas.

17. To promote increased economic activity in the metropolitan area through improved transportation.
18. To provide transportation facilities that improve the conduct and financing of government and that enhance property values in the metropolitan area.
19. To minimize the adverse effects of new transport facilities on activities and services in the metropolitan area.
20. To reduce the energy requirements of urban transport.
21. To reduce the consumption of scarce resources in the provision and use of transport facilities.
22. To achieve coordination between rail, bus, and highway facilities and services in the metropolitan area.
23. To promote the development of balanced transportation systems embracing various modes of transport in a manner that will serve the metropolitan area efficiently and effectively.
24. To provide more comfortable transport within the metropolitan area for all travellers.
25. To promote the multiple use of transport rights-of-way within the metropolitan area, e.g. rapid transit and highway in the same right-of-way.
26. To encourage productive and enjoyable harmony between man and his environment.
27. To improve travel opportunities for non-whites [sic].
28. To create new jobs through the provision, operation and maintenance of transport facilities.
29. To improve the reliability of the urban transportation system.
30. To reduce total demand for transport".

5.3.2 De Brucker and others

According to De Brucker *et al*. (1995:265), the consequences of transport infrastructure investments can be grouped into three main categories: unambiguously monetizable effects, environmental and safety effects, and socio-economic effects. These categories are expanded as shown below.

Unambiguously monetizable effects:

- Construction, maintenance expropriation and repair costs.
- Vehicle operating cost.
- Gain of travel time for users.
- Modification of the demand for traffic (traffic generation).
- Consequences for other transport modes.
- Consequences for the value of properties (including losses for traders due to disruption during construction).
- Economic activity induced by the project (sustainable value added).
- Financial receipts such as tolls, if applicable.

Various socio-economic effects:

- Redistribution of income between regions.
- Redistribution of income among categories of road users (e.g. car-drivers, pedestrians, residents).
- Redistribution of income among socio-economic groups.
- Contribution to sustainable employment.

Environmental and safety effects:

- Noise pollution.
- Air pollution.
- Safety.
- Consequences for material assets and cultural heritage.
- Consequences for environment quality, such as visual intrusion and community severance.

5.3.3 New Approach to Transport Appraisal (NATA)

NATA, introduced in the UK white paper "*A New Deal for Transport*", was developed by the DETR (Department of the Environment, Transport and the Regions) during the 1998 Roads

Review. It is aimed at accomplishing the following (UK DfT, 2004:3): (a) to choose between different options for solving the same problem; (b) to prioritize proposals; and (c) to assess value for money. Since its launch, it has evolved further and now forms the basis in the following instances (UK DfT, 2004:3): (a) the appraisal approach in multi-modal studies; (b) the appraisal of road schemes of the Highways Agency and major road and public transport schemes at a local level; (c) the strategic rail authority's appraisal criteria; (d) the project appraisal framework for seaports; (e) the appraisal process employed during the development of the government's airports strategy. The overall approach is depicted in Figure 5-3.

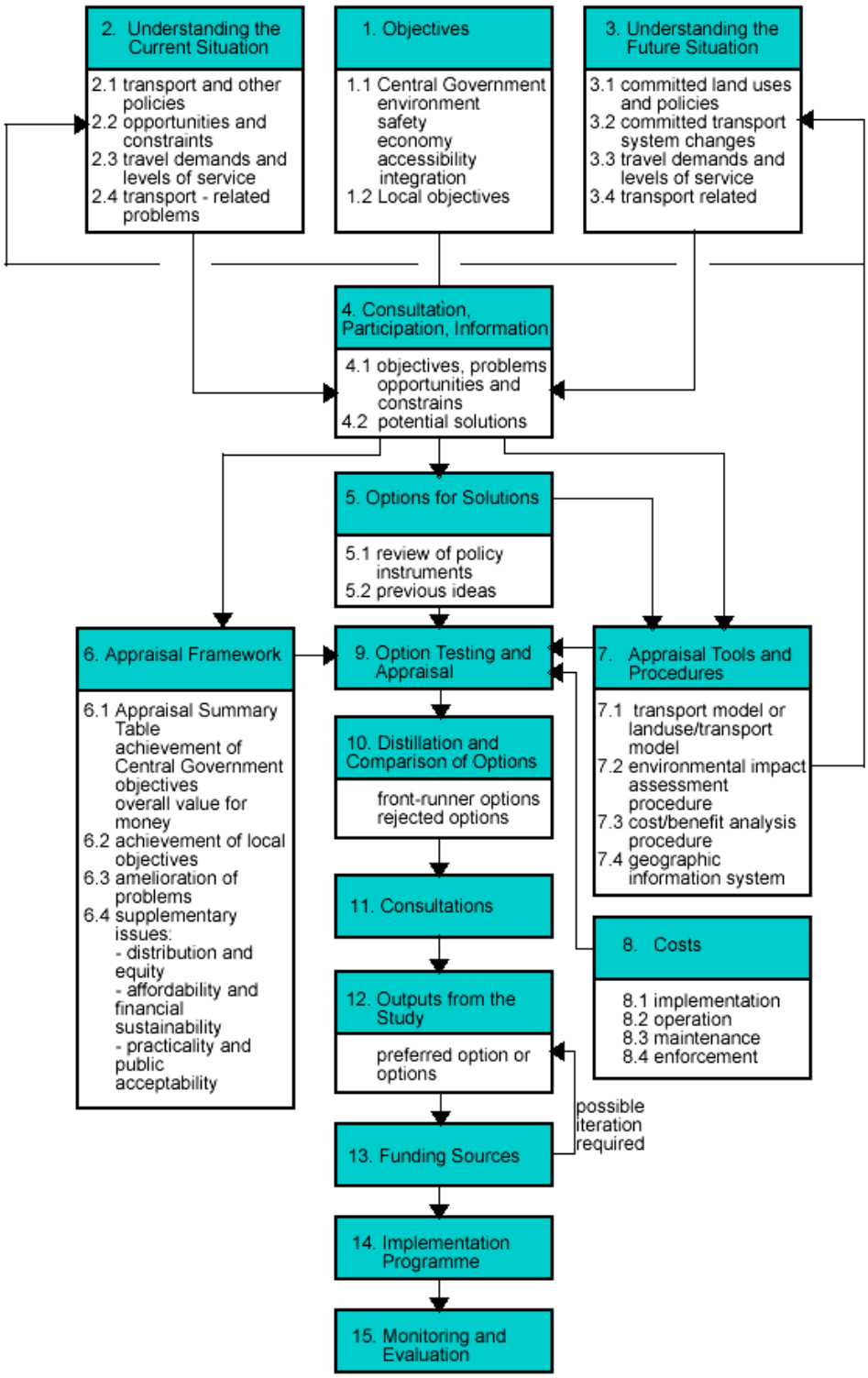


Figure 5-3: Overview of the NATA appraisal process

Source: UK DfT (2004:2).

The appraisal framework (Step 6 in Figure 5-3) has four “appraisal strands”, the scope and objective of which are explained below (UK DfT 2004:3-4).

First strand: Central government objectives: This involves an assessment of the degree to which the five central government objectives for transport (environment, safety, economy, accessibility and integration) would be achieved (Step 6.1 in Figure 5-3), as displayed on the Appraisal Summary Table (AST). The AST requires judgement to be made about the overall value-for-money of the project in achieving government’s objectives. The objective of the AST and its supporting detailed documents is consistency in viewing strategies and plans developed for the different study areas.

Second strand: Local and regional objectives: This involves an assessment of the degree to which objectives at a local and regional level would be achieved (Step 6.2 in Figure 5-3). This is deemed of particular interest to regional and local authorities and the local population, although a degree of overlap between this strand and the previous one is to be expected.

Third strand: Amelioration of identified problems: This involves an assessment of the extent to which the identified problem(s) (that gave rise to the need to intervene in the first place) would be “solved” by the project (Step 6.3 in Figure 5-3). The possibility of double-counting is evident between this strand and the two above – in particular the first strand, as achieving the objective of central government (first strand above) may also amount to solving the identified problem(s).

Fourth strand: Supporting analyses: This involves an assessment of three groups of additional objectives, namely: (a) distribution and equity; (b) affordability and financial sustainability; and (c) practicality and public acceptability (Step 6.4 in Figure 5-3). “Practicality”, in its turn, involves the following: feasibility (in terms of technical and legal issues, and political and funding aspects), enforcement, area of interest (breadth of the decision), complexity (depth of the decision), time scale, phasing, partitioning, the extent to which proposals are complementary of independent, conflicts, and the political nature of policies and proposals.

Regarding “Appraisal Tools and Procedures” (Step 7 in Figure 5-3), and in particular “land use / transport models” (Step 7.1 in the diagram), similar models that were explored in a “Europe” context (see Section 2.7 of this thesis) are: (a) SASI (short for Socio-economic And Spatial Impacts), IASON (building on SASI, and involving the integrated appraisal of spatial economic and network effects – both short and long term – of transport investment and

policies in the European Union) and MEPLAN, all of which can be termed spatial planning models; and (b) DELTA (derived from Development, Transition, Location, Employment and Area quality), which is described as eclectic, building on, amongst others, urban and regional economics, geography, and sociology. Regarding CBA (Step 7.3 in Figure 5-3), various software models are available for UK use, such as TUBA (Transport Users Benefit Appraisal), COBA11 (COst Benefit Analysis), and QUADRO4 (QUeues And Delays at ROadworks).

The five central government objectives for transport listed above (Step 1.1 in Figure 5-3: first strand) are expanded in Tables 5-3 to 5-7 below; in addition, sub-objectives are specified for each of these objectives (UK DfT 2004:4-5), as well as the means of assessment in each case (UK DfT 2004:6-7).

Table 5-3: NATA Objective 1: Environment

To protect the built and natural environment	
Sub-objective	**Means of assessment**
To reduce **noise**	Net properties win/lose; NPV (£m)
To improve **local air quality**	Concentrations weighted for exposure
To reduce **greenhouse gases**	Tonnes of C02
To protect and enhance the **landscape**	Score
To protect and enhance the **townscape**	Score
To protect the **heritage of historic resources**	Score
To support **biodiversity**	Score
To protect the **water environment**	Score
To encourage **physical fitness**	Score
To improve **journey ambience**	Score

Table 5-4: NATA Objective 2: Safety

To improve safety	
Sub-objective	**Means of assessment**
To reduce **accidents**	Present value of benefits (£m)
To improve **security**	Score

Table 5-5: NATA Objective 3: Economy

To support sustainable economic activity and get good value for money	
Sub-objective	**Means of assessment**
To get good value for money in relation to impacts on **public accounts**	Present worth of costs (£m)
To improve transport economic efficiency for **business users and transport providers**	Present worth of benefits (£m)
To improve transport economic efficiency for **consumer users**	Present worth of benefits (£m)
To improve **reliability**	Score
To provide beneficial **wider economic impacts**	Score

Table 5-6: NATA Objective 4: Accessibility

To improve access to facilities for those without a car and to reduce severance	
Sub-objective	**Means of assessment**
To improve **access to transport system**	Score

To improve access to facilities for those without a car and to reduce severance	
Sub-objective	**Means of assessment**
To increase **option values**	Present worth of benefits (£m)
To reduce **severance**	Score

Table 5-7: Objective 5: Integration

To ensure that all decisions are taken in the context of the government's integrated transport policy	
Sub-objective	**Means of assessment**
To improve **transport interchange**	Score
To integrate transport policy with **land-use policy**	Score
To integrate transport policy with **other government policies**	Score

The Appraisal Summary Table (AST), which has to be completed for each option, records the performance of a project (or option) on each sub-objective listed in Tables 5-3 to 5-7 above. The AST therefore is instrumental in making an assessment regarding the overall *"value-for-money"* of the project in achieving the five objectives of central government for transport (UK DfT, 2004:3). In doing this, all significant costs and benefits of an option should be taken into account; the positive balance of benefits and costs giving the "overall net value" of the option; in making an assessment of value for money, "overall net value" must be compared with the cost of the project. Judgment plays an important role in doing this, in particular regarding the relative importance of the various impacts – this is evident from the fact that "means of assessment" constitutes a mixture of quantitative and qualitative measures. This means that "different people may come to different conclusions about the "overall net value" of an option, depending upon the weights which they attach to the impacts" (UK DfT, 2004:8). It also follows that the Appraisal Summary Table (AST), which

summarizes the performance of a project in terms of the five objectives of central government, does not automatically provide a mechanistic way of expressing “project worth”, but rather serves to present impacts in a consistent manner so that decision makers have a more transparent basis for making a judgment.

5.3.4 Austroads guidelines

The Austroads Guide to Project Evaluation emphasizes the important distinction between the “purpose” of a project and “other criteria” to be taken into account in evaluating alternative solutions. The purpose of the project relates to the particular problem being addressed, such as to reduce casualty rates on a given road section, to reduce travel delays (e.g. for freight operators), to remove heavy truck traffic from a town centre, or to reduce travel and travel delays to a particular destination. “The ultimate value of the proposed solution will depend on how well it achieves the intended purpose of the project. A range of assessment criteria will usually be considered to demonstrate the value of the solution” Austroads, 2005a:3). They could include the benefits and costs of each alternative, impacts on adjoining land use, landowners and local communities, and environmental aspects.

The focus on a triple bottom line (TBL) approach is evident from the following statement: “In setting assessment criteria for project evaluation it is useful to consider the criteria under three categories, i.e., economic (financial), social and environmental” (Austroads, 2005a:11). The practical application of this concept is clear from the Multi Objective Decision Support Systems (MODSS) which was developed for road project evaluation, the first step of which involves the development of a standard set of objectives (see Table 5-8) from which decision criteria applicable to a particular decision making context can be selected.

Table 5-8: Austroads inventory of national objectives for use in project evaluation

Dimension	Description of objective	Type of objective
Economic	Efficient provision and operation of road infrastructure	Efficiency
	Lower road user resource costs	Efficiency
	Lower non-road costs of road users (regulations, etc)	Efficiency
	Increased regional development	Efficiency

Dimension	Description of objective	Type of objective
	Expansion of the scope of markets	Efficiency
	Economic based choices of transport vehicles, modes, routes, and times of user	Efficiency
	Supportiveness of effective land use	Efficiency
	Improved overall performance of the economy	Efficiency
	Reliable transport of people and goods	Efficiency
Safety	Lower levels of road related death, injuries and costs	Efficiency
	Safe transport of hazardous loads	Efficiency
Environmental	Lowered levels of air pollution and greenhouse gas emissions	Efficiency
	Reduced other adverse environmental impacts	Efficiency
Social	A basic level of accessibility	Equity
	Wider set of choices, opportunities for interaction	Social justice / functioning
	Fair distribution of costs and benefits	Efficiency
	Improved overall social functioning of the community	Social justice / functioning
National	Provided and operated with the efficiency required for Australia to compete in the global economy	National policy
	Provided and operated in manner compatible with the nation's goals, including defence	National policy

Source: Adapted from Austroads, (2005c:11).

5.3.5 HDM-4

Version 2.0 of HDM-4 (finalized in June 2005) was expanded to, amongst other things, allow users the option to use MCA as part of the HDM-4 routine (hdmglobal website). MCA in HDM-4 utilizes the Analytical Hierarchy Process (AHP) (explored in Chapter 3) which employs a 9-point scale in performing pairwise comparisons to enable (a) the scoring of alternatives (i.e. intra-criterion evaluation) and (b) determination of the relative performance of criteria (i.e. inter-criteria evaluation) (Engelbrecht, 2007:147). The decision criteria supported in the current version of HDM-4 are described in Table 5-9. "Attributes" (last column) are described as "surrogate measures of performance", and they may measure the achievement of objectives directly or indirectly. The attributes from HDM-4 outputs are mostly direct measures of the achievement of objectives. The measurement scale for an attribute is referred to as the performance index, which on the economic objective may be an economic indicator such as the net present value (NPV) (Odoki and Kerali, 2006:section 2.3).

Table 5-9: Criteria supported in HDM-4 Multi-criteria analysis

Category	Criteria / Objectives	Attributes
Economic	Minimize road user costs (RUC)	Total road user costs are calculated internally within HDM-4 for each alternative.
	Maximize net present value (NPV)	Economic net benefit to society is calculated internally within HDM-4 for each alternative.
Safety	Reduce accidents	Total number and severity of road accidents. These are calculated internally within HDM-4.
Functional service level	Provide comfort	Good riding quality to road users. This is defined on the basis of average IRI (international roughness index). The average IRI is calculated internally within HDM-4.
	Reduce road congestion	Delay and congestion effects. Level of congestion is defined in terms of volume-capacity ratio (VCR). VCR values are calculated internally within HDM-4.

Category	Criteria / Objectives	Attributes
Environment	Reduce air pollution	Air pollution is measured in terms of quantities of pollutants from vehicle emissions, which are computed internally within HDM-4.
Energy	Maximize energy efficiency	Efficiency in both global and national energy use in the road transport sector. Energy use is calculated internally within HDM-4.
Social	Maximize social benefits	Social benefits include improved access to social services (e.g. schools, health centres, markets, etc.). A representative value is externally user-defined for each alternative.
Political	Consider political issues	Fairness in providing road access, promotion of political stability, strategic importance of roads, etc. A representative value is externally user-defined for each alternative.

Source: Odoki and Kerali (2006:Table G5.1).

In selecting criteria, the user is cautioned against the possibility of double counting. "Safety", for example, is included in both the road user cost criterion and the safety criterion. Likewise, "travel time" is included in both the road user cost criterion and the congestion level criterion (Odoki and Kerali, 2006:section 3.2.2)

For the purpose of compiling an appraisal framework in this study, these criteria can be aggregated into three groups: (a) criteria that are addressed in conventional (narrow) CBA, either directly (e.g. "economic", "safety" and "energy) or indirectly (e.g. "functional service level"); (b) criteria that are not included in a narrow CBA but which are relevant and need to be treated as separate (additional) criteria (e.g. "environment" and "social" (but both with a different and/or expanded scope); and (c) criteria deemed not relevant in the CoT case (e.g. political).

5.3.6 Selected USA authorities

Introduction

The examples explored below arguably apply to cases where benefits cannot be measured merely as savings in (transport) cost, as this will result in an understatement of benefits. Instead, benefits in these cases need to be measured in terms of an appropriate measure of increased output; this results from their focus on traded industries. Traded industries serve as economic pumps that *add* to wealth, as opposed to local-serving industries that (mainly) facilitate the circulation and distribution of wealth (EDRG, 2008:2).

Ohio

The selection and funding of major transportation projects (i.e. projects costing more than $5 million) are overseen by the Ohio DOT's TRAC (Transportation Review Advisory Council). Projects are scored on transportation and economic development impacts. Projects are scored on three aspects: (a) transportation efficiency (70%); (b) economic development (30%); and (c) "other impacts" such as support for urban revitalization at brownfield sites (an additional 30% bonus points). No points are given for impacts on new retail development. Points for employment in the tourism sector are pro-rated according to the length of the tourist season (EDRG, 2008:18). "Major project selection criteria" are listed in Table 5-10.

Table 5-10: Ohio DOT TRAC Program: Major project selection criteria

Goal	Factors	Maximum score
Transportation efficiency	Average daily traffic	20
	Volume to capacity ratio	20
	Roadway classification	5
	Macro corridor completion	10
Safety	Accident rate	15
Transportation points – at least 70% of a project's base score		**70**

Goal	Factors	Maximum score
Economic development	Job creation (non-retail only)	10
	Job retention	5
	Economic distress	5
	Cost effectiveness of investment (jobs/$ invested)	5
	Level of investment	5
Economic development point – up to 30% of a project's base score		**30**
Funding	Public/private local participation	15
Multi-modal impacts	Unique multi-modal impact	5
Urban revitalization	Access to brownfield site	10
Total possible bonus points		**30**
Total possible points		**130**

Source: EDRG, 2008:18.

Wisconsin

The "Majors Program" of the Wisconsin DOT covers "Major Highway Projects", defined as system capacity, interchange and enhancement projects costing more than $2,5 million or over 2,5 miles in length. The scoring system used for selecting projects considers economic benefits, land development, traffic flow, safety, environmental and community impacts, with economic development factors allocated 40% of total scoring weight (EDRG, 2008:19). Goals and sub-goals (measures and components) are detailed in Table 5-11.

Table 5-11: Wisconsin WisDOT scoring system for major highway projects

Measure	Component	Weight (%)	Total weight (%)
Economic development	Existing business travel cost saving	10	40
	Connections on Corridors 2020 or NHS network	10	
	Increase productivity	20	
	Accommodate business growth sectors		
	Facilitates exports that bring in outside dollars		
Traffic flow	Level of service		20
Safety	Crash rate; severity proportion; pedestrian/bicycle impacts		20
Environmental	Natural, physical resources	5	10
	Socio-economic, cultural resources	5	
Community input	Public support or opposition		10
Total			100

Source: EDRG, 2008:19.

Missouri

The prioritization process of the Missouri DOT has been developed for “major projects”, defined as projects involving system expansion via opening new roadways, bridges and/or roadway expansion. Economic development and freight movement combined are allocated 20 percent of a total of 100 percent, with the weights of other objectives as shown in Table 5-12 (EDRG, 2008:20).

Table 5-12: Missouri roadway system scoring weights

Measure	Component	Weight (%)	Total weight (%)
Economic competitiveness			15
	Strategic economic corridor	40	
	Supports regional economic development plans	30	
	Level of economic distress	30	
Congestion relief			30
	Level of service	40	
	Daily usage	30	
	Functional class	30	
Efficient freight movement			5
	Truck volume	60	
	Freight bottlenecks	20	
	Intermodal freight connectivity	20	
Access to opportunity			5
	Vehicle ownership	75	
	Eliminate pedestrian/bicycle barriers	25	
Safety			30
	Safety index	80	
	Safety concern	20	

Measure	Component	Weight (%)	Total weight (%)
Quality of communities			5
	Complies with land use plans	50	
	Connectivity between cities	50	
Environmental protection			5
	Environmental impact	100	
System function			5
	Bridge condition	40	
	Pavement condition	40	
	Sub-standard roadway features	20	

Source: EDRG, 2008:20.

Virginia

Projects of the VDOT (Virginia DOT) are rated "internally" by staff of the VDOT Transportation and Mobility Planning Division, using the criteria and weights in Table 5-13. "A second step then considers public feedback, funding availability and timing or phasing issues for proposed projects" (EDRG, 2008:21).

Table 5-13: Virginia scoring weights for project prioritization

Objective	Sub-objective	Weight (%)
Efficient movement of people and goods		29
	Level of service	
	Volume to capacity ratio	

Objective	Sub-objective	Weight (%)
	Passenger car equivalents	
Safety and security		23
	Crash rate	
Retain and increase business and employment		18
	Average daily volume of tractor-trailer trucks for goods movement	
	Local unemployment rate (economically disadvantaged area)	
Quality of life and environmental impact		15
	Potential environmental or cultural impacts	
	Utilization of existing right-of-way	
System preservation and efficient system management		15
	Interchange spacing/mainline adequacy	
	Inclusion of HOV, bicycle, pedestrian facilities	
	Bridge deficiencies	
	Cost effectiveness of proposed recommendation	
Multi-modalism		Bonus points
	Highway component of multi-modal investment network	

Source: EDRG, 2008:21.

5.3.7 South African Department of Transport

The South African Department of Transport provided guidelines for the economic, financial and socio-technical evaluation of public transport projects in the case of alternative modes of

transport, for use by the department, the (then) South African Transport Services, provincial authorities, local authorities and institutions acting on their behalf (Groenewald and Stander, 1986:1). A distinction is made between the economic and financial feasibility analysis. For the economic analysis, the indicators IRR and NPV are suggested. Whereas the economic analysis focuses on the economic feasibility from the viewpoint of the community, the financial feasibility analysis focuses on the financial viability of the project from the viewpoint of the operator, considering measures such as the financial IRR, the minimum subsidy contribution, and the maximum loan that could be supported by net income – all based on actual cash flows. The socio-technical analysis focuses on feasibility of the project in terms of aspects that cannot be expressed in monetary terms, or cannot easily be quantified. This involves the analysis of the project from the viewpoint of three interest groups, each with its own set of criteria. These groups are: (a) passengers, considering the following criteria: availability, punctuality, comfort and safety; (b) operator, considering the following criteria: service area, reliability, capacity and safety; (c) community, considering the following criteria: quality of service, passenger attraction, impact on environment and energy consumption, and social benefits (Groenewald and Stander, 1986:1-3 to 1-4, 3-1 to 3-5).

5.3.8 Cape Town guidelines

In the document "Guidelines for conducting the economic evaluation of urban transport projects" (CMT-KMV, 1995), a distinction is made between "screening projects" and "prioritizing projects": "Due to the high cost of evaluation and design it is necessary to screen projects in order to determine which project proposals could proceed with further design and be subjected to a full project evaluation" (CMT-KMV, 1995:4). The "screening criteria" for transport project proposals listed below are suggested (CMT-KMV, 1995:Annexure E).

Economic development. This involves the extent to which the project will benefit the community and the business sector through aspects such as the following:

- The provision of access to business and residential land use development, and also to employment, educational and cultural opportunities.
- The reduction of the cost of goods transport and personal travel.
- The support of tourism.
- The optimal utilization of the existing transport infrastructure capacity and an optimal transport modal split.

Social development. This involves the extent to which "economic" benefits redress the unequal distribution of wealth and improve access to facilities and opportunities for the previously disadvantaged through aspects such as the following:

- The support of small and medium enterprises by providing better access to markets and business opportunities.
- The creation of semi-skilled and unskilled employment opportunities.
- The enhancement of lower order development opportunities, e.g. spaza shops.
- The reduction of travel time and distance (i.e. cost).

Sustainability of resources. The sustainable management of resources relates to the extent to which a project contributes to a reduction in pollution and energy consumption through aspects such as:

- The improvement in the use of energy efficient transport.
- A reduction in average trip length.
- A reduction in the total number of trips made.
- The contribution to the utilization of existing spare transport capacity.

Environmental acceptance. This involves adverse and irreversible impacts that the project may have on the natural and the built environment through aspects such as:

- Unacceptable levels of visual and noise intrusion.
- The destruction of buildings of historical significance.
- Unacceptable impacts on the natural environment.

Containment of urban sprawl. This involves the contribution of the project to the intensification of residential and related development, and the integration of the greater urban area through aspects such as:

- The support of corridor development in terms of the Metropolitan Spatial Development Framework (MSDF) requirements for access, mobility and protected transit.
- The promotion of development around existing employment centres and public transport interchanges.
- The encouragement of mixed use development.

- The improvement in the quality, efficiency and safety of public transport services.

5.3.9 East Rand Regional Services Council

Criteria used in the priority process at the (then) East Rand Regional Services Council (ERRSC) are evident from a description of the simplified process (simplified in terms of the number of project categories and criteria, and not in terms of the process) (Van Zyl *et al*., 1994:6-2). For each project, a priority index is determined to rank a project from high to low priority. A quantitative procedure as described below is used for this purpose; decision makers are, however, afforded the opportunity to change this ranking on the basis of information that could not be reflected in the priority index. The priority index is a function of three variables (Van Zyl *et al*., 1994:6-3):

PI = PS * CW * PR

where:

PI = priority index;

PS = policy support rating;

CW = project category weight;

PR = technical performance rating.

The *policy support rating* indicates the degree to which a project supports the policies and strategies of ERRSC for the region. The *project category weight* reflects the relative importance of the various project categories. The *technical performance rating* reflects the technical performance of a project in terms of various criteria.

Policy support rating: This is determined as the geometric mean of the rating of a project on the following four policy objectives of the ERRSC: (a) the development and implementation of the regional structure plan; (b) the supply of transport infrastructure to satisfy socio-economic needs; (c) the efficient operation of the transportation system; and (d) support of the public transport system within the context of the transportation system. Each project is rated on each of these policy objectives on a nine-point scale ranging from “totally opposed” to “totally supports” (Van Zyl *et al*., 1994:6-4). The policy support rating is then calculated as follows (Van Zyl *et al*., 1994:6-5):

PS = (R1*R2*R3*R4)^0,25

where R1 to R4 = the rating on the individual policies.

Project category weights: These are determined as the geometric mean of the main and the sub-category relative weights of the project type, by using the following formula (Van Zyl *et al.*, 1994:6-7):

CW = (main category relative weight * sub-category relative weight)^0,5

Weights were obtained from respondents, using appropriate techniques. The six main project categories and the sub-categories in each case are shown in Table 5-14, which also shows the weights in each case (in brackets).

Table 5-14: East Rand RSC project category structure

Main categories	**Road network (1,39)**	**Rail network (0,62)**	**Non-motorized transport (0,58)**	**Termini (1,22)**	**Land use (1,19)**
Sub-categories	Streets and bridges (1,25)	Light rail (0,94)		Modal transfer including taxi (1,30)	
	HOV lanes/ways (0.74)	Conventional rail (1,06)		Modal transfer without taxi (park and ride) (0,83)	
	Traffic management (1,01)			Bus terminus (0,85)	
				Taxi terminus (1,34)	
				Train station (0,68)	

Source: Adapted from van Zyl et al. (1994:6-7).

Technical performance rating: This is a measure of the need for the project and its ability to relieve that need, in other words of both a project's *need* and its *performance*. This rating is determined as the weighted average rating across all relevant criteria, such as the B/C ratio of the project. The technical performance rating for a given project is calculated as follows:

$PR_i = \sum(W_c*(R_{ci})/\sum(W_c)$

where:

PR_i = technical performance rating of project i;

W_c* = weight of criterion c;

$R_{ci)}$ = rating of project i on criterion c.

In order to make the performance rating of projects comparable between different categories, criteria weights are normalized so that the average weight for a set of criteria for a particular project category is equal to one (Van Zyl *et al*., 1994:6-9).

5.3.10 Port Elizabeth Municipality

The priority process developed for the Port Elizabeth Municipality (PEM) was first used in the 1993/1994 capital programme. Key elements of the process, as described by Van Zyl *et al.* (1994:7-1 to 7-7), are explained below. The priority index of a given project is calculated as a function of two variables:

PI = CW * PR

where:

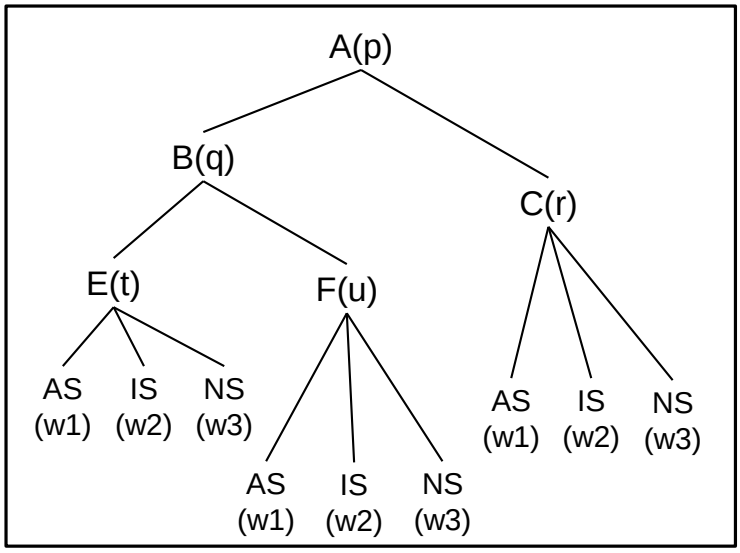
PI = priority index;

CW = project category weight;

PR = project performance rating;

and where the *project category weight* reflects the relative importance of the various project categories, and the *project performance rating* reflects the extent to which a project addresses a set of twelve predefined criteria.

Project category weight: The calculation of this weight is explained with reference to Figure 5-4 which shows an example of an extended project category structure, taking into account service levels. In particular, the figure represents an organization structure with A, B, C, … F representing organization units, and p, q, r, … u the corresponding organization unit (project category) importance weights.



Source: van Zyl et al. (1994:7-5).

Figure 5-4: Example of extended project category structure

Now, the absolute value of E, for example, i.e. E_w, is calculated as follows:

E_w, = cube root of (p * q * t)

In addition, the current service level of the recipient area for a project is also taken into account. This is done by assuming three service levels with associated information denoted in Table 5-15. Weights were determined by means of categorical judgment techniques.

Table 5-15: Importance ratings of the three service levels

Service level		**Weight**	
Description	**Denoted by**	**Value**	**Denoted by**
Adequately serviced areas	AS	0,61	W1
Inadequately serviced areas	IS	0,98	W2
Areas with no service	NS	1,42	W3

Source: van Zyl et al. (1994:7-4).

Therefore, for a given project category (say E), the following applies:

W_{AS} = fourth root of (p * q * t * w1);

W_{IS} = fourth root of (p * q * t * w2);

W_{NS} = fourth root of (p * q * t * w3)

Further, assume that a project is distributed across the three service levels in the proportions S_{AS}, S_{IS} and S_{NS} where:

S_{AS} = proportion of project servicing areas with adequate service;

S_{IS} = proportion of project servicing areas with inadequate service;

S_{NS} = proportion of project servicing areas with no service;

and where the values of S_{AS}, S_{IS} and S_{NS} are project-specific, and where:

$S_{AS} + S_{IS} + S_{NS}$ = 100%

This means that the importance rating of a given project can be calculated as follows:

CW = $(W_{AS} * S_{AS} + W_{IS} * S_{IS} + W_{NS} * S_{NS}) / (W_{AS} + W_{IS} + W_{NS})$

Project performance rating: This rating is a function of the extent to which a project is beneficial to an area or community; to determine this, a number of criteria have to be taken into account. It is noted, though, that "no standard set of criteria are available to provide such evaluation since circumstances, polices and requirements vary" (Van Zyl *et al*., 1994:7-6). The criteria listed in Table 5-16 were identified during a workshop, and a pairwise comparison procedure was used to weigh them.

Table 5-16: Project performance rating criteria and weights

Criteria	Weights
Urgency of project	0,89
Economic development	0,87
Benefit to community	0,85
Intensity of use	0,78
Community health and safety	0,89
Public support	0,81

Criteria	Weights
Project source	0,37
Preservation of capital assets or services	1,00
Socio-economic needs	0,80
Availability of external finance	0,53
Ability to utilize financial provisions	0,69
Effect on operating budget	0,92

Source: van Zyl et al. (1994:7-7).

Each project is rated against each criterion on a four point scale (0 = lowest, 3 = highest). A detailed description of criterion ratings is given in Annexure D. The project performance rating is then calculated as follows:

$PR_i = \sum(W_c * R_{ci}) / \sum W_c$

where:

PR_i = performance rating of project i;

W_c = weight of criterion c;

R_{ci} = rating of project i on criterion c.

5.4 Decision criteria suggested for CoT

5.4.1 Identifying criteria

A general pattern emerging from the analysis of decision criteria suggested locally and abroad (in the preceding section) is the importance of the following goals and objectives which also are deemed relevant to CoT context: efficiency, equity, and sustainability. The importance of efficiency has been dealt with extensively in preceding sections; but the concepts “equity” and “sustainability” require further exploration in order to determine their role in and contribution to the appraisal framework; in particular, what each involves, why each is important and how performance in terms of these criteria can best be determined in a CoT context. A further criterion that did not receive a great deal of attention in the preceding

section but is deemed important in a CoT context, is also explored, namely compatibility (or "goodness-of-fit").

Equity

According to Stopher *et al*. (1977:5), equity in the context of urban transport planning can be interpreted as the idea of fairness: that no one should get preferential treatment and no one should be discriminated against. Equity therefore refers to the ethical desirability of the distributional effects of a project, by identifying winners and losers in terms of three aspects: *benefits* (e.g. accessibility and mobility, greater transport choice, reduced travel time, or increased safety); *costs* (e.g. who pays for the services (through user fees, taxes, etc.), and how the costs paid compare to the benefits received); and *externalities* (including air and noise pollution, loss of visual amenity and open space, community severance, vibrations, related property price effects and quality of life issues) (Austroads, 2005e:2-3). In doing this, the following groups/issues are important; they relate to age, gender, people with disabilities, and "other socially or economically disadvantaged groups" (Austroads, 2005e:17).

Raux and Souche (2004:195-196) list three types of equity, based on Rawls's principle of justice, applicable in the context of transport *pricing:* spatial equity, horizontal equity, and vertical equity. In terms of *spatial equity* (referring to the principle of liberty), the right of access to jobs, goods, and services should be guaranteed from any location. *Horizontal equity* (referring to the principle of equal opportunity) involves the equality of treatment of different users (involving both the polluter pays principle, and the user pays principle). *Vertical equity* (referring to the principle of difference) focuses on social inequalities, and "assessing the outcome of policies with reference to the well-being of the most disadvantaged, which one should attempt to maximize" (Raux and Souche, 2004:196). Within the context of *appraisal* (as opposed to pricing), it is argued that vertical equity in particular is most relevant.

