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TRANSPORT PROJECT EVALUATION: INTEGRATING COST-BENEFIT AND MULTI-CRITERIA EXAMINATION BY THE USE OF SEGREGATED INVESTMENT RETURN RATES (SIRR)

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Abstract

Two main project evaluation approaches exist: cost-benefit analysis (CBA) and multi-criteria analysis (MCA). Related to a European road evaluation method (EURET 1.1) and the MCA-method, WARP, the paper proposes a set of so-called segregated investment return rates (SIRR) to integrate advantages of CBA with those of MCA.

CURRENT APPROACHES AND VALUATION PRINCIPLES IN SOCIO-ECONOMIC ANALYSIS

The main approaches to socio-economic analysis

Different evaluation frameworks for road projects are currently in use in different European countries. The frameworks differ with regard to the impacts or effects considered, the effect measurement methods, the effect valuation principles and the economic indices calculated for the evaluation result. There are also differences in the various approaches according to the extent to which monetary values are applied within the frameworks. Although monetary values for different units, or shadow prices in some cases, should only be seen as a kind of weight, the adoption and use of monetisation can be applied to characterize the overall evaluation approach. With a strong emphasis on the use of monetary values, the approach can be seen as a conventional cost-benefit analysis (CBA), while multi-dimensional analysis represents a multi-criteria approach (MCA).

On this basis and with attention to intermediate "broad" approaches, the four categories in Table 1 of national methods have been recognized within the European Research for Transport (EURET) programme, in connection with committee work on establishing a European evaluation method (CEC 1994, phase I rep.: 17).

Table 1 Characterisation of overall evaluation approach in different European countries

Conventional cost-benefit analysis	Broad framework with emphasis on cost-benefit methods	Broad framework with emphasis on multi-criteria methods	Mainly multi-criteria analysis with limited cost-benefit analysis
Denmark	Germany	France	Belgium
Greece	Italy		Netherlands
Ireland	United Kingdom		
Portugal			
Spain			

The two main approaches, CBA and MCA, are different in various ways. The methodological approach taken with MCA, can be indicated with the following quotation by the European Conference of Ministers of Transport (ECMT 1981: 16, 23), Group of Experts:

> Multi-criteria analysis is a fairly recent method for assessing and selecting projects exerting complex socio-economic effects. In this method, the individual assessment elements are taken separately and measured in the appropriate dimensions. .. the criteria will have to be weighted among each other because they are not of equal relevance. Determining the weights requires much responsibility and expertise from the decision-maker as the weights have considerable influence on the results of the assessment.

Multi-criteria analysis stems from the field of operations research and its developers understand it as being different in evaluation approach compared with the economics-based cost-benefit analysis. Thus, in a comprehensive presentation of MCA methods for regional planning Seo and Sakawa (1988: xiii) stated that:

> ... there exists the situation where the market price mechanism is not any longer well-functioning and for which alternative evaluation criteria have not yet been well established. The market price mechanism combined with the efficient allocation of resources has not worked as the proper evaluation index for planning. This problem is known as "market failure". A major subject of MCDM [multi-criteria decision methods] research is thus to resolve the theoretical evaluation problem. .. this research .. highly intends to take problem-solving as well as problem-finding aspects into major consideration; thus this is an "engineering" .. approach in contrast to an "economics" approach.

Valuation principles for impacts in socio-economic analysis

The necessary background for carrying out socio-economic project evaluation is the valuation of the different types of benefits or effects accruing from the project. A key to the understanding of the difference between CBA and MCA is the certainty, or the lack of same, which can be obtained for the impact prices applied. In many cases the benefits concern project consequences which are not traded on any market. For these non-marketed effects several different valuation approaches are used.

