THE APPRAISAL OF TRANSPORT INFRASTRUCTURE PROJECTS: POTENTIAL ROLE OF STATE-OF-THE-ART DECISION SUPPORT TOOLS

I C SCHUTTE

CSIR Transportek, PO Box 395, Pretoria, 0001, icschutt@csir.co.za

ABSTRACT

This paper investigates the scope of state-of-the-art decision support tools for improving decision making in the public sector and hence ensuring better governance outcomes. This is done with specific reference to the evaluation of transport infrastructure projects, given that project evaluation (or determining project worth) is a prerequisite for informed decision making, where project worth is expressed in terms of the degree of alignment of project impacts with policy goals and objectives at national, regional and local level. As project evaluation and selection in this case imply decision making in a multi-criteria decision making (MCDM) context, an appropriate MCDM tool was selected for this purpose. It is also shown how this tool can be applied in a transport environment.

1. STUDY OBJECTIVE

This paper reports on a recent study by the author, aimed at exploring the decision making environment with respect to transport infrastructure projects and investigating the potential of currently available software for improving the appraisal process in the different spheres of government in South Africa, in order to increase the likelihood of efficiency in the allocation of scarce resources and a better alignment of project impacts with national, regional and local goals. Investment decisions involving transport infrastructure are critical not only because of the long-term and diverse nature of the impacts of such investments, but also because of the magnitude of such investments: *Firstly*, there are a considerable number of authorities in South Africa involved in investing in transport infrastructure. Investment decisions are made in all three spheres of government. *Secondly*, the total amount of funds involved in this process is considerable by most standards. *Thirdly*, the investment activity is of an ongoing nature, given the annual budget cycle.

2. IMPACTS OF TRANSPORT INFRASTRUCTURE PROJECTS

2.1 Features of transport infrastructure

Transport infrastructure is instrumental in shaping our physical and economic landscape. Urban form and fabric, and land use and intensity, are to a large extent determined by the configuration, capacity and condition of the road and rail network and the location of airports. The efficiency of the transport system (comprising both infrastructure and operations) is an important determinant of the relative competitiveness of a city, region or country. Reinforcing the importance of transportation as a "key shaper" of our physical and economic landscape, is the fact that transport infrastructure can, for all practical purposes, be regarded as "permanent", given its long economic (physical) life.

Proceedings of the 24th Southern African Transport Conference (SATC 2005) 11 – 13 July 2005
ISBN Number: 1-920-01712-7 Pretoria, South Africa
Produced by: Document Transformation Technologies cc Conference organised by: Conference Planners

2.2 Impacts of transport infrastructure projects

For the purpose of this study, *impacts* are defined as *consequences* of the project, manifesting over the entire economic life of the project (which normally is long-term for infrastructure projects). A World Bank definition of impact is as follows: *Positive or negative, primary and secondary long term effects produced by a development intervention, directly or indirectly, intended or unintended.* Transport infrastructure projects typically have many and varied impacts. Project impacts can manifest under a number of headings, as listed in the table below.

Potential impacts of transport infrastructure projects	
Total transport cost	Access to business and retail centres
Vehicle operating cost	Affordability of other "necessary" projects
Road collision cost	Policies, strategies and priorities
Travel time cost	Other initiatives and projects
Economic growth	Land use and urban form
Job creation	Crime
Income levels	Increased and accessibility
Fiscal impacts	Environment
Investment	Economic empowerment
Income distribution	Skills transfer
Economic development	Poverty alleviation
Traffic levels and composition	Health
Responsibilities of relevant authorities	Protection of capital assets.
Land and property values	

2.3 Dimensions of impacts

In measuring impacts, it is important that the following dimensions of impacts should be considered:

- Temporal (time) dimension, i.e. the timing of impacts, bearing in mind that projects should be analysed over a number of years and that the analysis period used in project evaluation should ideally coincide with the economic life of the facility.
- Spatial distribution of impacts, i.e. the specific area within the municipal area that will be impacted, bearing in mind that different sub-areas within the municipal area have different socio-economic attributes and different socio-economic development objectives and priorities.
- Affected parties, e.g. which age and income groups will be affected. This distinction is important as public sector investment is often intended to benefit specific groups within the community.