Sustainability (environmental externalities)

The World Commission on Environment and Development (Brundtland Commission) defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Austroads, 2005b:6). However, according to Austroads (2005b:6), "sustainability is one of the most misunderstood concepts in environmental economics. Often it is no more than a vague claim that a project is environmentally benign. This is unfortunate, as the notion of sustainability is both of vital

importance and capable of precise meaning in economics". In the context of road pricing, Ubbels (2005:3) notes that "it is arguable that promoting environmental objectives is consistent with the aim of securing welfare maximisation through economic efficiency, in particular when social welfare incorporates environmental social costs and benefits".

In a comparison of the externality unit cost for passenger vehicles and buses, expressed in cents per vehicle kilometre for both urban and rural conditions, the following components of externality cost are noted: air pollution, greenhouse effect, noise, water, nature and landscape, urban separation, and upstream and downstream costs (Austroads, 2008:25). The following components of emissions (contributing to air pollution) are listed: carbon dioxide equivalent, carbon monoxide, oxides of nitrogen, particulate matter, and total hydrocarbons (Austroads, 2008:30). In the UK, as indicated in the NATA overview (see Section 5.3.3), the objective "protecting and building the natural environment" involves the following aspects: noise, local air quality, greenhouse gases, the landscape, the townscape, the heritage of historic resources, biodiversity, the water environment, physical fitness and journey ambience (UK DfT 2004:4-5).

In a South African context, the objective of an environmental impact assessment is described as follows: "to identify and analyze, for each project alternative considered, the relevant environmental attributes, issues and solutions; to compare the environmental consequences of each alternative, and propose that alternative which causes the least environmental damage while still meeting the identified transport need and economic evaluation requirements; and to identify measures required to minimize environmental impacts or to restore the affected environment to an acceptable level, and to quantify the cost of such measures" (CMT-KMV, 1995:C.1). Specific aspects to be considered are dealt with in Section 5.7.

Compatibility (goodness of fit)

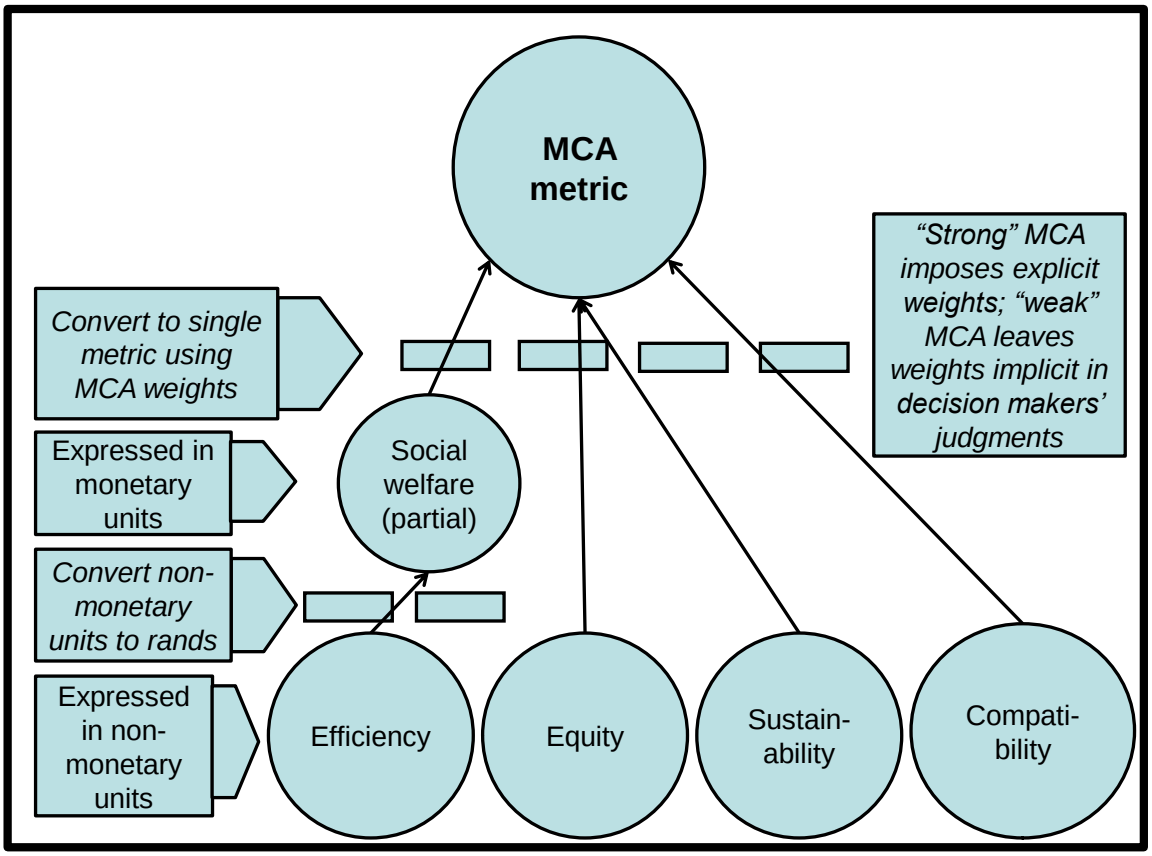
A project may be feasible from the perspective of efficiency, equity and sustainability, but not desirable from the perspective of being aligned ("fitting in") with other projects, identified goals and objectives, and strategic initiatives. For example, it may directly or indirectly enhance private transport, whereas the long-term goal may be not to promote private transport; or it may stimulate urban development in a location not earmarked as a growth point. Consequently, approving (and implementing) such a project may jeopardize the likelihood of reaching stated goals and objectives. For the purpose of developing an

appraisal framework, compatibility therefore constitutes an important decision criterion. It may be argued that this criterion should be broken down into three aspects: (a) intra-functional goodness of fit – relating to the compatibility with other modes of transport – "balancing the difference elements of land transport, such as TI projects, public transport projects, safety projects); (b) inter-functional compatibility (relating to e.g. transport function and housing function), and (c) "policy objectives", relating to the compatibility of the project with other, broad policy objectives.

Conclusion

From the discussion above, it follows that four decision criteria are deemed relevant in the case of CoT: (a) *efficiency*, which deals with the requirement of the optimal allocation of scarce resources; (b) *equity*, which involves the objective of a fairer distribution of income between persons benefitting from the project; (c) *sustainability*, which focuses on minimizing negative impacts on the environment; and (d) *compatibility*, which addresses the requirement that a project must be aligned to stated goals and objectives.

Given these criteria, the appraisal framework can be depicted as shown in Figure 5-5. It can also be presented as a (simple) value tree, as shown in Figure 5-6.



Source: Adapted from Austroads (2005b:23).

Figure 5-5: Suggested CoT appraisal strategy

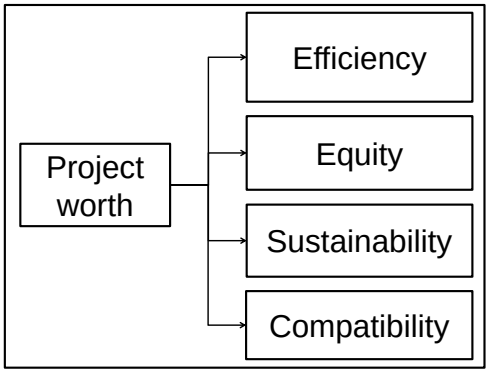


Figure 5-6: Value tree for CoT

5.4.2 Assessing criteria

The set of decision criteria suggested in Figures 5-5 and 5-6 above is assessed in this section from different perspectives. The first is in terms of the requirements for identifying decision criteria as explored in Section 3.3.5 and summarized below.

Value reference: Criteria should be linked to the fundamental goals of stakeholders, enabling decision makers to specify preferences.

Understandability: Decision makers must have a shared understanding of key concepts used in the analysis; for example the concept behind each criterion must be clear; and there must be a common view about the preferred direction of performance of alternatives.

Measurability: The performance of alternatives against the specified criteria must be measurable, and be expressed on either a quantitative or qualitative measurement scale.

Non-redundancy: Duplication in measuring performance (i.e., two criteria measuring the same aspect) must be avoided.

Judgmental independence: The preferences with respect to one criterion must not depend on the level of another.

Operationality: The information demanded by the model must not place excessive demands on the decision makers; therefore, there must be a balance between the importance of information needed and time constraints, and this will impact on the initial specification of the model.

Completeness and conciseness: Decision criteria should cover all relevant goals and objectives – nothing more and nothing less.

It is clear that the set of decision criteria selected for CoT can be justified on each of these requirements. The matter of measurability – measuring performance in terms of each of these criteria – is explored further in the remainder of this section.

From the perspective of "best practice" (as dealt with above), it is clear that the essence of criteria suggested locally and abroad is contained in the four criteria suggested for CoT, but without the risk of duplication, and further meeting the requirement of operationality by enabling the calculation of a single metric for project worth. Regarding the four USA states, though, it is important to note the emphasis on *traded industries* and *freight movement*, and the consequent cause and effect relationship between transportation efficiency and economic development – and the implied risk of double counting. Also, weights are "given" – it is maintained that allocating weights is the responsibility of the political decision makers, and that the robustness of these weights should be determined by software such as DEFINITE.

Finally, from the perspective of the CoT vision, goals and objectives contained in planning documents such as the ITP and IDP: although it was found that “operational” decision criteria could not (directly) be derived from them, it is clear that (at least) there will be no conflict between the stated goals and objectives and the “operational” decision criteria suggested for CoT, and that the decision criteria will, in fact, contribute to reaching the identified goals and objectives.

5.4.3 Suggested criteria: Revisiting the CoT case

Given the decision criteria selected for CoT, and given the focus of this thesis on budget-type projects in municipal road/transport authorities as opposed to one-off projects, the CoT appraisal context needs to be reconciled with comments made in Section 1.4.2 regarding the following: (a) a possible classification system for the impacts of TI projects, (b) types of project appraisal, and (c) the nature of impacts of projects in urban areas involving different modes and TDM projects.

Firstly, the classification system for project impacts (Schutte, 1983:7-8) was developed with one-off projects in mind. This means that not all categories of impacts may be relevant in the case of municipal projects of a budget-type nature. For example, *strategic factors* (defined as the importance of the project for national defence and security) and *political factors and national prestige* (described as factors which often may be of overriding importance) clearly relate to large, one-off national projects and therefore may not be relevant in the case of budget-type projects of municipal authorities. On the other hand, *convenience (*defined as the degree to which the proposed facility will lead to increased convenience for both users of the facility and third parties) is one of the aspects affecting quality of service; this determines demand which, in its turn, will be reflected by the economic efficiency of the project.

Secondly, Adler (1987:3-4) lists the following six types of appraisal:

- Economic appraisal, involving economic costs and the size and distribution of benefits.
- Technical appraisal, involving engineering, design, and environmental matters and capital and operating costs.
- Institutional appraisal, involving management, organizational and staffing problems.
- Financial appraisal, involving funding, cash flow needs and the financially viability of the project, to be carried out on behalf of the enterprise responsible for the project;

and usually summarized in the enterprise's income and cash flow statements and balance sheets.

- Commercial appraisal, involving the procurement of goods and services to implement and operate the project and the marketing arrangements for the sale of its output.
- Social appraisal, addressing social objectives such as a more equitable income distribution, improved nutrition and health, and the social, cultural, and human variables affecting the project, e.g. involuntary population resettlements or the role of women in development.

As with the project impact classification above, it is argued that these types of appraisal very probably relate to large, one-off projects. In particular, in the case of CoT-type projects, only an economic appraisal and a social appraisal will be relevant. The following types of appraisal will not be relevant for the reasons given, from which it will be clear why these aspects, by their nature, are important in the case of big, one-off projects:

- Technical appraisal: With budget-type projects, the technical feasibility is typically ensured prior to projects being submitted for approval; therefore, all candidate projects can be assumed to be technically viable.
- Institutional appraisal: Budget-type projects do not require special institutional arrangements as may be the case with big, one-off projects. The administration arrangements within road authorities are normally sufficient to meet any institutional requirements.
- Financial appraisal: This would typically apply in the case of big, one-off projects such as the Gautrain, and/or toll road projects; at present, the latter fall outside the ambit of road authorities in the municipal sphere of government.
- Commercial appraisal: Again, this would typically (only) apply in the case of one-off projects such as the Gautrain.

Thirdly, it needs to be indicated how impacts listed by Litman (2001:9) in the case of urban projects involving different modes of transport and/or TDM projects are handled. The following impacts are listed:

- Downstream congestion: Building a new link or upgrading an existing link can have negative impacts on other links of the network or other modes by increasing traffic levels on such links on modes.

- Parking costs: Upgraded road infrastructure may increase the demand for parking space, whereas transit projects of TDM initiatives will lower demand.
- Roadway impacts: Large, heavy vehicles may impose high traffic congestion and road wear costs and may require special facilities. This may lead to additional cost.
- Traffic impacts on non-motorized modes: Delays, discomfort and increased risk of collisions to cyclists and pedestrians are often ignored.
- Vehicle ownership and mileage-based depreciation: An improved road network and/or increased travel options can reduce the number of vehicles per household.
- Transportation choice: No consideration is given to options that increase choice and improve access to non-drivers.
- Environmental costs: These are often ignored.
- Land use objectives: Projects may contribute to urban sprawl. This may be contrary to the community's strategic land use objectives, but may nevertheless not be included in the analysis.

The first three aspects listed above are typically taken care of by most multi-modal network-wide transportation models which take into account inter-dependencies of the different elements of the transport system (e.g. links of the network), in order to compute network costs on a "before" and "after" basis; these, in their turn, constitute important inputs into the appraisal process. To the extent that the fourth impact is not addressed in this way, special attention may be warranted. This also applies to the next two impacts (vehicle ownership and mileage-based depreciation, and transportation choice), although it could be argued that they involve long-term, structural changes to the economy, warranting separate analyses of a specialized nature. Finally, the last two impacts are important; their role in an appraisal framework is evident from their inclusion in the list of decision criteria suggested for CoT.

5.5 Identification of alternatives

5.5.1 Introduction

Regarding the *set of alternatives* to be evaluated, it is often found with authorities such as the CoT that the list of proposals in the budget constitutes a mixture of the following types of project: ongoing and/or committed and/or new projects; maintenance and/or construction projects; multi-year projects; projects managed by difference departments; projects funded

from different internal and external budgets; and projects involving internal/external stakeholders. As such, it is clear that not all projects on such a list warrant appraisal.

To illustrate the list of projects to be subjected to the appraisal process in the case of CoT, the consolidated CoT transport budget for the 2006/07 financial year (see Table 5-17) serves as a starting point; the 2006/07 financial year being the first financial period in the latest available ITP document at the time of this analysis. The consolidated budget is made up of (a) the *capital budget* of the Transport Development Division (ITP document Table 12.1) (CTMM, 2007:12-2) and the Roads and Stormwater Division (ITP document Table 12.2) (CTMM, 2007:12-2), (b) the *operations budget* of the Transport Development Division (ITP document Table 12.3) (CTMM, 2007:12-3) and the Roads and Stormwater Division (ITP document Table 12.4) (CTMM, 2007:12-4), and (c) the *internal planning budgets* for the two divisions (ITP document Table 12.5) (CTMM, 2007:12-5).

In addition, a distinction is made between "CoT" and "Other" (see the first column of the table). "Other" refers to "external stakeholders" (GDPTRW and SANRAL) who also invest in the CoT transport infrastructure (CTMM, 2007:12-3), but over which CoT does not have direct control. "CoT" refers to both internal and external funds; the latter consisting mainly of the Municipal Infrastructure Grant (MIG) which, by definition, is of a capital nature. The MIG budget for the Transport Development Division is given in Table 12.6 of the ITP document (CTMM, 2007:12-6), and in Table 12.7 of the ITP document (CTMM, 2007:12-6) for the Roads and Stormwater Division.

Table 5-17: CoT consolidated transport budget for 2006/7 (ZAR million)

Item	Capital budget			Operations budget			Planning budget			Total budget		
	Tpt Dev	Roads & SW	Total	Tpt Dev	Roads & SW	Total	Tpt Dev	Roads & SW	Total	Tpt Dev	Roads & SW	Total
CoT:												
Internal	26.0	221.0	247.0	179.0	482.0	661.0	8.0	7.0	15.0	213.0	710.0	923.0
External:												
MIG	5.0	58.0	63.0							5.0	58.0	63.0
Other	0.0	4.0	4.0							0.0	4.0	4.0
Total	5.0	62.0	67.0							5.0	62.0	67.0
Total CTMM	31.0	283.0	314.0	179.0	482.0	661.0	8.0	7.0	15.0	218.0	772.0	990.0
Other:												
GDPTRW	0.0	0.0	0.0							0.0	0.0	0.0
SANRAL	0.0	30.0	30.0							0.0	30.0	30.0
Total Other	0.0	30.0	30.0							0.0	30.0	30.0
Total: CoT & Other	31.0	313.0	344.0	179.0	482.0	661.0	8.0	7.0	15.0	218.0	802.0	1020.0

Source: As set out above.

5.5.2 Identifying projects to be subjected to the appraisal process

In essence, identifying projects to be subjected to appraisal involves eliminating non-relevant projects from the consolidated transport budget. Therefore, given the focus in this thesis on capital projects, the operations and planning budgets in the consolidated budget need not be considered further for the purpose of identifying projects to be subjected to appraisal. Also, the GDPTRW and SANRAL projects need not be considered as the CoT has no mandate in this regard. This leaves the capital budget of two "transport divisions" in CoT which totals R314 million for the 2006/07 financial year, as shown in Table 5-17. As mentioned in the ITP document, the projects constituting this amount were identified either internally, mostly by technical staff identifying the need for intervention in a particular case, or externally, mainly through the various stakeholder participation structures, such as the different ward committees (CTMM, 2007:3-10).

The detailed capital budget for the Roads and Stormwater Division is given in Annexure A of this thesis; that of the Transport Development Division, is contained in Annexure B. Given the focus in this thesis on TI projects, projects from the Transport Development Division (involving public transport) also need to be eliminated. Regarding the remaining projects, the following applies:

- By definition and as indicated in Annexure A of this document, the capital budget for Roads and Stormwater includes a number of projects relating to drainage – all such projects should be eliminated.
- All projects relating to maintaining the existing road network should be eliminated as it could be argued that they constituted committed funds – when a project is accepted for implementation, by implication its corresponding maintenance over its economic life is also "accepted", and all funds needed for system maintenance should be managed separately.
- Of the remaining projects, those that are contractually committed should be removed because, by definition, they have already passed the appraisal and decision making phase and therefore need not be subjected to the appraisal process again.
- Finally, any other non-relevant projects should be removed. Examples are Project no 710227: Parking Bays / Bays at Schools, and Project no 710228: Cycle and Pedestrian Paths for Tshwane (both on page 1 of Annexure A).

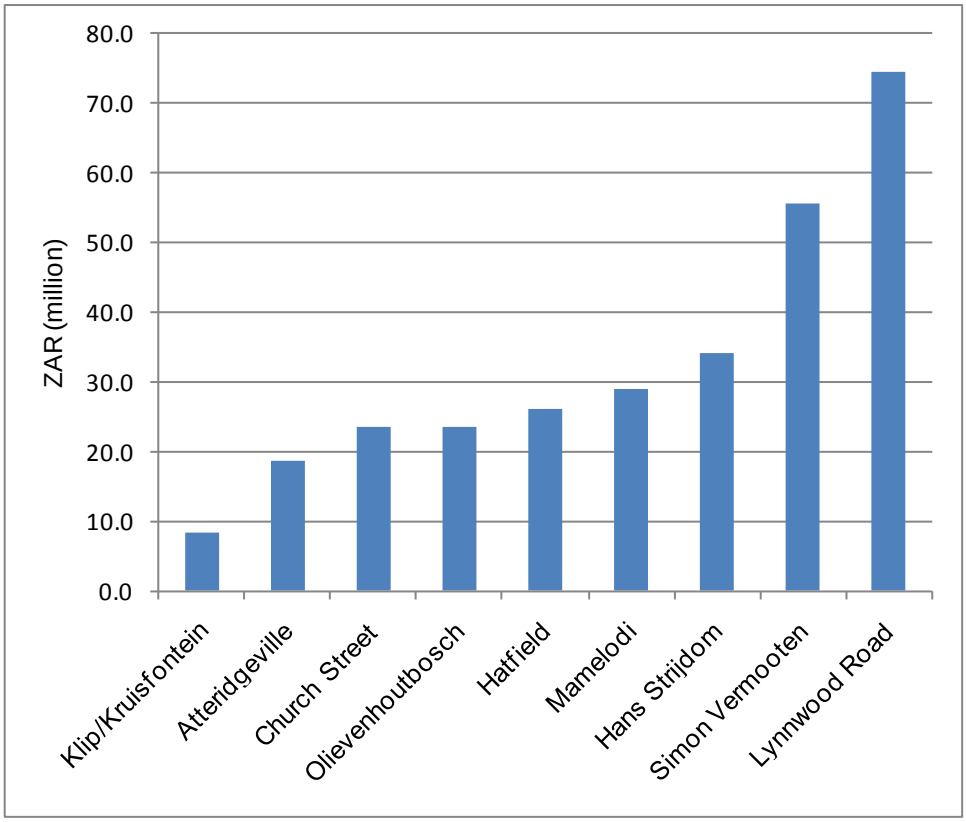
The “cleaned-up” list of projects, all involving TI projects, is given in Table 5-18.

Table 5-18: List of TI projects to be appraised

Proj IDP no	Project name	Fund	Financial year / million ZAR					
			6/7	7/8	8/9	9/10	10/11	Total
710331	Road infrastructure Klip/Kruisfontein	1	3.4	5.0	0.0	0.0	0.0	8.4
710597	Mateteng main transport route: Stinkwater	5	15.0	10.5	0.6	0.6	0.6	27.3
710928	Doubling of Church Street over railway line	1	1.0	0.0	0.0	17.5	5.0	23.5
710930	Upgrading of the road network in Hatfield	1	0.0	0.0	3.0	13.0	10.0	26.0
710936	Real Rover Road to Serapeng Road	Mix	11.3	5.5	4.5	2.0	2.0	25.3
	CoT	*1*	*6.9*	*5.5*	*4.5*	*0.0*	*0.0*	
	MIG	*5*	*4.4*	*0.0*	*0.0*	*2.0*	*2.0*	
710937	Access road to Mamelodi X18 (K54)	Mix	0.5	5.0	5.0	5.0	5.0	20.5
	CoT	*1*	*0.5*	*5.0*	*5.0*	*0.0*	*0.0*	
	MIG	*5*	*0.0*	*0.0*	*0.0*	*5.0*	*5.0*	
710939	Doubling of Lynnwood Road	1	12.0	25.0	26.5	1.0	10.0	74.5
710940	Improving of Hans Strijdom Drive (west)	1	0.0	3.0	19.0	12.0	0.0	34.0
710943	Doubling of Stormvoel Road	Mix	0.0	0.0	3.6	17.6	20.0	41.2
	CoT	*1*	*0.0*	*0.0*	*3.6*	*12.6*	*20.0*	
	MIG	*5*	*0.0*	*0.0*	*0.0*	*5.0*	*0.0*	
711325	Olievenhoutbosch activity spine	1	3.5	5.0	5.0	5.0	5.0	23.5
711800	Doubling of Simon Vermooten Road	1	11.0	22.5	20.0	2.0	0.0	55.5
711863	Internal roads: Northern areas	Mix	30.4	38.8	36.8	60.0	70.0	236.0
	CoT	*1*	*28.5*	*5.0*	*15.2*	*10.0*	*20.0*	
	MIG	*5*	*1.9*	*33.8*	*21.6*	*50.0*	*50.0*	
712253	New access to Odenburg Gardens	Mix	0.0	0.4	1.0	0.0	0.0	1.4
	CoT	*1*	*0.0*	*0.0*	*1.0*	*0.0*	*0.0*	
	MIG	*5*	*0.0*	*0.3*	*0.1*	*0.0*	*0.0*	
712521	Collector road backlog: Mamelodi	1	0.5	3.5	0.0	10.0	15.0	29.0
712522	Collector road backlog: Atteridgeville	1	0.5	3.0	0.0	5.0	10.0	18.5
	Total Fund 1: COT		67.8	82.5	102.7	88.1	95.0	436.1
	Total Fund 3: Other		0.0	0.0	0.0	0.0	0.0	0.0
	Total Fund 5: MIG		21.3	44.6	22.3	62.6	57.6	208.4
	Total all funds		89.1	127.2	125.0	150.7	152.6	644.5

Source: Adapted from CTMM (2007:Appendix A1).

As shown in this table, proposed TI projects will be funded either internally (i.e. using CoT funds), or externally – mostly through the Municipal Infrastructure Grant (MIG), which is aimed at fully subsidizing the capital cost of providing basic services to poor households (CTMM, 2007:20). As such funds should be regarded as dedicated funds, requiring a separate process for their approval, it is maintained that they should also be removed from the list of projects to be subjected to the appraisal process. This leaves the list of projects in Figure 5-7, ranked in terms of total cost from least to most costly, i.e. from below R10 million to over R70 million. They add up to R292,9 million, less than 16 percent of the total of R1 855,8 million for the Roads and Stormwater Division (see Annexure A).



Source: Adapted from CTMM (2007:Appendix A1).

Figure 5-7: List of CoT TI projects to be subjected to appraisal

5.6 The need for a two-phased approach

The need for a two-phased approach results from the fact that project appraisal involves both (first) the evaluation of mutually exclusive alternatives and (then) the ranking of independent projects. This corresponds to the notion of screening projects in terms of their "musts" in a "pre-MCA"; "musts are minimal (or satisficing) levels that must be achieved, as a *conditio sine qua non*, for a project to be considered acceptable to all stakeholders" (De Brucker and Verbeke, 2006:9). In a sense, it also corresponds to the β-classification of projects on which a pre-MCA is based; a β-classification "subdivides the group of actions (projects) into three categories: K_1 (a category of alternatives with a desirability that is firmly established); K_3 (a category of alternatives with an undesirability that is firmly established); and K_2 (a category of alternatives that requires further study regarding the projects' desirability" (de Brucker *et al*., 1995:272).

These two aspects are outlined below in more detail.

1. Select the best option from each set of mutually exclusive alternatives, using relevant criteria and measurement units. If the null alternative is indicated the best, the project is by definition not feasible and should be discarded.

For each set of mutually exclusive alternatives, score each alternative in terms of the relevant criteria.

Normalize scores and select best option.

2. Rank independent projects in terms of relevant criteria and measurement units.

For the independent projects on the list, score each in terms of the relevant criteria.

Normalize scores and rank independent projects in terms of their scores.

The need to include both the comparison of mutually exclusive alternatives and the ranking of independent projects in the framework means that the MCA steps outlined in Section 3.3.2 will now change as shown in Figure 5-8. This, in effect, constitutes a flow diagram in a functional sense; in practice, though, the actual sequence to be adopted will be dictated by the specific decision support software, as is demonstrated in Chapter 6.

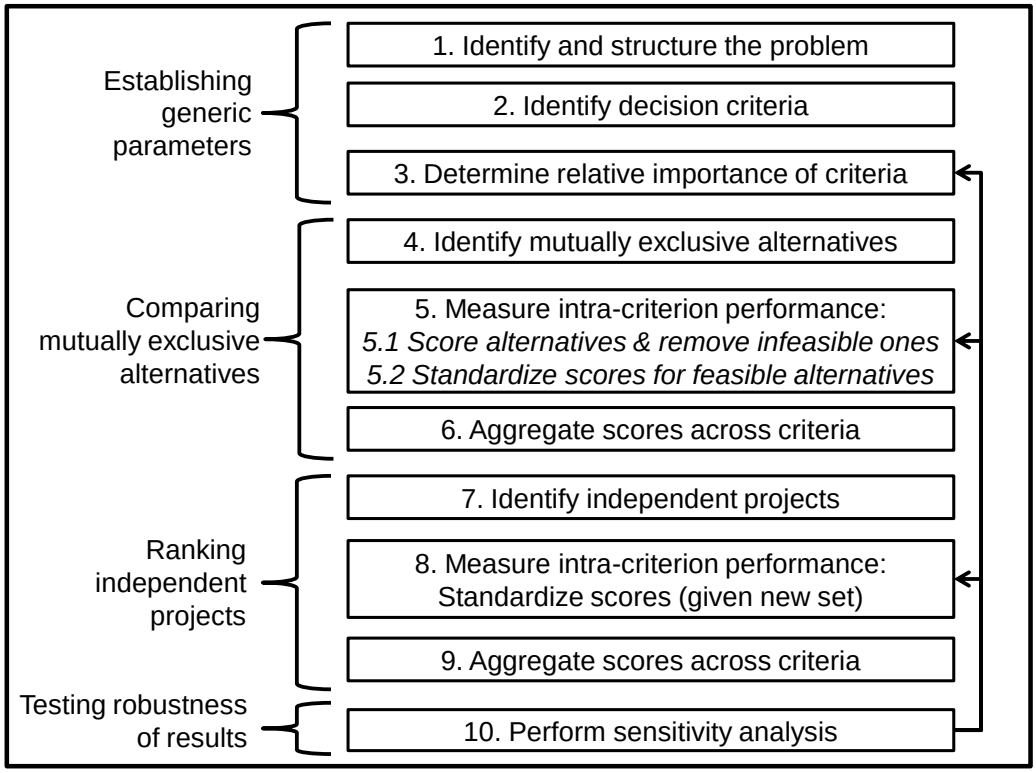


Figure 5-8: Steps constituting the two-phased MCA approach

5.7 Measuring intra-criterion performance

This section explores the measurement of intra-criterion performance, given the decision criteria suggested for the framework (efficiency, equity, sustainability and compatibility), and the need to adopt a two-phased approach, resulting from the need to first compare mutually exclusive alternatives and then rank independent projects, as explained in the previous section.

5.7.1 Efficiency

Six CBA techniques (methods) were discussed in Section 2.2.6:

- Equivalent Uniform Annual Cost (EUAC) technique
- Present Worth of Cost (PWOC) technique
- Net Present Value (NPV) technique
- Equivalent Uniform Annual Net Return (EUAR) technique
- Benefit/Cost (B/C) ratio

- Internal Rate of Return (IRR) technique

The following was also noted: (a) when mutually exclusive alternatives are compared, all six techniques will give the same answer if applied correctly; (b) when independent projects are ranked, only the B/C technique and the IRR technique can be used as the other four techniques cannot accommodate difference in scale between independent projects. For the purposes of the appraisal framework, the EUAC method is suggested in the case of mutually exclusive alternatives because of its inherent logic of seeking the "lowest cost" alternative from a set of options for achieving a given goal. For independent projects, the IRR method is suggested, because (arguably) its meaning is better understood than the B/C ratio. In order to distinguish them from measurement units in the case of equity, they are denoted by Eff EUAC and Eff IRR (short for "Efficiency EUAC" and "Efficiency IRR" respectively).

Value can also be added to information presented to decision makers by graphically supplementing the results of the BCA. For example, benefits (and costs) can be disaggregated to better inform decision makers of the "type" of benefit (e.g. savings in VOC, savings in collisions, and savings in travel time) and "beneficiaries" of benefits (e.g. benefit by vehicle type), as shown in Figure 5-9.

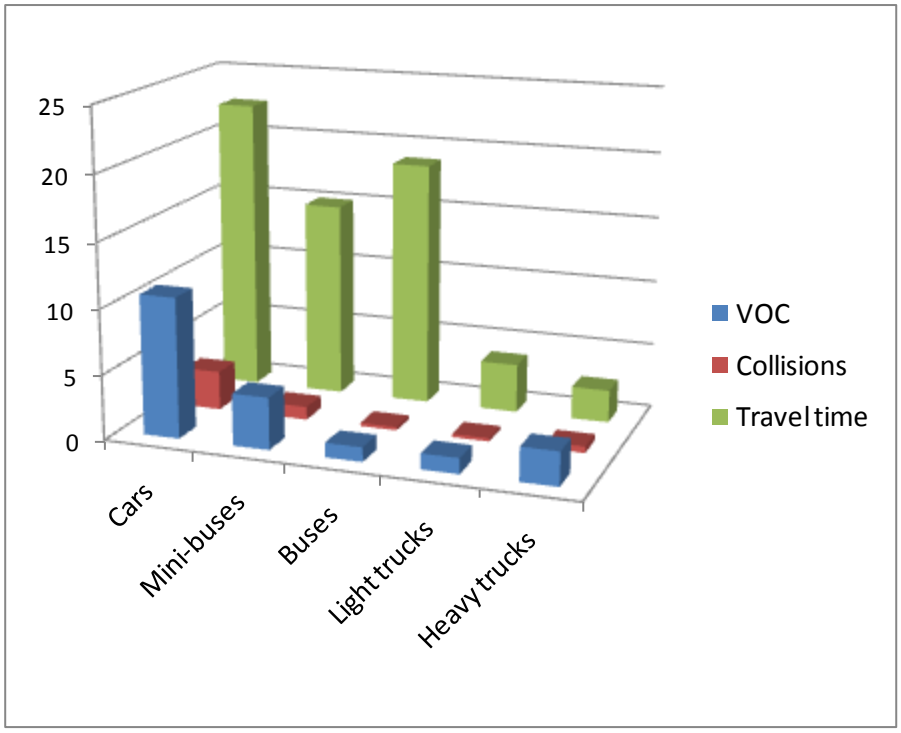


Figure 5-9: Breakdown of total benefits

No need is foreseen to add an additional layer to the value (decision) tree in the case of efficiency.

5.7.2 Equity

There are various terms (concepts) and techniques used in the context (ambit) of equity (Austroads, 2005e:24-32). The Gini index is a measure of the distribution of income in a society. The Gini index (coefficient) is a ratio, calculated by dividing the area between the diagonal in Figure 5-10 and the Lorenz curve by the total area of the half square in which the curve lies (CMT-KMV, 1995:A.1/1). This means that the Gini coefficient is a number between 0 and 1, with 0 indicating perfect equality (everyone has the same income) and 1 indicating perfect inequality (one person earns all the income, everyone else earns nothing) (Austroads, 2005e:24).

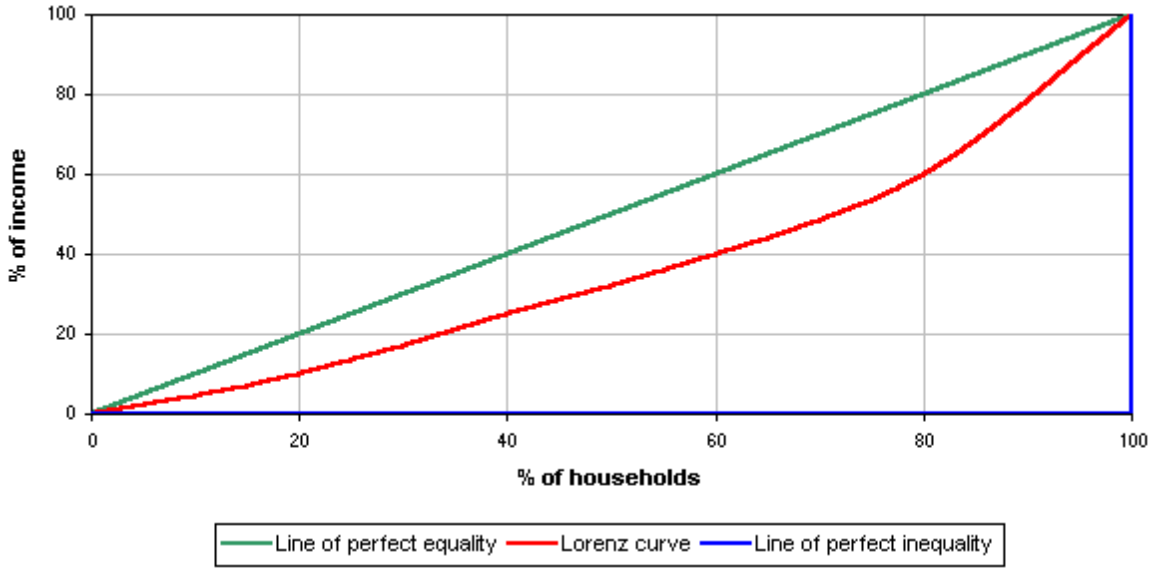


Figure 5-10: Lorenz curve

Source: Austroads, 2005e:24.