The different valuation principles currently in use for evaluation of road infrastructure projects can be classified as follows (Sassone and Schaffer 1978) (CEC 1994):

1. *Effects for which prices exist.* Here, market based values are available and provide useful information for project evaluation. Consistent treatment of taxes and subsidies are required throughout the evaluation. Where market prices are distorted through monopoly, regulation or failure to internalize external effects of the analysis (so-called externalities), etc, it may be necessary to take these distortions into account, to maintain consistency in the evaluation. The prices obtained in this way, such as the social values of project effects are sometimes referred to as shadow prices.
2. *Effects for which prices can be imputed from quasi-market observations.* Here, no direct markets exist, but values can be inferred from observed or stated human behaviour. The principal methods in this connection are revealed preference (RP) and stated preference (SP). The methods are applied in connection with travel time and safety unit prices, but they are useful also for environmental effects. In recent years the SP methodology has undergone rapid development.
3. *Effects for which surrogate prices can be used.* These methods make use of indicators such as the cost of replacing a lost asset or amenity as a surrogate for foregone benefits. Such methods suffer from obvious short-comings and are less satisfactory than 1. and 2. above. Nevertheless, used with care, they may provide helpful indications of maximum and minimum values.
4. *Effects which can be indicated only by use of quantitative, physical measures.* This category comprises effects inappropriate for use with one of the methods above. Noise units, in some frameworks, fall into this category, while in other frameworks either a surrogate or a quasi-market approach has been adopted.
5. *Effects which can only be indicated by use of a qualitative description.* This category comprises effects, for example land scape values, for which none of the above approaches are relevant. Procedures are available for dealing with these types of effects, based on professional or political judgement.

A general trend has been a methodological "increase" in the estimation of unit prices in the above method categories. For example, noise effects range, from initially qualitative statements associated with some point scores, through quantitative annoyance assessments based on defined annoyance units to economic noise cost estimates made by using methods in category 3 and 2. Noise is one of the impacts considered in the EURET evaluation framework to assess the impact on the local environment.

Scope of the Segregated Investment Return Rates (SIRR) approach

The scope of the paper is to examine whether the outlined differences in impact valuation uncertainty can be applied in a systematic way. Specifically, a so-called Segregated Investment Return Rates (SIRR) approach is proposed which integrates CBA and MCA analysis methodology.

The SIRR principles are set forth by the use of the European evaluation framework developed in the EURET programme and the specific MCA method WARP (weight and rank procedure). The EURET evaluation framework is described next and then principles of WARP are outlined. The following section describes the SIRR principles and gives a presentation of a calculation example. The final section gives conclusions and perspective.

PRINCIPLES OF SEGREGATED INVESTMENT RETURN RATES

The EURET evaluation method

The outcome of the EURET committee work 1991-1994 is a method for evaluation of new road construction which addresses medium-sized road infrastructure projects. The committee found that small projects and so-called mega-projects require different treatment.

The framework set up within the evaluation method for European road investments has six mandatory and three discretionary impacts or effects. These are shown in Table 2 together with the recommended impact variables (CEC 1994: 20).

Table 2 Impacts and impact variables in the EURET evaluation framework for medium-sized road projects

Mandatory impacts	Variables
Construction costs	Materials, labour, land and property acquisition (including compensation)
Maintenance costs	Structural repairs, carriageway delineation, signing, enforcement of traffic regulations
Vehicle operating costs	Changes in fuel and oil consumption, tyre wear, vehicle maintenance, depreciation
Travel time savings	Business time, non-business time
Safety	Fatalities, severe and slight injuries, damage only accidents
Local environment	Noise and air pollution, impact on natural environment (eg loss of open space/amenity), severance, visual impact
Discretionary impacts	**Variables**
Strategic environment	Greenhouse effect and strategic atmospheric pollution, loss of important ecological sites, sites of special scientific interest, historical and archaeological sites of value, energy consumption
Strategic planning and economic development	Land use, economic development/employment impact
Strategic policy	Conformity to larger sector plans, peripherality/distribution, transit

The valuation and measurement methods to be used are summarised in Table 3, where the following abbreviations for different valuation methods are applied: Revealed preference (RP), willingness-to-pay (WTP), contingent valuation method (CVM), stated preference (SP) and travel cost method (TCM) (CEC 1994: 61). These valuation methods, their theoretical basis and implied uncertainties are discussed in the EURET 1.1 committee report.

With regard to the MCA methodology to be used, the EURET committee has decided to recommend money as the common denominator (CEC 1994: 75):

> Monetary valuation .. has advantages of transparency and communicability into political debate which pure multi-criteria methods may not. Additionally, we are not here dealing with a closed set of criteria to evaluate, but have circumstances where additional, unexpected criteria may be added, especially in the discretionary elements of the appraisal. It is a relatively difficult process to accommodate extra impacts within conventional multi-criteria analysis, because of the need to obtain new judgements from the decision makers about relativities and to renormalise weights. A cost-benefit analysis (alternatively, a linear additive multi-criteria model with money as the common denominator for weights) opens up a range of independent possibilities for establishing the weights for new impacts and avoids any need to renormalise.
>
> An additional argument for the money denominator is that it can facilitate, if necessary, comparison between social/economic valuations of schemes and financial assessments and potentially broad comparisons across sectors of the economy.