2.4 Problems with measuring project impacts

In measuring impacts, a number of problems may be encountered, as impacts may be *contradictory* or *overlapping*, be expressed in *different units* or can be expressed in *qualitative terms* only. These problems (described below) contribute to the fact that expressing "project worth" as a single number or score is difficult, if not impossible:

- Economic efficiency and equity are examples of conflicting impacts (criteria): efficiency considerations would normally direct investment to densely populated, affluent urban areas where, in the case of road infrastructure projects, high traffic volumes and high values of travel time will ensure that the project is economically justified. On the other hand, “equity” considerations would direct investment to lesser-developed (rural) areas, benefiting lower income groups.

- Job creation and income levels are examples of overlapping impacts (criteria), as an improvement in the one normally is associated with a corresponding improvement in the other. With overlapping impacts, double counting can easily occur.
- Different impacts may be expressed in different units. For example, the impact “economic efficiency” may be expressed in different ways, e.g. as a ratio (benefit-cost ratio) or as a percentage (rate of return). “Job creation”, as an example of another type of impact, is likely to be expressed as “number of jobs additional to the base case”.
- Some impacts can only be expressed in qualitative terms.

2.5 Determining project worth

“Project worth” (feasibility) can have different meanings. Some of these are explained below.

2.5.1 Economic worth

A project’s economic worth is the extent to which it makes sense from the economic point of view of the community, i.e. the extent to which it facilitates the optimal allocation and use of scarce economic resources. To determine this, the benefit and cost stream associated with the project during the analysis period must be determined, where *costs* are defined as economic (resource) costs and *benefits* as savings in costs.

2.5.2 Financial worth

A project’s financial worth is the extent to which it makes sense from the financial viewpoint of the concessionaire responsible for constructing, maintaining and managing the asset. In this case, the stream of cash inflows and outflows during the analysis should be estimated and evaluated to determine if it will render a sufficient financial return on investment (including a premium for risk).

2.5.3 Catalyst for growth and development

The worth of a project (or portfolio of projects) as a catalyst for economic growth and development depends on its ability to create conditions conducive to economic growth and development, manifesting in positive macro-economic and socio-economic impacts.

2.5.4 Aggregate worth

“Aggregate worth” is defined as a project’s performance in terms of *all* relevant criteria for project prioritisation and selection. These criteria should ideally resemble the likely impacts of investment in transport infrastructure. It is also clear that “aggregate worth” is relevant in the transport authority context as decisions are to be made in terms of the whole spectrum of criteria. It also follows that concepts such as “economic worth” and “financial worth” merely constitute subsets of this all-encompassing quantum. Given the problems with measuring project impacts, it is also clear that the determination of “aggregate worth” implies a multi-criteria context.

2.6 Project prioritisation and selection

The concepts “project prioritisation” and “project selection” are linked in as far as the former precedes the latter in the project life cycle. Projects first have to be prioritised (ranked) in terms of their aggregate worth before project selection can take place. It is further important to distinguish between *mutually exclusive alternatives* and *independent projects*. The context dealt with in this paper is that of “independent projects”, where budget constraints require that the “best” independent projects (i.e. the optimal portfolio) be selected from the set of available (candidate) projects.

3. NATURE OF MCDM

3.1 MCDM context

The MCDM context is characterised by the existence of a number of decision criteria that conflict to a substantial extent. MCDM is not confined to infrastructure projects only. Most (if not all) everyday decisions require multiple, conflicting criteria to be considered in making a decision. For the purpose of this paper, the MCDM context is described by the existence of the following:

- Alternative strategies (options)
- Multiple criteria (factors) affecting the “worth” of these strategies (i.e. the project is evaluated in terms of more than one attribute)
- The fact that this context normally calls for only one decision to be made.

MCDM is capable of addressing both the selection of the best alternative from a set of mutually exclusive alternatives and the ranking of “independent projects”. It attempts to quantify total “worth” of the different options, and in the mutually exclusive context this means that the option with the highest score would be preferred to other options. In the case of independent projects, this means that projects can be ranked in terms of their overall worth and projects be selected for inclusion in the portfolio (starting with the project with the highest score) until funds are depleted.