Other accepted composite development indicators are the United Nations Institute on Social Development index, and the Physical Quality of Life Index. The latter is impractical to use for the evaluation of individual projects, for the following reasons: "it is a very complex approach which cannot be warranted for relatively small investments; and marginal social alterations of a single project are often not measurable" (CMT-KMV, 1995:A 1).

A Social Impact Assessment ("perhaps the most common technique to identify social impacts of transport projects" according to Austroads (2005e:7)) identifies and assesses potential impacts of a project for an area or community. Sinclair Knight Merz (1998) (in Austroads, 2005e:26) notes that a Social Impact Assessment requires the following: (a) description of the existing and the probable future social characteristic of an area; (b) a description of probable changes; (c) analysis of how probable changes will impact on the community at both a broad (regional) and local level; and (d) an examination of measures for ameliorating impacts. Typical social impacts of a freeway construction projects are given in Table 5-19.

Table 5-19: Social impacts in the case of a road development project

Social impact	Issues to consider
Displacement or isolation of residents	Adequacy of the compensation and the relocation process, reduced land value, emotional issues including grief.
Displacement or isolation of commercial and community facilities	Adequacy of the compensation and the relocation process, economic hardships for existing or new businesses, reduced land value, clientele cut off, inaccessibility of services or inconvenience for customers.
Barrier effects: effects on social interaction	Effects on community cohesion, disruption of friendships or family contact, changes in convenience and travel time.
Barrier effects: effects on business, recreation or services	Inconvenience, changes to accessibility and travel time.
Noise effects	Physiological, psychological and social changes due to increased noise levels.
Safety	Effects on personal, family or child safety on a localised scale dependent on proximity to freeway or changes to traffic conditions in surrounding area.
Health effects	Physiological changes resulting from air and water quality.
Environmental quality effects	Changes in air or water quality as they affect people's lifestyle and enjoyment of their environment, recreation, indoor and outdoor living.
Land use changes	Changes in zoning from residential to commercial areas or development in a previously undeveloped area, loss of recreational or public space.
Aesthetics	Changes to visual landscape, physical intrusion, scale, loss of

Social impact	Issues to consider
	open space, changes in flora or fauna.
Cultural heritage	Disturbance or destruction of heritage sites.

Source: FHWA, 1982 (in Austroads, 2005e:27).

For the purposes of this thesis, it could be argued that this type of analysis is over-extensive in the case of budget type projects, and more suited to one-off type projects such as the Gautrain. It should also be noted that social impacts are classified differently by different practitioners, for example air pollution constitutes both an environmental impact to be considered in the Environmental Impact Assessment and a social impact (due to health risk) – therefore to be considered in the Social Impact Assessment. It is therefore noted that "The practitioner is often faced with a series of complexities inherent in impact assessment statements, which can lead to serious double counting issues in the economic evaluation of projects. It is very important to remember that a thorough evaluation (BCA) should take into account a broad range of social impacts, especially those which are easily quantifiable and monetised such as relocation, pollution mitigation measures and safety. Furthermore, an MCA type evaluation has the added benefit of including social impacts which are more difficult to monetize such as community severance or loss of character or open space" (Austroads, 2005e:27).

The Social Equity Impact Assessment and the Cumulative Impact Statement are described as derivatives of the Social Impact Assessment (Austroads, 2005e:7). The Social Equity Impact Assessment considers the winners and losers of a given project. According to Levinson (2002) (in Austroads, 2005e:28), a set of specified (winner and loser) population subgroups would normally be specified, and the outcomes of the project (such as travel time and delay, accessibility, consumer surplus, air pollution, noise pollution, accidents) be assessed for each of these population subgroups. Cumulative Effects Assessment (CEA) or Cumulative Impact Assessment (CIA) focus on the changes in the distribution of impacts over time and as a result of the cumulative effects of successive project activities (Austroads, 2005e:28).

A more direct approach for addressing equity involves considering the current service level of the recipient area of a project. As was noted in the overview of the Port Elizabeth priority process (Table 5-15), three service levels are assumed: (a) adequately serviced areas; (b)

inadequately serviced areas; and (c) areas with no services. Areas with no services were deemed most “needy”, with consequently the highest weight, and areas that were adequately serviced, receive the lowest weight. The next step in determining the importance of a project then was to determine the percentage of a project in each of these service levels.

Perhaps the most direct (and operational) method for addressing equity involves the use of equity weights – described as “a method of formally incorporating concepts of fairness into economic analysis” (Austroads, 2005e:25). With this method, the fundamental point of departure “is that additional income is relatively more important to lower-income groups than to higher-income groups”; stated differently, the marginal utility of their income is higher than that of prosperous individuals (CMT-KMV, 1995:A.3). Therefore, “the net change in total utility or social welfare is thus equal to the weighted sum of the changes in individual income, where the weight allocated to each individual is equal to the marginal utility of his income” (Sugden and Williams, 1987:205). Algebraically, the following therefore applies:

$dU = MU_1dy_1 + MU_2dy_2 + ... + MU_ndy_n$

where:

dU = net change in total utility or social welfare;

$dy_1, dy_2, \ldots dy_n$ = monetary benefits for individuals 1, 2, … n;

$MU_1, MU_2, \ldots MU_n$ = marginal utility which these individuals attach to the additional income.

Although income distribution weighting can be calculated on the basis of either income or consumption (CMT-KMV, 1995:A.7), Floor, Pienaar and Botes (1993) (in CMT-KMV, 1995:A.7), argue that they should ideally be based on per capita consumer spending rather than income, for the following reasons: “the relationship between income and welfare is not very clear; it will take a considerable amount of calculation to deduce disposable income from total income; and it is difficult to determine the percentage of income transferred to and from the specific area being studied”. This means that the income distribution weighting can be expressed as follows (Pearce and Nash, 1981:35):

$Y_w = C_p / C_u$

where:

Y_w = income distribution weight;

C_p = average per capita consumer spending of the population; and

C_u = average per capita consumer spending of those whom the project benefits.

It is clear that Y_w will be consistently progressive, i.e. the lower the level of consumption spending, the greater the weight (CMT-KMV, 1995:A.8).

It is thus clear that economic evaluation, which focuses on maximising economic efficiency, assumes an optimal income distribution within the community (i.e. the marginal utility of the income of all individuals is equal), whereas social evaluation, which focuses on maximising distributive efficiency (CMT-KMV, 1995:A.4-5) addresses cases where this assumption does not hold.

The application of this method is demonstrated below by means of a hypothetical example, assuming a project within each of five regions that differ in terms of income distribution (indicated here as expenditure per capita). Table 5-20 contains assumptions for calculating the equity weight. The Efficiency and Equity B/C ratios are calculated in Table 5-21. Figure 5-11 highlights the fact that the Equity B/C ratio will be "boosted" in areas of low income (i.e. it will be higher than the Efficiency B/C ratio) and "penalized" in areas with high income, and be equal to the Efficiency B/C ratio in the "average income" region. In general therefore, the Equity B/C ratio can be interpreted as follows:

- Equity B/C ratio < 1: Not acceptable from an income distribution perspective;
- Equity B/C ratio = 1: Indifferent from an income distribution perspective;
- Equity B/C ratio > 1: Acceptable from an income distribution perspective.

Table 5-20: Assumptions for calculating equity weights

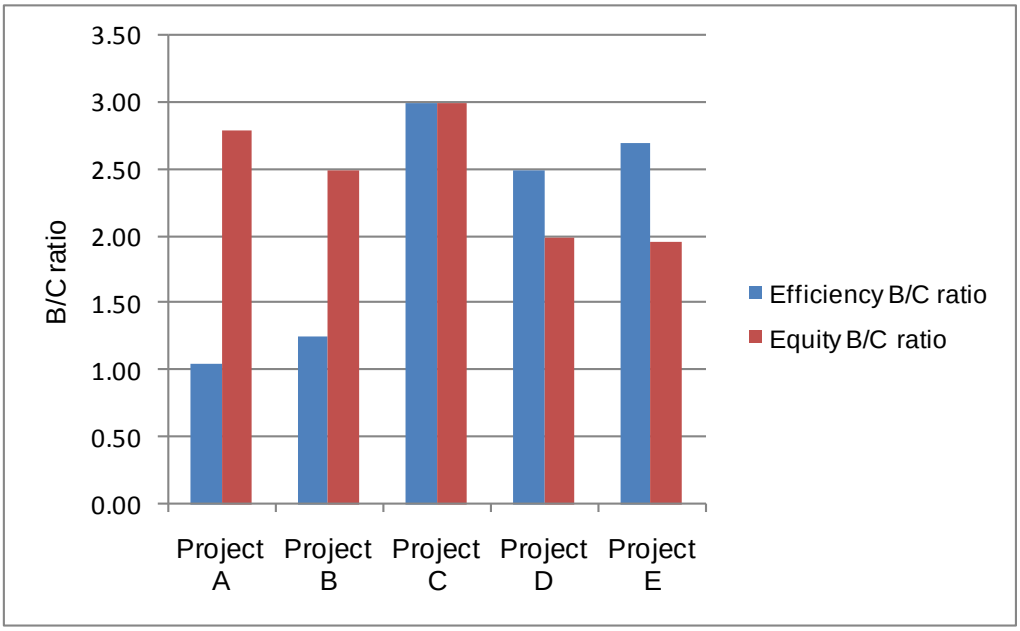
Region	Total annual household expenditure ($ billion)	Population (million)	Annual expenditure per capita ($ thousand)	Equity weight
1	0.825	0.275	3.00	8/3
2	1.500	0.375	4.00	8/4
3	2.600	0.325	8.00	8/8
4	5.000	0.500	10.00	8/10
5	6.875	0.625	11.00	8/11
Average	16.800	2.100	8.00	8/8

Source: Adapted from CMT-KMV (1995:A.2.1).

Table 5-21: Calculation of efficiency and equity B/C ratio

Region	Project	Present worth of initial cost ($ million)	Present worth of benefits ($ million)	Efficiency B/C ratio	Equity weight	Weighted equity benefits ($ million)	Equity B/C ratio
1 (low income)	A	15.000	15.750	1.05	8/3	42.000	2.80
2(middle low income)	B	12.000	15.000	1.25	8/4	30.000	2.50
3 (average income)	C	20.000	60.000	3.00	8/8	60.000	3.00
4 (middle high income)	D	22.000	55.000	2.50	8/10	44.000	2.00
5 (high income)	E	30.000	81.000	2.70	8/11	58.909	1.96

Source: Adapted from CMT-KMV (1995:A.2/2).



Source: Adapted form CMT-KMV (1995:A.2/2).

Figure 5-11: Efficiency and Equity B/C ratios for different income regions

In practice, though, it is seldom found that project benefits will be limited to the geographical region (district, zone) in which a project is situated, as assumed in this example. This is particularly true for TI projects. Calculating equity weights from information collected during roadside interviews constitutes one option for dealing with this problem; "region" in Tables 5-20 and 5-21 would then become "income group".

Also, it could be argued that the method outlined above focuses only on "those who benefit" and does not consider "those who pay", that is it does not accommodate both "winners" and "losers" (as in the case of the "Social Equity Impact Assessment outlined above). To the extent that this is true, it could be argued that the method is theoretically flawed (or, at least,

incomplete,). On the other hand, it can be shown that, mathematically, this does not matter, as the ranking will not differ. For example: assuming a progressive tax regime, costs will always be borne more by higher income groups (whereas no costs may be recouped from persons in lower income groups). Regardless of the applicable tax regime, this will always result in a lower value for cost for the purpose of calculating an Equity B/C ratio, in its turn resulting in a higher Equity B/C ratio. As all projects will all be affected by the same factor, project ranking will not be affected by including (or excluding) the "cost side". For the sake of completeness, though, it could be argued that a "cost side approach" should be adopted or "marginal" projects might be incorrectly disqualified (and excluded from the analysis), as shown in the Table 5-22 for hypothetical values.

Table 5-22: Calculation of efficiency and equity B/C ratios for different scenarios

Efficiency B/C ratio					**Equity B/C ratio when excluding the "cost side"**			**Equity B/C ratio when including the "cost side" (see Note 1)**	
Region	Project	Present worth of initial cost ($ million)	Present worth of benefits ($ million)	Efficiency B/C ratio	Equity weight	Weighted equity benefits ($ million)	Equity B/C ratio	PW of initial cost ($ million) at Regime 1 ($ million)	Equity B/C ratio when including the "cost side"
5 (high income)	E	15.000	16.000	***1.07***	8/11	11.636	***0.78***	11.645	***1.00***
Note 1: Assuming a tax regime involving a 10%, 30% and 60% tax accountability for the average, middle high and high income groups respectively.									

Given the following indices:

Efficiency B/C ratio = 1,07

Equity B/C ratio excluding the cost side = 0,78

Equity B/C ratio excluding the cost side = 1,00

it is clear that this project would have been excluded from the analysis if the "cost side" were excluded in calculating the Equity B/C ratio, whereas the inclusion of the "cost side" results in an Equity B/C ratio of 1,00, signalling that this project is acceptable from an equity perspective, and that it should thus be included in the analysis. It is also important to note that, in this example, and using the "equity weights" of the preceding table, the Equity B/C ratio when the "cost side" is included, is less than the Efficiency B/C ratio – in this case, 1,00 and 1,07 respectively. This further means that, in this case, an Efficiency B/C ratio of 1,00

would imply an Equity B/C ratio (including the “cost side”) of less than 1,00, rendering the project not feasible from an equity perspective, and not fit for inclusion in the analysis.

Finally, it should be noted that equity weights may have different meanings. Sassi, Archard and Le Grand, 2001) (in Austroads, 2005e:25), for example, note the following: “Equity weights provide a method of formally incorporating concepts of fairness into economic analysis. Equity weights are numbers that express the relative importance of equity concepts. Weights express the extent society is prepared to sacrifice efficiency in pursuit of fairness. The greater the equity weight, the more efficiency gain a society is willing to trade-off to achieve improved fairness”. They continue as follows: “The underlying assumption to the development and application of such weights is that the concepts of equity and efficiency can be traded off against each other. The application of weights is thus used to effect a balancing of conflicting, but commensurable objectives when making complex resource allocation decisions” (Sassi *et al*., 2001) (in Austroads, 2005e:25). For the purposes of the appraisal framework, though, it is argued that “efficiency” and “equity” should be kept separate (as opposed to calculating an adjusted measure by combining efficiency and equity), and that both the efficiency and the equity indicators (B/C ratio or IRR) be calculated as inputs into the MCA process where the necessary “trading-off” will take place.

5.7.3 Sustainability

In a South African context, the following aspects have been identified for consideration (CMT-KMV, 1995:C.2):

- Transport noise.
- Vibration and low frequency noise.
- Transport related air pollution.
- Visual impact (aesthetics).
- Community severance.
- Ecological impacts.
- Impact on land form and water systems.
- Impact on the built environment.

For the purpose of the appraisal framework, it is suggested that these aspects be combined into a single metric, to be measured on a five-point performance scale, where “1” would indicated “least negative effect on the environment” and would therefore be the highest (best) score, and “5” would indicate “the most negative effect” and therefore the lowest (worst) score.

5.7.4 Compatibility

As in the case of sustainability, it is suggested that compatibility with stated goals and objectives, strategic initiatives and other projects be measured on a five-point performance scale, where “1” would indicated “total compatibility” and therefore be the highest (best) score, and “5” would indicate “total incompatibility” and therefore the lowest (worst) score.

5.7.5 Concluding note

Table 5-23 summarizes the measurement units suggested for criteria in each case (mutually exclusive alternatives and independent projects) and justifies their choice, on the basis of the notion that “only differences matter”. This applies particularly to mutually exclusive alternatives, and means that an impact can be ignored if it does not differ between mutually exclusive alternatives. For example, if equity impacts are the same for all mutually exclusive alternatives, they need not be scored and can in fact be omitted from the analysis as it will not affect the outcome.

Table 5-23: Criteria and measurement units

Context	Criteria relevant in both contexts	Criteria relevant in given context, and justification	Measurement unit for a given criterion, and justification for its use
Comparison of mutually exclusive alternatives	Efficiency	Always relevant, as efficiency will typically differ between mutually exclusive alternatives	Eff EUAC, as (a) it is applicable to mutually exclusive projects and (b) it addresses the intuitive requirement of minimizing cost
	Equity	Always relevant as equity, being a function of benefits and costs, will typically differ between mutually exclusive alternatives	Equity NPV (Eq NPV), as it best portrays the ideal of maximizing the positive difference between “equity benefits” and “equity costs”

Context	Criteria relevant in both contexts	Criteria relevant in given context, and justification	Measurement unit for a given criterion, and justification for its use
	Sustainability	Typically relevant, as sustainability may differ between mutually exclusive alternatives	Rating on a 5-point performance scale
	Compatibility	Not normally relevant, as compatibility does not normally differ between mutually exclusive alternatives (and thus will not affect the decision)	If relevant, rating on a 5-point performance scale
Ranking of independent projects	Efficiency	Yes, as efficiency typically will differ between independent projects	Eff IRR relative to the null alternative, as (a) EUAC cannot be used for independent projects, and (b) it is based on the logical notion of benefits to be more than costs
	Equity	Yes, as equity will differ between independent projects	Equity B/C (Eq B/C) ratio relative to the null alternative (and including the cost side), for the same reasons given for the Eff B/C ratio
	Sustainability	Yes, as sustainability will differ between independent projects	Rating on a 5-point performance scale
	Compatibility	Yes, as compatibility will differ between independent projects	Rating on a 5-point performance scale

5.7.6 Assessment of decision tree

Based on the previous discussion, the decision tree for CoT and performance measurement units are summarized in Figure 5-12. Regarding this figure, the following notes are applicable:

- Mut exl alt = mutually exclusive alternatives.
- Ind proj = independent projects.

- With Eq NPV and Eq B/C, the "cost side" is included; this relates to the fact that the marginal utility of income (expenditure) of "those who pay" must also be taken into account.

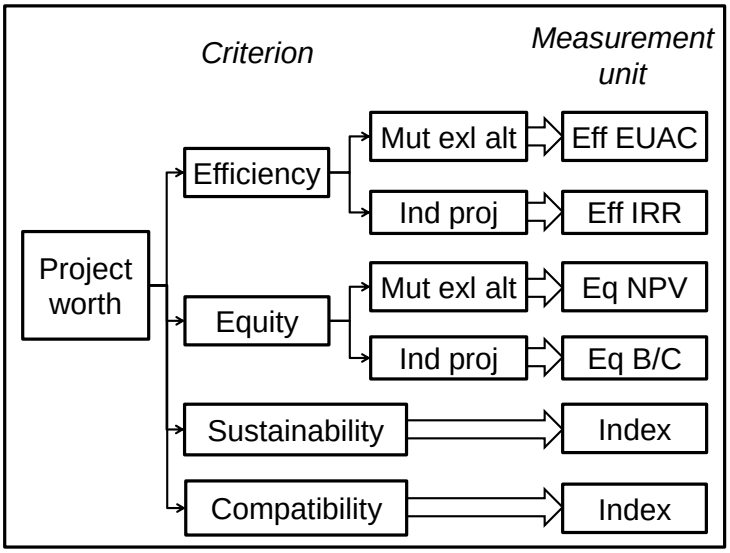


Figure 5-12: Suggested CoT decision tree and performance measurement units

Keeney and Raiffa (1976) (in Engelbrecht, 2007:126-130) list five criteria for determining if a ranked (decision) tree is of "sufficient quality":

Completeness: All criteria relevant to the decision maker should be included.

Operationality: The attributes at the lowest level (at the end of the branches) must be operational (measurable).

Decomposability: The decision maker must be able to consider a criterion without reference to other criteria.

Absence of redundancy: Two or more criteria should not relate to the same objective.

Minimum size: The value tree should be as small as possible (in terms of the number of levels) without losing important information, as a meaningful analysis may become difficult if the value tree is too large; this means that no value will be added after the some optimal level of disaggregation is exceeded.

It is clear that the decision tree suggested for CoT complies with all these requirements.

5.7.7 Market prices and resource cost

Given the focus of efficiency on the optimal allocation of scarce resources, it follows that economic (resource) cost must be used in calculating Eff EUAC and Eff IRR. As benefits are defined as cost savings relative to the null alternative, this implies that both benefits and costs are valued at resource cost. However, in modelling consumer behaviour, for instance for the purpose of modal or route choice, market prices should be used as consumers base their choices on (inter alia) actual (market) prices.

Equity, on the other hand, involves the use of market prices as the utility of income (expenditure) to those who benefit and those who pay are based on market prices. For this reason, consumer surplus analysis should also be carried out at market prices.

5.8 Roles and responsibilities of stakeholders

Stakeholders in the process, for the purpose of the framework, are deemed to involve the following: the community, politicians (as elected representatives of the community), technocrats (professionals in the employ of the authority), external experts, and the facilitator (the person/team guiding stakeholders through the process). Each stakeholder has a unique role and responsibility, as Table 5-24 attempts to set out with reference to the steps of the two-phased approach described in Figure 5-8 above. Preceding these steps, though, is the identification of needs and problems. This is the combined responsibility of all stakeholders – as indicated in Section 1.3.2, the various stakeholder participation structures are aimed at facilitating the public consultation process. Needs and problems can however also be identified “directly” by technocrats.

Table 5-24: Roles and responsibilities of stakeholders

Item	Responsibility
1 Identify and structure the problem (referring to the process of appraising and selecting projects)	Facilitator, with inputs from all stakeholders.
2 Identify decision criteria	Facilitator (with assistance of external experts); buy-in of politicians is a prerequisite for the process.

Item	Responsibility
3 Determine relative importance of criteria	Politicians
4 Identify mutually exclusive alternatives	Technocrats
5.1 Score projects: Efficiency, equity and sustainability	Technocrats (with assistance from external experts)
5.1 Score projects (continued): Compatibility	Politicians
5.2 Standardize scores	Facilitator
6 Aggregate scores across criteria	Facilitator
7 Identify independent projects	Facilitator
8 Standardize scores (given new set of projects)	Facilitator
9 Aggregate scores across criteria	Facilitator
10 Perform sensitivity analysis	Facilitator

These roles and responsibilities can also be grouped according to the different stakeholders, as done below.

Technocrats:

- Identify needs/projects (also with input from politicians, as well as stakeholder participation structures as listed in Section 1.3.2).
- Identify mutually exclusive alternatives for each project.
- Score projects in terms of the following criteria: efficiency, equity and sustainability.
- Separate feasible and infeasible projects and remove infeasible projects from the process.

Politicians:

- Agree on the problem structure and overall objective.

- Agree on the decision criteria.
- Determine the relative importance of decision criteria.
- Score projects in terms of the criterion “compatibility”.

Facilitator (with external technical input):

- Standardize scores for mutually exclusive alternatives.
- Aggregate scores for mutually exclusive alternatives and identify “winners” from each set.
- Standardize scores for independent projects and rank them.
- Conduct a sensitivity analysis to determine the robustness of results.

5.9 Implications for specialized decision support tools

5.9.1 Background

The suggested framework has implications for the choice of an appropriate tool for executing it. In order to explore these implications, it is necessary to compare the scope and focus of HDM-4 with that of similar software for urban networks (urban transport planning). Software for CBA also needs to be juxtaposed against software for MCA.

From the document “*Overview of HDM-4, Volume 1”* (Kerali, 2000), it is clear that HDM evolved from a road engineering stance, with the focus on technical (engineering) aspects (roads in rural areas in developing countries). This is evident from the “typical” topics covered in that document (and all other documentation on HDM), such as:

- Pavement type and structures
- Road deterioration models (to predict performance of paved and gravel roads, i.e. to predict road deterioration over time as a function of aspects such as construction type/method, traffic loading (involving both volume and composition), maintenance strategy (type, frequency), material type, climate).
- Road maintenance strategies (e.g. type and frequency of overlay/seal).
- Drainage systems.

Much research effort has gone into modelling the various relationships. In the case of VOC, an important focus has been on road roughness as a determinant of VOC, where road

roughness, in its turn, was modelled as a function of aspects such as maintenance strategy and frequency, climate, and traffic. In its turn, maintenance type and frequency has been treated as a function of funding levels. It thus follows that HDM (traditionally) focuses on single-link roads in developing areas, adopting an engineering approach to managing rural road networks, in particular their construction and maintenance. Network effects are not as important as on urban networks because of lower traffic levels and less interdependency between the different elements (links) of the network. Key differences between urban and rural projects in terms of aspects such as focus, number of links, appropriate software, are summarized in Figure 5-13.

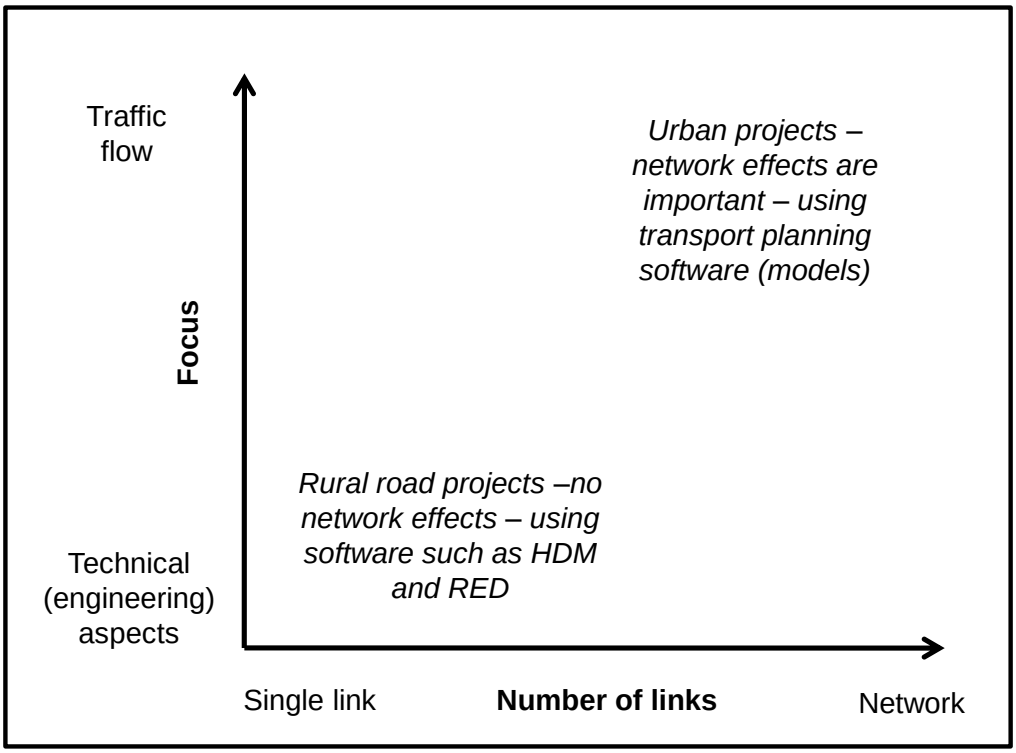


Figure 5-13: Key differences between urban and rural projects

The implications of "add-ons" for applying the appraisal framework are explained below.

Relationship between HDM and DEFINITE: HDM is essentially CBA software, with an MCA add-on (but with an initial focus on rural roads, involving a single link of the network, as opposed to urban roads, implying a network with interactive links); likewise, DEFINITE is essentially MCA software, with a CBA add-on (and where this is a generic, "non-specialized" CBA module – not customized to the unique requirements of TI at all). Neither HDM nor DEFINITE can satisfactorily perform both CBA and MCA.

Relationship between CBA and MCA: As with corresponding software, CBA should be done separately, using specialized ("dedicated") CBA tools (software), and the outcome should feed into the MCA process, using appropriate (dedicated) MCA tools.

For the purposes of an appraisal framework, it is therefore clear that the use of specialized software tools is non-negotiable – this means that "add-ons", as explained above, do not constitute an optimal option.

5.9.2 Role of urban transport demand models

Given the complex nature of the interrelationships between and interdependencies of the links of the urban transport network, transportation models are indispensable for determining the network effects of a project and for quantifying total network (user) cost on a "with" and "without" basis. Transportation models fall into three groups (Austroads, 2005b:45-46). (a) *Four-step models* involve procedures for trip generation, trip distribution, mode choice and route assignment. They are mainly "gravity models", using an analogy of Newton's law of gravitation. Criticism of this type of model is based on their lack of an underlying rationale, for example cheaper travel is not considered as one of the independent variables in determining trip generation, and land use is not allowed to change endogenously as a result of changes in accessibility. (b) *Discrete choice models* are aimed at addressing the lack of economic rationale in four-step models; they are essentially specialized econometric models. They are seldom used in practice, though, as they are complex and furthermore do not have a good record of accuracy. (c) *Land-use interaction models* attempt to consider accessibility as a factor determining land use. However, they are data-intensive, complex and lack robustness; as a result they tend to be used experimentally and at strategic level only.

Examples of models commonly used are the TRIPS package, the EMME/2 toolkit and the VLC-Zenith and VLC-Transcend modelling software. "All of these transport demand models provide detailed trip information for passengers and freight and there are emerging expectations of these models to accommodate environmental issues and development and other impacts. However, none of these transport demand models has an evaluation model formally linked to them" (Austroads, 2005c:8).

5.10 Summary

The basic approach developed in Chapter 4 involves an MCDM-type approach – using the MCDM value measurement model – with economic efficiency as one of the decision criteria. This model requires the following steps:

- Identify and structure the problem.
- Identify alternatives.
- Identify decision criteria.
- Determine relative importance of criteria.
- Measure intra-criterion performance.
- Aggregate scores across criteria.
- Perform sensitivity analysis.

This chapter focuses on customizing this basic approach to the CoT context. To this end, attention is focused on the second, third and fifth steps – identifying decision criteria (in addition to economic efficiency that was identified in Section 4.4.3), identifying alternatives and measuring intra-criterion performance. Identifying decision criteria involves both an analysis of the CoT decision making environment and an analysis of the approach adopted by a selected number of external institutions or suggested by independent sources. Regarding the remaining four steps not dealt with in this section, it is argued that they are sufficiently taken care of by the software suggested for this purpose. This chapter also explores a number of additional aspects relating to customizing the framework, such as the need for a two-phased approach, which results from the distinction between mutually exclusive alternatives and independent projects and which directly impacts on intra-criterion performance measurement, in particular the choice of performance measurement units.

Decision criteria from the CoT planning environment

This involves a scrutiny of the statutory environment and spatial framework impacting on the CoT, as well as CoT policy imperatives, its vision, mission, goals and objectives regarding the transport function. The following was found:

- In general, the relevant CoT planning documents, in particular the ITP and the IDP documents, are not very helpful for the purpose of identifying a list of decision criteria.

- Those objectives that do qualify as decision criteria, are not operational as no performance (measurement) scale is suggested.

Decision criteria from other contexts

To supplement this top-down approach (i.e. the analysis of CoT goals and objectives), decision criteria suggested by a selected number of "other" institutions and researchers – both local and abroad – are scrutinized. A total of ten sources were consulted; they can be classified into five groups as follows: (a) views on decision criteria from independent researchers; (b) criteria suggested by (or for) road/transport authorities abroad; (c) criteria used by a selected number of road/transport authorities in the USA; (d) criteria suggested by the South African Department of Transport; and (e) criteria suggested for a number of South African urban municipalities (or regional authorities). The following criteria emerged from this analysis: efficiency, equity, sustainability, and compatibility.

Decision criteria suggested for CoT

Based on the discussion above, it is argued that four decision criteria are deemed relevant in the case of CoT, namely: (a) *efficiency*, which deals with the requirement of the optimal allocation of scarce resources; (b) *equity*, which involves the objective of a fairer distribution of income between persons benefitting from the project; (c) *sustainability*, which focuses on minimizing negative impacts on the environment; and (d) *compatibility*, which addresses the requirement that a project must be aligned to stated goals and objectives. This set of decision criteria suggested for CoT were assessed from various perspectives, and was found acceptable in all cases.

Identification of alternatives

To explain the identification of projects to be subjected to the appraisal process in the case of CoT, the consolidated CoT transport budget for the 2006/07 financial year was used as a starting point. In essence, identifying projects to be subjected to appraisal involves eliminating non-relevant projects from the consolidated transport budget. It was found that, from the initial budget, only nine projects need to be subjected to the appraisal process.

Need for a two-phased approach

The need for a two-phased approach arises from the fact that project appraisal involves both the evaluation (comparison) of mutually exclusive alternatives and the ranking of

independent projects. This implies that the typical steps of the MCA value function model need to be "customized"; these ten steps can be grouped under the following four headings:

Establish generic parameters: (1) identify and structure the problem; (2) identify decision criteria; (3) determine relative importance of criteria.

Compare mutually exclusive alternatives: (4) identify mutually exclusive alternatives; (5) measure intra-criterion performance: (a) s*core alternatives and remove infeasible ones; (b) standardize scores for feasible alternatives;* (6) aggregate scores across criteria.

Rank independent projects: (7) identify independent projects; (8) measure intra-criterion performance - standardize scores (given a new set of projects); (9) aggregate scores across criteria.

Test the robustness of results: (10) perform sensitivity analysis.

Measuring intra-criterion performance

The following performance measurement units are considered appropriate for the decision criteria suggested for CoT:

Efficiency:

- Mutually exclusive alternatives: Eff EUAC
- Independent projects: Eff IRR

Equity:

- Mutually exclusive alternatives: Eq NPV
- Independent projects: Eq B/C ratio

Sustainability:

- Mutually exclusive alternatives and independent projects: Index

Compatibility:

- Mutually exclusive alternatives and independent projects: Index.

Market prices and resource cost

Given the focus of efficiency on the optimal allocation of scarce resources, it follows that economic (resource) cost must be used in calculating Eff EUAC and Eff IRR. However, in modelling consumer behaviour, as for the purpose of modal or route choice, market prices

should be used, as consumers base their choices on (inter alia) actual (market) prices. Equity, on the other hand, involves using market prices as the utility of income (expenditure) those who benefit and those who pay are based on market prices. Consumer surplus analysis therefore should also be carried out at market prices.

Roles and responsibilities of stakeholders

The process of identifying needs and problems, and appraising and selecting projects, involves a number of stakeholders: the community, politicians (as elected representatives of the community), technocrats (professionals in the employ of the authority), external experts, and the facilitator (the person guiding stakeholders through the process). Each stakeholder has a unique role and responsibility, as set out with reference to the steps of the two-phased approach described above.

Need for specialized decision support tools

For the purpose of applying the appraisal framework, the use of a specialized software tool is non-negotiable. The output of various other tools can, however, serve as input into the "main" tool, for example in the case of a CBA. Given the complex nature of the interrelationships between and interdependencies of the links of the urban transport network, transportation models are indispensable for determining the network effects of a project and for quantifying total network (user) cost on a "with" and "without" basis. These models can be grouped in three categories (a) four-step models; (b) discrete choice models; and (c) land-use interaction models. Examples of models commonly used are the TRIPS package, the EMME/2 toolkit and the VLC-Zenith and VLC-Transcend modelling software.

6. APPLYING THE FRAMEWORK TO COT PROJECTS

6.1 Introduction

In this chapter the appraisal framework that was developed in previous sections is applied to CoT projects identified as "eligible" for appraisal, as argued in Section 5.5. A key objective of this chapter is to demonstrate how the framework will affect project ranking and thus project selection. It is also aimed at indicating how currently available decision support tools can facilitate project appraisal and ensure better outcomes of the decision making process.

To achieve all this, this chapter revisits key aspects of the framework, and lists the relevant CoT projects. Accepting the fact that an appropriate tool is invaluable in facilitating the application of the framework, it considers criteria for selecting such a tool and explores key aspects of DEFINITE, the tool utilized for this purpose. The framework is then applied to both a set of mutually exclusive alternatives and a set of independent projects, using the decision criteria suggested in the framework as opposed to the ITP (functional or departmental) and IDP (process-related) prioritization process currently used by CoT (described in Section 1.4.4). This chapter also deals with the dilemma facing the decision maker, resulting from conflicting rankings in terms of the suggested decision, and discusses how this could be resolved.