Table 3 Valuation and measurement methods in the EURET evaluation framework for medium-sized road projects

Mandatory impacts	Valuation/measurement methods available
Construction	Factor cost, market prices adjusted for distortions and/or strategic environmental reasons, shadow prices
Maintenance	As construction
Vehicle operating costs	As construction
Travel time savings	Work time: RP, wage rates and resource costs Non-work time: WTP from RP, CVM, SP
Safety	Indirect costs: human capital, WTP to avoid risk Direct costs: resource costs of medical and emergency services Non-economic costs: imputed value for pain and suffering
Local environment	Air pollution: SP, indirect methods (dose response) Noise: RP (hedonic pricing), SP, CVM Amenity/landscape: TCM, CVM, SP, expert judgement Severance: RP, SP, ranked scales
Discretionary impacts	**Valuation/measurement methods available**
Strategic environment	Political judgement, descriptive methods, targets
Strategic planning and economic development	Net employment, expert/professional judgement, political objectives
Strategic policy	Indication of positive, negative, neutral effect

The framework and methodology results of the EURET Concerted Action 1.1 committee are seen as an initial step towards a more cohesive and consistent approach to evaluation of European road investments.

Required framework calculations with regard to sensitivity examination of the different impacts involved in the EURET 1.1 evaluation methodology can be handled with the WARP multi-criteria analysis method described below. Afterwards, on this basis, the SIRR principles can be demonstrated by the use of a calculation example.

The WARP multi-criteria analysis methodology

The PC-based technique WARP for supporting transport investment decisions integrates several features, which make it useful in decision-making environments, where no definite description of the investment objectives can be obtained (Leleur 1992). WARP can facilitate investment decisions, characterized by a large degree of robustness in an environment somewhat lacking in political consensus about investment objectives.

The WARP method aims especially at many projects and many attributes selection problems and emphasizes decision-maker inspection and judgement of information not accessible with the usual non-interactive cost-benefit technique. The selection problem can be defined as drawing a subgroup of "best" projects out of a larger group of projects all considered for implementation under a limited budget. Sometimes the subgroup consists of only a single project. The problem is well-known in transport planning and decision-making and occurs under other label names, like the project-ranking problem or the prioritization problem.

A basic assumption, when applying WARP, is that any project can be represented by a set of effects describing the various consequences of the project. All effects must be quantitative, but not necessarily in monetary units. Effects generally appear as number of travelling hours saved per year, number of prevented accidents with personal injury, etc. Several effects are difficult to monetise, for example environmental consequences of transport projects. Effects in a WARP analysis can also be judgmental ones, assessed on a numerical scale.

The weighting technique of WARP calculates benefit unit prices for all the effects involved for a given project pool and for a specific set of weights. The weights, expressed as percentages adding up to 100%, indicate the relative desirability of various planning objectives for the transport investment programme.

For an effect i the unit price UP_i is calculated from:

$$UP_i = \frac{Weight_i \cdot Price\ Base}{\sum_{n=1}^{N} Effect_{in}} \qquad (1)$$

with

UP_i: Unit price for project consequence no. i with i = 1,..,I.

$Weight_i$: Weight assigned to project consequence no. i (as a percentage).

Price Base: For example 10% of the sum of the total investment costs for all projects in the pool.

$Effect_{in}$: Quantitative measure for project consequence no. i for project no. n with n = 1,..,N.

With the unit prices determined, the sum of benefits for each project is found by adding its benefit components. Then, a ranking index is obtained by dividing this sum by investment costs, after which each project can be ranked according to its index value.

The WARP PC-program can handle up to I = 10 effects and as many as N = 1000 projects (Jensen and Leleur 1989). For a set of weights, the resulting ranking of projects is a consequence of the preferences expressed by the weight profile. In 1993 the WARP program was used in a Danish Road Directorate study to rank and sensitivity test 246 urban through-roads projects (COWIconsult 1993).