The fact that most decisions are “multi-criteria” can be approached in one of the following ways:

- The decision maker can act on gut feel
- He can adopt a system of ad hoc voting (or scoring) rules
- He can apply more formal MCDM procedures.

3.2 Advantages of going the MCDM route

According to Stewart et al (1997), there are a number of important spin-offs from going the more formal MCDM route:

- Balance between over-reductionistic simplistic rules and formulae, and seat of the pants flying (in unfamiliar territory)
- Transparency and accountability – the audit trail
- Facilitation of communication between divergent interests – providing a “common currency”
- Means of identifying needs/preferences in realistic contexts, as opposed to the futility of seeking context-free “values”.

3.3 Basic procedure for MCDM

According to Stewart et al (1997), the “process of MCDM” involves the following steps:

- Problem structuring
- Identification of the ”value tree” (objectives, goals, criteria)

- Identification of alternatives to be evaluated and compared
- Within-criterion evaluation and comparisons
- Aggregation across criteria (importance "weights")
- Sensitivity.

The process can also be described in a different way as consisting of the following steps:

- Construction of a criteria hierarchy
- Selection of indicators
- Scoring of alternatives in terms of the criteria
- Standardisation (and transformation) of scores
- Weighting of the criteria
- Calculation of a weighted score for each alternative
- Ranking of alternatives.

3.4 Requirements for constructing a value tree

Regarding the establishment of a family of criteria (criteria hierarchy) for use in decision analysis, Keeney and Raiffa (in Stewart et al: 1997) provide the following properties of criteria:

- Complete: Ensure that all substantial interests are incorporated
- Operational: Ensure that the criteria are meaningful and understandable to all role-players
- Decomposable: Ensure as far as is possible that the criteria are defined in such a way that meaningful rank orders of alternatives according to one criterion can be identified, without having to think about how well the alternatives perform according to other criteria (the so-called condition of preferential independence)
- Non-redundant: Avoid double-counting of issues
- Minimum size: Try to use as few criteria as possible consistent with completeness, i.e. avoid introduction of many side issues which have little likelihood of substantially affecting the final decision.

4. ROLE AND SCOPE OF ELECTRONIC DECISION SUPPORT TOOLS

4.1 Role and scope

To ensure that scores and weights can be easily visualised, adapted and tested for sensitivity, most of the commercially available tools provide a range of visually interactive, computer-assisted procedures (Belton: 1999).

Besides supporting users with the basic MCDM steps as outlined above, these tools offer a varied range of other functions and options, including:

- Problem structuring (which is particularly useful during the initial stages of exploring strategic decision options)
- Group decision support (incorporation of different opinions in an interactive group setting)
- Cost-benefit analysis and/or cost-effectiveness analysis
- Sensitivity testing (assessing the sensitivity of the end-results to changes in the underlying criteria scores)
- Visual display of criteria hierarchies and decision options
- Scenario-building.

In addition, there are also GIS-based multi-criteria decision-support tools that allow for the incorporation of spatial data and indicators.

4.2 Criteria for selecting appropriate tool

Cloete (2002) mentions that criteria for comparing and selecting decision-support tools could include the following objectives that may in some cases be 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 apply the tools concerned optimally. 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 don't 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.

5. OVERVIEW OF DEFINITE

5.1 Background

In the supporting documentation, DEFINITE is described as follows: DEFINITE (DEcisions on a FINITE set of alternatives) is 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. It 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. DEFINITE can be used by the busy professional with no prior experience of such software, as well as the sophisticated user.*

DEFINITE was developed by the Vrije Universiteit of Amsterdam in the Netherlands. The first version of DEFINITE was released in 1994. It has a wide variety of users. 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.

5.2 Application

It is necessary to distinguish between two applications of DEFINITE:

- To identify the best alternative from a finite set of options in order to select one
- To rank a finite set of alternatives in terms of their “worth”.