6.2 Key aspects of the framework revisited

The appraisal framework developed in Chapters 4 and 5 can be described as an MCA type approach of the value function kind with the following four decision criteria: (a) efficiency (focusing on the economic feasibility of the project, i.e. involving the optimal allocation of scarce resources; (b) equity (dealing with the income distribution impacts of the project); (c) sustainability (addressing "green issues"); and (d) compatibility (involving the "goodness-of-fit" of the project with stated goals and objectives, and key initiatives). The fact that efficiency constitutes one of the decision criteria means that a CBA constitutes an element of the framework. In this regard it was argued that a partial equilibrium type approach (as opposed to a general equilibrium type approach) would suffice in the case of the kind of CoT project addressed in this thesis (such as "Category AB: Budget cycle type projects with local economic impacts only" (the "typical" case)). The preference for "narrow CBA" as opposed to "broad CBA" was also substantiated. In addition, the need for a two-phased approach was argued, given the need to address both (the comparison of) mutually exclusive alternatives

and (the ranking of) independent projects. Suitable performance measurement units for each of the various decision criteria were also suggested for use in intra-criterion performance measurement.

6.3 CoT projects considered for application

In the “real” world, projects will be identified in one of two manners (or both):

- By technocrats, on the basis of the functional deficiency of elements of the transport system.
- By politicians and community structures (regarding the latter, see Section 1.3.2), identifying community needs (and thus projects).

For the purpose of this thesis, though, the list of projects contained in the relevant planning documents (ITP and IDP documents) was used as a starting point, and it was argued (in Section 5.5) that irrelevant projects (e.g. committed projects) should be eliminated from the list. This resulted in the following nine projects considered in this section for the purpose of applying the framework:

- Road infrastructure Klip/Kruisfontein.
- Collector road backlog: Atteridgeville.
- Doubling of Church Street over railway line.
- Olievenhoutbosch activity spine.
- Upgrading of road network in Hatfield.
- Collector road backlog: Mamelodi.
- Improving of Hans Strijdom Drive (west).
- Doubling of Simon Vermooten Road.
- Doubling of Lynnwood Road.

6.4 The need for appropriate tools

6.4.1 Introduction

Although the focus of this chapter is on demonstrating the application of the framework, the role of appropriate tools should not be underestimated. Tools are important not only for

facilitating the process, but also for their potential to improve the quality of decision making outcomes. In this section, attention is therefore briefly focused on the criteria that need to be taken into consideration in selecting a tool, as well as selected aspects of DEFINITE, the tool used for this purpose.

6.4.2 Criteria for selecting a decision support tool

Cloete (2003:36-37) lists ten criteria that should be considered in comparing and selecting decision-support tools. It should be noted that, as with the decision making in an MCDA environment, some of these objectives are contradictory.

Simplicity: Because of the frequently low levels of electronic literacy among decision-makers, especially in developing countries, the simpler the user interface, the better.

Cost: Inexpensive DSS tools will for obvious reasons be more popular.

Hardware requirements: Computer memory and general capacity are perpetual constraints on decision-support systems. The less capacity needed, the more application potential the DSS tool will have, especially in developing countries.

Access and maintenance: Access to DSS tools, training opportunities and the maintenance and upgrading of those tools are essential in order to optimally apply the tools concerned. Off-the-shelf software is therefore potentially more useful than specially designed software that needs specialist maintenance and upkeep.

Visual images: DSS tools with strong visual and graphic capabilities will have a better impact for presentation purposes in developing countries, where the levels of literacy are traditionally low.

Specificity: DSS tools that can be applied to achieve specific decision-making objectives are preferred to tools that can only indirectly resolve specific questions of concern.

Versatility/Flexibility: DSS tools that are able to address more than one problem, can be applied in different settings for different purposes, and that do not need specialised training, are preferable to tools that do not conform to these requirements.

Compatibility: The level of compatibility and integration of DSS tools with other programs is essential to optimise application potential. Compatibility with existing mainstream business applications is therefore essential.

Transparency: The desire of decision-makers to keep control of the decision-making process necessitates tools that are relatively transparent and simple, in order to achieve legitimacy in the perception of the decision-maker.

Scientific rigour: The more rigorous the scientific base of the tool, the more reliable it will be.

6.4.3 Background to DEFINITE

DEFINITE was developed by the Vrije Universiteit of Amsterdam in the Netherlands. The first version of DEFINITE appeared in 1994. It has a wide variety of users, in both the public and the private sector. Within the Dutch government, users include almost all ministries, provinces, public bodies and a number of larger cities. Outside government, the main users are consultancy and engineering firms.

DEFINITE (derived from "DEcisions on a FINITE set of alternatives") is described as "a decision support software package that has been developed to improve the quality of decision making. DEFINITE is, in fact, a whole toolkit of methods that can be used on a wide variety of problems. If you have a problem to solve, and you can identify alternative solutions, then DEFINITE can weigh up the alternatives for you and select the best alternative. The program contains a number of methods for supporting problem definition as well as graphical methods to support representation. To be able to deal with all types of information, DEFINITE includes multi-criteria methods, cost-benefit analysis and graphical evaluation methods. Related procedures, such as weight assessment, standardization, discounting and a large variety of methods for sensitivity analysis are also available. A unique feature of DEFINITE is a procedure that systematically leads an expert through a number of rounds of an integrative assessment session and uses an optimization approach to integrate all information provided by the expert to a full set of value functions".

"DEFINITE supports the whole decision process, from problem definition to report generation. The structured approach ensures that the decision arrived at are systematic and consistent" (Janssen, Herwijnen and Beinat, 2001:9).

6.4.4 DEFINITE terminology and procedures

In a number of instances, the terminology used by DEFINITE differs from that used in this thesis. The first two columns in Table 6-1 contain items and definitions from the DEFINITE manual (Janssen *et al.*, 2001:362), with corresponding terminology used in this thesis (and further notes where necessary) in the third column.

Table 6-1: Comparison of terminology

DEFINITE terminology		Terminology used in thesis
Item	**Definition**	
Alternative	A possible solution for a decision problem.	Option, project, or mutually exclusive alternatives and independent projects.
Tree structure	Hierarchical structure of effects, groups of effects, etc.	Decision tree, value tree.
Effect	Characteristic or attribute of an alternative that can be used to rank alternatives.	Decision criterion.
Effect group	Group of effects linked to a specific topic or interest.	Decision criteria aggregated under appropriate headings to constitute main categories of criteria.
Score	An appraisal of an alternative for a specific effect.	The performance of an option (mutually exclusive alternative or independent project) in terms of a given decision criterion.

In addition, the following differences are relevant:

- DEFINITE uses the term “effects table”, whereas “evaluation matrix” is used in this thesis.
- In this thesis, alternatives are normally listed vertically (in the left hand column) and criteria horizontally (in the top row) in the evaluation matrix; with DEFINITE it is the other way round.
- DEFINITE refers to the “standardization” of scores instead of their normalization; also, DEFINITE does not use the term “partial value functions” in this regard. In addition,

the difference between scores, standardized (normalized) scores and total scores should be noted.

- DEFINITE uses a different sequence of steps for undertaking an MCA; this confirms the earlier statement in this thesis that the sequence suggested in Section 3.3.2 merely serves as a guideline.
- DEFINITE offers a number of methods that are not applicable to CoT, such as the following MCA methods: Electre 2, Regime and Evamix.

6.5 Application to mutually exclusive alternatives

6.5.1 Introduction

In applying the framework to mutually exclusive alternatives, attention is firstly focused on the requirement that feasible alternatives should be separated from infeasible alternatives and that the latter should be removed from the analysis, after which the "conflict" that may arise between alternatives should be resolved.

All relevant calculations are based on a traffic growth factor of 3 percent per annum. Also, for illustrative purposes, a discount rate of 10 percent per annum (in real terms) is used. This is higher than the discount rate of 8 percent normally used but, as noted by Mullins *et al*. (2007:67), 8 percent may possibly be regarded as "generous" for South Africa. Other assumptions are that resource cost is equal to 90 percent of market prices in the case of recurring cost, and 95 percent of market price in the case of causal cost (i.e. the cost that has to be incurred in order to obtain benefits (defined as savings in recurring cost relative to the null alternative).

6.5.2 Separating feasible and infeasible alternatives

In terms of the appraisal framework, the comparison of mutually exclusive alternatives involves two aspects: firstly, determining the feasibility of alternatives, and secondly, ranking feasible alternatives in terms of their performance. This means that alternatives that are not feasible should be excluded from the analysis, bearing in mind that, according to the framework, "feasibility" is defined in a total sense, meaning that an alternative should be feasible in terms of *all* criteria. This aspect is demonstrated below with reference to the criteria "efficiency" and "equity" in the case of the CoT project "Collector road backlog: Mamelodi" which appears on the list in Section 6.3.

In Section 6.6 the Eff IRR and Eq B/C ratio for this project are given as 14,8 percent and 5.2 respectively. This corresponds to mutually exclusive alternative a_3 in Table 6-2. The calculations made in this regard and the assumptions on which calculations are based are also explained in Section 6.6. For the purpose of demonstrating the requirement of separating feasible and infeasible alternatives, the set of mutually exclusive alternatives constituting the Mamelodi project as listed in Table 6-2 were assumed, i.e. the null alternative plus five more mutually exclusive alternatives. In order to "link" Alternative 3 to the list of independent projects in Section 6.6, the table includes the columns "Eff IRR relative to null alternative" and "Eq B/C relative to null alternative". For the purpose of demonstrating the framework to a set of mutually exclusive alternatives, the table also has columns for "Eff EUAC", "Eff NPV" and "Eq NPV". Although "Eff NPV" is not required in terms of the framework, it is included here to highlight differences between "Eff NPV" and "Eq NPV". In calculating the values in this table, the "analytical procedures" expounded in Section 2.2.6 were used.

Table 6-2: Mutually exclusive alternatives: Collector road backlog in Mamelodi

Mut exl alts	Efficiency						Equity			
	Present worth of total causal cost	Annual recurring cost at zero time	Present worth of benefits	Eff EUAC	Eff NPV	Eff IRR relative to null alter-native	Present worth of total causal cost	Present worth of benefits	Eq NPV	Eq B/C relative to null alter-native
	ZAR million	ZAR million p.a.	ZAR million	ZAR million p.a.	ZAR million	% p.a.	ZAR million	ZAR million	ZAR million p.a.	Ratio
a_0	0	9.0	NA	11.4	NA	NA	0	NA	NA	NA
a_1	5.1	7.9	11.9	10.6	6.8	24.3	4.2	35.4	31.2	8.5
a_2	15.0	7.8	13.0	11.6	-2.0	7.9	12.3	38.6	26.3	3.1
a_3	22.2	5.9	33.5	10.1	11.2	15.6	18.2	99.2	81.0	5.5
a_4	30.1	5.6	36.7	10.6	6.6	12.3	24.6	108.8	84.2	4.4
a_5	35.3	5.3	39.9	10.8	4.6	11.3	28.8	118.3	89.5	4.1

For the purposes of this section, the methodology for weighing benefits that was explored in Section 5.7.2 is being used in the case of equity, resulting in the equity weights shown in Table 6-3.

Table 6-3: Equity weights for different income groups

Income group	Total annual household expenditure ($ billion)	Population (million)	Annual expenditure per capita ($ thousand)	Equity weight
Low	2.276	0.275	8.28	8/3
Middle low	4.139	0.375	11.04	8/4
Middle	7.173	0.325	22.07	8/8
Middle high	13.795	0.500	27.59	8/10
High	18.968	0.625	30.35	8/11
Average	46.352	2.100	22.07	8/8

Source: Adapted from CMT-KMV (1995:A.2.1).

The graphs below are based on the values contained in the table. The first graph (Figure 6-1) identifies Alternative 3 as the best from the perspective of efficiency, as it has the lowest Eff EUAC.

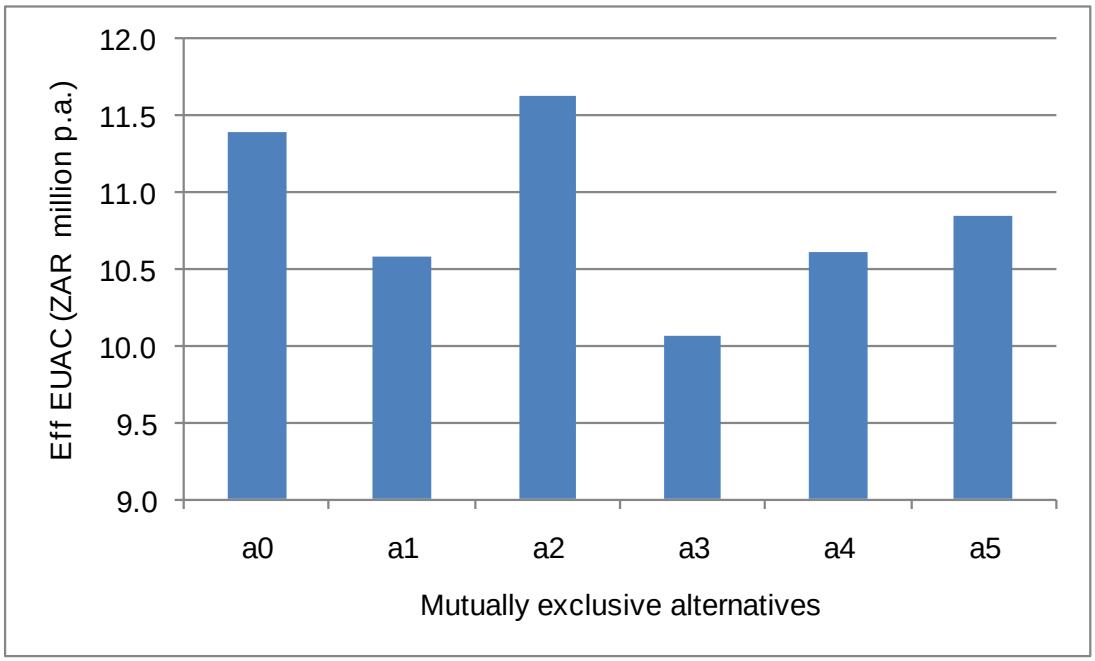


Figure 6-1: Eff EUAC

This is echoed by the graph in Figure 6-2 which identifies Alternative 3 as best in terms of "efficiency", since it has the highest Eff NPV. Both graphs, though, identify Alternative 2 as infeasible: with the first graph, because its Eff EUAC is higher than that of the null alternative, and with the second paragraph, because its Eff NPV is negative. This means that Alternative

2, as required in terms of the framework, must not be considered further and be removed from the process.

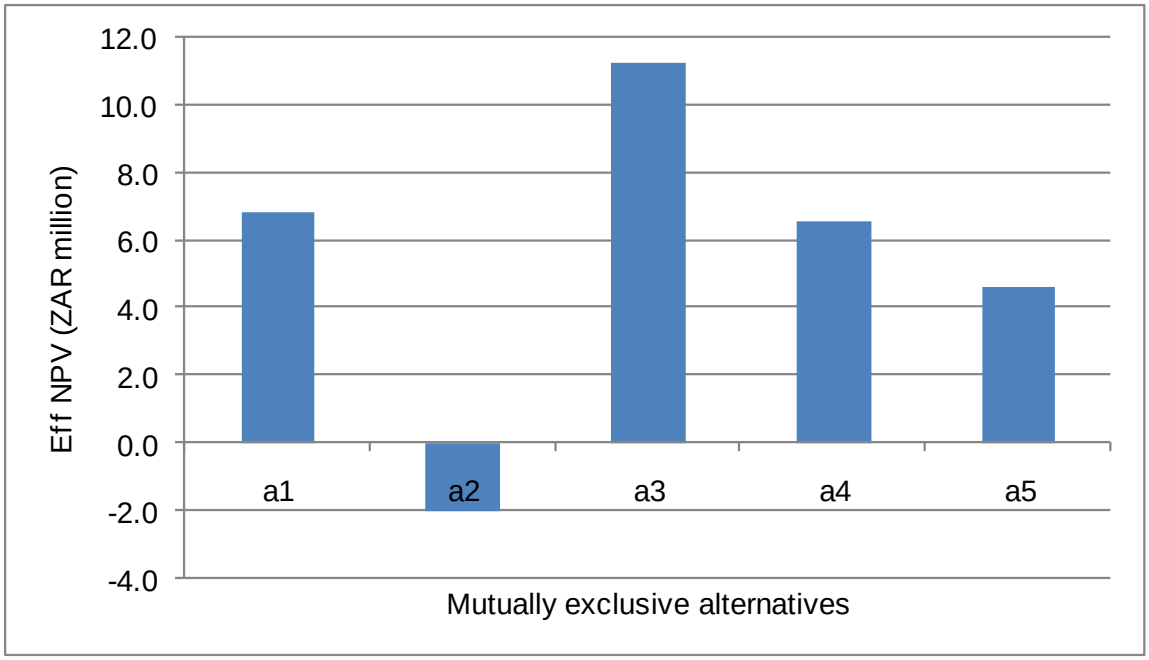


Figure 6-2: Efficiency NPV

The graph in Figure 6-3 firstly shows that all mutually exclusive alternatives are feasible in terms of equity, since the Eq NPV for all alternatives is positive. It should be noted, however, that this may not always be the case, especially with projects benefiting mostly persons in the higher income groups, in which case negative Eq NPVs may result. In any case, Alternative 2 should not be considered further as it is not feasible in terms of efficiency. The graph also shows that Alternative 5 is preferred in terms of equity as it has the highest Eq NPV. This means that a conflict has now arisen: in terms of efficiency, Alternative 3 is preferred; in terms of equity, Alternative 5 is preferred. Resolving this conflict is dealt with in Section 6.5.3.

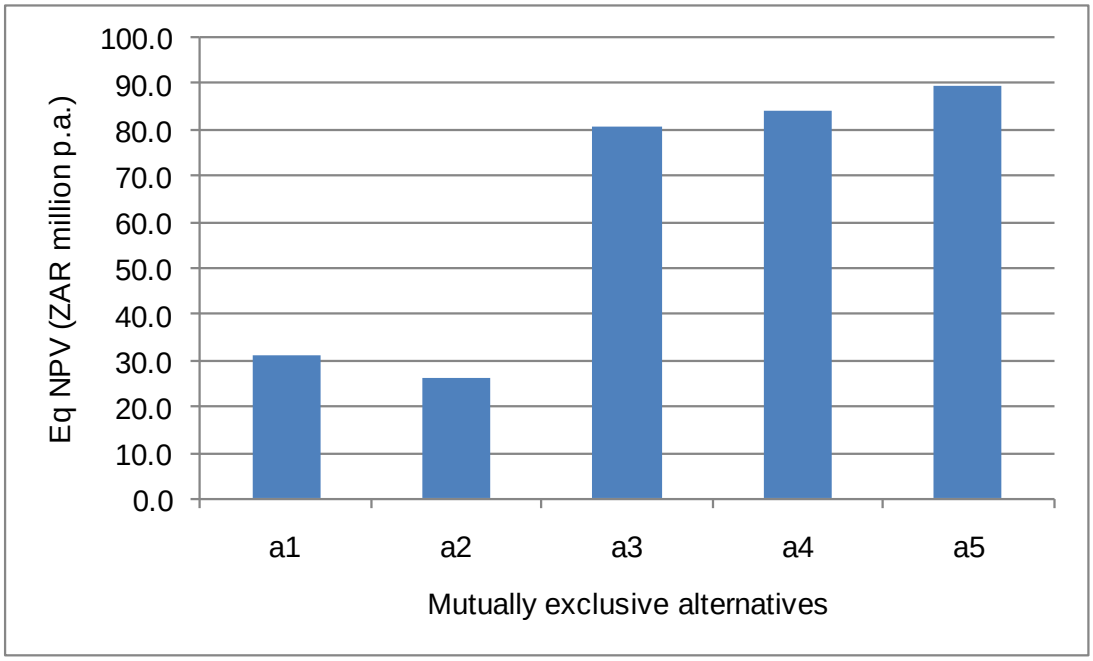


Figure 6-3: Eq NPV

In summary, it should be noted that there are three possibilities regarding any given set of mutually exclusive alternatives:

- All alternatives are feasible, i.e. each alternative is feasible in terms of all criteria: In this case, all alternatives should be subjected to ranking in order to determine the best, for inclusion in the list of independent projects.
- Only some alternatives are feasible in terms of all criteria: In this case, infeasible alternatives should be excluded from the appraisal.
- No alternatives are feasible in terms of all criteria: This implies a no-go situation for the purpose of appraisal, as the null alternative should remain the status quo. An example of this is the case of a set of four alternatives, with all alternatives not feasible in terms of a given criterion, alternatively, a situation where Alternative 1 is not feasible in terms of the first criterion, Alternative 2 is not feasible in terms of the second criterion, Alternative 3 is not feasible in terms of the third criterion, and Alternative 4 is not feasible in terms of the fourth criterion.

Also, if all infeasible alternatives have been identified and removed from the analysis, only feasible alternatives will remain which, by definition, will all be superior to the null alternative (against which they had been measured). This means that the null alternative can (must) also be removed from the analysis, as is demonstrated in the next section.

6.5.3 Comparison of mutually exclusive alternatives

In order to demonstrate the application of the framework to a set of mutually exclusive alternatives, the information in Table 6-2 regarding the performance of mutually exclusive alternatives in terms of efficiency and equity is expanded in Table 6-4 to also include scores for the criteria "sustainability" and "compatibility". By definition, these scores relate to the relative performance of alternatives considered feasible in terms of these criteria (sustainability and compatibility). From Table 6-4 it is also clear that, for the reasons given above, the null alternative and Alternative 2 have been removed from further analyses.

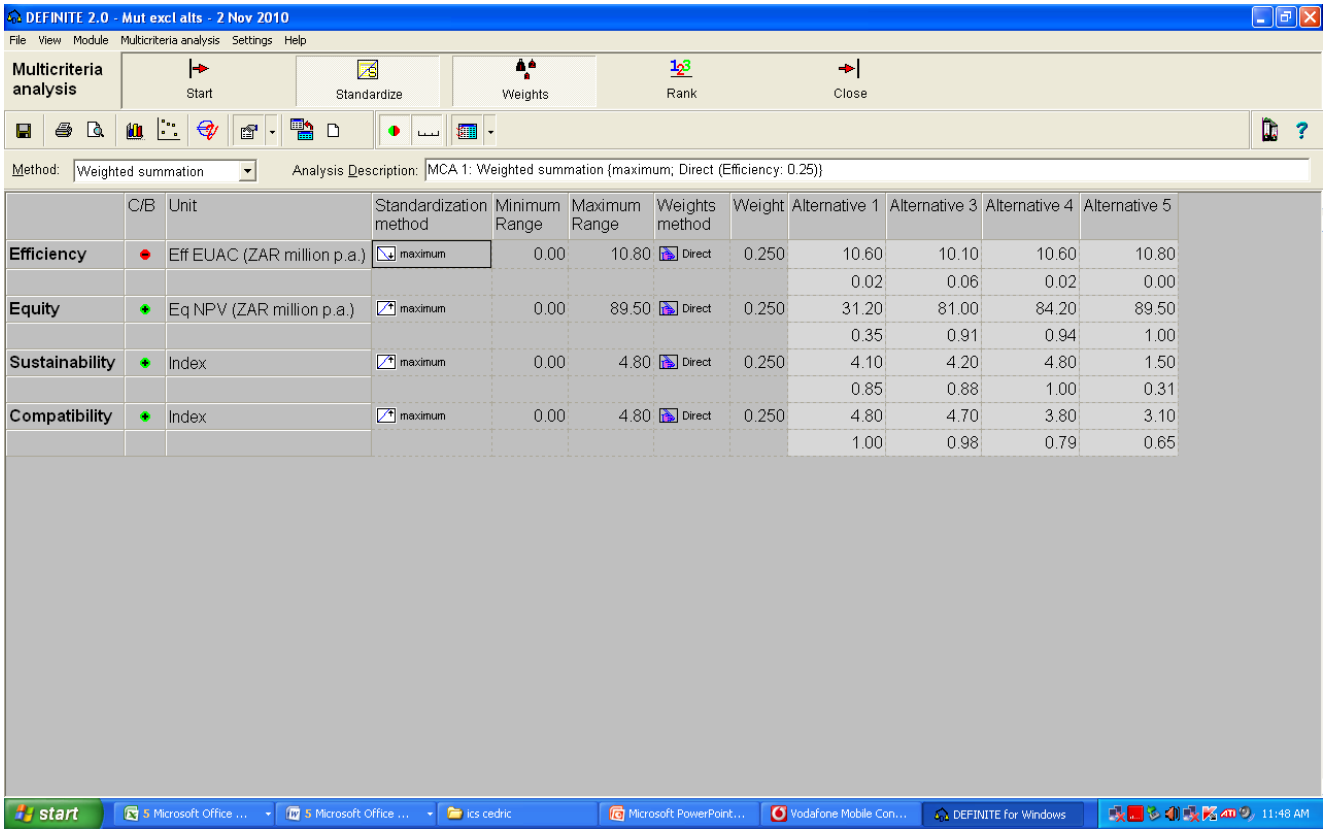
Table 6-4: Scores for collector road backlog in Mamelodi

Mutually exclusive alternatives	Criteria / measurement unit			
	c_1	c_2	c_3	c_4
	Efficiency	Equity	Sustain-ability	Compat-ibility
	Eff EUAC (ZAR million p.a.)	Eq NPV (ZAR million p.a.)	Index	Index
a_1	**10.6**	**31.2**	**4.1**	4.8
a_3	10.1	**81.0**	**4.2**	**4.7**
a_4	**10.6**	**84.2**	4.8	**3.8**
a_5	**10.8**	89.5	**1.5**	**3.1**

The values in this table clearly illustrate the dilemma facing the decision maker:

- In terms of efficiency, Alternative 3 is the best (having the lowest Eff EUAC).
- In terms of equity, Alternative 5 is the best (having the highest Eq NPV).
- In terms of sustainability, Alternative 4 is the best (having the highest score).
- In terms of compatibility, Alternative 1 is the best (having the highest score).

A tool such as DEFINITE is indispensable in applying the framework and solving this conflict. The screen dump from DEFINITE (Figure 6-4) summarizes all input data used in the analysis in DEFINITE format. The first column, for example, lists the decision criteria used in the analysis, and the last four columns show the "actual" scores for each alternative on each criterion, as well as "standardized" scores (the latter a value between 0 and 1, being a function of the standardization method used for each criterion).



	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weights method	Weight	Alternative 1	Alternative 3	Alternative 4	Alternative 5
Efficiency		Eff EUAC (ZAR million p.a.)	maximum	0.00	10.80	Direct	0.250	10.60	10.10	10.60	10.80
								0.02	0.06	0.02	0.00
Equity		Eq NPV (ZAR million p.a.)	maximum	0.00	89.50	Direct	0.250	31.20	81.00	84.20	89.50
								0.35	0.91	0.94	1.00
Sustainability		Index	maximum	0.00	4.80	Direct	0.250	4.10	4.20	4.80	1.50
								0.85	0.88	1.00	0.31
Compatibility		Index	maximum	0.00	4.80	Direct	0.250	4.80	4.70	3.80	3.10
								1.00	0.98	0.79	0.65

Figure 6-4: Input data and standardized scores for mutually exclusive alternatives

The second column in Figure 6-4 indicates whether a criterion is interpreted as a benefit or a cost (in DEFINITE terminology), where “benefit” is interpreted as “more is better” and “cost” as “less is better”. This is illustrated in the two graphs below. The first graph (Figure 6-5) shows that “efficiency”, being defined as a cost, has a negative slope. Likewise, the second graph (Figure 6-6) shows that “equity”, defined as a benefit, has a positive slope

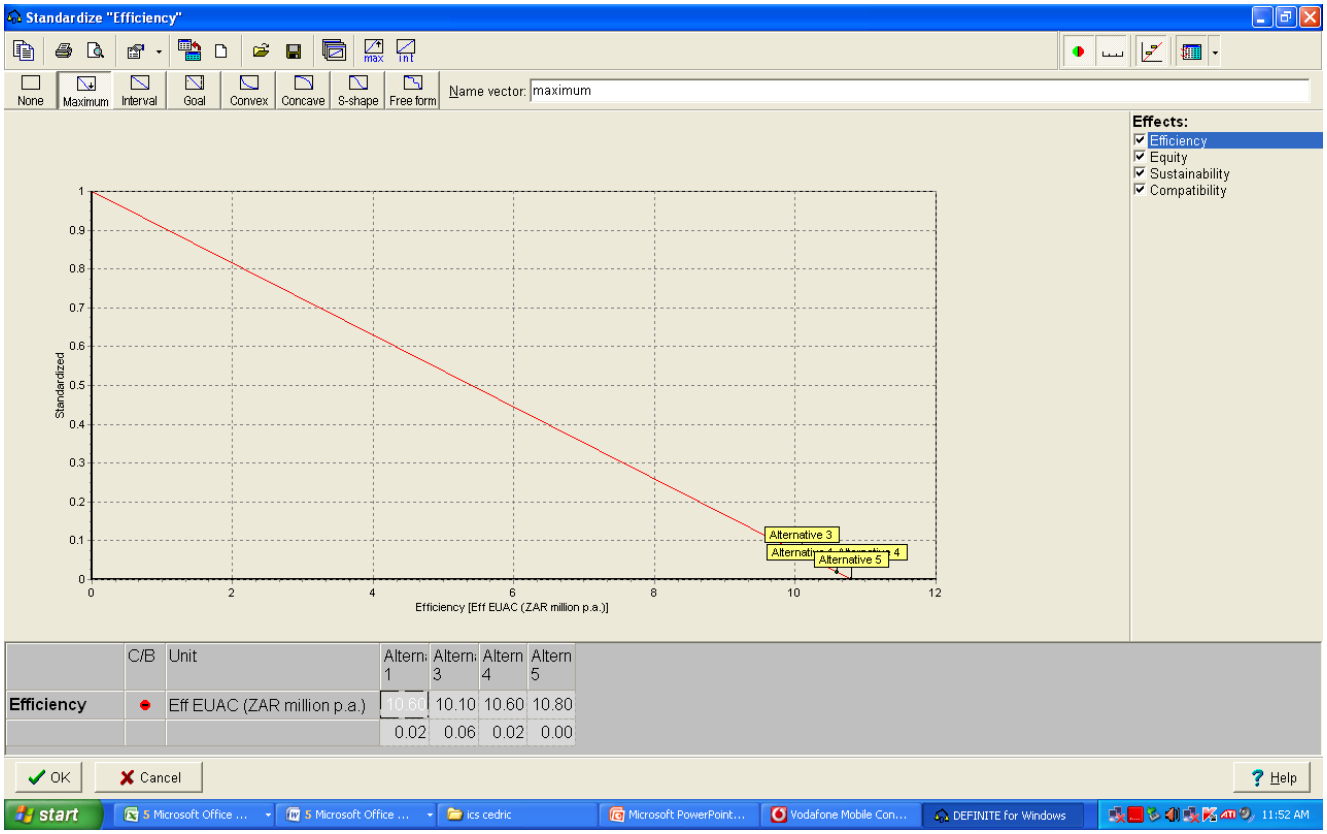


Figure 6-5: Standardization of scores for criterion "efficiency"

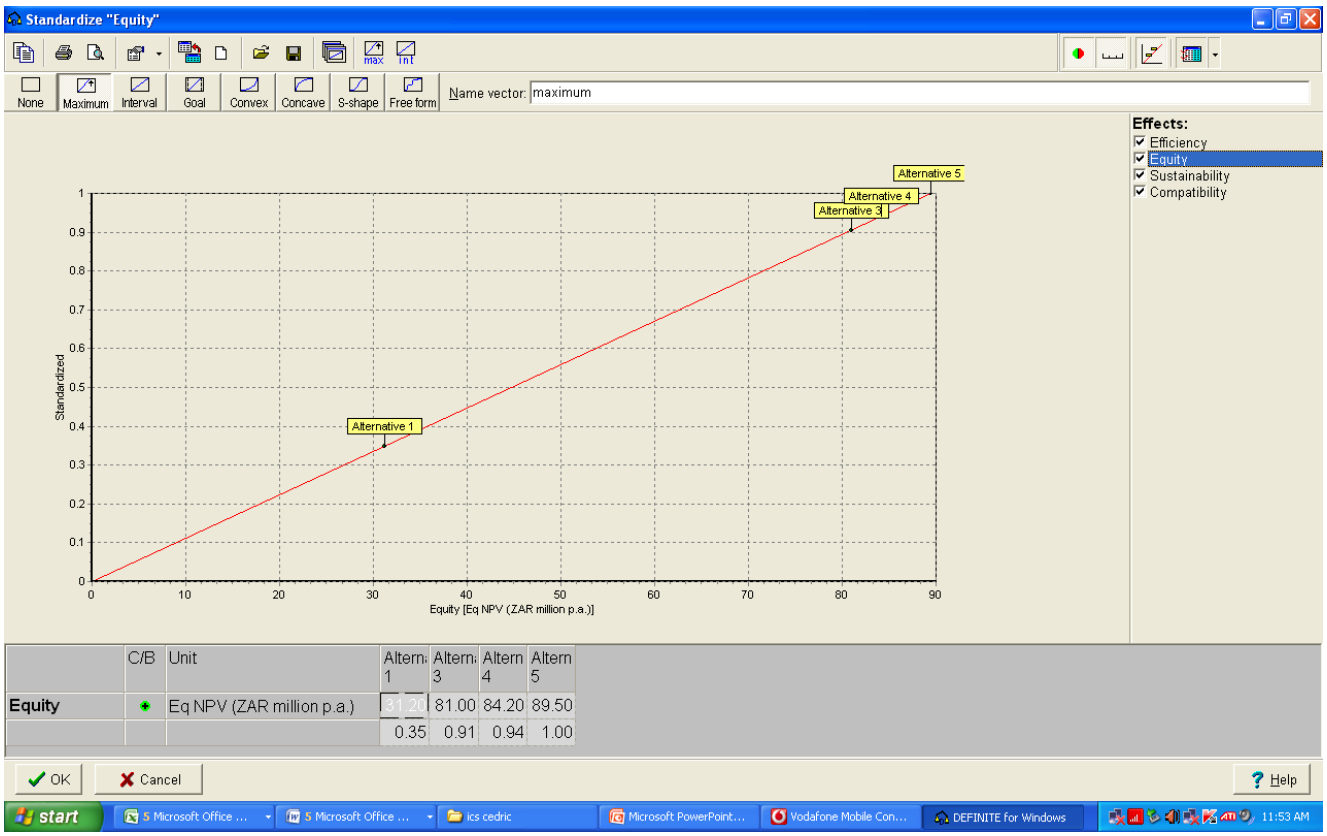


Figure 6-6: Standardization of scores for criterion "equity"

Figure 6-7 shows the ranking of mutually exclusive alternatives when the decision criteria are considered of equal relative importance, i.e. each having a weight of 0.25.

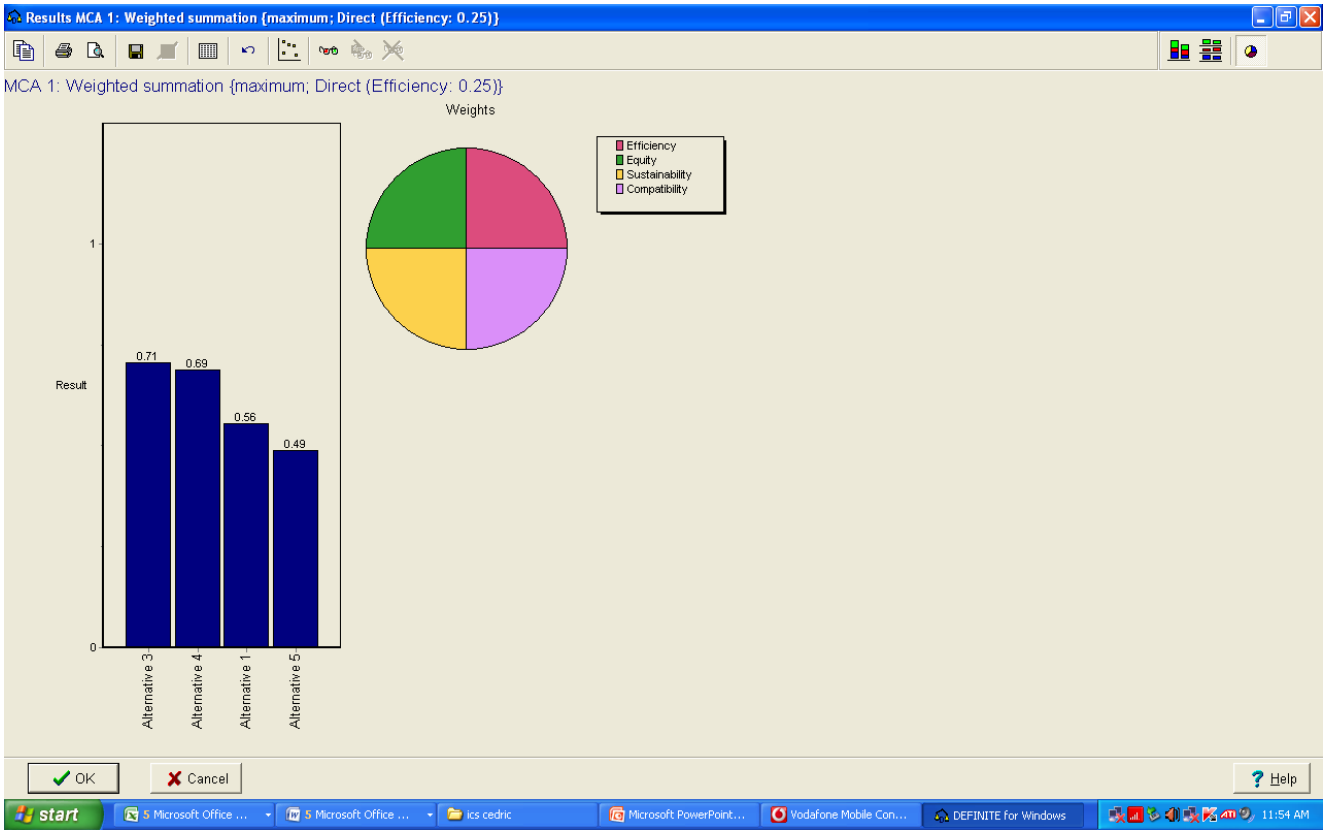


Figure 6-7: Ranking of mutually exclusive alternatives

Since Alternative 3 is indicated as the best alternative from this set of mutually exclusive alternatives, it now becomes an independent project which should be added to the list of independent projects, which have to be ranked together with all other independent projects identified in the manner described above.