The price base has no influence on the ranking of projects, but serves the purpose of scaling the unit prices. Instead of a price base of 10% of the sum of the total investment costs for all projects in the pool, one of the effects could be used as the scaling factor. This is especially relevant when the chosen effect for scaling has a clear economic interpretation. The PC-program makes it possible to make such adjustments easily. This feature makes WARP useful to apply with regard to the proposed segregated investment rates described later.

An important feature of WARP is the capacity to work with many different weight sets and to illustrate variations for individual projects with so-called rank variation graphs.

The notion behind conventional CBA is that the decision-maker is assumed to have an objective function, an entity which he or she aims to maximize, subject to various constraints (Dasgupta and Pearce 1978: 21-22). This idea of maximization is closely related to estimating and applying a correct price set.

The idea of WARP as a multi-criteria analysis (MCA), is that a generally accepted objective function should be defined interactively. If a single weight or price set cannot be agreed upon, a set of strategies should be used as a basis for decision-making.

It is important to observe that weights have a special meaning in WARP, because they have been formulated in combination with prices and a specific project pool, see equation (1). For a given effect, the size of the weight indicates the fraction of total project pool benefits associated with a particular effect. A large weight means a strong influence on the ranking outcome for the effect under consideration—a low weight renders the opposite.

In accordance with this weight definition, the weight profile can be used as an overall expression for the emphasis given to priority criteria and their associated selection objectives. For example, a large weight on travel time means a high unit price per hour, which will improve the ranking (lower the rank number) for projects which are especially favourable with regard to travel time savings.

It should be noted that scaling problems, generally attributed to conventional additive weighting, are overcome in WARP due the applied combination of weights and prices. A change of scaling unit for one of the impacts will simply change the unit price also, without affecting the weight which then in WARP can function properly as a policy-variable (prices and impact unit net changes enter the utility function; not non-dimensional weights as in conventional, additive weight models) (Leleur 1992).

The SIRR-principles

Often the set of effects underlying a priority model is not homogeneous concerning the possibilities for quantification and monetisation. On the basis of these uncertainties, the effects may be split or segregated, for example, into three groups. Group I consists of effects which can both be quantified and monetised, group II consists of effects which can be quantified but not easily monetised, while group III is made up of effects which are often best described qualitatively or quantified solely using indicative, simple point scales.

In the case of the European evaluation model described in previously, group I effects consist of traditional traffic-economic effects, group II of local environmental effects and group III of non-local effects.

The definition and application of segregated investment return rates can be used to combine a cost-benefit approach with a multi-criteria approach.

Since group I effects (variables/impacts) can be monetised, these effects can be evaluated and aggregated to express, for example, a first year rate of return (FYRR). This is termed the A-rate (other types of economic indices can also be used; the FYRR criterion has both advantages and shortcomings not to be discussed in this context as it is just used to represent a possible economic index).

Group II effects are quantifiable but more difficult to value, which means that the unit prices for these effects—to be found by an applicable valuation methodology—are less certain than is the case with unit prices for group I effects. The return of the investment from a project, due to its group II effects, is added to the A-rate, whereby the B-rate is obtained.

Group III effects are even more uncertain. They might, in some cases, be most properly addressed qualitatively with a description. Quantitative measures are also possible in some cases. If it is decided that qualitative consequences should enter a quantitative, multi-criteria examination, it might be done using a simple point scale, for example as -3, -2, -1, 0 +1, +2, +3. The point "return" (benefit or disbenefit) obtained by a project can be multiplied with the investment cost to take project size into consideration. Weights to be applied in the multi-criteria analysis (MCA) appear on the basis of (very uncertain) unit prices for the project scores. The return of the investment from group III variables is added to the B-rate, whereby the C-rate is obtained.

From a practical point of view, it should be required that: 1) a project seems reasonable on the basis of A, B and C-rates and that 2) the project seems robust when compared with competing projects in the MCA. The triple index combination for each project of A, B and C-rates should be seen as the specific result of the project evaluation for that project. The D and E-rates to be introduced below only serve the purpose of testing the robustness of the priority ranking of the project.

The principles can be illustrated by an example where 25 projects compete for implementation under a budget limitation. The projects are first described in a project-effect matrix: monetised group I variables, quantitative group II variables and qualitative group III variables. Some of these group III variables can be made quantitative using an applicable impact assessment method. Others can be described by a simple point scale for application to the MCA.