The former application is similar to the economic evaluation of mutually exclusive alternatives where the objective is the selection of the most economic mutually exclusive alternative (where *mutual exclusive* implies that the selection of one alternative obviates the need for the selection of other alternatives). The latter application is similar to the ranking of economically justifiable independent projects in terms of an appropriate “economic” criterion, and where the term *independent* implies that all projects could be selected subject to budget constraints.

5.3 Program structure

The program structure is displayed in the image of the appropriate DEFINITE screen below.

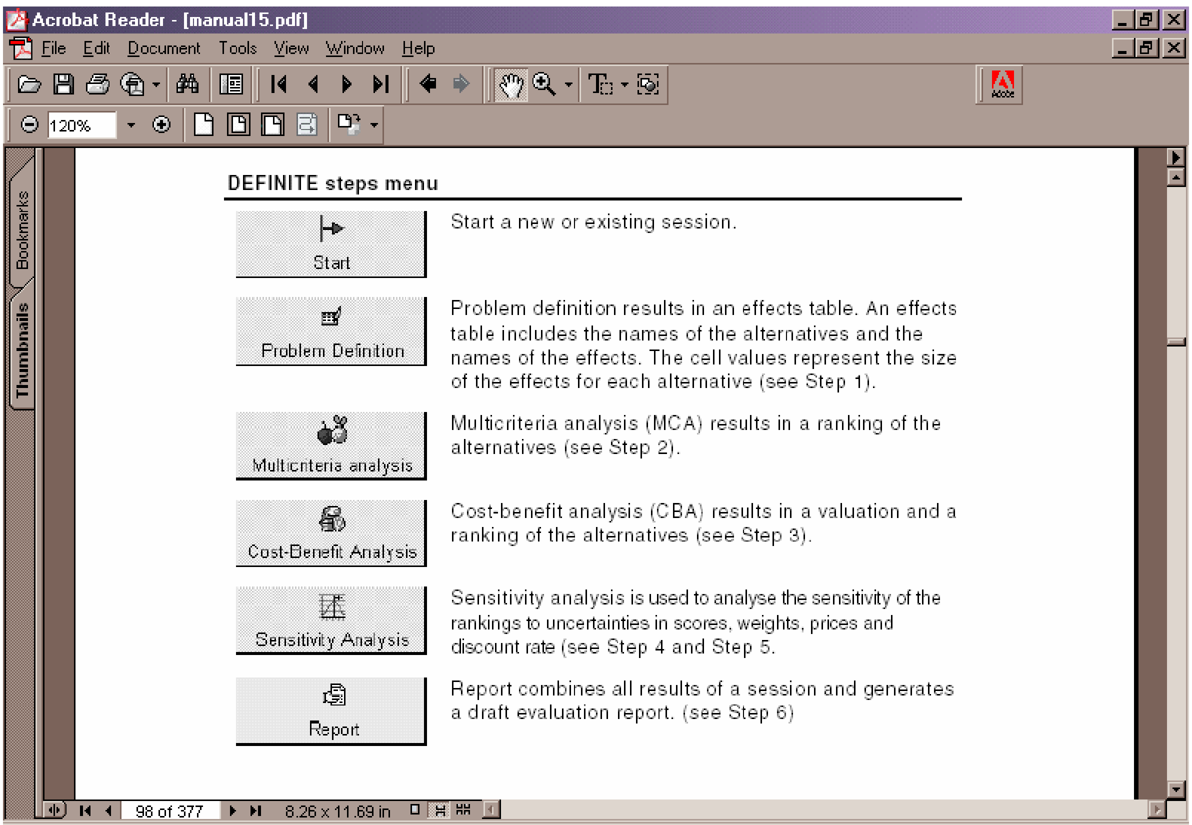

Figure 1: Program structure of DEFINITE

6. APPLICATION OF DEFINITE IN A TRANSPORT CONTEXT

6.1 DEFINITE inputs

To demonstrate the application of DEFINITE in a transport context, five hypothetical transport infrastructure projects in an urban environment were used, on the assumption that all projects are technically feasible and economically justified (i.e. that each has a benefit/cost ration of at least 1). This means that each project had already been subjected to a screening process involving the comparison of mutually exclusive alternatives.