It should also be noted that Alternative 3 implies a “compromise solution”. Table 6-4 shows that, although it is best in terms of efficiency, it is only third best in terms of equity, and second best in terms of both sustainability and compatibility. This implies a trade-off of performance in terms of the relative importance attached to decision criteria.

6.6 Independent projects

6.6.1 Introduction

This section first focuses attention on the input data used in demonstrating the application of the framework to independent projects; more specifically, on justifying assumed input values,

given the lack of actual data. Given these assumed values for project performance, this section explores the challenges facing the decision maker in selecting projects, as well as the fundamental differences between the approach suggested in the framework and the prioritization methods currently used (namely the ITP (functional or departmental) and IDP (process-related) prioritization processes). Finally, it focuses on ranking projects in terms of project worth, as suggested by the framework.

6.6.2 Input data

Efficiency parameters

As noted above, input data on project performance in terms of the decision criteria suggested in the framework are, by implication, not readily available. As a starting point, however, the cost estimates provided in the ITP document were used. Costs were typically spread out over an anticipated implementation (construction) period (not exceeding five years) as shown in Table 6-5.

Table 6-5: TI projects to be appraised

Proj IDP no	Project name	Financial year / million ZAR						PW of con-struct-ion cost	PW of maint-enance cost (million ZAR)	PW of residual value (million ZAR)	PW of total causal cost (million ZAR)
		Yr1	Yr2	Yr3	Yr4	Yr5	Total				
710331	Road infrastructure Klip/Kruisfontein	3.4	5.0	0.0	0.0	0.0	8.4	7.2	1.6	0.1	8.2
712522	Collector road backlog: Atteridgeville	0.5	3.0	0.0	5.0	10.0	18.5	12.6	2.7	0.2	14.3
710928	Doubling of Church St over railway line	1.0	0.0	0.0	17.5	5.0	23.5	16.0	3.4	0.2	18.2
711325	Olievenhoutbosch activity spine	3.5	5.0	5.0	5.0	5.0	23.5	17.6	3.8	0.3	20.1
710930	Upgrading of road network in Hatfield	0.0	0.0	3.0	13.0	10.0	26.0	17.3	3.7	0.3	19.8
712521	Collector road backlog: Mamelodi	0.5	3.5	0.0	10.0	15.0	29.0	19.5	4.2	0.3	22.2
710940	Improving of Hans Strijdom Dr (west)	0.0	3.0	19.0	12.0	0.0	34.0	25.0	5.4	0.4	28.5
711800	Doubling of Simon Vermooten Rd	11.0	22.5	20.0	2.0	0.0	55.5	45.0	9.7	0.7	51.3
710939	Doubling of Lynnwood Road	12.0	25.0	26.5	1.0	10.0	74.5	58.4	12.6	0.9	66.6
	Total	31.9	67.0	73.5	65.5	55.0	292.9	218.5	47.0	3.2	249.2

On the assumption that the costs shown for years 1 to 5 constitute total cost in each case, the present worth (PW) of total causal cost was calculated for each project (last column), where this was defined as the discounted value of all costs needed to “invoke” savings in recurring costs (i.e. the total of user costs, consisting of vehicle operating cost, travel time cost and accident cost) over the analysis period of 20 years, and where this cost is expressed as a resource cost, which is assumed as 0,95 of market prices.

Therefore:

PW of total causal cost (at resource cost)

= (PW of construction cost + PW of maintenance cost – PW of residual value) x 0,95.

In the case of the last project (Lynnwood Road), for example, this results in the following:

PW of construction cost

PW of construction cost (at market prices) =

12,0/(1,1)+25,0/(1,1)^2+26,5/(1,1)^3+1,0/(1,1)^4+10,0/(1,1)^5

PW of maintenance cost

PW of maintenance cost = PW of construction cost x 2% x (EtPW,i%,n)

where:

(E_tPW,i%,n) = exponential series present worth factor at a traffic growth rate of 3 percent p.a., and a (real) discount rate of 10 percent p.a., over a 20 year period;

and where a facility maintenance cost of 2 percent p.a. at zero point in time, growing exponentially at 3 percent p.a. over the analysis period, is assumed.

PW of residual value

PW of residual value = PW of construction cost x 10 percent / 1,1^20;

where the opportunity cost of the facility at the end of the analysis period was taken at 10 percent, representing the market value of the land it occupies.

On the assumption that all projects on this list are economically feasible (i.e. feasible in terms of “efficiency”), it follows that the present worth of savings in recurring cost would at least be equal to the present worth of total causal cost. Specific values for the former (for the purpose of demonstrating the application of the framework) were selected on the basis of typical performance of transport projects in similar analyses. In the case of the Church Street project (“Doubling of Church Street over the railway line”), this amounts to an Eff IRR (relative to the null alternative) of 25,6 percent p.a. (Table 6-6), and in the case of the Mamelodi project (“Collector road backlog: Mamelodi”), to an Eff IRR (relative to the null alternative) of 15,6 percent p.a. (Table 6-7).

Table 6-6: Doubling of Church Street over railway line

Mut exl alts	Efficiency				Equity		
	Present worth of total causal	Annual recurring cost at zero time	Present worth of benefits	Eff IRR relative to null alternative	Present worth of total causal cost	Present worth of benefits	Eq B/C relative to null alternative
	ZAR million	ZAR million p.a.	ZAR million	% p.a.	ZAR million	ZAR million	Ratio
a_0	0	8.8	NA	NA	0	NA	NA
a_1	18.2	4.6	45.2	25.6	14.9	50.2	3.4

Table 6-7: Collector road backlog: Mamelodi

Mut exl alts	Efficiency				Equity		
	Present worth of total causal	Annual recurring cost at zero time	Present worth of benefits	Eff IRR relative to null alternative	Present worth of total causal cost	Present worth of benefits	Eq B/C relative to null alternative
	ZAR million	ZAR million p.a.	ZAR million	% p.a.	ZAR million	ZAR million	Ratio
a_0	0	9.0	NA	NA	0	NA	NA
a_1	22.2	5.9	33.5	15.6	18.2	99.2	5.5

There are two reasons for the expected Eff IRRs of projects serving persons in the higher income groups to be generally higher than for projects serving persons in the lower income groups (as shown in Table 6-9). Firstly, traffic volumes in general are higher in higher income areas, meaning that more vehicles/persons can "contribute" to savings in recurring cost. Secondly, and perhaps more importantly, time savings of persons in higher income groups are valued more highly than those from lower income groups. This is confirmed in Table 6-8, containing "suggested input values" for CBA.

Table 6-8: Estimated time cost by income group (2006 ZAR): Gauteng

Income group	Value of a working hour (ZAR/hr)	Value of a recreational hour for all persons	Value of a recreational hour for workers
Low	8,42	0,65	1,92
Middle	24,02	1,99	5,48
High	108,84	10,71	24,83
Total	41,14	3,38	9,39

Source: Mullins et al. (2007:92).

The fact that a distinction is made in CBA between the value of (travel) time of persons in different income groups, as shown in Table 6-8, serves to substantiate the claim of some critics that CBA is "pro-rich". In the context of the framework, however, and within the specific objective of addressing efficiency, it can be claimed that this distinction is justified, and that "value of time" should in fact be interpreted as the "economic value of time" which necessarily will depend on income group.

Equity parameters

The next step involves the calculation of parameters for equity, with the ultimate aim of determining the Eq B/C ratio relative to the null alternative. To accomplish this, the relationship between (the performance indicators for) efficiency and equity, as argued previously, was used, together with an assumption regarding the weighted average expenditure of beneficiaries in the case of each project. For example, the present worth of total causal cost (for determining equity parameters) was calculated as follows (this applies to all projects):

$PWTC_{Eq}$ = ($PWTC_{Eff}$ x 10% x 8/8 + $PWTC_{Eff}$ x 30% x 8/10 + $PWTC_{Eff}$ x 60% x 8/11) / 0,95

where $PWTC_{Eq}$ = Present worth of total cost in the case of equity, and

$PWTC_{Eff}$ = Present worth of total cost in the case of efficiency.

This reflects the fact that, in terms of the tax regime, it was assumed that 10, 30 and 60 percent respectively of total cost is borne by persons in the average, mid-high and high income groups; in addition, 8/8, 8/10 and 8/11 are the corresponding "equity weights". The value of 0,95 represents the ratio between resource cost and market prices.

In the case of the Church Street projects, the present worth of benefits was calculated as follows:

PWB_{Eq} = PW_{Eff} x 8/8 / 0,9

where:

PWB_{Eq} = Present worth of benefits in the case of equity,

PW_{Eff} x = Present worth of benefits in the case of efficiency,

and where the factor "8/8" reflects the fact that that the "weighted average beneficiary" is assumed to be in the middle income group. In the case of the Mamelodi project, the

corresponding figure was 8/3, reflecting the fact that the "weighted average beneficiary" in this case is assumed to be in the low income group.

Parameters for sustainability and compatibility

By implication, no information is available for the criteria sustainability and compatibility. For the purpose of demonstrating the framework in the case of independent projects, the performance values shown in Section 6.6.3 (Table 6-9) were used. They are essentially indices in the range 1 to 5, where 1 and 5 respectively represent "least acceptable" and "most acceptable". Regarding the requirement to separate feasible and infeasible projects (alternatives) as explored in the sections above on mutually exclusive alternatives, it is important to note though, that by implication, all projects are deemed feasible.

6.6.3 Implications of input data for project selection

Using decision criteria suggested in the framework

Assumed input values that were used to demonstrate the application of the framework to independent projects are summarized in Table 6-9.

Table 6-9: Scores for CoT projects

Project		Decision criteria			
Name	PW of total causal cost (million ZAR)	Efficiency	Equity	Sustain-ability	Compat-ibility
		Eff IRR (% p.a.)	Eq B/C (ratio)	Index	Index
Road infrastructure Klip/Kruisfontein	8.2	16.0	5.6	4.1	4.8
Collector road backlog: Atteridgeville	14.3	13.0	4.6	3.2	4.1
Doubling of Church St over railway line	18.2	25.6	3.4	4.5	3.8
Olievenhoutbosch activity spine	20.1	11.9	1.3	4.9	4.2
Upgrading of road network in Hatfield	19.8	23.1	2.4	3.5	3.2
Collector road backlog: Mamelodi	22.2	15.6	5.5	4.2	4.0
Improving of Hans Strijdom Dr (west)	28.5	19.3	2.0	4.5	4.1
Doubling of Simon Vermooten Rd	51.3	19.9	2.1	4.8	4.2
Doubling of Lynnwood Road	66.6	20.2	1.9	4.2	4.4

From this table the dilemma facing the decision maker is evident, namely that no single project is preferred in terms of all four decision criteria:

- In terms of both equity and compatibility, the Klip/Kruisfontein project is preferred.
- In terms of efficiency, the Church Street project is preferred.
- In terms of sustainability, the Olievenhoutbosch project is preferred.

In addition, given the fact that the total cost of feasible projects typically exceeds available funds (i.e. that project selection essentially always takes place under conditions of budget constraints, requiring some ranking method), decision making is complicated because different rankings are obtained for the different decision criteria. In the case of the criteria efficiency and equity, for example, the respective rankings are shown in Figures 6-8 and 6-9. As shown, the projects ranking first, second and third in the case of efficiency are totally different from those in the case of equity. Also, whereas the Church Street projects ranks first in the case of efficiency, it only ranks fourth in the case of equity.

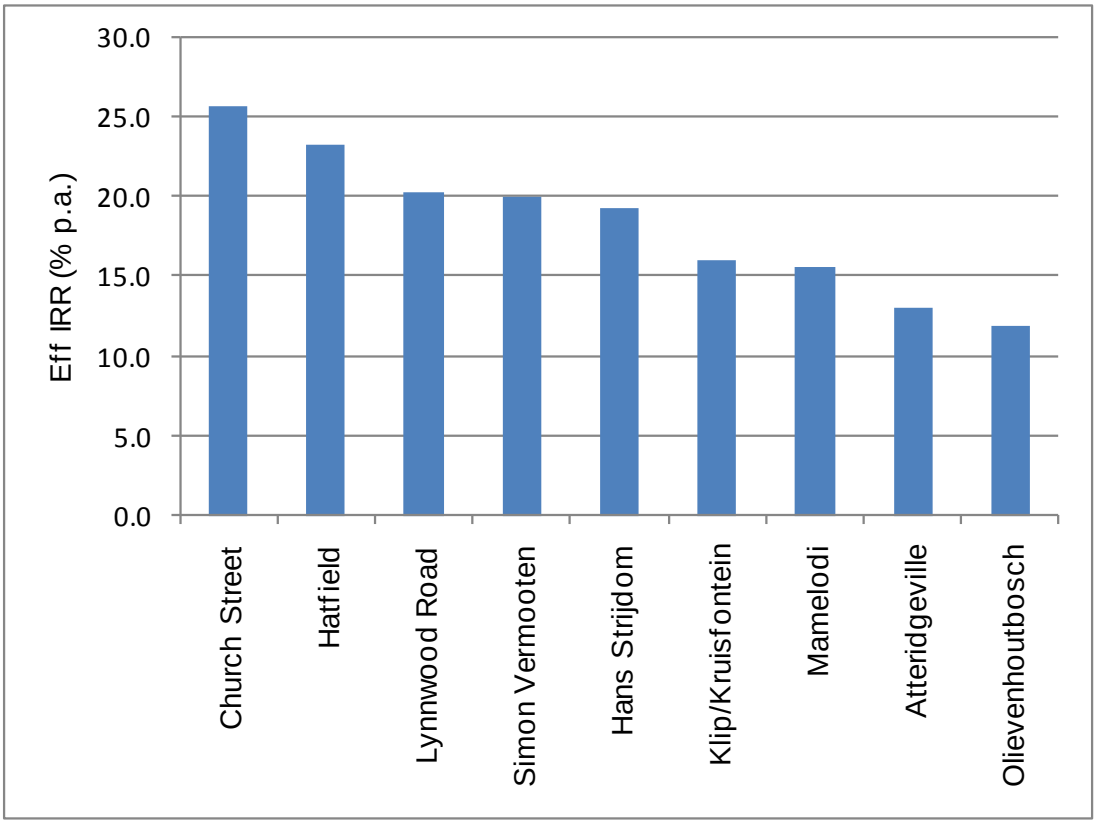


Figure 6-8: Ranking of projects in terms of efficiency

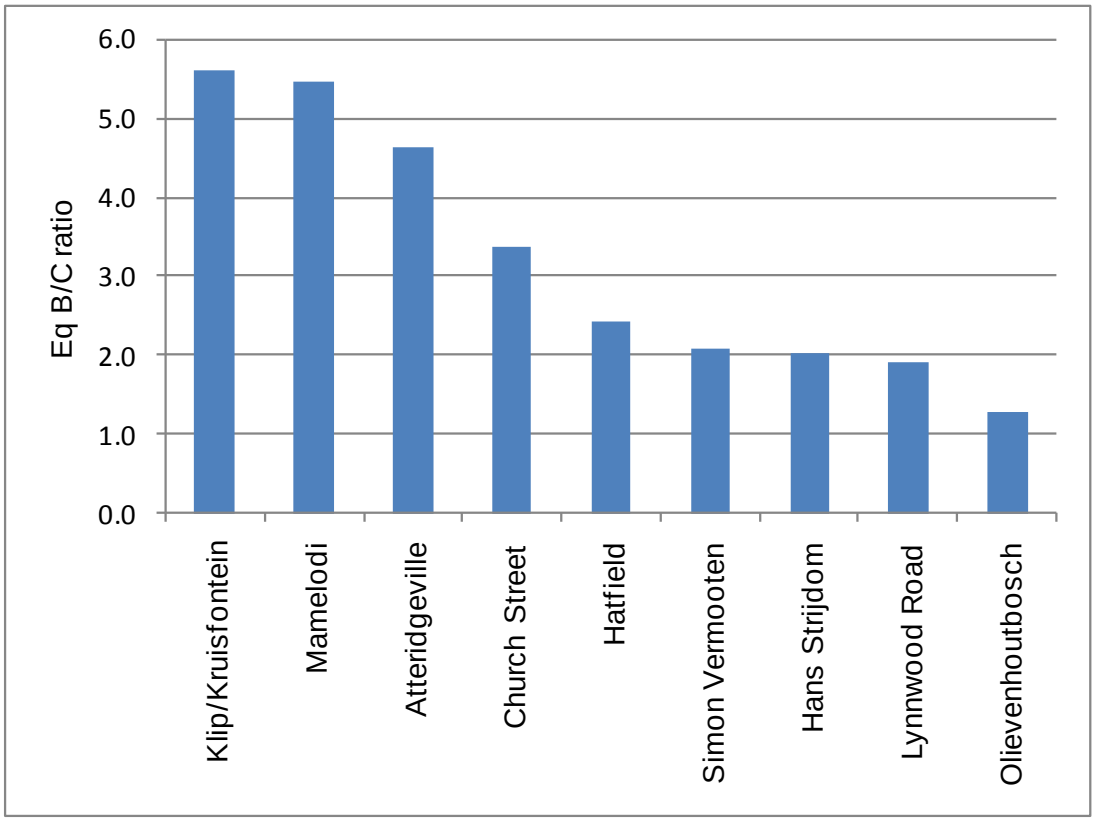


Figure 6-9: Ranking of projects in terms of equity

Using decision criteria currently considered in CoT

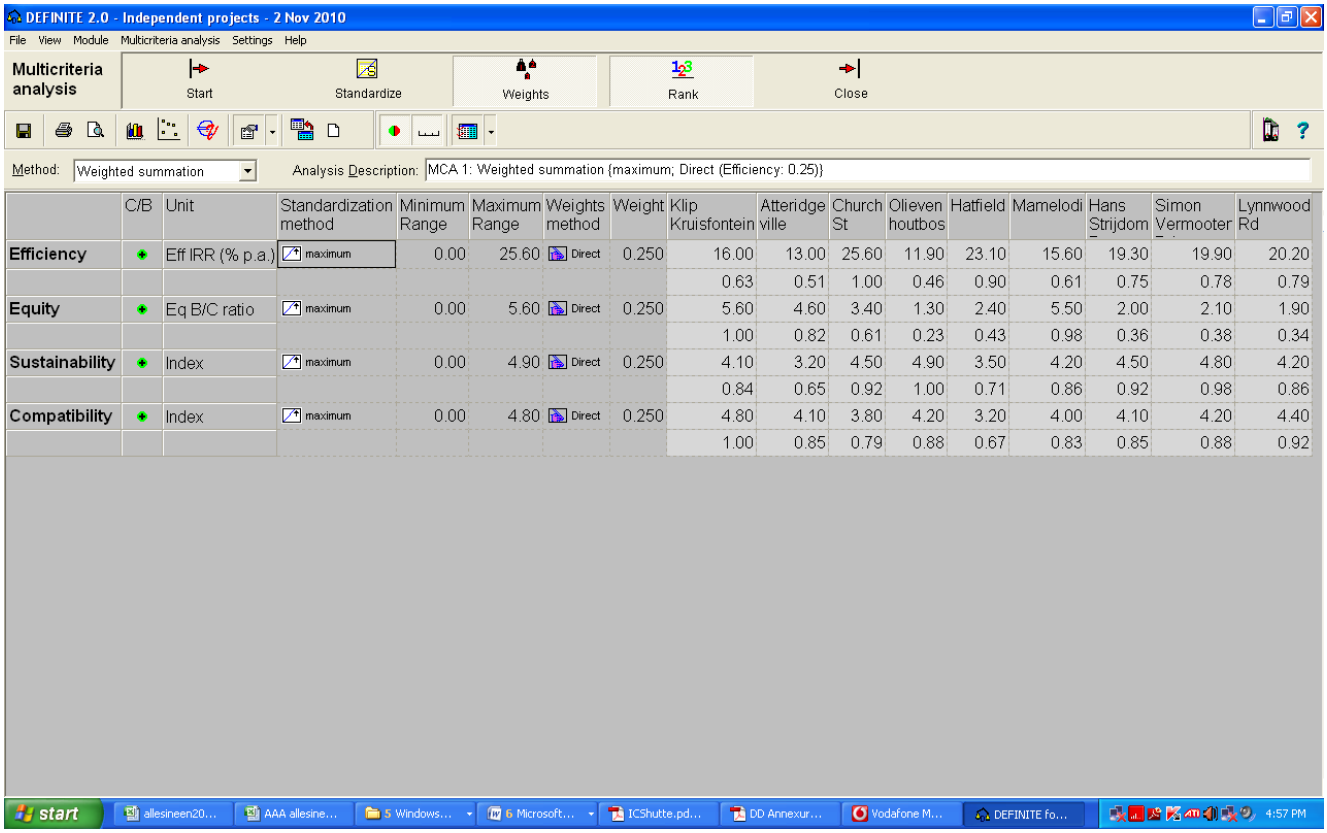
A similar dilemma to that noted above (in the case of the framework) is facing the decision maker in the case of the current CoT processes for project prioritization. As explained in Section 1.4.4, two processes are used for project prioritization in the CoT, namely the ITP (functional or departmental) and IDP (process-related) prioritization processes (CTMM, 2007:12-1). The ITP prioritization procedure is based essentially on functional/technical considerations; this may include return of investment as well as political influence from within the transport sector, whereas the IDP prioritization process reflects "municipal priority areas". They result in different rankings, namely the "ITP priorities" and the "IDP priorities" – this is to be expected, given their different perspectives.

For the purposes of project appraisal, it is argued that both the ITP and IDP objectives are valid, but that other objectives (criteria) should also be considered in determining project worth for the purpose of project ranking. An exclusive focus on functional (engineering) aspects means that other important objectives (criteria) – such as those considered in the framework (namely efficiency, equity, sustainability and compatibility) – are excluded. The way in which functional/technical considerations are accommodated in the framework is by requiring that all mutually exclusive alternatives should first be screened for "technical feasibility". These technically feasible alternatives must then be subjected further to other "types" of feasibility analyses, such as efficiency, equity, etc. The objective of "municipal priority areas", on the other hand, is accommodated in the framework by the introduction of the decision criterion "compatibility".

6.6.4 Project ranking according to project worth

The problem of conflicting project rankings can be resolved by taking into account the relative importance attached to these criteria. These "weights" clearly are a critical input by the politicians (decision makers) who, being the elected representatives of the community, should articulate society's aspirations, goals and objectives, and who, in the last instance, should take responsibility for all decisions made.

Project ranking is undertaken in this section by using the input values for the different CoT projects contained in Table 6-9, and assuming equal weights for the four decision criteria. Input values in "DEFINITE format" as well as standardized values for project scores and other parameters are contained in Figure 6-10.



	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weights method	Weight	Klip Kruisfontein	Atteridge ville	Church St	Olieven houtbos	Hatfield	Mamelodi	Hans Strijdom	Simon Vermooter	Lynnwood Rd
Efficiency		Eff IRR (% p.a.)	maximum	0.00	25.60	Direct	0.250	16.00	13.00	25.60	11.90	23.10	15.60	19.30	19.90	20.20
								0.63	0.51	1.00	0.46	0.90	0.61	0.75	0.78	0.79
Equity		Eq B/C ratio	maximum	0.00	5.60	Direct	0.250	5.60	4.60	3.40	1.30	2.40	5.50	2.00	2.10	1.90
								1.00	0.82	0.61	0.23	0.43	0.98	0.36	0.38	0.34
Sustainability		Index	maximum	0.00	4.90	Direct	0.250	4.10	3.20	4.50	4.90	3.50	4.20	4.50	4.80	4.20
								0.84	0.65	0.92	1.00	0.71	0.86	0.92	0.98	0.86
Compatibility		Index	maximum	0.00	4.80	Direct	0.250	4.80	4.10	3.80	4.20	3.20	4.00	4.10	4.20	4.40
								1.00	0.85	0.79	0.88	0.67	0.83	0.85	0.88	0.92

Figure 6-10: Summary of input data and standardized values for project scores

The three graphs below (Figures 6-11, 6-12 and 6-13), each with a unique weights vector and therefore project ranking, highlight the relative importance of decision criteria for project ranking. The graphs also show the contribution of (project performance in terms of) each criterion to total project worth. Results are summarized in Table 6-10 with reference to the "top five" projects in each case; this underlines the importance of the input of politicians by providing "weights". For example, with an emphasis on efficiency, four of the five projects are benefiting persons in the higher income groups (third column). With an emphasis on equity (last column), only two of the five projects are serving persons in the higher income groups; the top three positions, now are taken by projects serving persons in the lower income groups.

Table 6-10: Top five projects for different weight vectors

Rank	Equal weights	Preference for efficiency	Preference for equity
	All projects having weight = 0,25	**Efficiency = 0,55, other criteria = 0,15 each**	**Equity = 0,55, other criteria = 0,15 each**
1	Klip/Kruisfontein	Church Street	Klip/Kruisfontein
2	Church Street	Klip/Kruisfontein	Mamelodi
3	Mamelodi	Hatfield	Atteridgeville
4	Simon Vermooten Drive	Simon Vermooten Drive	Church Street
5	Lynnwood Road	Lynnwood Road	Simon Vermooten Drive

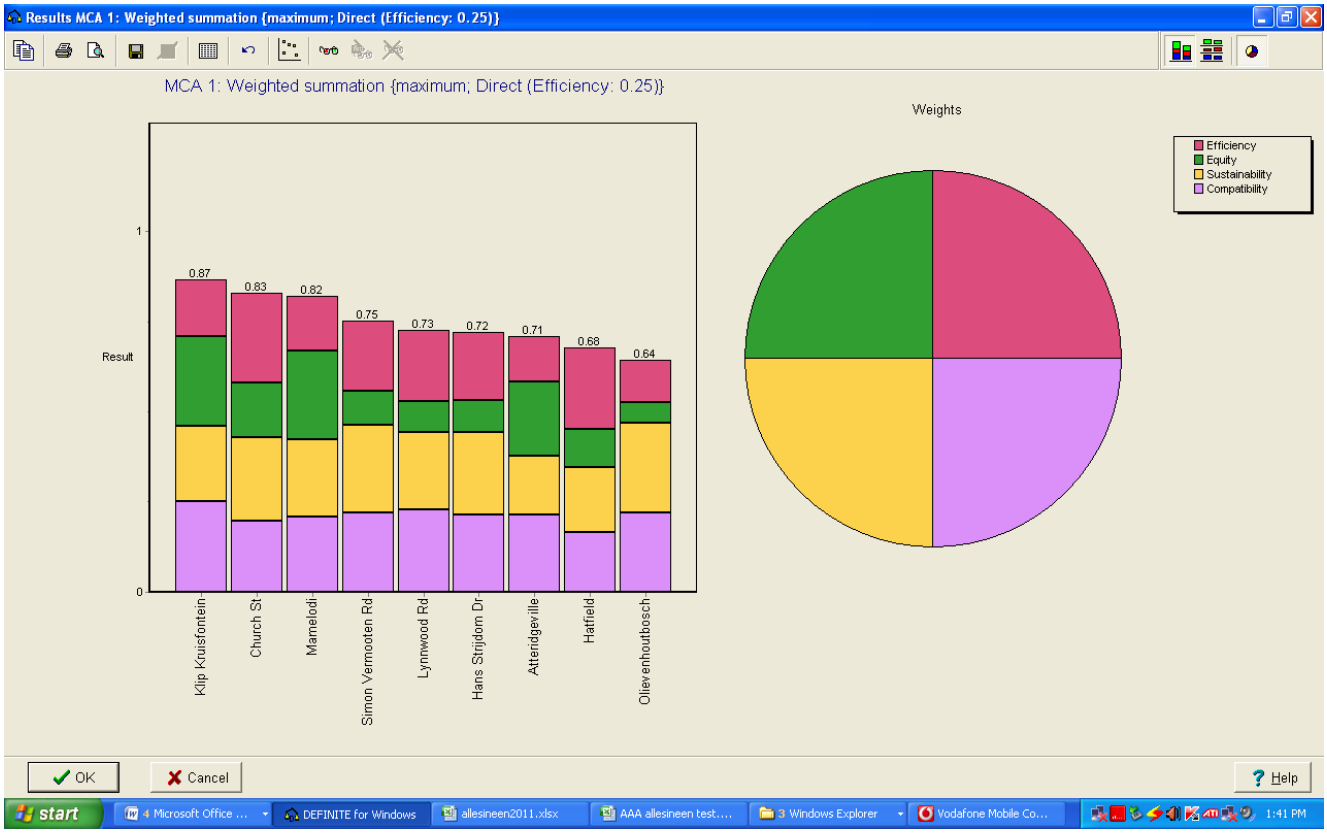


Figure 6-11: Project ranking with equal weights

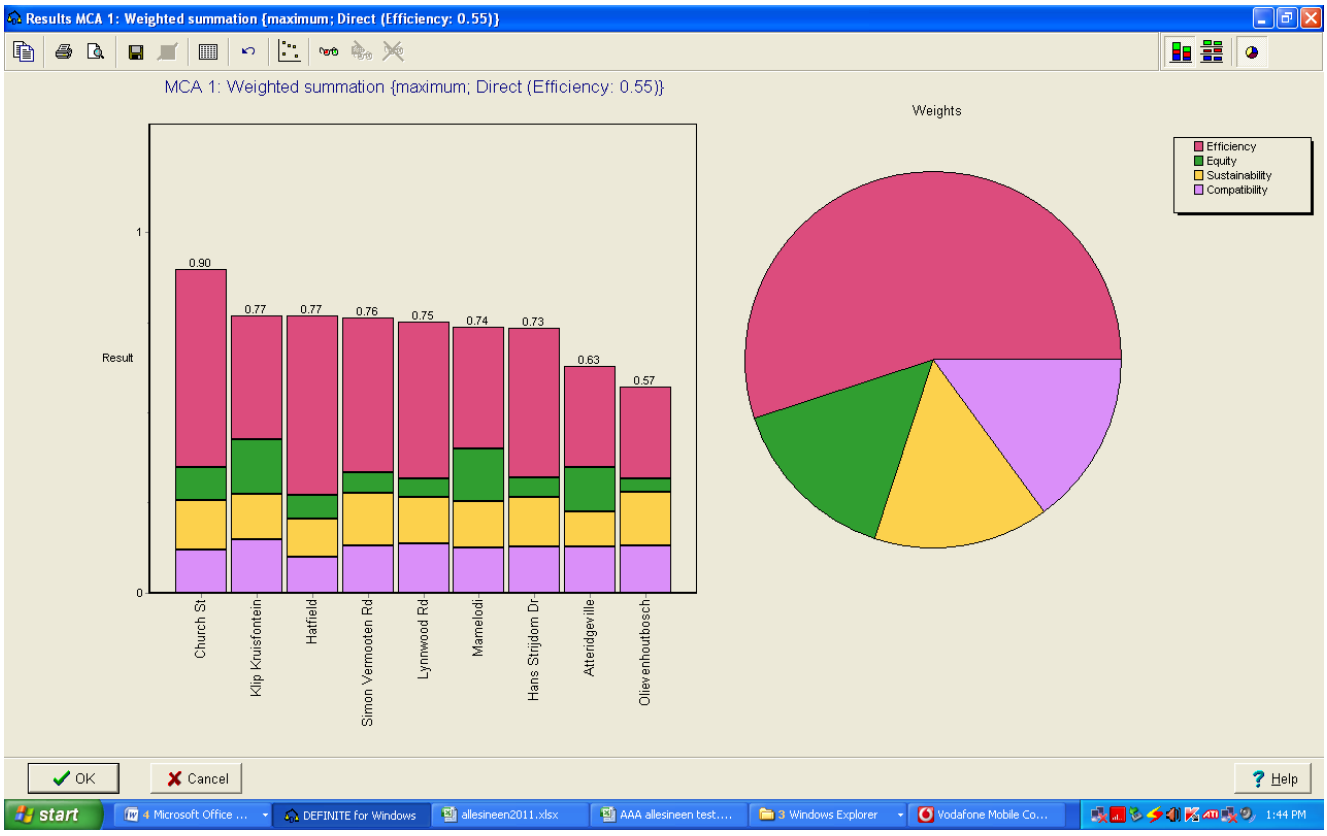


Figure 6-12: Project ranking with efficiency = 0.55, other criteria = 0,15 each

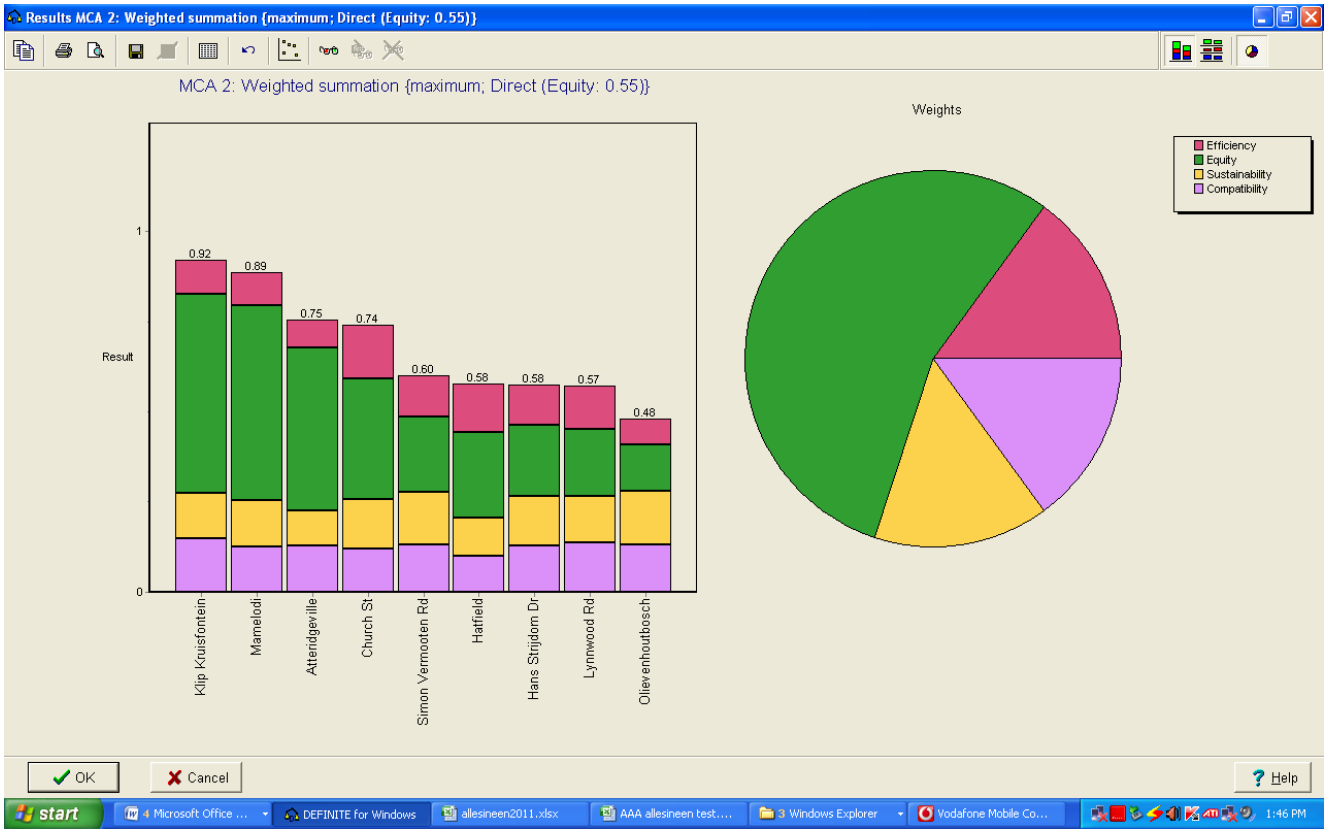


Figure 6-13: Project ranking with equity = 0.55, other criteria = 0,15 each

Finally, Figure 6-14 shows project ranking in the case of equal weights, but with the standardized scores for each criterion on each project shown separately.