Then all the A-rates for the projects are calculated. The B-rates are calculated from an assessment of the benefit value associated with the group II effects in the pool from so-called "best-knowledge" prices. This can be done by use of available estimates of unit prices, for example by averaging some estimates which are based on valuation principles that can be seen as reasonably valid and acceptable within the actual study. Similarly, the C-rates can be calculated. These rates also express some averaging approach, where D-rates and E-rates are "high" and "low" valuation alternatives for group II and III variables compared with the C-rates. A numerical example shown in Table 4 gives the principles of the methodology.

The rates for the individual projects are calculated in WARP on the basis of the set of index values and the corresponding weight profile which is the specific program input. The five different rates defined in Table 4 can be interpreted in the following way:

A-rate: Basic traffic and safety economic return from investment. The A-rate is not changed in the MCA and not translated by weights replacing unit prices when examining ranking robustness (group I effects).

B-rate: The A-rate supplemented with consideration of the local impacts. These must be constructed by applying average valuation principles and otherwise (group I+II effects).

C-rate: The B-rate supplemented with the consideration of non-local effects (group I+II+III effects).

D-rate: High valuation alternative for local and non-local effects. In the example an increase of 50% is used as seen by the changed index values.

E-rate: Low valuation alternative for local and non-local effects. In the example a decrease of 50% is used as seen by the changed index values.

Table 4 Numerical example illustrating principles behind segregated investment return rates with group I effects aggregated in the example, and group II and III made up of 6 and 3 effects respectively

Index and rel: Effect:	A-rate		B-rate		C-rate		D-rate		E-rate	
Effects I	100	100%	100	50%	100	43.5%	100	33.9%	100	60.6%
Effect IIa	0	0%	30	15%	30	13.0%	45	15.3%	15	9.1%
Effect IIb	0	0%	30	15%	30	13.0%	45	15.3%	15	9.1%
Effect IIc	0	0%	10	5%	10	4.3%	15	5.1%	5	3.0%
Effect IId	0	0%	10	5%	10	4.3%	15	5.1%	5	3.0%
Effect IIe	0	0%	10	5%	10	4.3%	15	5.1%	5	3.0%
Effect IIf	0	0%	10	5%	10	4.4%	15	5.1%	5	3.0%
Effect IIIa	0	0%	0	0%	10	4.4%	15	5.1%	5	3.0%
Effect IIIb	0	0%	0	0%	10	4.4%	15	5.0%	5	3.1%
Effect IIIc	0	0%	0	0%	10	4.4%	15	5.0%	5	3.1%
Totals	100	100%	200	100.%	230	100%	295	100.0%	165	100.0%

The 25 projects are ranked in accordance with their rates, which produce 5 rankings, labelled A - E, shown in two rank variation graphs. The first graph, see Figure 1, compares A, B and C. It is seen that projects 1, 3, 4, 7 and 22 are overall good projects. The projects are further examined by comparing A, C, D and E rankings, see Figure 2. The overall good-projects are not in this case affected relatively when taking account also of the rankings D and E.