It was further assumed that impacts (criteria) to be considered in appraising these projects would be the following:

- Economic efficiency, in terms of discounted total transport cost and expressed as the benefit/cost ratio
- Economic growth, as manifested by both:
  - Number of new jobs to be created
  - Cost per new job
- Equity, as manifested by both:
  - Number of persons to benefit
  - Cost per person to benefit
- Environmental *impacts*, as manifested by visual and noise pollution.

The "performance" of each project is shown in the table below.

Table 1: Performance of projects on selected criteria													
D:\myfilesC\ctmm08.xls sheet4 2/7/2004													
Impact				**Performance**									
Category	**Level 1**	**Level 2**	**Unit**	**Proj1**	**Proj2**	**Proj3**	**Proj4**	**Proj5**	**Proj6**	**Proj7**	**Proj8**	**Proj9**	**Proj10**
Economic efficiency	Transport cost	NA	B/C ratio	1.40	1.10	1.70	1.05	2.10	1.05	1.10	1.25	1.15	1.22
Macro-economic	Economic growth	Employ-ment	Number new jobs	200	500	150	350	300	400	300	50	250	150
		Cost	Cost/job (R mill)	0.32	0.39	0.50	0.73	0.15	0.12	0.29	0.30	1.73	1.15
Socio-economic	Equity	Persons	Number persons in target group	150	100	750	1 600	800	350	250	450	800	550
		Cost	Cost/person (R mill)	0.44	0.05	0.63	0.60	0.32	1.44	0.55	1.63	1.20	1.32
Environ-ment	Visual / noise	NA	Qualitative	- - -	- -	0	- - - -	-	- -	0	0	- - - -	- - - - -

The impacts listed below imply a value tree, the DEFINITE equivalent of which is showed below.

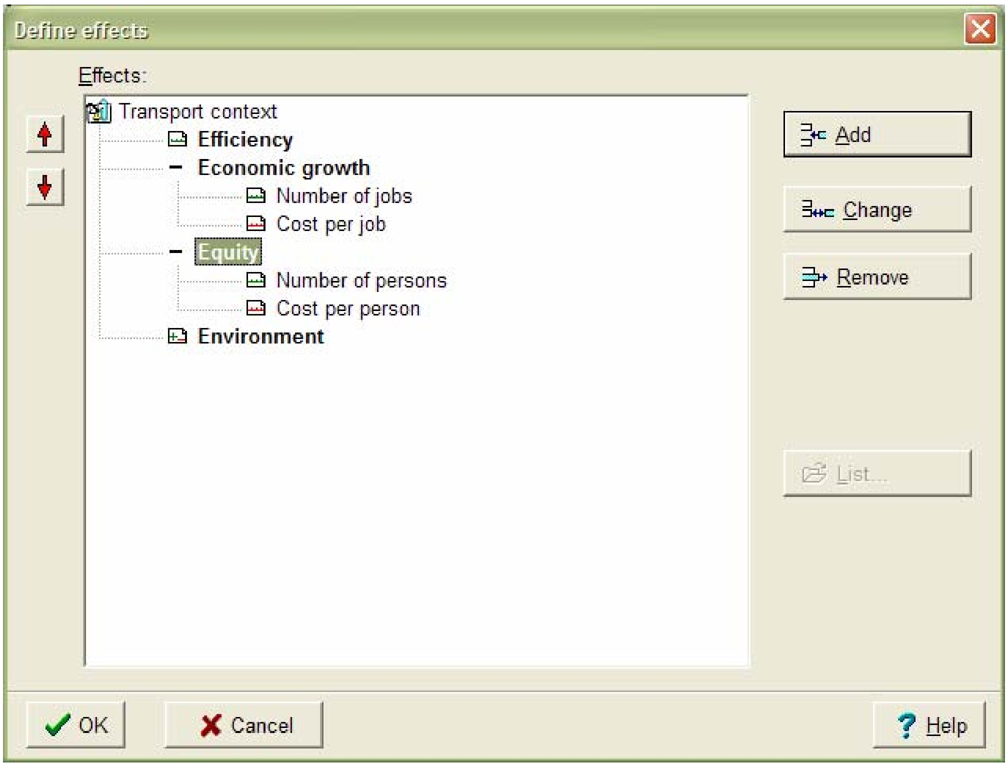

Figure 2: DEFINITE version of value tree

6.2 DEFINITE outputs

The outputs of DEFINITE can be presented in various formats. One such format is shown in the figure below.