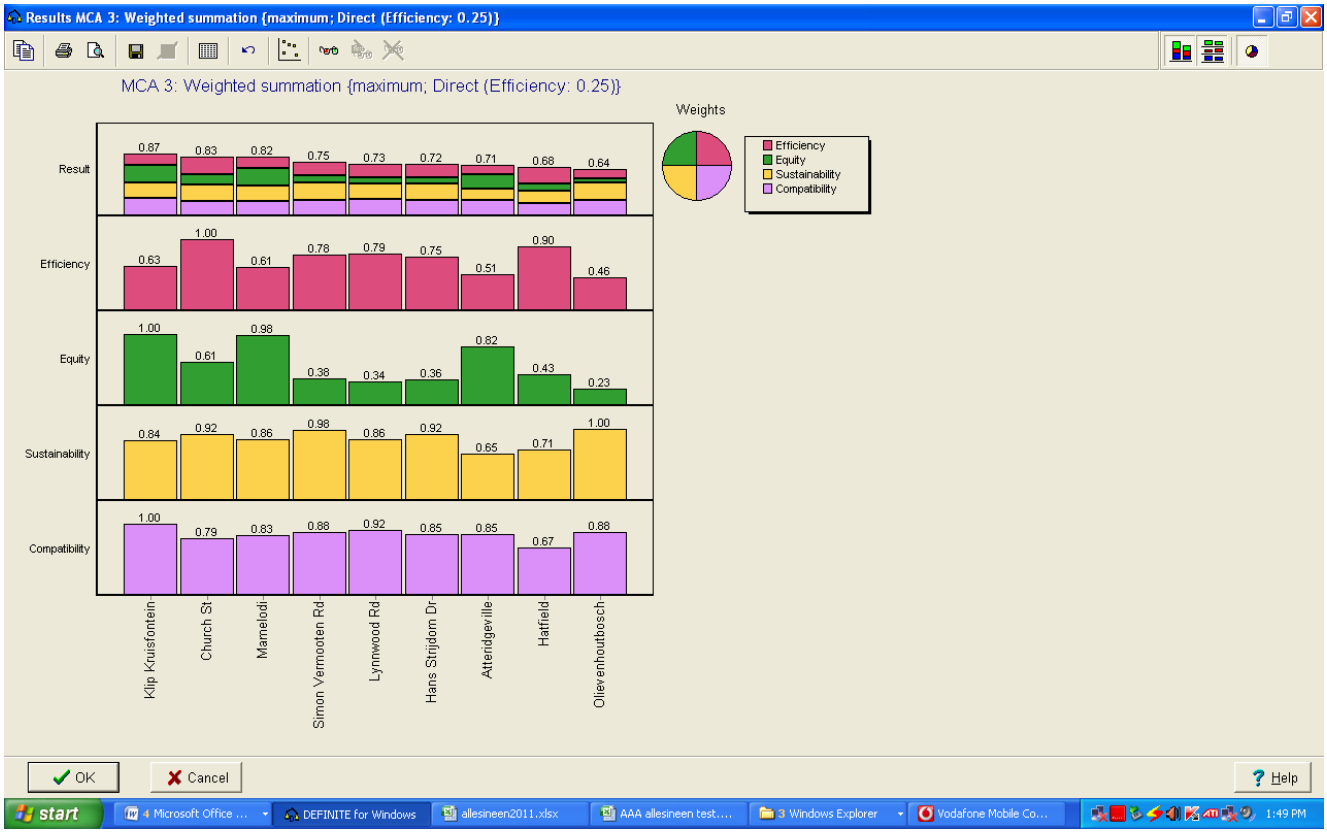


Figure 6-14: Project ranking (disaggregated) with equal weights

Further analysis of weight vectors for project ranking

The five graphs in Figures 6-15 to 6-19 depict total scores for different "perspectives". For "Total" (Figure 5-15), projects are ranked (on the top line) according to total scores for the selected weight vector (i.e. efficiency = 0,55, and other criteria having equal weights of 0,15 each). For "Perspective: Efficiency" (Figure 5-16), projects are ranked (on the second line) according to total scores for the weight vector efficiency = 0,5, with the other criteria having equal weights (i.e. 0,5 / 3). Likewise, for "Perspective: Equity" (Figure 5-17), the following weight vector is assumed: equity = 0,5, with the remaining criteria having equal weights. The same reasoning applies to "Perspective: Sustainability" and "Perspective: Compatibility" (Figures 5-18 and 5-19 respectively). In all cases, "total scores" are disaggregated according to the contribution to total score for each perspective, which is a function of the weight vector in each case.

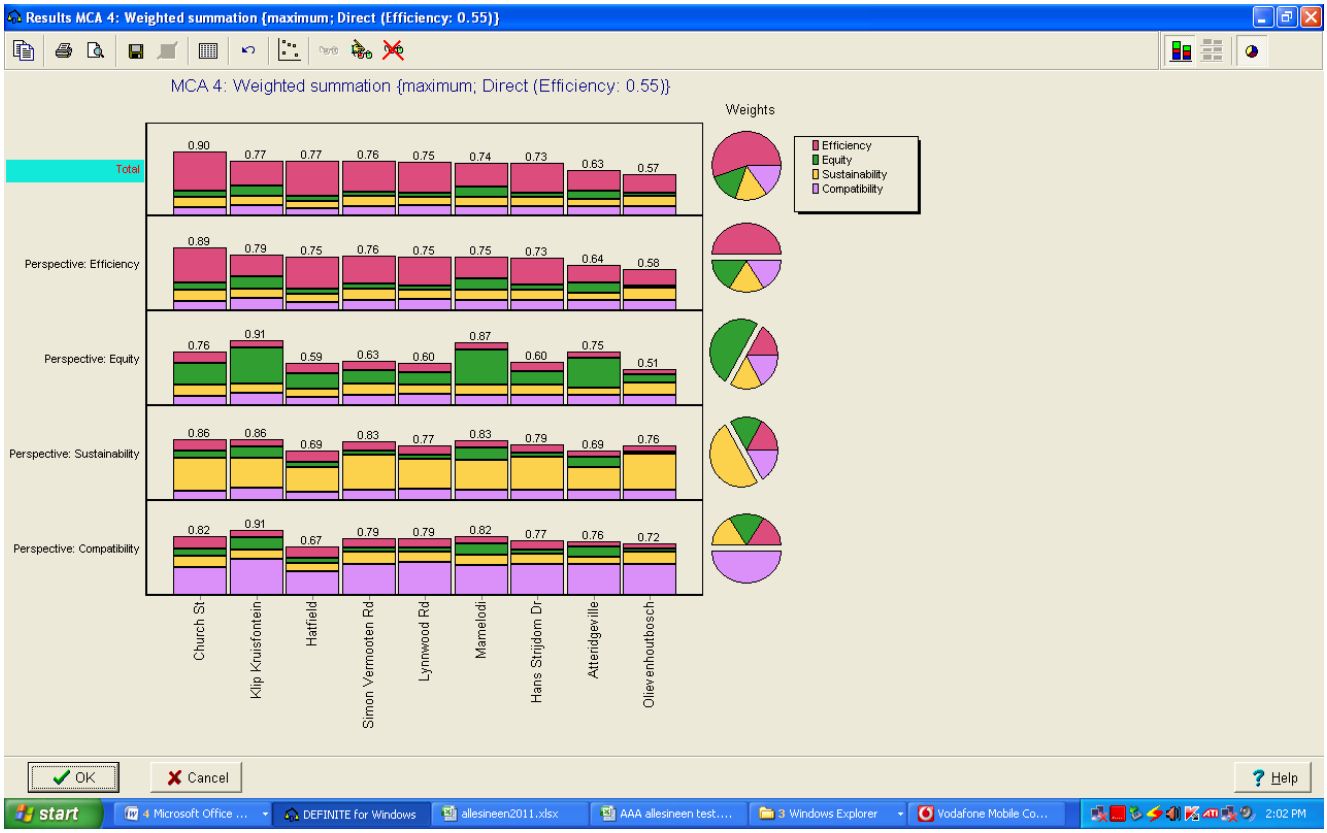


Figure 6-15: Perspective: Total (disaggregated)

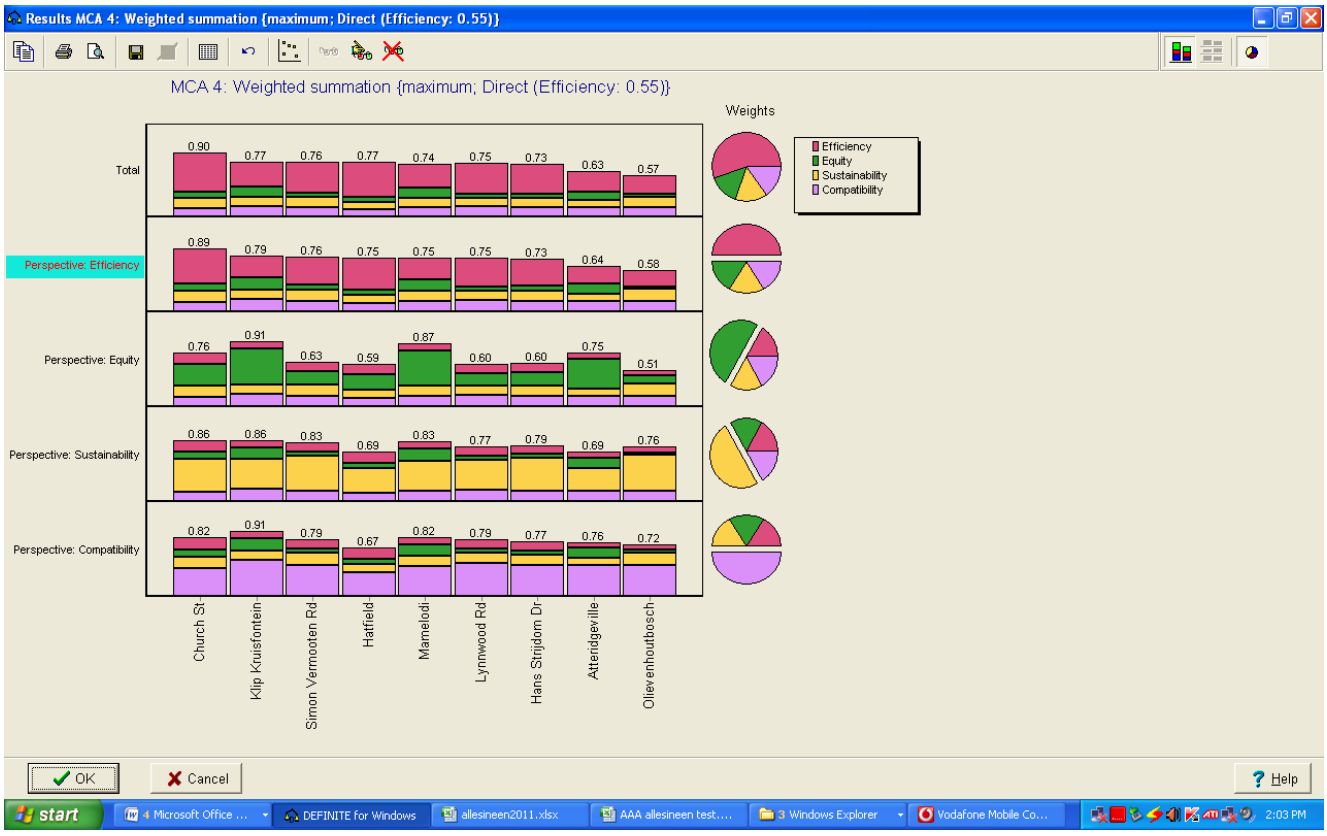


Figure 6-16: Perspective: Efficiency (disaggregated)

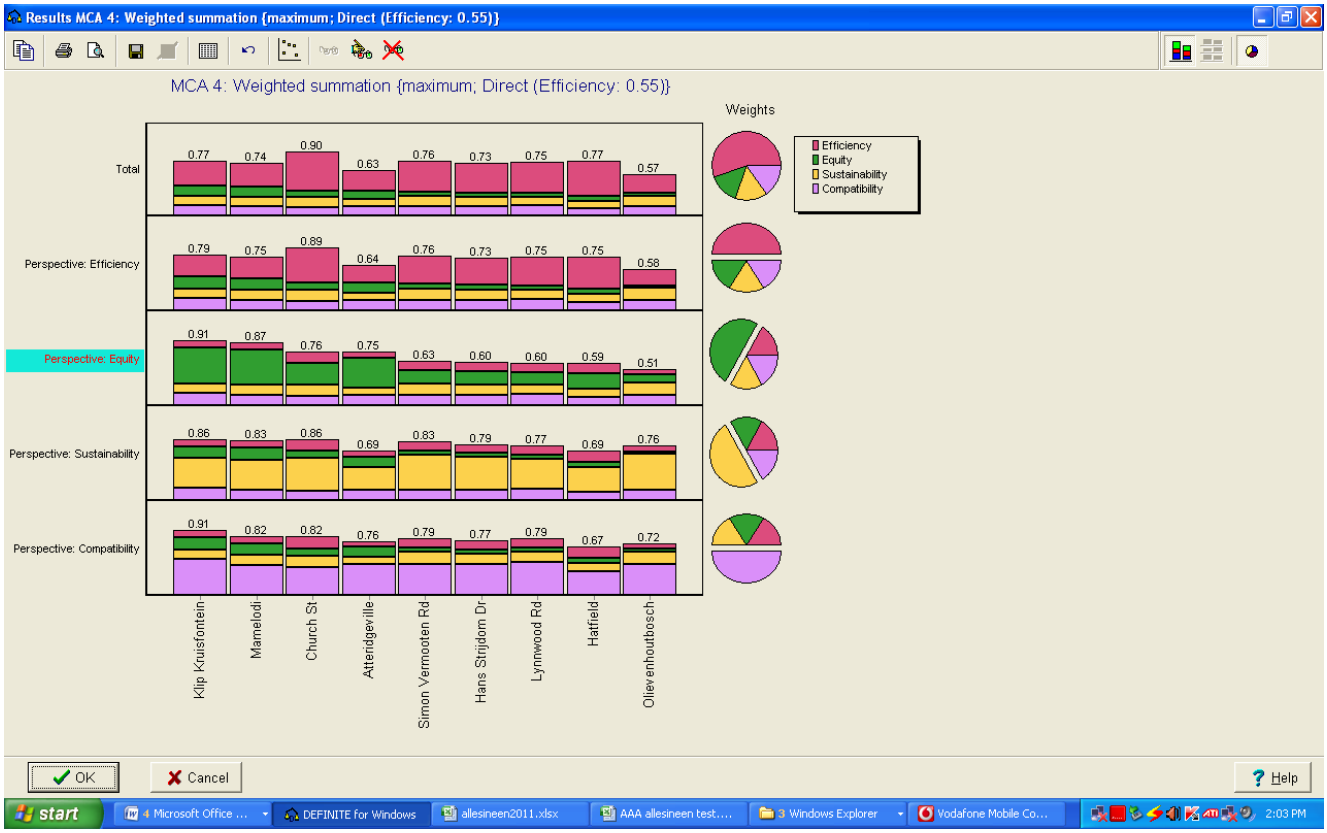


Figure 6-17: Perspective: Equity (disaggregated)

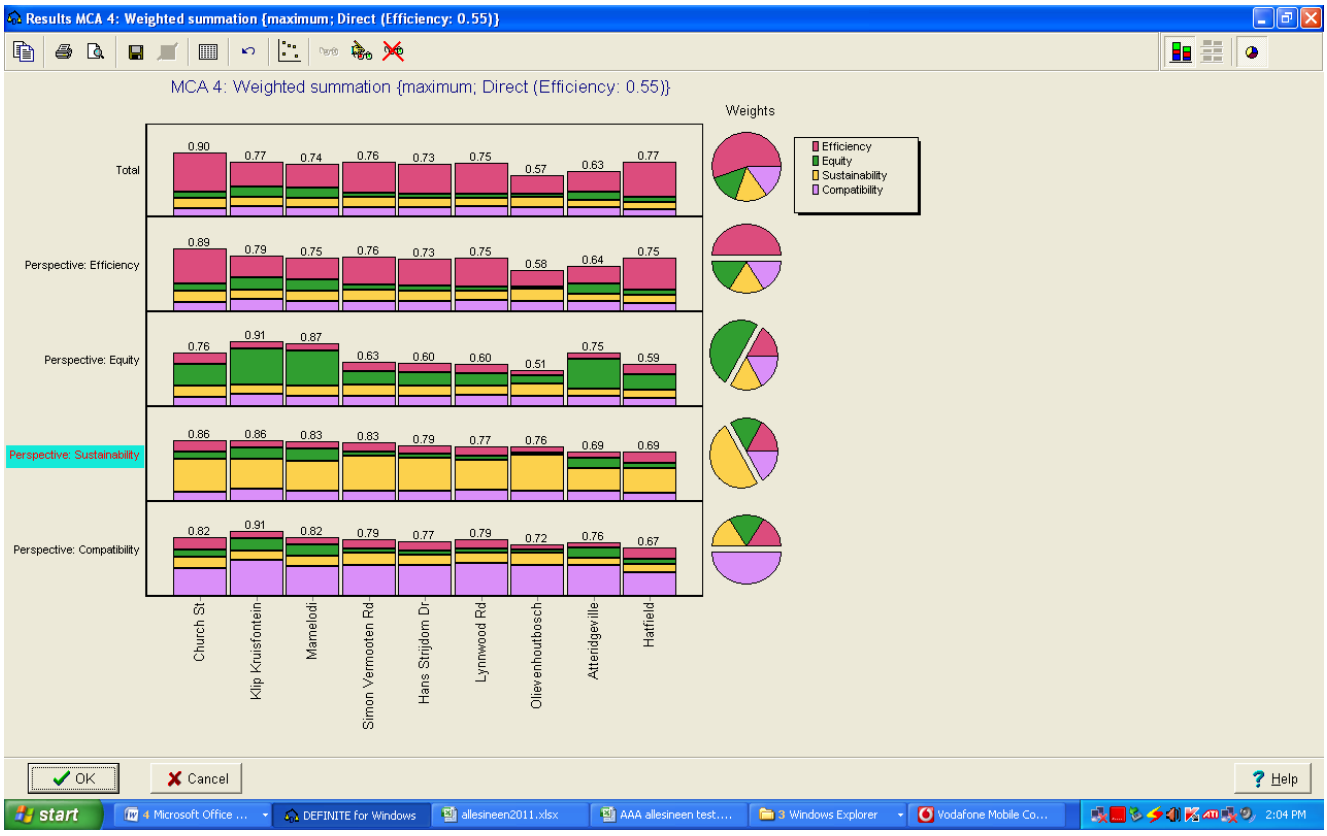


Figure 6-18: Perspective: Sustainability (disaggregated)

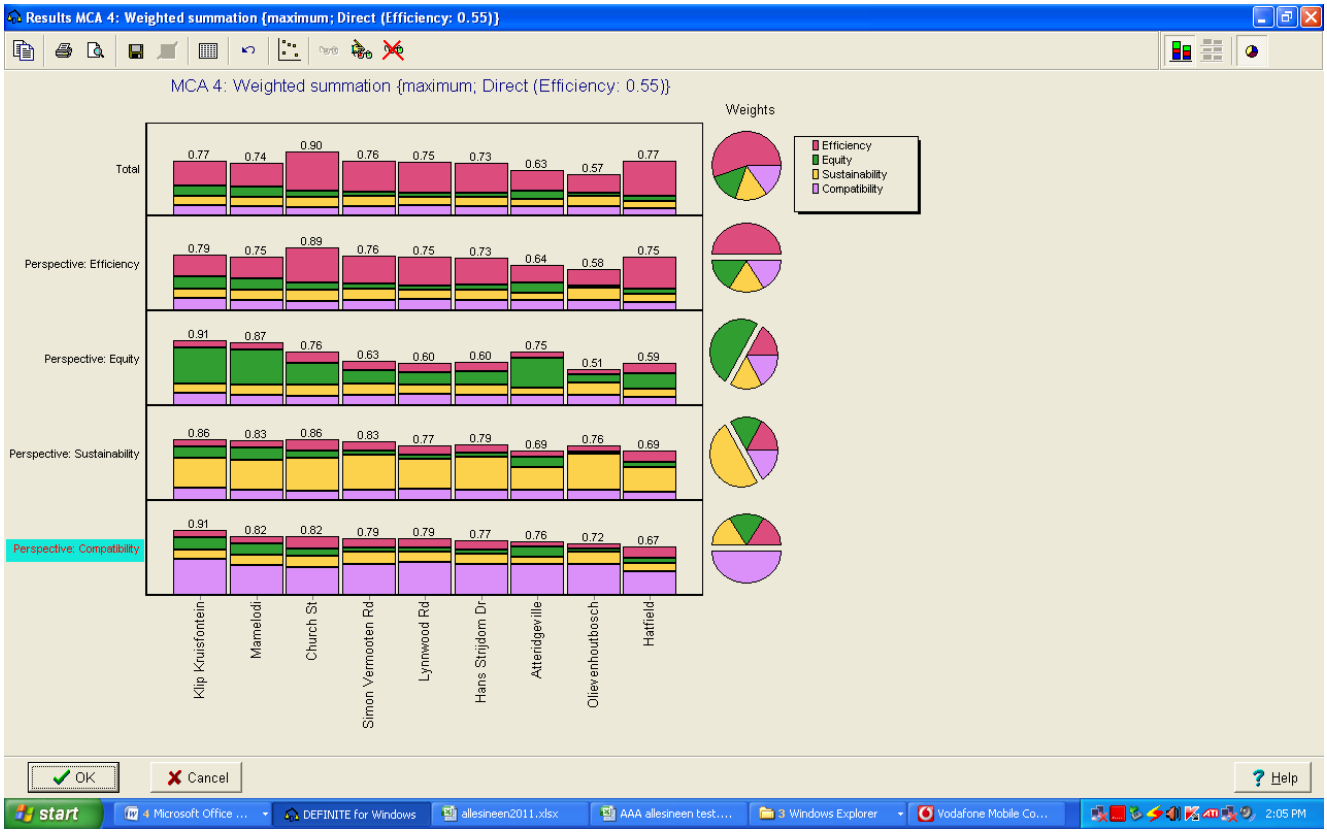


Figure 6-19: Perspective: Compatibility (disaggregated)

The graph in Figure 6-20 depicts the results of the "perspectives" analysis in a different (and most useful) format; it shows how project ranking changes with different perspectives. Project ranking is shown on the Y axis, and perspectives on the X axis, where:

- Result number 1 = "Perspective: Total".
- Result number 2 = "Perspective: Efficiency".
- Result number 3 = "Perspective: Equity".
- Result number 4 = "Perspective: Sustainability".
- Result number 5 = "Perspective: Compatibility".

For example, it shows that the Church Street project is dominant in three perspectives (namely "Perspective: Total", "Perspective: Efficiency" and "Perspective: Sustainability"). In both the remaining two perspectives, the graph shows that the Klip/Kruisfontein project dominates. On the other hand, the Olievenhoutbosch project ranks lowest in three of the five perspectives. On the remaining two perspectives, the Hatfield project ranks lowest.

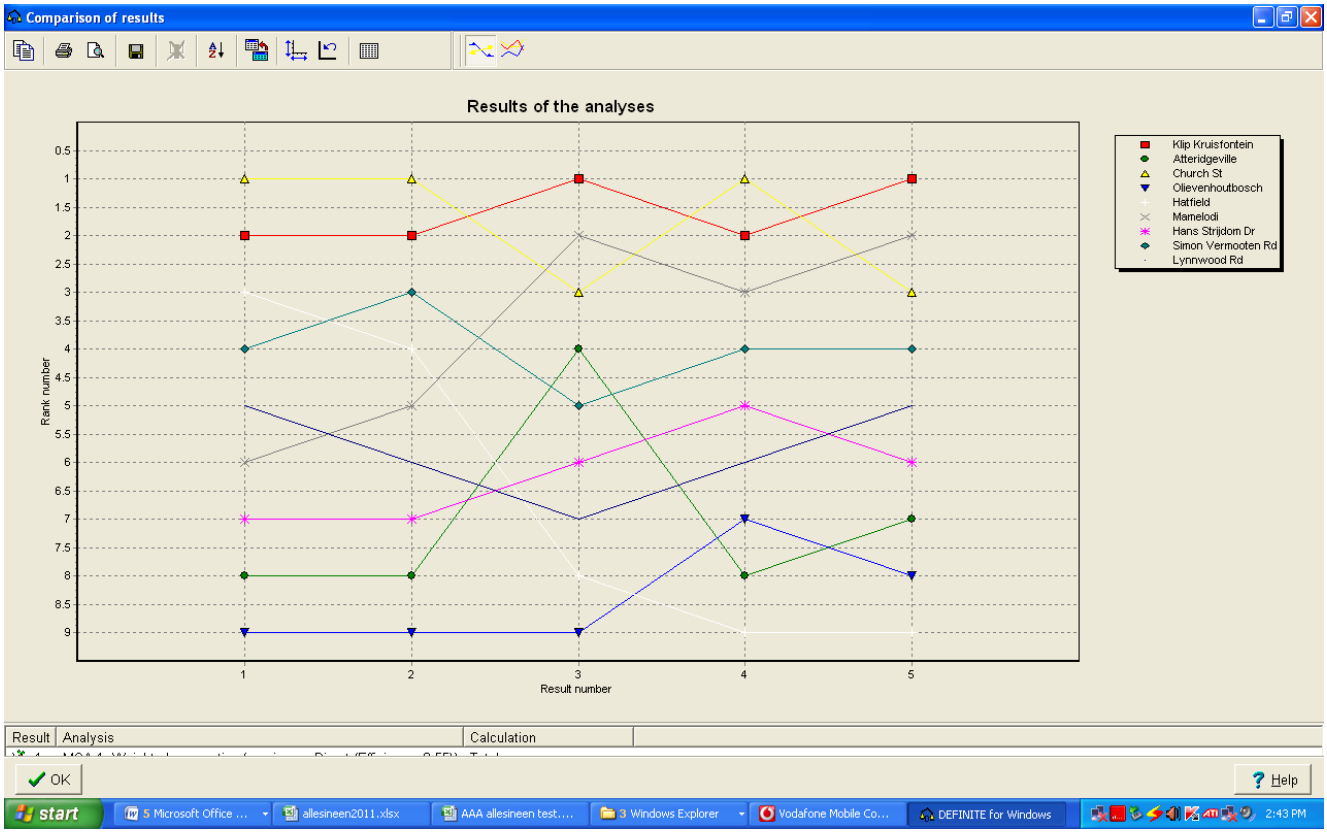


Figure 6-20: Project ranking for different perspectives (graph format)

6.7 Summary

This chapter focuses on the application of the appraisal framework developed in previous chapters to those CoT projects identified as "eligible" for appraisal in Section 5.5. This is done to demonstrate how the framework would affect project ranking and selection, and to indicate how currently available decision support tools could facilitate project appraisal and ensure better outcomes of the decision making process. To this end, the chapter revisits key aspects of the framework, and lists the relevant CoT projects. It discusses criteria for selecting a tool and explores key aspects of DEFINITE, the tool utilized for this purpose. The framework is then applied to both a set of mutually exclusive alternatives and a set of independent projects. It is argued that the framework, by using defendable decision criteria, is superior to the CoT methods currently used. The chapter deals with the dilemma facing the decision maker resulting from conflicting rankings in terms of the suggested decision criteria, and suggests how this could be addressed.

Revisiting key aspects of the framework

The appraisal framework developed in previous chapters for the type of CoT project addressed in this thesis (Category AB: Budget cycle type projects with local economic impacts only) is described as an MCA type approach of the value function kind with the following four decision criteria: (a) efficiency (focusing on the economic feasibility of the project, i.e. involving the optimal allocation of scarce resources), (b) equity (dealing with the income distribution impacts of the project), (c) sustainability (addressing "green issues"), and (d) compatibility (involving the "goodness-of-fit" of the project with stated goals and objectives, and key initiatives). CBA constitutes an element of the framework due to the fact that efficiency constitutes one of the decision criteria. In this regard it was argued that a partial equilibrium type approach (as opposed to a general equilibrium type approach) would suffice in the case of the kind of CoT project addressed in this thesis (namely "Category AB: Budget cycle type projects with local economic impacts only" (the "typical" case). The preference for "narrow CBA" rather than "broad CBA" was also substantiated. In addition, the need for a two-phased approach was argued, given the need to address both (the comparison of) mutually exclusive alternatives and (the ranking of) independent projects. Suitable performance measurement units for each of the various decision criteria were also suggested for use in intra-criterion performance measurement.

CoT projects considered for application

For the reasons given in Section 5.5, the following nine projects considered in this section for the purpose of applying the framework:

- Road infrastructure Klip/Kruisfontein.
- Collector road backlog: Atteridgeville.
- Doubling of Church Street over railway line.
- Olievenhoutbosch activity spine.
- Upgrading of road network in Hatfield.
- Collector road backlog: Mamelodi.
- Improving of Hans Strijdom Drive (west).
- Doubling of Simon Vermooten Road.
- Doubling of Lynnwood Road.

Criteria for selecting decision support tools

Decision support tools are important for facilitating the appraisal process and improving the quality of decision making outcomes. A number of criteria should be considered in selecting a decision support tool for the purpose of applying the framework, namely (a) simplicity; (b) cost; (c) hardware requirements; (d) access and maintenance; (e) visual images; (f) specificity; (g) versatility/flexibility; (h) compatibility; (i) transparency; and (j) scientific rigour.

Background to DEFINITE

DEFINITE (derived from "**DE**cisions on a **FINITE** set of alternatives") is a decision support software package developed to improve the quality of decision making. It was developed by the Vrije Universiteit of Amsterdam in the Netherlands. It has a wide variety of users, in both the public and the private sector.

DEFINITE terminology and procedures

In a number of instances, the terminology used by DEFINITE differs from that used in this thesis. For example, DEFINITE refers to "alternatives" whereas "option", "project", "mutually exclusive alternative" and "independent project" are used in the thesis. Other examples are "tree structure" instead of "decision tree" (or "value tree"), "effect" instead of (decision) criterion, "effects table" instead of "evaluation matrix", and "standardization" (of scores) instead of "normalizing". Also, alternatives are normally listed vertically (in the left hand column) and criteria horizontally (in the top row) in the evaluation matrix; whereas DEFINITE does it the other way round.

Application of framework to mutually exclusive alternatives

In applying the framework to mutually exclusive alternatives, attention was firstly focused on the requirement that feasible alternatives should be separated from infeasible alternatives and that the latter should be removed from the analysis. To demonstrate this, a set of mutually exclusive alternatives was assumed for one of the nine projects listed above, namely the "Collector road backlog in Mamelodi". Assumptions made for this purpose were justified. It was shown that, of the original six alternatives, two need to be excluded from the list, namely Alternative 2 (as it is not feasible in terms of all the decision criteria considered) and the null alternative (as it is dominated by all remaining alternatives). In general, there are three possibilities regarding any given set of mutually exclusive alternatives: (a) all alternatives are feasible in terms of all criteria – in this case, all alternatives should be subjected to ranking in order to determine the best, for inclusion in the list of independent

projects; (b) only some alternatives are feasible in terms of all criteria – in this case, infeasible alternatives should first be excluded from the appraisal before the remaining (feasible) alternatives are ranked; (c) no alternatives are feasible in terms of all criteria – this implies a no-go situation for the purpose of appraisal, as the null alternative should remain the status quo. Also, when infeasible alternatives have been identified and removed from the analysis, only feasible alternatives will remain which, by definition, will all be superior to the null alternative, and the latter can also be removed from the analysis.

It was demonstrated how "conflict" that might arise between alternatives could be resolved if there is no single alternative preferred in terms of all criteria. The final ranking of a set of mutually exclusive alternatives is a function of the relative importance attached to the decision criteria, which underlines the importance of the input of politicians as key stakeholders in the process.

Application of framework to independent projects

This involves three aspects; input data, challenges facing the decision makers, and ranking projects.

Attention first focused on the *input data* needed to demonstrate the application of the framework; or rather, on justifying assumed input values, given the lack of actual data. Input data involve the values (scores) needed for project performance in terms of efficiency (Eff IRR), equity (Eq B/C ratio), sustainability (index), and compatibility (index). The logical starting point was efficiency; for this the cost breakdowns for the relevant projects in the ITP document, were used to calculate the "present worth of total causal cost" for each project. The values obtained in this manner were then used as inputs in assuming values for the present worth of savings in recurring cost for each project. This enabled efficiency parameters to be determined for each project. Equity scores were derived from efficiency scores, considering the marginal utility of income (expenditure), which is a function of income group. In the case of sustainability and compatibility, no performance data were available, and values were chosen in such a way as to best demonstrate key aspects of the framework.

Given these assumed input values, *challenges facing the decision maker* in ranking projects were highlighted. For example, it was shown that there is no single project indicated best in terms of all four criteria; also, different rankings are obtained, as shown in the case of (for example) efficiency and equity. Despite these challenges, it is argued that the framework, by considering a set of defendable decision criteria, is superior to the current methods used in

CoT, namely the ITP (functional or departmental) and IDP (process-related) prioritization process – neither of which is defendable in terms of the framework. Although it is accepted that both the ITP and IDP objectives are valid, they arguably are not the only ones to be considered. An exclusive focus on functional (engineering) aspects (ITP approach) by definition means that other important criteria – such as those considered in the framework (namely efficiency, equity, sustainability and compatibility) – are excluded. The way in which functional/technical considerations are accommodated in the framework is by requiring that all mutually exclusive alternatives should first be screened for "technical feasibility". These technically feasible alternatives must then be subjected further to other "types" of feasibility analyses, such as efficiency, equity, etc. The objective of "municipal priority areas" (IDP approach), on the other hand, is accommodated in the framework by the introduction of the decision criterion "compatibility".

Regarding the *ranking of projects*, it is shown that the relative importance of decision criteria is critical in making a "trade-off" between projects. This underlines the importance of the weight vector in the analysis, to be used for all projects, and for both the comparison of mutually exclusive alternatives and the ranking of independent projects. It also underlines the critical role of decision makers – to articulate the goals and aspirations of the community they represent, and to present this in the form of a set of weights.

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

Key aspects of this thesis, expounded in more detail in Chapter 1, are recapped below in order to set the scene for the ensuing sections of this chapter.

Problem statement

Given the study context, described in terms of both theory and the CoT situation, the problem addressed in this thesis can be described in terms of four aspects: (a) the diverse nature and extent of project impacts; (b) the role and limitations of traditional appraisal methods; (c) limitations of the current CoT project prioritization procedures; and (d) the emerging use of IT in the public sector.

Research need

CBA, with its initial focus on economic efficiency, was traditionally accepted and used as the tool for project appraisal. However, given the diverse nature and scope of investment in transport infrastructure, its suitability is questionable to the extent that it focuses on allocative efficiency only. Moreover, attempts to broaden its scope to include other objectives, such as equity, have been met with criticism from some quarters. In the meantime, MCA – from the domain of operational research – has been mooted as a tool for project appraisal, but it also has its critics. This aside, its application at a practical level needs to be explored; in particular, the set of decision criteria appropriate to CoT needs to be identified and intra-criterion performance measurement needs to be examined, specifically the choice of appropriate measurement units in each case.