The rank variation graphs which are intuitively understandable to decision-makers make it possible to see whether a project has a generally high, middle or low ranking, or the extent to which it changes its rank number under different weight profiles.

```
Rank variation graph for project: Euret

Project              *25  20   15   10   5   1
---------------------*:----:----:----:----:---:
                     *:    :    :    :    :   :
1                    *:    :    :    :    : BA:
                     *:    :    :    :    : C :
                     *:    :    :    :    :   :
2                    *:    :  A--------B  :   :
                     *:    :    :    : C  :   :
                     *:    :    :    :    :   :
3                    *:    :    :    :    A--B:
                     *:    :    :    :    :  C:
                     *:    :    :    :    :   :
4                    *:    :    :    :    :A--B
                     *:    :    :    :    :   C
                     *:    :    :    :    :   :
5                    *B-----------------A :   :
                     *C    :    :    :    :   :
                     *:    :    :    :    :   :
6                    *:    :  B--C----------A :
                     *:    :    :    :    :   :
7                    *:    :    :    : A-BC   :
                     *:    :    :    :    :   :
8                    *:    :    :  B--A   :   :
                     *:    :    :  C :    :   :
                     *:    :    :    :    :   :
9                    *:    :   B-----AC   :   :
                     *:    :    :    :    :   :
10                   *:    :    :  A-CB   :   :
                     *:    :    :    :    :   :
11                   *:    :    :   A---C-B   :
                     *:    :    :    :    :   :
12                   *:    CA   :    :    :   :
                     *:    :B   :    :    :   :
                     *:    :    :    :    :   :
13                   *:    :CA  :    :    :   :
                     *:    : B  :    :    :   :
                     *:    :    :    :    :   :
14                   *:    B-C----A  :    :   :
                     *:    :    :    :    :   :
15                   *:  AB:    :    :    :   :
                     *:   C:    :    :    :   :
                     *:    :    :    :    :   :
16                   *:    :   AC-B  :    :   :
                     *:    :    :    :    :   :
17                   *:    :    : C--B---A:   :
                     *:    :    :    :    :   :
18                   *:CB-------A    :    :   :
                     *:    :    :    :    :   :
19                   *:    A--C-B    :    :   :
                     *:    :    :    :    :   :
20                   *:A-------C-B   :    :   :
                     *:    :    :    :    :   :
21                   *:B-CA:    :    :    :   :
                     *:    :    :    :    :   :
22                   *:    :    :    :    :B--A
                     *:    :    :    :    :C  :
                     *:    :    :    :    :   :
23                   *:    :    :A------BC:   :
                     *:    :    :    :    :   :
24                   *A-------------B:    :   :
                     *:    :    :   C:    :   :
                     *:    :    :    :    :   :
25                   *: AB :    :    :    :   :
                     *: C  :    :    :    :   :
```

Figure 1 WARP results: Rank variation graph examining rankings based on A, B and C-rates

```
Rank variation graph for project: Euret

Project                    *25   20    15    10    5    1
---------------------------*:----:----:----:----:---:
                           *:    :     :     :     :   :
1                          *:    :     :     :     : CA:
                           *:    :     :     :     : D :
                           *:    :     :     :     : E :
                           *:    :     :     :     :   :
2                          *:    :  A---E----CD :    :
                           *:    :     :     :     :   :
3                          *:    :     :     :    AE-C:
                           *:    :     :     :     :  D:
                           *:    :     :     :     :   :
4                          *:    :     :     :     :A--C
                           *:    :     :     :     :   D
                           *:    :     :     :     :   E
                           *:    :     :     :     :   :
5                          *C---------E--------A  :   :
                           *D    :     :     :     :   :
                           *:    :     :     :     :   :
6                          *:    D-----C-----E----A :
                           *:    :     :     :     :   :
7                          *:    :     :     : A--C    :
                           *:    :     :     :     D   :
                           *:    :     :     :     E   :
                           *:    :     :     :     :   :
8                          *:    :     :D-C--A     :   :
                           *:    :     :     :E    :   :
                           *:    :     :     :     :   :
9                          *:    :     :     AC--E:   :
                           *:    :     :     D     :   :
                           *:    :     :     :     :   :
10                         *:    :     :   ADC     :   :
                           *:    :     :   E :     :   :
                           *:    :     :     :     :   :
11                         *:    :     :    A--DC  :   :
                           *:    :     :     :  E  :   :
                           *:    :     :     :     :   :
12                         *:    CA    :     :     :   :
                           *:    :D    :     :     :   :
                           *:    E     :     :     :   :
                           *:    :     :     :     :   :
13                         *:    :CAD  :     :     :   :
                           *:    : E   :     :     :   :
                           *:    :     :     :     :   :
14                         *:    : C---EA    :     :   :
                           *:    : D   :     :     :   :
                           *:    :     :     :     :   :
15                         *:E-AC:     :     :     :   :
                           *:  D :     :     :     :   :
                           *:    :     :     :     :   :
16                         *:    :   AC-D    :     :   :
                           *:    :   E:      :     :   :
                           *:    :     :     :     :   :
17                         *:    :   D--C--E---A:    :
                           *:    :     :     :     :   :
18                         *:C-E------A      :     :   :
                           *:D   :     :     :     :   :
                           *:    :     :     :     :   :
19                         *:    AE-C-D      :     :   :
                           *:    :     :     :     :   :
20                         *:A--E----C---D   :     :   :
                           *:    :     :     :     :   :
21                         *: DCA:     :     :     :   :
                           *: E  :     :     :     :   :
                           *:    :     :     :     :   :
22                         *:    :     :     :     :C-EA
                           *:    :     :     :     :D  :
                           *:    :     :     :     :   :
23                         *:    :     :A--E----C:    :
                           *:    :     :     :   D:    :
                           *:    :     :     :     :   :
24                         *A-------E-----C-D     :   :
                           *:    :     :     :     :   :
25                         *E-A-D:     :     :     :   :
                           *: C  :     :     :     :   :
```