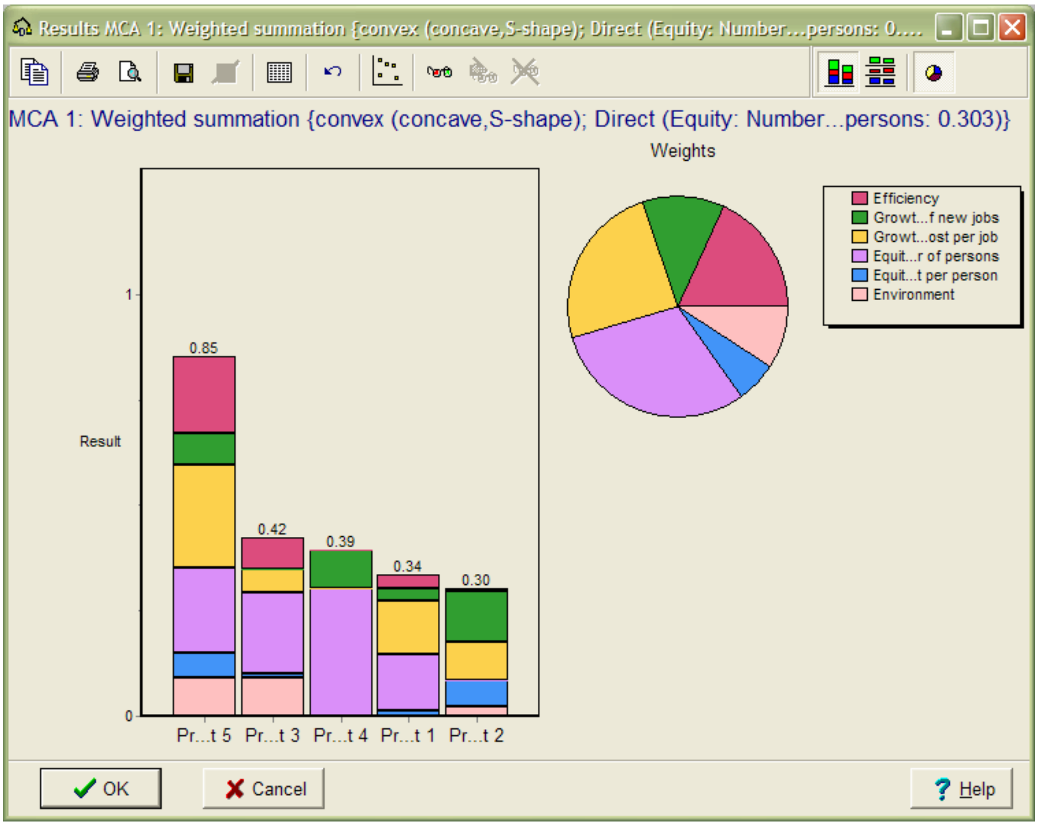

Figure 3: Example of presentation of results

7. WAY FORWARD

It is maintained that available state-of-the-art decision support tools can potentially improve decision making in a transport context. A number of problems may however be encountered with the practical implementation of these tools. The challenge would be to manage these problems in such a manner as to ensure that the benefits offered by these tools are maximised.

8. REFERENCES

[1] Stewart, JT et al. Multiple criteria decision analysis: Procedures for consensus-seeking in natural resource management. WRC Report No. 512/1/97, Pretoria, 1997

[2] Belton, V. Multi-criteria problem structuring and analysis in a value theory framework. In: Gal, T, Stewart, TJ and Hanne, T (eds): Multi-criteria decision making: Advances in MCDM models, algorithms, theory and applications, Kluwer, Amsterdam, 1999

[3] Cloete, F. Improving effective governance outcomes with electronic decision support tools. MCDA Workshop, CSIR, Stellenbosch, 6 June 2002.