From the practical perspective of the transport authority, on the other hand, it is argued that a method is needed to rank projects in terms of their total worth, so that project selection can then start from the project with the highest priority (namely the project with the highest project worth), proceeding down the list until available funds are depleted. This need to prioritize projects follows from the fact that the total cost of implementing feasible projects almost always exceeds available funds. In the specific case of the CoT, problems regarding project appraisal are evident from the fact that different methods of project ranking – none of which is defensible – are used, sometimes resulting in rankings that are contradictory. All of this points to the need for an appraisal framework that accommodates the diverse nature of project impacts as well as the specific decision making environment of the CoT. Also,

application of the framework at a practical level, using appropriate decision support software that could potentially improve the quality of decision making, needs to be demonstrated.

Study objective

The overall objective is to develop an appraisal framework for TI projects in the municipal sphere of government in South Africa, with reference to the CoT. To this end, three sub-objectives are relevant:

- *Sub-objective 1:* To develop a basic approach that combines the best elements of traditional methods, taking into account the diverse nature and scope of the impacts of TI projects.
- *Sub-objective 2:* To customize this basic approach to the CoT decision making context.
- *Sub-objective 3:* To apply the appraisal framework (i.e. the basic approach, customized to the CoT decision making context) to projects in the CoT environment, in order to demonstrate the application of the framework at a project level and the implications thereof, as well as the potential of decision support software for improving the quality of decision making and ensuring better governance outcomes.

Study method

The study method involved five functional steps: (a) overview of traditional methods; (b) overview of MCDM; (c) developing the basic approach; (d) customizing the basic approach; and (e) applying the framework.

7.2 Final summary

The thesis is summarized below in terms of the five functional steps which constitute the study method as described above.

7.2.1 Overview of traditional methods

Traditional methods of project appraisal that were explored as part of the literature survey were: (a) CBA; (b) general equilibrium analysis; and (c) spatial models. Key aspects of these methods were explored in order to set the scene for the remainder of this thesis; in particular, to justify their role in an appraisal strategy. These aspects are summarized below.

CBA

Context and objective: CBA (also termed Social Cost-Benefit Analysis) originated when the concept of consumers' surplus was linked to the net gain to communities from government projects. It is rooted in welfare economic theory and aimed at ensuring that a project contributes towards the goal of economic efficiency (defined as the maximization of social welfare – or the collective material wants of individuals – within the constraints imposed by the scarcity of resources). The distinction between a "pure" and a "potential" Pareto improvement is important; in practice, however, the latter mostly applies – this means that equity considerations are excluded from the analysis. To determine whether a project will bring about a Pareto improvement (whether pure or potential) requires benefits and costs to be correctly valued; benefits should be valued in terms of the willingness-to-pay concept, and inputs (costs) in terms of opportunity costs. A comparison between CBA (applied in the public sector) and its private sector equivalent (financial analysis) highlights important differences, such as the fact that social welfare (welfare impacts) includes all the consequences that a project has for the social milieu of a human being.

Aspects not included in CBA: The following aspects are traditionally excluded from CBA: (a) sunk costs; (b) transfer payments; (c) land prices; (d) impacts relating to the financing decision; (e) depreciation; (f) transmitted impacts; and (g) regional development.

Mutually exclusive alternatives and independent projects: The former are defined as alternative options for accomplishing a stated objective. The latter relate to different (unrelated) objectives to be accomplished.

Project evaluation, ranking and selection: Project appraisal includes both the evaluation and the ranking of technically feasible projects. The former involves the comparison of mutually exclusive alternatives, and the latter the ranking of independent projects. The completion of both is a prerequisite for project selection.

Analytical procedures: A project is deemed feasible if discounted benefits over the analysis period exceed discounted costs (or are at least equal to discounted costs). Six techniques are commonly used to establish this; they are all based on the principle of discounted cash flow analysis (DCFA), meaning that the time value of money is taken into account. These techniques can be classified under three headings. The *least cost approach* makes use of the Equivalent Uniform Annual Cost (EUAC) technique and the Present Worth of Cost (PWOC) technique. The *maximization of net benefits approach* can be split into two parts:

(a) difference between costs and benefits, involving the Net Present Value (NPV) technique and the Equivalent Uniform Annual Net Return (EUAR) technique, and (b) the ratio between benefits and costs, involving the Benefit/Cost (B/C) ratio. The *investment approach* involves the Internal Rate of Return (IRR) technique. When mutually exclusive alternatives are compared, all six techniques will give the same answer if applied correctly. When independent projects are compared, only the B/C technique and the IRR technique can be used, as the other four techniques do not accommodate difference in scale between projects.

Narrow and broad CBA: The impacts of TI projects can be classified in different ways, for example according to affected party, distinguishing between: (a) the operator (transport authority); (b) users of the facility; and (c) non-users. Contrary to this approach, *narrow CBA* is defined as involving only tangible impacts which, in the case of TI projects, translate into total transport cost, consisting of road agency costs (comprising the cost of constructing and maintaining road infrastructure) and road user costs (comprising vehicle operating cost, collision cost and travel time cost). Total transport cost can also be disaggregated into initial cost and recurring cost; or intervention cost and (resulting) impacts. Narrow CBA can be broadened in two ways: by including in the analysis (a) less tangible impacts; and/or (b) objectives other than efficiency (e.g. equity, through the use of weights). Regarding the role of decision makers, the conventional school of thought favours narrow CBA, viewing CBA as just one input into the decision making process, whereas the “decision making” school of thought supports broad CBA, viewing it as encapsulating most, if not all, of the process.

Application of CBA: Project impacts can be local or external. This means that CBA applications could be classified in terms of two attributes: (a) definition of benefits; and (b) scope of CBA. These CBA applications can also be related to different projects categories (and appraisal contexts).

CBA and road infrastructure management: In addition to CBA being used as a stand-alone tool, it can also be viewed in the context of “road infrastructure management” which is aimed at managing the entire road network as a national asset. A road management system (RMS), defined as a computer-based system for facilitating road management, is instrumental in accomplishing this, but needs to be supplemented by other tools to address specific objectives. HDM-4 and the RED model are examples of such tools. They can be classified into eight groups: (a) comprehensive tools for road management; (b) tools focusing on accessibility, poverty alleviation, community participation; (c) tools developed in response to stakeholder requirements for feedback/information; (d) tools aimed at economic efficiency

in resource allocation; (e) tools suited for multiple criteria decision making; (f) tools aimed at road cost recovery; (g) generic planning tools; and (h) tools aimed at improving organizational efficiency.

Highway Development and Management model (HDM-4): HDM was initiated by the World Bank in 1968 with a focus on the analysis of design specifications and maintenance options. It is a world-wide tool for application at different levels: (a) the technical and economic appraisal of road *projects*; (b) the preparation of road investment *programmes*; and (c) the analysis of road network *strategies*. In addition to predicting road deterioration over time and road user effects, it also predicts road user cost, and social and environmental effects. The latter (social and environmental effects) comprise vehicle emissions, energy consumption, traffic noise and other welfare benefits to the population served by the roads. Improvements to HDM-4 Version 2.0 (relative to the previous version 1.3) fall in four areas: (a) new analysis tools; (b) usability; (c) connectivity with external systems; and (d) reporting. New analysis tools include Multi Criteria Analysis (MCA), sensitivity analysis, budget scenario analysis and asset valuation.

Roads Economic Decision model (RED): RED was developed by the World Bank in the late 1990s, in response to the need for a tool for economic analyses in the case of low volume roads. Requirements for such a tool were that it should be less data-intensive than HDM-4, and be able to consider other costs and benefits such as those associated with non-motorized traffic, social delivery and the environment.

Results from ex-post evaluations: The post-completion evaluation of projects is important as it provides information on: (a) how effectively stated objectives were met; (b) how effective the project evaluation methods were; and (c) how efficient the project implementation process was. A recent study involving a number of major infrastructure projects from around the globe focused on the “megaproject paradox” (i.e. the increase of these projects in terms of magnitude, frequency and geographical spread, in spite of their poor performance), and identified reasons for project failure. Four reasons for project failure were indicated: (a) cost overruns, (b) over-optimistic demand predictions, (c) the fact that the extent and magnitude of actual environmental impacts are often very different from predicted forecasts, and (d) the fact that regional, national and international development effects often do not materialize or are too diffuse to be detected.

General equilibrium models

General equilibrium (GE) models constitute an extension of and supplement to CBA in the case of large projects under certain conditions. CBA focuses on "local" (first round) impacts, addressing projects in a micro-economic sense, constituting a partial equilibrium (PE) analysis, and providing a single measure of project worth (e.g. B/C ratio and variations thereof). In contrast, GE analysis focuses on economy-wide impacts, addressing a project in a macro-economic sense, and providing a number of "indicators" such as impact on private consumption, investment, exports, imports, inflation, total GDP and GDP on an industry by industry basis. Whilst CBA does provide a clear "accept/reject" rule; GE analysis does not do this directly. GE analysis involves a number of models and approaches, as listed below.

I/O models: An I/O table is a summarized version of all transactions that took place between the main economic stakeholders in a particular year, breaking them down by the main sectors of the economy, thus showing the interdependence of sectors within an economy by calculating the relevant multipliers and leakages.

Social Accounting Matrix (SAM): A SAM builds on the I/O table and can be regarded as an extension thereof. They can be designed with a special emphasis on social rather than economic attributes. In doing this, they also provide information about equity and distribution issues.

Computable General Equilibrium (CGE) models: CGE models predict consumer and producer behaviour more realistically than I/O tables and SAMS. This is achieved by modelling their reactions to changes in market conditions such as price.

Economic impact analysis: An economic impact analysis examines the nature and distribution of secondary economic impacts and outcomes that traditionally fall outside the scope of CBA. This is done by studying changes occurring across broadly defined sectors of the economy, with the intent of ascertaining who gains and who loses as a result of the project, and by how much.

Spatial models

In addition to considering total project impacts, it is also important to analyze impacts from a spatial perspective (i.e. their geographical distribution). There are two reasons for this: (a) project impacts are not normally "spread out" evenly over the study area, and (b) zones (regions) differ in terms of their socio-economic profiles. Spatial analysis allows decision makers to ensure that benefits "reach" identified target groups, e.g. lower income groups

and, in so doing, to meet policy objectives and criteria in this regard. This is particularly important as a “pure Pareto” scenario does not address the objective of a fair distribution of positive project impacts between affected parties (and, by implication, between affected regions).

The seven models/approaches examined can be classified into three groups, according to the dominant discipline involved (although a clear-cut distinction is not always possible): (a) CGEurope, REMI and TREDIS can be termed economic models; (b) SASI, IASON (which builds on SASI) and MEPLAN can be termed spatial planning models; and (c) DELTA can be described as eclectic, building on, amongst others, urban and regional economics, geography, and sociology.

7.2.2 Overview of MCDM

A synoptic overview of MCDM (exploring key concepts without indulging in technical (mathematical) detail) is necessary as the nature and impacts of TI projects point to the fact that their appraisal essentially takes place in a multiple objective decision making environment, requiring an “MCA-type” approach to be adopted. In providing this overview, reference is made to the CoT case where necessary. Key aspects are summarized below.

MCDM context

Basic notion: Decision making is difficult for a number of reasons: (a) the interests and expectations of decision makers may differ; (b) uncertainty may prevail; (c) decision makers may be confronted with multiple, conflicting objectives; and (d) stakeholders may have different perspectives.

Defining MCDM: MCDM can be defined in different ways, e.g. the process of decision making in contexts where a substantial conflict between objectives exists. It can also be seen as an umbrella term, including a number of divergent schools of thought that have developed over time. Although mostly presented in the context of mutually exclusive alternatives, MCDM applies to both mutually exclusive alternatives and independent projects.

MCDM applications: MCDM has (at least) five applications: (a) discrete choice problems; (b) multi-objective design problems; (c) mixed design and evaluation problems; (d) project evaluation, prioritization and selection; (e) classification of alternatives. The last two of these applications are particularly relevant in the CoT case.

Typologies and classification of MCDM contexts: MCDM applications could be grouped according to seven *"problematiques"* (problem contexts), namely: (a) the choice; (b) the sorting; (c) the ranking; (d) the description (or learning); (e) the design; and (f) the portfolio problematique, MCDM problem contexts can also be classified according to their *characteristics*: (a) one-off versus repeated problems; (b) number of stakeholders involved; (c) status and influence of the client; (d) the relevant "problematique"; (e) the range of available alternatives; (f) facilitated versus "do-it yourself" analysis. The "CoT case" involves three problematiques: the sorting, ranking and portfolio problematique; and it is characterized as (a) one of repeated problems; (b) a large number of stakeholders constituting three main groups; (c) that Council would be the final decision maker; (d) that Council typically is confronted by a finite, relatively large number of alternatives which, in total, exceed available funds; and (e) MCDM should preferably be conducted by external consultants with a proven track record.

The role of MCDA in decision making: MCDM can facilitate decision making in a number of ways: by accommodating multiple, conflicting data, by structuring the problem, by providing a focus and language for discussion, by helping decision makers learn about the problem situation, their own values and those of others, by guiding them in identifying a preferred course of action, by complementing and challenging intuition, and by providing an audit trail for a decision. On the other hand, though, the following is often incorrectly believed about MCA: (a) it will give the right answer; (b) it provides an objective analysis that relieves decision makers of the responsibility of making difficult judgments; and (c) it takes the pain out of decision making.

The MCDM process: MCDM typically does not present itself as a well-defined set of alternatives and criteria, leaving the decision maker to merely focus on the evaluation of alternatives. Although not a structured process, it nevertheless involves the following stages: (a) the identification of a problem or issue, (b) problem structuring, (c) model building, (d) using the model to inform and challenge thinking, and (e) determining an action plan. These stages can be grouped into three key phases: (a) the problem identification and structuring phase; (b) the model building and use phase; and (c) the development of action plan phase.

Stakeholders in the MCDM process: Stakeholders differ in terms of type and role: The *decision maker* has the responsibility for the decision to be made. The *facilitator* guides and assists the decision maker by managing group processes. The *analyst* works independently and gathers information required by the process and captures expertise that adds value to it.

The *client* contracting the facilitator/analyst may or may not be the final decision maker, but could also be a person or group given the responsibility of exploring the issue and making recommendations; alternatively, the client may be one of several stakeholder groups.

Ranking and rating: Ordinal importance refers to the order of importance of decision elements (e.g. first, second). *Cardinal importance* refers to the difference in magnitude between the importance of any two decision elements (e.g. one element is three times more important as another). *Ranking* refers to the process of assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made. With r*ating,* decision elements are assigned scores between 0 and 100. In the case of ranking, a distinction is also made between *regular* and *ordinal* ranking; both have advantages and disadvantages. Ranking provides a measure of the ordinal importance of decision elements; rating provides a measure of both ordinal and cardinal importance.

Instrumentally rational behaviour: The notion of ”instrumentally rational behaviour” holds a central position in almost all decision making techniques. In making choices, a person (or group of decision makers, as would be the case for CoT) is deemed instrumentally rational if he has preferences that satisfy four axioms relating to reflexivity, completeness, transitivity and continuity. When the first three of these axioms hold, a person has a well-defined preference ordering. If the continuity axiom also holds, the preference ordering can be represented by a utility function.

Models for representing preferences: All models contain two primary elements: (a) preferences in terms of each criterion (i.e. intra-criterion comparisons), and (b) an aggregation model (i.e. inter-criteria comparisons). With *value function models* (also known by various other names), a single, unique numerical score representing “project worth” is constructed for each alternative, to represent the degree to which any one alternative is preferred to another. With the *outranking approach*, generally applied to discrete choice problems, a pairwise comparison of alternative courses of action (alternatives) is conducted in terms of each criterion first in order to determine the extent to which a preference for one over the other can be asserted. *Satisficing models* (also known as goal programming and reference point methods) attempt to establish desirable or satisfactory levels of achievement for each of the criteria, and then to discover options which are in some sense closest to achieving identified desirable goals or aspirations.

Value function models

This type of model is deemed most appropriate to the CoT context as it allows the ranking of projects. It can be described in terms of seven steps. AHP and SMART are important tools in the context of value function tools, as is the treatment of uncertainty.

Step 1: Identifying and structuring the problem: This is aimed at ensuring a common understanding of the problem, the decision to be made, and the relevant decision criteria.

Step 2: Identifying alternatives: In order to ensure that opportunities are not missed out, *all* alternatives must be included in the analysis. As the evaluation of mutually exclusive alternatives precedes the ranking of independent projects, the set of mutually exclusive projects (including the null alternative) must be a *complete* set, containing *all* options for addressing an identified problem/need. *Value-focused thinking* is important in identifying *good* alternatives, as is the correct *scoping of the problem*. Regarding independent projects, there are three possibilities: they may be completely independent; or any two or more may have positive or negative synergy.

Step 3: Identifying decision criteria: A (decision) criterion is a particular point of view or interest according to which alternatives are compared. Decision criteria have to comply with eight requirements: (a) value reference; (b); understandability; (c) measurability; (d) non-redundancy; (e) judgemental independence; (f) balancing completeness and conciseness; (g) operationality; and (h) simplicity versus complexity. A value tree (or decision tree or ranked tree) is a hierarchical presentation of decision criteria. It may be desirable in some cases, and can be developed in a *top-down* and/or a *bottom-up* manner. Criteria for developing a value tree are: (a) completeness; (b) operationality; (c) decomposability; (d) absence of redundancy; and minimum size.

Step 4: Determining inter-criteria preferences: This involves establishing the relative importance to be attached to each decision criterion. A number of methods could be used for this purpose, such as: (a) intuitive methods; (b) revised Churchman-Ackhoff technique; (c) Zeleny's entropy method; (d) swing weighting; and (e) the Analytical Hierarchy Process (AHP).

Step 5: Measuring intra-criterion performance: This involves defining partial (or utility) functions for each criterion to reduce performances in the [0-1] interval. It involves both *scoring* alternatives and *standardizing* scores. In scoring alternatives, an appropriate scale

for each criterion must be selected, and two reference points (maximum and minimum) must be assigned to this scale, using for example a local scale or a global scale.

Step 6: Aggregating scores across criteria: This step involves calculating a single numerical score representing "project worth" for each alternative, to represent the degree to which any one alternative is preferred to another.

Step 7: Examining sensitivity of the results: Sensitivity analysis aims to establish if the preliminary results of the analysis are robust, or if they are sensitive to changes in certain aspects of the model, such as score(s) and/or weight(s). Sensitivity analysis can be viewed from three perspectives: (a) the technical perspective; (b) the individual perspective; and (c) the group perspective

SMART and AHP: These are important in the context of value function models. SMART (first described by Von Winterfeldt and Edwards in1986) is a collection of techniques rather than a single process, the main commonality between techniques being their reliance on direct numerical estimation methods. AHP is a method of MCDA (or MCDM) developed by Saaty in 1980, based on the pairwise comparison of criteria and of alternatives.

Dealing with uncertainty: Uncertainty is, to a lesser of greater extent, inherent in most decision making situations. It may arise for different reasons and can take on different forms. It can be managed, but not eliminated. Both internal and external uncertainty is important. Options for addressing uncertainty include: (a) scenario planning; (b) decision theory; and (c) treating risk as a decision criterion.

7.2.3 Developing the basic approach

As noted in Section 1.5, project selection in the case of the local impact, budget-type context in road authorities requires feasible projects to be ranked in terms of total worth. Two opposing (fundamentally different) methods were presented for this purpose, namely broad CBA (in Chapter 2) and MCDM (in Chapter 3). This section explores their role (if any) in the suggested basic approach. To this end, attention was focused on a number of aspects discussed below.

Broad CBA versus MCA: There are key differences between the two methods for determining total worth, (broad CBA and MCA). With broad CBA, all impacts are expressed in monetary units and project worth is expressed as "social welfare". With MCA, project

worth is expressed as a single MCA metric, and weights are used to reflect the relative importance of impacts.

Examining project impacts: This was important in order to ensure the correct approach in considering economic impacts in the proposed appraisal framework (in particular the choice between a CBA and a general equilibrium type approach), and also to explore the whole spectrum of impacts for further consideration in Chapter 5. It also constitutes the first step of a "bottom-up" approach to building a decision (value) tree as opposed to a top-down approach. Is has been argued that these approaches should be used in parallel because they are complementary and inform each other, thus ensuring a complete array of decision criteria.

Impacts of municipal projects: In quantifying impacts, one needs to note the *temporal (time) dimension of impacts and their spatial distribution,* as well as the characteristics of affected parties. A number of problems may also be encountered: Impacts may be contradictory; they may be overlapping; they may be expressed in different units; and/or it may only be possible to express them in qualitative terms. The probable impacts of urban projects that were listed (in excess of 30) were grouped under the following headings:

- Impacts relating to a better transport system.
- Impacts relating to a more efficient macro-economic environment.
- Impacts relating to equity.
- Impacts relating to the environment.
- Impacts relating to other aspects not included above.

The case for a partial equilibrium type approach: Impacts in the first category (also known as direct or first round impacts) require a partial equilibrium analysis, which focuses on project efficiency in a micro-economic sense. Impacts in the second category (also known as indirect or second round impacts) require a general equilibrium analysis, which focuses on projects in a macro-economic sense. For the purpose of an appraisal framework, it was argued that including them both in project appraisal would amount to double counting. Given the requirement of *ranking* for the purpose of an appraisal framework, it was argued that a partial equilibrium type of analysis (i.e. CBA) constitutes the preferred choice.

The case for narrow CBA: Narrow and broad CBA differ in various ways, as in the role to be played by decision makers. The conventional school of thought, favouring narrow

(economic) CBA, argues that CBA provides only one of the inputs in the decision making process. The decision making school of thought, favouring broad CBA, argues that decision makers' more subjective beliefs should be included as part of CBA. For the purpose of an appraisal framework, narrow CBA is preferred as even narrow CBA already constitutes a soft approach.

The case for MCA: The strength of the argument for adopting an MCA type approach is directly proportional to the diverse nature of the impacts of TI projects.

Suggested framework: This involves an MCA type approach with economic efficiency as one of the decision criteria. This means that a narrow CBA should always be conducted.

Criticism on CBA: This was dealt with, followed by issues not currently addressed in CBA, as well as a number of "continuing" issues and methodological challenges for which consensus amongst scholars has not been reached.

Causes of project failure: Projects often fail because of risk-negligence and lack of accountability. Problems with the conventional approach to appraisal include: (a) a pre-feasibility analysis is not undertaken; (b) the focus is on technical solutions; (c) externalities are not addressed timely; (d) stakeholders are not optimally involved; (e) risk analysis is neglected; and (f) institutional, organizational and accountability issues are not adequately addressed.

Suggested cures: Four inter-related solutions are suggested for project failure: (a) risk and accountability should be more centrally based in decision-making; (b) a rearrangement of public and private responsibilities may be required; (c) four basic instruments of accountability are suggested (listed below); (d) two alternative models for accountable decision-making are proposed: the state-owned enterprise (SOE) approach and the build-operate-transfer (BOT) approach.

Instruments of accountability: The four instruments are: (a) transparency; (b) performance specifications; (c) regulatory regime; and (d) involvement of risk capital.

7.2.4 Customizing the basic approach

The basic approach developed for CoT in the previous step involves an MCDM-type approach – in particular, the MCDM value measurement model – with economic efficiency as one of the decision criteria. This model requires the following steps:

- Identify and structure the problem.

- Identify alternatives.
- Identify decision criteria.
- Determine relative importance of criteria.
- Measure intra-criterion performance.
- Aggregate scores across criteria.
- Perform sensitivity analysis.

To customize this approach to the CoT, attention was focused on the second, third and fifth steps on this list – identifying relevant decision criteria (in addition to economic efficiency), identifying alternatives and measuring intra-criterion performance. Identifying decision criteria involves both an analysis of the CoT decision making environment and an analysis of the approach followed by a selected number of external institutions or suggested by independent sources. Regarding the remaining four steps not dealt with, it was argued that they are sufficiently taken care of by the software suggested for this purpose. A number of related aspects were also discussed. Key aspects are summarized under the headings below.

Identifying decision criteria from the CoT planning environment: This involves a scrutiny of the statutory environment and spatial framework impacting on CoT, as well as CoT policy imperatives, its vision, mission, goals and objectives regarding the transport function. The following was found:

- In general, the relevant CoT planning documents, in particular the ITP and the IDP documents, are not very helpful for the purpose of identifying a list of decision criteria.
- Those objectives that do qualify as decision criteria, are not operational, as no performance (measurement) scale is suggested.

Exploring decision criteria from other contexts: To supplement this top-down approach (i.e. the analysis of CoT goals and objectives), decision criteria suggested by a selected number of other institutions and researchers – both local and abroad – were scrutinized. A total of ten sources were consulted in five groups: (a) views on decision criteria from independent researchers; (b) criteria suggested by (or for) road/transport authorities abroad; (c) criteria used by a selected number of road/transport authorities in the USA; (d) criteria suggested by the South African Department of Transport; and (e) criteria suggested for a number of South

African urban municipalities (or regional authorities). The following criteria emerged from this analysis: efficiency, equity, sustainability, and compatibility.

Decision criteria suggested for CoT: Based on the discussion above, it was argued that four decision criteria were relevant in the case of CoT, namely: (a) *efficiency*, which deals with the requirement of the optimal allocation of scarce resources; (b) *equity*, which involves the objective of a fairer distribution of income between persons benefiting from the project; (c) *sustainability*, which focuses on minimizing negative impacts on the environment; and (d) *compatibility*, which addresses the requirement that a project must be aligned with stated goals and objectives. This set of decision criteria suggested for CoT was assessed from various perspectives, and was found acceptable in all cases.

Identification of alternatives: To illustrate the identification of the list of projects to be subjected to the appraisal process in the case of CoT, the consolidated CoT transport budget for the 2006/07 financial year was used as a starting point. In essence, identifying projects to be subjected to appraisal involves eliminating non-relevant projects from the consolidated transport budget. It was found that, from the initial budget, only nine projects needed to be subjected to the appraisal process.

Suggested two-phased approach: The need for a two-phased approach results from the fact that project appraisal involves both the evaluation of mutually exclusive alternatives and the ranking of independent projects. This implies that the typical steps of the MCA value function model need to be customized. These ten steps can be grouped under the following four headings: *Establishing generic parameters* involves: (1) identifying and structuring the problem; (2) identifying decision criteria; (3) determining the relative importance of criteria. *Comparing mutually exclusive alternatives* involves: (4) identifying mutually exclusive alternatives; (5) measuring intra-criterion performance (scoring alternatives and removing infeasible ones; and standardizing scores for feasible alternatives); (6) aggregating scores across criteria. *Ranking independent projects* involves: (7) identifying independent projects; (8) measuring intra-criterion performance (that is, standardizing scores, given a new set of projects); (9) aggregating scores across criteria. *Testing the results* involves: (10) performing a sensitivity analysis.

Measuring intra-criterion performance: Performance measurement units were suggested for each of the decision criteria deemed relevant to CoT. For *efficiency*, Eff EUAC was suggested in the case of mutually exclusive alternatives, and Eff IRR in the case of

independent projects. For *equity*, Eq NPV was suggested in the case of mutually exclusive alternatives, and Eq B/C ratio in the case of independent projects. For *sustainability* and *compatibility*, a (performance) index was suggested in the case of both mutually exclusive alternatives and independent projects.

Market prices and resource cost: Economic (resource) cost must be used when dealing with efficiency, given its focus on the optimal allocation of scarce resources IRR. However, in modelling consumer behaviour, as for the purpose of modal or route choice, market prices should be used as consumers base their choices on (inter alia) actual (market) prices. Equity, on the other hand, involves using market prices as the utility of income (expenditure) those who benefit and those who pay are based on market prices. Consumer surplus analysis should therefore also be carried out at market prices.

Roles and responsibilities of stakeholders: A number of stakeholders are involved in the process of identifying needs and problems, and appraising and selecting projects. They include the community, politicians (as elected representatives of the community), technocrats (professionals in the employ of the authority), external experts, and the facilitator (the person guiding stakeholders through the process). Each stakeholder has a unique role and responsibility, as set out with reference to the steps of the two-phased approach.

Need for specialized decision support tools: For the purpose of applying the appraisal framework, the use of a specialized software tool is non-negotiable. The output of various other tools can, however, serve as input into the main tool, for example in the case of a CBA. Given the complex nature of the interrelationships between and interdependencies of the links of the urban transport network, transportation models are indispensable for determining the network effects of a project and for quantifying total network (user) cost on a "with" and "without" basis. These models can be grouped into three categories (a) *four-step models;* (b) *discrete choice models; and* (c) *land-use interaction models*. Examples of models commonly used are the TRIPS package, the EMME/2 toolkit and the VLC-Zenith and VLC-Transcend modelling software.

7.2.5 Applying the appraisal framework to CoT projects

The appraisal framework developed above was applied to those CoT projects identified as "eligible" for appraisal, in order to demonstrate how the framework would affect project ranking and selection, and to indicate how currently available decision support tools can facilitate project appraisal and ensure better decisions. To this end, key aspects of the

framework were revisited, and the relevant CoT projects were listed. Criteria for selecting a tool were considered and key aspects of DEFINITE, the tool utilized for this purpose, explored. The framework was then applied to both a set of mutually exclusive alternatives and a set of independent projects. It was argued that the framework, by using defendable decision criteria, is superior to the CoT methods currently used. The dilemma facing the decision maker resulting from conflicting rankings in terms of the suggested decision criteria was highlighted and means of addressing this were presented.

Revisiting key aspects of the framework: The appraisal framework is described as an MCA type approach of the value function kind with the following four decision criteria: (a) efficiency (focusing on the economic feasibility of the project, i.e. involving the optimal allocation of scarce resources), (b) equity (dealing with the income distribution impacts of the project), (c) sustainability (addressing "green issues"), and (d) compatibility (involving the "goodness-of-fit" of the project with stated goals and objectives, and key initiatives). CBA constitutes an element of the framework because efficiency is one of the decision criteria. In this regard it was argued that a partial equilibrium type approach (as opposed to a general equilibrium type approach) would suffice in the case of the kind of CoT project addressed in this thesis (namely "Category AB: Budget cycle type projects with local economic impacts only" (the "typical" case)). The preference for "narrow CBA" as opposed to "broad CBA" was also justified. In addition, the need for a two-phased approach was argued, given the need to address both (the comparison of) mutually exclusive alternatives and (the ranking of) independent projects. Suitable performance measurement units for each of the various decision criteria were also suggested for use in intra-criterion performance measurement.

CoT projects considered for application: For the reasons given in Section 5.5, the following nine projects were considered in Chapter 6 for the purposes of applying the framework:

- Road infrastructure Klip/Kruisfontein.
- Collector road backlog: Atteridgeville.
- Doubling of Church Street over railway line.
- Olievenhoutbosch activity spine.
- Upgrading of road network in Hatfield.
- Collector road backlog: Mamelodi.
- Improving of Hans Strijdom Drive (west).

- Doubling of Simon Vermooten Road.
- Doubling of Lynnwood Road.

Criteria for selecting decision support tools: Decision support tools are important for facilitating the appraisal process and improving the quality of decisions. A number of criteria should be considered in selecting a decision support tool for the purpose of applying the framework: (a) simplicity; (b) cost; (c) hardware requirements; (d) access and maintenance; (e) visual images; (f) specificity; (g) versatility/flexibility; (h) compatibility; (i) transparency; and (j) scientific rigour.

Background to DEFINITE: DEFINITE (derived from "**DE**cisions on a **FINITE** set of alternatives") is a decision support software package developed to improve the quality of decision making. It was developed by the Vrije Universiteit of Amsterdam in the Netherlands. It has a wide variety of users, in both the public and the private sector.

DEFINITE terminology and procedures: In a number of instances, the terminology used by DEFINITE differs from that used in this thesis. For example, DEFINITE refers to "alternatives" whereas "option", "project", "mutually exclusive alternative" and "independent project" are used in the thesis. Other examples are "tree structure" instead of "decision tree" (or "value tree"), "effect" instead of (decision) criterion, "effects table" instead of "evaluation matrix", and "standardization" (of scores) instead of "normalizing". Also, alternatives are normally listed vertically (in the left hand column) and criteria horizontally (in the top row) in the evaluation matrix; whereas DEFINITE does it the other way round.

Applying the framework to mutually exclusive alternatives

In applying the framework to mutually exclusive alternatives, attention first focused on the requirement that feasible alternatives should be separated from infeasible alternatives and that the latter should be removed from the analysis. To demonstrate this, a set of mutually exclusive alternatives was assumed for one of the projects listed above, namely the "Collector road backlog in Mamelodi". Assumptions made for this purpose were justified. It was shown that, of the original six alternatives, two needed to be excluded from the list, namely Alternative 2 (as it was not feasible in terms of all the decision criteria considered) and the null alternative (as it was dominated by all remaining alternatives). It was noted that, in general, there are three possibilities regarding any given set of mutually exclusive alternatives: (a) all alternatives are feasible in terms of all criteria – in this case, all alternatives should be subjected to ranking in order to determine the best, for inclusion in the

list of independent projects; (b) only some alternatives are feasible in terms of all criteria – in this case, infeasible alternatives should first be excluded from the appraisal before the remaining (feasible) alternatives are ranked; (c) no alternatives are feasible in terms of all criteria – this implies a no go situation for the purpose of appraisal, as the null alternative should remain the status quo. Also, when infeasible alternatives have been identified and removed from the analysis, only feasible alternatives will remain which, by definition, will all be superior to the null alternative, and the latter can also be removed from the analysis.

The discussion also demonstrated how conflict that may arise between alternatives could be resolved. It was shown that the final ranking of a set of mutually exclusive alternatives is a function of the relative importance attached to the decision criteria, which underlines the importance of the input of politicians as key stakeholders in the process.

Applying the framework to independent projects

This involves three aspects; input data, challenges facing the decision makers, and ranking projects.

Discussion first focused on the *input data* needed to demonstrate the application of the framework; or rather, on justifying assumed input values, given the lack of actual data. Input data involve the values (scores) needed for project performance in terms of efficiency (Eff IRR), equity (Eq B/C ratio), sustainability (index), and compatibility (index). The logical starting point was efficiency; for this the cost breakdowns for the relevant projects in the ITP document were used to calculate the "present worth of total causal cost" for each project. The values obtained in this manner were then used as inputs in assuming values for the present worth of savings in recurring cost for each project. This enabled efficiency parameters to be determined for each project. Equity scores were derived from efficiency scores, considering the marginal utility of income (expenditure), which is a function of income group. In the case of sustainability and compatibility, no performance data were available, and values were chosen in such a way as to best demonstrate key aspects of the framework.

Given these assumed input values, *challenges facing the decision maker* in ranking projects were highlighted. For example it was shown that there was no single project indicated best in terms of all criteria; also, different rankings were obtained, as shown in the case of (for example) efficiency and equity. Despite these challenges, it was argued that the framework, by considering a set of defendable decision criteria, is superior to the current methods used in CoT, namely the ITP (functional or departmental) and IDP (process-related) prioritization

process – neither of which is defendable in terms of the framework. Although it was accepted that both the ITP and IDP objectives were valid, they arguably were not the only ones to be considered. An exclusive focus on functional (engineering) aspects (ITP approach) means that other important objectives (criteria) – such as those considered by the framework (namely efficiency, equity, sustainability and compatibility) – are excluded. The way in which functional/technical considerations are accommodated in the framework is by requiring that all mutually exclusive alternatives should first be screened for "technical feasibility". These technically feasible alternatives must then be subjected further to other types of feasibility analyses, such as efficiency, equity, and so on. The objective of "municipal priority areas" (IDP approach), on the other hand, is accommodated in the framework by the introduction of the decision criterion "compatibility".

Regarding the *ranking of projects*, it was shown that the relative importance of decision criteria is critical in making a "trade-off" between projects. This underlines the importance of the weight vector in the analysis, to be used for all projects, and for both the comparison of mutually exclusive alternatives and the ranking of independent projects. It also underlines the critical role of decision makers – to articulate the goals and aspirations of the community they represent, and to present this in the form of a set of weights.

7.3 Key findings

Findings on a number of key issues affecting the study objective and sub-objectives are summarized in this section.

7.3.1 Contexts for project appraisal

Projects, and consequently the contexts for project appraisal, can be classified in different ways. For the purpose of this thesis, the classification system depicted in Table 7-1 was deemed relevant.

Table 7-1: Classification of projects (and appraisal contexts)

Scope of economic impacts	Frequency of occurrence	
	One-off	Budget cycle
Local	Category AA: Not applicable, as one-off	Category AB: Budget cycle type

Scope of economic impacts	Frequency of occurrence	
	One-off	**Budget cycle**
	projects by definition will have wide (regional and national) impacts.	projects with local economic impacts only (the "typical" case).
External	Category BA: One-off projects which, by definition, have wide economic impacts, extending beyond the study area and across regional borders.	Category BB: Budget cycle type projects with external economic impacts (not the typical case).