Figure 2 WARP results: Rank variation graph examining rankings based on A, C, D and E-rates

To the extent that the project evaluation model is accepted by decision-makers, predominantly the relevance of the priority criteria used, it should be possible to agree about projects generally with a high priority as desirable for implementation, and about generally low ranking projects as undesirable. This kind of agreement is robust to underlying preferences since the classification does not need a clarified preference order with regard to the investment strategies. The debate may then appropriately be concentrated on projects being sensitive to strategy choice. Some of these "middle-of-the-road" projects may qualify for construction for very specific reasons, others may not.

Applying SIRR makes it possible to provide both "absolute" and "relative" assessment information to decision-makers. The absolute assessment information is made up of the actual levels of A, B and C-rates.

For different projects these rates can be inspected and compared. To exemplify such a comparison: proj. x can be preferred to proj. y even if C(x) is less than C(y) because A(x) is bigger than A(y), and otherwise. The rates are based on current "best knowledge" impact estimation models and prices. The segregated rates make it possible to apply multi-criteria analysis methodology in such a way that the CBA part of the analysis is not changed while other parts enter the MCA in accordance with their particular level of estimation certainty. In this way relative assessment information is obtained without affecting the most certain absolute assessment information expressed through the A-rates. At the same time the MCA maintain unit price interpretation for all involved impacts in the evaluation study which is one of the important attributes of CBA.

CONCLUSIONS AND PERSPECTIVE

The idea of applying segregated investment return rates (SIRR) is to combine the absolute assessment of the cost-benefit analysis with the relative assessment of the multi-criteria analysis.

The paper has demonstrated that this type of analysis can be carried out by dealing systematically with the different categories of impact uncertainties associated with the set of impacts involved in a particular evaluation study. Based on the EURET evaluation framework for medium-sized road projects three such categories were identified as traditional traffic-economic effects, local environmental effects and other, non-local effects.

The possibilities for estimating and assessing these three groups were described as ranging from "monetising possible" to "only qualitatively describable, for example by the use of a simple point scale". Based on the multi-criteria analysis method WARP (suitable because of its weight definition and rank variation graphs) SIRR principles were presented as specific, so-called A, B and C-rates. It was demonstrated that CBA and MCA analysis principles could be integrated in a consistent way maintaining the main methodological advantages from both approaches to project appraisal.

The SIRR principles will be implemented in a geographic information systems (GIS) based decision support system to be developed in the Danish research project GIS-T. In this project three interrelated levels will be applied: I) the traffic modelling level, II) the impact modelling level, and III) the decision support level (Nielsen 1994).

Often these analyses have been made separately in different software systems with incongruent data formats. The overall, integrated GIS-T approach will not only facilitate specific work, but will also make it possible to improve the quality testing of the various submodels in the model system.

With respect to improvement of present practices for supporting transport investment decisions a special concern for the evaluation research at the Institute of Roads, Transport and Town Planning at the Technical University of Denmark is overall assessments of decision uncertainty. Both quantitative and qualitative methodologies are currently developed and integrated (Leleur 1989) (Khisty and Leleur 1993). As concerns quantitative methodology a desirable end result is a system with a model capability, from linking various uncertainties in the modelling system to each other, to estimate the robustness of a specific appraisal result. Such an aggregate "technical" model robustness result should then be combined with "decision-making" uncertainty (policy strategies) and other uncertainties and factors considered within descriptive decision theory (Steinbruner 1976) (Dawes 1989) (Carroll and Johnson 1990) to obtain some kind of overall robustness. Such an assessment will provide useful background information for specific transport investment decisions. The presented SIRR approach is seen as promising as it can integrate the most valuable attributes of CBA and MCA in quantitative evaluation methodology and at same time in factual decision-making can help organizing complex evaluation information in an intuitively understandable way to decision-makers. In this way the SIRR approach can support also the qualitative search-learn-negotiate aspects of transport investment decision-making.

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