The specific "appraisal context" of a project has definite implications for project appraisal (i.e. the approach to be adopted and the appraisal tools to be used). It therefore also dictated the appraisal framework developed in this thesis, which focused on CoT projects in "Category AB: Budget cycle type projects with local economic impacts only" (termed "typical" projects for the purpose of this thesis).

7.3.2 Functional requirements for an appraisal framework

Given the characteristics of the project type addressed in this thesis (i.e. "typical" projects, as defined above), a critical requirement for the framework was that it must enable *feasible* projects to be *ranked* in terms of their overall worth. This meant that project appraisal must be able to accomplish both the *evaluation* of options (to separate those that are feasible from those that are not), and the *ranking* of feasible projects.

7.3.3 Role of traditional methods

Traditional methods, for the purposes of this thesis, were regarded as including the following: (a) partial equilibrium analysis (i.e. CBA), addressing projects in a micro-economic sense by focusing on "local" (first round) impacts; (b) general equilibrium (GE) analysis, focusing on economy-wide impacts, addressing a project in a macro-economic sense, and providing a number of indicators (e.g. impact on private consumption, investment, exports, imports, inflation, total GDP and GDP on an industry-by-industry basis); and (c) spatial models, facilitating a better understanding of the geographical distribution of impacts. As argued in the thesis, GE models constitute an extension of CBA and can be used to supplement it in

the case of large projects under certain conditions. The risk of double counting in doing this, though, should be noted. Also, GE analysis does not provide a clear "accept/reject" rule. In the case of "typical" projects (being the focus of this thesis), CBA – which allows for projects to be evaluated *and* ranked – was considered most appropriate. GE models generally will be applicable in the case of projects with external impacts, often resulting from structural changes. In their turn, spatial models are typically applicable in a regional and/or national scale and not at a local (urban) scale, due to the lack of information in the latter case. Also, they do not involve the appraisal of projects, but merely an interpretation of the nature and scope of impacts.

7.3.4 Role of CBA

The historical emphasis placed on CBA underlines the importance of economic efficiency (defined as the optimal allocation of scarce resources). As economic efficiency continues to remain an important objective of society, CBA therefore continues to constitute an important element of the appraisal framework. But given the diverse nature of project impacts, affecting other objectives of society as well, the inevitable conclusion is that "CBA is necessary, but not enough".

7.3.5 Preference for narrow CBA

As argued in this thesis, narrow CBA is seen as focusing only on economic efficiency, whereas broad CBA is seen as an attempt to accommodate other objectives as well, such as equity (income distribution). For the purpose of an appraisal framework, it was concluded that narrow CBA was the way to go, dealing with other project impacts by way of an MCA.

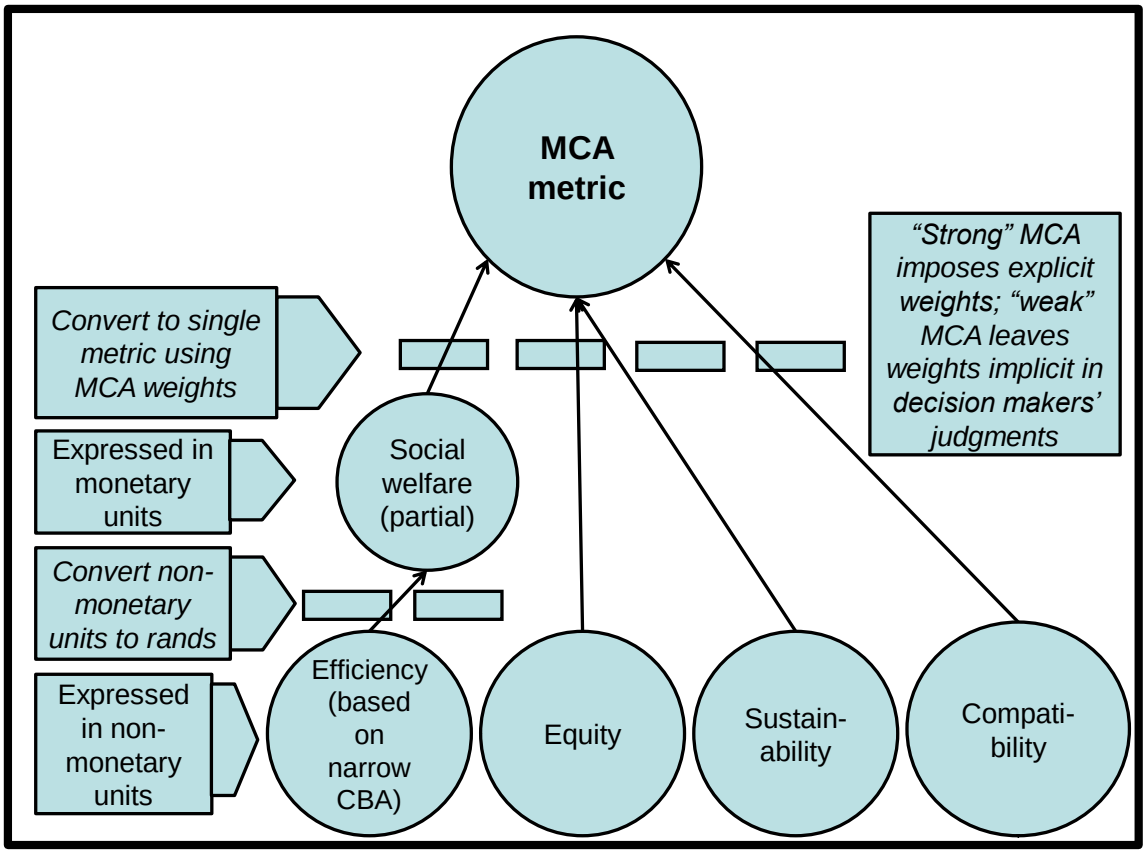
7.3.6 Value function models

There are several models for determining preferences in the context of multi-criteria problems, namely (a) Multi-Attribute Value Theory models (MAVT) (also known as value function models or value measurement models), (b) outranking models and (c) satisficing models. These all contain two primary components: (a) preferences in terms of each criterion (i.e. intra-criterion comparisons), and (b) an aggregation model (i.e. inter-criteria comparisons, i.e. combining preferences across criteria). The most appropriate method in a given situation will depend on the context. For the purpose of the appraisal framework, value function type models were preferred as they address both the *choice problematique* (i.e. making a simple choice from a set of alternatives) and the *ranking problematique* (i.e. placing

options in some form of preference order). Value function models imply a number of functional steps, which are reflected in the appraisal framework developed for CoT.

7.3.7 Decision criteria

Determining (establishing) a "basic approach" constitutes the first step in developing an appraisal framework. Customizing this basic approach (i.e. MCA, with economic efficiency as one of the decision criteria) to the CoT context, involved a number of aspects, one of which was the identification of a set of decision criteria applicable to the CoT. As decision criteria arguably should reflect the aspirations of the community, relevant CoT policy documents, in particular the ITP and the IDP documents, were scrutinized with the focus on aspects such as vision and mission statements, and stated goals and objectives. This did not prove helpful due to their generalized nature, and/or the fact that they were not "operational" in many instances. An analysis of the approach adopted by a selected number of external institutions or suggested by independent sources was therefore undertaken as well. A general pattern emerging from this analysis of decision criteria suggested locally and abroad was the importance of the following objectives which were deemed relevant to the CoT context as well as efficiency, namely, equity, sustainability and compatibility. The "extended" basic approach is depicted in Figure 7-1.



Source: Adapted from Austroads (2005b:23).

Figure 7-1: Essence of the CoT appraisal strategy

With reference to the current CoT method, it was accepted that both the ITP and IDP objectives were valid, but they arguably were not the only ones to be considered. An exclusive focus on functional (engineering) aspects (ITP approach) means that other important criteria – such as those considered by the framework (namely efficiency, equity, sustainability and compatibility) – are excluded. The way in which functional/technical considerations are accommodated in the framework, is by requiring that all mutually exclusive alternatives should first be screened for "technical feasibility". These technically feasible alternatives must then be subjected further to other types of feasibility analyses, such as efficiency, equity, and so on. The objective of "municipal priority areas" (IDP approach), on the other hand, is accommodated in the framework by the introduction of the decision criterion "compatibility".

7.4 Achievement of research objectives

7.4.1 Main objective

The overall objective was to develop an appraisal framework for TI projects in the municipal sphere of government in South Africa, with reference to the CoT. In order to meet this objective, three sub-objectives were identified. They have all been achieved, as argued below.

7.4.2 Sub-objective 1

Sub-objective 1: *To develop a basic approach that combines the best elements of traditional methods, bearing in mind the diverse nature and scope of the impacts of TI projects.*

The basic approach that was developed for CoT involves an MCDM-type approach, in particular the MCDM value measurement model, with economic efficiency as one of the decision criteria. This model involves the following steps:

- Identify and structure the problem.
- Identify alternatives.
- Identify decision criteria.
- Determine relative importance of criteria.
- Measure intra-criterion performance.
- Aggregate scores across criteria.
- Perform sensitivity analysis.

The basic approach is described in more detail in Chapter 4 of this thesis, and summarized in Section 7.2.3 above.

7.4.3 Sub-objective 2

Sub-objective 2: *To customize this basic approach to the CoT decision making context.*

Customizing the basic approach to the CoT involved the second, third and fifth steps of the list above (identifying those alternatives that should be subjected to the appraisal process; identifying the relevant decision criteria (in addition to economic efficiency); and measuring intra-criterion performance). Identifying decision criteria involved both an analysis of the CoT

decision making environment and an analysis of the approach adopted by a selected number of external institutions or suggested by independent sources. Regarding the remaining four steps not dealt with, it was argued that they will be sufficiently taken care of by the appraisal process itself and/or the software suggested for this purpose. The following decision criteria (in addition to efficiency, which involves the optimal allocation of scarce resources) were identified: equity (focusing on the income distribution aspects of the projects); sustainability (focusing on environmental impacts); and compatibility (focusing on the alignment of a project with stated goals and objectives). A number of additional aspects, relating to customizing the framework, were also explored, such as the need for a two-phased approach which emanates from the distinction between mutually exclusive alternatives and independent projects, and appropriate measurement units to facilitate intra-criterion performance measurement.

The customization of the basic approach to the CoT decision making context is described in more detail in Chapter 5 of the thesis, and summarized in Section 7.2.4 above.

7.4.4 Sub-objective 3

Sub-objective 3: *To apply the appraisal framework (i.e. the basic approach, customized to the CoT decision making context), to projects in the CoT environment, in order to demonstrate the application of the framework at a project level, as well as the potential for available decision support software for improving the quality of decision making and ensuring better governance outcomes.*

The appraisal framework developed above was applied to CoT projects that were identified as eligible for appraisal. This was done to demonstrate how the framework would affect project ranking and selection, and to indicate how currently available decision support tools could facilitate project appraisal and ensure better outcomes of the decision making process. The framework was applied to both a set of mutually exclusive alternatives and a set of independent projects. It was argued that the framework, by using defendable decision criteria, is superior to the CoT methods currently used. Also discussed was the dilemma facing the decision maker resulting from conflicting rankings in terms of the suggested decision criteria, and how this could be resolved.

The application of the appraisal framework to projects in the CoT environment is described in more detail in Chapter 6 of the thesis, and summarized in Section 7.2.5 above.

7.5 Significance of thesis

The framework developed in this thesis could provide authorities in the municipal sphere of government with a defendable method for ranking TI projects in order to ensure that the best set of projects are selected for implementation under conditions of budget constraints. Critical elements of this framework are the decision criteria to be included in the appraisal process (namely efficiency, equity, sustainability and compatibility), and the measurement units to be utilized in establishing intra-criterion performance, given the need to consider both mutually exclusive alternatives and independent projects. It is believed that these four criteria are the embodiment of community values, aspirations, goals and objectives insofar as TI projects are concerned. Contrary to this, the current CoT criteria (technical feasibility, and compliance with municipal priorities) – although valid – are arguably incomplete. Also, no solution is provided to the problem of conflicting rankings (in terms of the ITP rankings and the IDP rankings) that may arise from adopting these criteria.

The framework developed in this thesis, on the other hand, includes both these criteria. "Municipal priorities" are addressed directly by including the criterion "compatibility", while "technical feasibility" is addressed indirectly by including only technically feasible alternatives in each set of mutually exclusive alternatives. Furthermore, the framework also resolves the problem of conflicting rankings in a structured manner, by using an overall MCA approach and basing the relative importance of decision criteria on the inputs of politicians who, by implication, are tasked with the responsibility of articulating community goals and objectives.

7.6 Shortcomings of thesis

In the case of the CoT, obtaining up-to-date information proved to be a problem. The main source of information was official planning documents, in particular the ITP and the IDP documents. This could be termed undesirable, given the time lag between the actual planning process and the publication of such documents.

7.7 Conclusions and recommendations

A final conclusion of this thesis is that the appraisal framework that was developed constitutes a step in the right direction by presenting a systematic method for prioritizing projects that is both logical and defendable. It could also well apply to road authorities in all spheres of government. It is therefore recommended that it be implemented as soon as

possible. At the same time, it is recommended that a number of aspects be subjected to further study. The most important of these are listed below:

- Given the fact that the criterion “compatibility” also includes “fairness of spatial distribution” of projects over time, the potential problem of project size needs to be addressed. This is especially important in the case of big projects – for example if there are funds for only one big project, each area should get its turn over time. It is important to include the notion of fairness in the criterion “compatibility” as fairness is not addressed by the other decision criteria; if not, the issue will remain unaddressed.
- Weights for the marginal utility of income/expenditure need to be customized and validated for each study context.
- Income tax distribution needs to be validated.
- Methods of measuring performance in terms of sustainability and compatibility need to be explored further.
- Although not linked to project ranking, methods of improving the budgeting process need to be investigated – it is no use having a defendable priority list, but insufficient funds. This is particularly critical if funds are not allocated “fairly” to different departments, and some departments are in fact penalized by being given insufficient funds. This involves the principle of equalizing the marginal return on investment between functional units within the organization.

These aspects aside, the contribution of this study is a systematic protocol for the appraisal of TI projects in an essentially multi-criteria decision making environment. The thesis shows how current thinking and available tools can be utilized to this end. This will ensure that tax payers’ money is spent wisely as far as TI projects are concerned, implying firstly “value for money”, and secondly the optimal use of investment options as instruments towards attaining policy objectives in the municipal sphere of government.

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Annexure A:

Capital budget for Transport, Roads and Stormwater

Capital budget for Transport, Roads and Stormwater									
Proj IDP no	Project name	Fund	Financial year / million ZAR						
			6/7	7/8	8/9	9/10	10/11	Total	Contr
710115	Contributions: Services for township development	1	10.0	15.0	15.0	26.7	26.7	93.5	Yes
710116	Essential/unforeseen stormwater drainage problems	1	5.0	5.0	5.5	9.0	6.5	31.0	
710117	Apies River: Canal upgrading, Pretoria central	1	0.6	0.6	0.6	0.6	0.6	2.8	
710127	S/W box culvert under railway line, H'kraal	1	0.5	3.8	1.0	0.0	0.0	5.3	
710128	Concrete canal: Sam Malema Road, Winterveldt	1	1.0	2.6	0.0	0.0	0.0	3.6	
710129	Major stormwater system, Mamelodi X 8	1	0.3	0.9	2.0	0.0	0.0	3.2	
710139	Stormwater system In Eersterust X 2	1	2.5	3.7	1.5	0.0	0.0	7.7	
710143	Major stormwater systems: Klip/Kruisfontein	1	3.0	1.0	4.0	4.0	4.0	16.0	Yes
710220	Rehabilitation of stormwater systems & sidewalks	Mix	12.5	13.0	16.0	20.6	21.6	83.7	
	CoT	*1*	*4.0*	*3.0*	*3.0*	*10.6*	*11.6*		
	MIG	*5*	*8.5*	*10.0*	*13.0*	*10.0*	*10.0*		
710221	Replacement of traffic signs	1	4.0	3.7	3.9	4.1	4.3	19.8	
710223	Rehabilitation of bridges	1	1.5	1.6	1.7	1.7	1.8	8.3	
710226	Essential & unforeseen road improvements	Mix	0.9	1.2	1.5	2.0	2.5	8.1	
	CoT	*1*	*0.9*	*1.2*	*1.5*	*2.0*	*2.5*		
	Other	*3*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*		
710227	Parking bays / bays at schools	1	0.4	0.8	1.0	1.0	1.0	4.2	
710228	Cycle and pedestrian paths for Tshwane	1	3.0	3.0	2.0	4.5	5.0	17.5	
710229	Traffic calming and pedestrian safety for Tshwane	1	4.3	5.0	3.0	8.5	9.5	30.3	
710257	Establish road reserves for main routes	1	1.0	0.0	0.0	0.0	0.0	1.0	
710259	Upgrading of roads in Marabastad	Mix	4.0	4.0	4.0	4.0	0.0	16.0	Yes
	CoT	*1*	*4.0*	*4.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*0.0*	*0.0*	*4.0*	*4.0*	*0.0*		
710331	Road infrastructure Klip/Kruisfontein	1	3.4	5.0	0.0	0.0	0.0	8.4	
710395	Traffic lights/traffic signal system	1	2.5	2.6	3.0	3.5	4.0	15.6	
710398	Traffic signals to meet legal requirements	1	1.0	2.7	2.7	3.0	3.0	12.4	Yes
710399	Extension of Atcon traffic control system	1	1.0	2.0	2.0	2.0	2.0	9.0	
710402	Implement real time traffic control pilot project	1	1.0	4.0	4.0	4.0	4.0	17.0	
710574	Upgrade Saxby/Old Jhb Road intersection	1	1.3	0.0	0.0	0.0	0.0	1.3	Yes
710578	Upgrade intersections: De Villebois Mareuil	1	1.0	1.0	0.0	0.0	0.0	2.0	Yes
710597	Mateteng main transport route: Stinkwater	5	15.0	10.5	0.6	0.6	0.6	27.3	
710609	Shova Kalula bicycle project	Mix	1.0	0.7	0.7	0.7	0.7	3.8	Yes
	CoT	*1*	*0.3*	*0.0*	*0.0*	*0.0*	*0.0*		
	Other	*3*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*		
710901	Major collector road: Soshanguve Block DD/CC	1	9.5	0.0	0.0	0.0	0.0	9.5	Yes
710902	Rehabilitation of roads	Mix	27.7	25.6	24.9	50.8	56.3	185.3	
	CoT	*1*	*27.7*	*1.3*	*10.0*	*42.0*	*47.5*		
	MIG	*5*	*0.0*	*24.3*	*14.9*	*8.8*	*8.8*		
710928	Doubling of Church Street over railway line	1	1.0	0.0	0.0	17.5	5.0	23.5	
710930	Upgrading of the road network in Hatfield	1	0.0	0.0	3.0	13.0	10.0	26.0	
710936	Real Rover Road to Serapeng Road	Mix	11.3	5.5	4.5	2.0	2.0	25.3	
	CoT	*1*	*6.9*	*5.5*	*4.5*	*0.0*	*0.0*		
	MIG	*5*	*4.4*	*0.0*	*0.0*	*2.0*	*2.0*		
710937	Access road to Mamelodi X18 (K54)	Mix	0.5	5.0	5.0	5.0	5.0	20.5	
	CoT	*1*	*0.5*	*5.0*	*5.0*	*0.0*	*0.0*		
	MIG	*5*	*0.0*	*0.0*	*0.0*	*5.0*	*5.0*		

Capital budget for Transport, Roads and Stormwater (continued)									
Proj IDP no	Project name	Fund	Financial year / million ZAR						
			6/7	7/8	8/9	9/10	10/11	Total	Contr
710939	Doubling of Lynnwood Road	1	12.0	25.0	26.5	1.0	10.0	74.5	
710940	Improving of Hans Strijdom Drive (west)	1	0.0	3.0	19.0	12.0	0.0	34.0	
710943	Doubling of Stormvoel Road	Mix	0.0	0.0	3.6	17.6	20.0	41.2	
	CoT	*1*	*0.0*	*0.0*	*3.6*	*12.6*	*20.0*		
	MIG	*5*	*0.0*	*0.0*	*0.0*	*5.0*	*0.0*		
710965	11th Road Winterveldt	5	5.6	2.0	0.0	0.0	0.0	7.6	Yes
711010	Sekampaneng (bus and taxis)	5	2.0	3.0	0.0	0.0	0.0	5.0	Yes
711014	Major routes Block M	Mix	7.8	0.0	0.0	0.0	0.0	7.8	Yes
	CoT	*1*	*5.8*	*0.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*2.0*	*0.0*	*0.0*	*0.0*	*0.0*		
711164	Block W - Stormwater drainage	Mix	4.1	2.7	1.0	1.0	1.0	9.8	
	CoT	*1*	*0.4*	*2.7*	*1.0*	*1.0*	*1.0*		
	MIG	*5*	*3.7*	*0.0*	*0.0*	*0.0*	*0.0*		
711213	Stormwater drainage Mahube Valley	Mix	2.0	3.2	3.8	0.0	0.0	9.0	Yes
	CoT	*1*	*0.0*	*2.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*2.0*	*1.2*	*3.8*	*0.0*	*0.0*		
711259	Stormwater upgrading: Unit A and X	Mix	1.5	0.0	0.0	0.0	0.0	1.5	
	CoT	*1*	*0.5*	*0.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*1.0*	*0.0*	*0.0*	*0.0*	*0.0*		
711262	Magriet Monamodi stormwater system	Mix	3.0	3.0	1.0	0.0	0.0	7.0	Yes
	CoT	*1*	*0.0*	*3.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*3.0*	*0.0*	*1.0*	*0.0*	*0.0*		
711263	Major stormwater drainage system: Cambridge Road	1	1.0	0.0	0.0	0.0	0.0	1.0	
711264	Major stormwater Drainage System: Matenteng	Mix	3.0	10.0	10.0	10.0	5.0	38.0	Yes
	CoT	*1*	*3.0*	*10.0*	*10.0*	*10.0*	*5.0*		
	MIG	*5*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*		
711265	Hartebeest Spruit: Canal upgrading	1	4.0	5.0	5.0	0.0	0.0	14.0	
711267	Moreleta Spruit: Flood structure	1	2.5	2.8	1.8	1.8	1.8	10.5	
711268	Montana Spruit: Channel improvements	1	6.0	7.0	0.0	0.0	0.0	13.0	
711269	Stormwater box culvert: Meadow Ave	1	0.5	0.0	0.0	5.0	5.0	10.5	
711270	Stormwater culvert underneath N1 freeway	1	3.0	0.0	0.0	0.0	0.0	3.0	
711273	Major stormwater drainage system: Majaneng	Mix	3.0	7.0	6.0	6.0	6.0	28.0	Yes
	CoT	*1*	*3.0*	*7.0*	*6.0*	*6.0*	*6.0*		
	MIG	*5*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*		
711275	Major stormwater canal: Hennopspark	1	1.5	0.0	0.0	0.0	0.0	1.5	Yes
711276	Stormwater drainage systems: Lyttelton A.H.	1	1.0	0.0	0.0	0.0	0.0	1.0	Yes
711278	Replacement stormwater box culvert: 15th Ave	1	0.6	0.0	0.0	0.0	0.0	0.6	
711284	Major stormwater drainage channels: Ga-Rankuwa	5	5.0	8.0	8.0	8.0	8.0	37.0	Yes
711285	Stormwater drainage systems in Ga-Rankuwa View	5	4.0	5.0	4.0	4.0	4.0	21.0	Yes
711301	Upgrading of road network in Menlyn node	1	9.2	7.0	0.0	0.0	0.0	16.2	Yes
711324	Upgrading of Lavender Road	1	0.2	0.0	0.0	0.0	0.0	0.2	
711325	Olievenhoutbosch activity spine	1	3.5	5.0	5.0	5.0	5.0	23.5	
711800	Doubling of Simon Vermooten Road	1	11.0	22.5	20.0	2.0	0.0	55.5	

Capital budget for Transport, Roads and Stormwater (continued)									
Proj IDP no	Project name	Fund	Financial year / million ZAR						
			6/7	7/8	8/9	9/10	10/11	Total	Contr
711863	Internal roads: Northern areas	Mix	30.4	38.8	36.8	60.0	70.0	236.0	
	CoT	*1*	*28.5*	*5.0*	*15.2*	*10.0*	*20.0*		
	MIG	*5*	*1.9*	*33.8*	*21.6*	*50.0*	*50.0*		
712026	Potgieter Street safety measures	Mix	0.3	0.0	0.0	0.0	0.0	0.3	Yes
	CoT	*1*	*0.3*	*0.0*	*0.0*	*0.0*	*0.0*		
	MIG	*5*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*		
712217	Centurion Lake and Kaal Spruit	1	0.3	0.2	0.8	18.5	10.0	29.7	
712219	Flooding backlogs: Stinkwater & New Eersterust area	1	1.3	5.0	0.8	2.0	5.5	14.6	
712220	Flooding bBacklogs: Sosh & Winterveldt area	1	1.3	5.0	1.0	5.0	11.0	23.3	
712221	Flooding backlogs: Mabopane area	1	0.6	4.0	4.0	8.8	8.8	26.2	
712223	Flooding backlogs: Mamelodi, Eersterust & Pta Eastern	1	1.3	5.0	0.6	5.5	5.5	17.8	
712253	Formalise and align new access to Odenburg Gardens	Mix	0.0	0.4	1.0	0.0	0.0	1.4	
	CoT	*1*	*0.0*	*0.0*	*1.0*	*0.0*	*0.0*		
	MIG	*5*	*0.0*	*0.3*	*0.1*	*0.0*	*0.0*		
712501	Traffic flow and safety on corridors	1	1.5	1.5	1.5	2.0	3.5	10.0	
712502	Traffic flow improvement at intersections	1	2.0	2.0	2.0	6.5	7.0	19.5	
712503	Flooding backlog: Network 3, Kudube Unit 11	1	0.0	1.0	1.3	2.6	0.0	4.9	
712504	Flooding backlog: Network 2F, Kudube Unit 6	1	0.0	1.0	1.6	5.0	0.0	7.6	
712505	Flooding backlog: Network 2A & 2D, Marokolong	1	0.0	5.0	2.8	9.0	0.0	16.8	
712506	Flooding backlog: Network 5A, Matanteng	1	1.3	1.8	0.0	0.0	0.0	3.0	
712507	Flooding backlog: Network 2H, Kudube Unit 7	1	1.3	1.9	0.0	0.0	0.0	3.1	
712508	Flooding backlog: Network 1B, Suurman	1	0.0	1.0	1.7	6.5	0.9	10.1	
712509	Flooding backlog: Network 1D, Suurman	1	0.0	1.0	1.7	6.5	2.0	11.2	
712510	Flooding backlog: Network 1E, Suurman	1	0.0	3.0	1.7	6.5	1.2	12.4	
712511	Flooding backlog: Network C5, C6, C11 & C13,	1	0.0	4.5	2.7	7.0	0.0	14.2	
712512	Flooding backlog: Network 5D, Mandela Village Unit 12	1	1.3	2.4	0.0	0.0	0.0	3.7	
712513	Flooding backlog: Soshanguve South & Akasia area	1	0.0	4.0	4.0	8.0	10.0	26.0	
712514	Flooding backlog: Olievenhoutbosch & Centurion area	1	0.0	1.5	3.0	10.0	18.0	32.5	
712515	Flooding backlog: Network 2B, Ramotse	1	0.0	2.5	1.4	5.0	0.0	8.9	
712516	Flooding backlog: Network 2D, New Eersterust X2	1	0.0	3.0	1.3	2.0	0.0	6.3	
712517	Flooding backlog: Network 94/B58 to 79/24, Soshanguve	1	0.0	0.0	1.4	4.2	0.0	5.6	
712518	Flooding backlog: Drainage canals: Hans Strydom Dr,	1	1.0	2.5	6.0	0.0	0.0	9.5	
712519	Flooding backlog: Network 2B, New Eersterust X1	1	2.0	5.5	1.4	3.6	0.0	12.5	
712520	Flooding backlog: Network 1A, 1C & 1F, Ramotse	1	3.0	10.0	10.0	0.0	0.0	23.0	
712521	Collector road backlog: Mamelodi	1	0.5	3.5	0.0	10.0	15.0	29.0	
712522	Collector road backlog: Atteridgeville	1	0.5	3.0	0.0	5.0	10.0	18.5	
712523	Flooding backlog: Network 3A, Kudube Unit 9	1	1.3	2.8	0.0	0.0	0.0	4.1	
712524	Waterkloof Airforce base SW canal	3	3.6	0.0	0.0	0.0	0.0	3.6	
	Total Fund 1: COT		220.6	274.4	246.4	363.2	331.1	1,435.8	
	Total Fund 3: Other		4.3	0.7	0.7	0.7	0.7	7.1	
	Total Fund 5: MIG		58.0	98.1	71.0	97.4	88.4	412.9	
	Total all funds		282.9	373.2	318.1	461.3	420.2	1,855.8	

Source: Adapted from CTMM (2007:Appendix A1).

Annexure B:

Capital budget for Public Transport

Capital budget for Public Transport						
Proj IDP no	Project name	Fund	Financial year / million ZAR			
			6/7	7/8	8/9	Total
710657	Mabopane Station modal interchange	Mix	4.00	7.00	4.00	15.00
	CoT	*1*	*1.00*	*3.00*	*4.00*	
	MIG	*5*	*3.00*	*4.00*	*0.00*	
710658	Ga-Rankuwa Hospital bus and taxi facilities	Mix	2.00	1.05	2.00	5.05
	CoT	*1*	*2.00*	*0.25*	*0.00*	
	MIG	*5*	*0.00*	*0.80*	*2.00*	
710661	Pretoria CBD public transport facilities	1	2.50	2.00	3.00	7.50
710662	Bus and taxi lay-by's	1	3.00	3.00	3.00	9.00
710664	Eerste Fabrieke Station north and south	1	2.50	0.75	0.25	3.50
710667	Dairymall taxi rank: Paving, shelters, lights	1	6.00	5.00	2.00	13.00
710670	Marabastad bus facilities	Mix	0.00	4.00	4.00	8.00
	CoT	*1*	*0.00*	*1.00*	*1.00*	
	MIG	*5*	*0.00*	*3.00*	*3.00*	
710671	Eastlynn bus and taxi facilities	5	0.00	4.00	0.50	4.50
710743	Saulsville Station pedestrian facilities	1	2.50	0.00	0.00	2.50
711754	Klipkruisfontein multimodal transfer facility	Mix	5.00	1.50	0.00	6.50
	CoT	*1*	*3.50*	*0.00*	*0.00*	
	MIG	*5*	*1.50*	*1.50*	*0.00*	
712376	Menlyn public transport facility	1	1.95	0.00	0.00	1.95
712382	Rainbow Junction/Pta North public transport: 2010	5	0.00	2.00	0.00	2.00
712485	CCTVs at cashiers	1	0.25	0.00	0.00	0.25
712486	Air compressor	1	0.10	0.00	0.00	0.10
712487	Eersterust (Pretoria) intermodal facility	1	1.00	0.00	0.00	1.00
	Total Fund 1: COT Internal funding		26.30	15.00	13.25	54.55
	Total Fund 5: Municipal Infrastructure Grant (MIG)		4.50	15.30	5.50	25.30
	Total all funds		30.80	30.30	18.75	79.85

Source: Adapted from CTMM (2007:Appendix A2).

Annexure C:

DEFINITE: Key aspects

Features of DEFINITE

Key features of DEFINITE include 7 measurements scales, 7 standardization methods, 4 MCA methods, and 5 methods for determining criteria weights, as noted below.

Measurement scales:

- Ratio scale.
- Interval scale.
- Monetary scale.
- Ordinal scale.
- ---/+++ scale.
- Nominal scale.
- Binary scale).

Standardization methods:

- Maximum standardization.
- Interval standardization.
- Goal standardization.
- Convex standardization.
- Concave standardization.
- S-shape standardization.
- Free form standardization.

Note: The last four of these methods involve the use of a value function.

MCA methods:

- Weighted summation.
- Electre 2 method.
- Regime method.
- Evamix method.

Methods for determining criteria weights:

- Direct assessment.
- Pairwise comparison.
- Expected value method.
- Random weights.
- Extreme weights.

In addition, DEFINITE allows for the presentation of information in a range of graphical output format, and allows for the analysis of uncertainty and sensitivity (i.e. testing the robustness).

Program structure

DEFINITE involves the seven steps (modules) listed in the table below. These steps are explained in more detail in the sections following this table.

DEFINITE program structure		
Step		**Ref to DEFINITE user manual**
#	**Description**	
0	Getting started	p93-99
1	Problem definition	p101-144
2	Multi-criteria analysis	p145-230
3	Cost-benefit analysis	p231-254
4	Sensitivity analysis for MCA	p255-289
5	Sensitivity analysis for CBA	p291-321
6	Report	p323-355

Annexure D

Port Elizabeth Municipality criteria rating system

Port Elizabeth Municipality criteria rating system				
Criterion	**Rating**			
	3	**2**	**1**	**0**
Urgency	If project not started within first year of programme, it will have severe adverse consequences	If not started within the second year of the programme, severe adverse consequences	If not started within the third year of the programme – severe adverse consequences	No measurable consequences if project is not started in next 3 years of the programme
Economic development	Project will encourage capital investment by public or private sector, improve job opportunities and increase Council's tax base	Project will improve Council's tax base and improve job opportunities	Project will improve Council's tax base or improve job opportunities	Project will have no or adverse economic development impacts
Benefit to the community	Between 50 and 100% of the PE population or all PEM Departments could benefit from the project	Between 24 and 50% of the PE population or more than one PEM department could benefit from the project	Between 5 and 25% of the PE population or one PEM department could benefit from the project	Less than 5% of the PE population could benefit from the project
Intensity of use	Project will be used throughout the year	Project will be used in more than just one season	Project will be used only in one season of the year	Project will be used only on occasions

Port Elizabeth Municipality criteria rating system				
Criterion	**Rating**			
	3	**2**	**1**	**0**
Health and safety	Project is needed to alleviate an existing health or safety hazard	Project is needed to alleviate a potential health or safety hazard	Project will maintain or promote health or safety	No health or safety impact
Public support	Public has demonstrated a widespread and strong desire for Council to undertake project by means of surveys, public meetings, petitions and other clear indicators	Project introduced by Councillors to address needs identified by constituent communities or by Council staff in public participation process	Public support for project is implicit and the community is likely to be aggrieved if the project is not carried out	No obvious or implicit public expression of support for the project
Project source	Project emanates from strategies or long term plans and programmes, adopted by Council	Project emanates from adopted policies of Council, and/or regional or structure plans formally accepted by Council	Project emanates from Departmental plans or project is in compliance with legal requirements	Project does not emanate from any plan of Council or its departments
Preservation	Project is critical to	Project is	Project will	No existing

Port Elizabeth Municipality criteria rating system				
Criterion	**Rating**			
	3	**2**	**1**	**0**
of assets or services	protect the structure or operational integrity of an existing Council asset or service	needed for repair or replacement of an existing Council asset to ensure efficient municipal operations	improve asset or service or deter future deterioration and expenditure	asset or service involved
Socio-economic needs	Project provides for the most basic needs (shelter, services, job opportunities) of disadvantaged groups of city's population – poor, aged, handicapped, etc	Project provides for improvement, to higher standards of existing basic facilities and services to disadvantaged groups	Project provides for improving comfort, entertainment, enjoyment or genera amenity of disadvantaged groups	Project does not meet any particular need of disadvantaged groups
Availability of external financing	External finance available, will probably be sufficient to cover total project cost	External finance available will probably fund at least 50% of project, but project will be jointly funded by Council	Potential for external finance exists and has been applied for	No external finance exists or it exits but has not been applied for
Ability to	Project	Certain steps	Preliminary	Planning and

Port Elizabeth Municipality criteria rating system				
Criterion	**Rating**			
	3	**2**	**1**	**0**
utilize financial provisions	management schedules indicate that all steps are complete and financial provisions will be fully utilized before end of finance year	are not yet complete but project management schedule indicates provisions can be utilized by end of financial year	planning and design has been completed	design has not commenced
Effect on operating budget	The project will result in an effective decrease in operating budget	There will be no or a minimal effect on operating budget as a result of the project	Increases arising from capital charges only will be incurred on the operating budget as a result of project	Significant increases will be incurred from an ongoing liability for operating expenditure as a result of project

Source: van Zyl et al. (1994:G-2 to G-3).