Decision aiding is more than aiding to choose: the role of structuring decision situations related to transport systems

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Abstract

In the last 20 years there has been a major shift in the field of decision analysis going from evaluation methods towards structuring issues and, more recently, robustness issues. We consider that this shift is important and goes in the right direction but it has not been paralleled in the area of transport evaluation. The main thesis in the paper is that it is essential to keep at the same time "rational" methods of evaluation (such as cost-benefit analysis and environmental impact assessment) and a sound management of the decision-making process. Our view is that sophisticated methods cannot compensate for an insufficient attention to the structuring phase of the process. After a presentation of the overall characteristics of cost-benefit analysis and environmental impact assessment, some theoretical aspects of structuring are analysed and the activities involved in such a process are described. Structuring is also illustrated by an example on a public transport system in Brazil.

Keywords: Decision analysis; Structuring; Transport system; Cost-benefit analysis; Environmental impact assessment

1. Introduction

Transport is a major component of economic activity, both in itself and as an input factor to most other economic activities. It further plays an important role in the daily life of citizens. The construction and operation of transport systems, such as new roads and rail links, involve large amounts of investment. Moreover, as these systems frequently extend over long distances, they can have many effects on communities and ecosystems such as noise, pollution problems at local and global levels, accidents and fragmentation of natural habitats.

Cost-benefit analysis (CBA) has been considered as the standard framework for evaluating transport policies and infrastructure investments, and for supporting public decision-making. CBA has become increasingly popular in the second part of the 20th century (Vreeker et al., 2002).

Starting in the 1960s, society's growing concern with the quality of the environment began to be incorporated into specific legislation. The idea of assessing environmental impacts of proposed policies and development projects originated in the USA with the National Environmental Policy Act of 1969 (NEPA), which became effective on January 1, 1970.

Environmental impact assessment (EIA) was introduced as a means of accounting for the environmental impacts of development activities into the decision-making process, thus counteracting the economic and engineering dominance in existing appraisal practice.

Legal requirements for EIA were established in many countries during the 1970s and 1980s. With the Rio (1992), Kyoto (1997) and Johannesburg (2002) agreements, an increased emphasis is being placed on implementing development projects that are efficient in terms of environmental, as well as economic and social objectives (PIARC, 2003).

Decision-making processes related to transport systems are very complex because they involve considerations on technical, economic, environmental, social and political issues. They are characterized by many actors who frequently have conflicting objectives.

CBA offers no clear guidance for the conduction of such processes and this aspect may be crucial in practice. Indeed, a recent study on economic evaluation methods for road projects reveals that many countries use CBA as a component of the evaluation but they recognize the need for an evaluation framework that takes account of all relevant factors (PIARC, 2004).

We consider that multi-dimensional problems need to be addressed by a multiple criteria approach which is referred to as multiple criteria decision analysis (MCDA). In the last 20 years there has been a major shift in the field of decision analysis going from evaluation methods (e.g. expected utility or multiple attribute aggregation methods) towards structuring issues and, more recently, robustness issues. A good example is the difference between Keeney and Raiffa (1976) - almost entirely devoted to assessment techniques, and Keeney (1992) - almost no techniques, and when technique is used, it is not very sophisticated.

We believe that this shift is important and goes in the right direction but it has not been paralleled in the area of transport evaluation.

In response to a "crisis" of evaluation methods economists and professionals working in transport evaluation have reacted towards more sophistication, meaning mainly new methods to convert non-monetary effects and new models to assess environmental impacts.

It seems that this has not led to an increased acceptation of such methods by the general public as attested by the prevalence of the NIMBY (Not In My Back Yard) syndrome throughout. A possible reaction to that is "the participation of the public" by means of Agenda 21 and related procedures. This has not been fully successful either (see Damart and

Roy (2005) for a discussion on the difficulties to conciliate CBA and stakeholders' participation).

This has contributed to create o very uncomfortable situation with the co-existence of three main types of methods: CBA with its strong normative slant, EIA with very sophisticated methods that remains insufficiently connected with CBA and therefore only play a minor role, and political management of decision-making processes with Agenda 21-like procedures.

We have no miracle solution out of this problem. Indeed, the evaluation of transport systems is very complex. Our view is that it is essential to keep at the same time evaluation methods with a strong normative appeal (investments are huge) that would be embedded in a decision-making process managed in such a way as to avoid transforming them into pure political processes.

It seems essential to avoid creating a gap between the "rational" methods of evaluation (CBA and EIA) and a sound management of decision-making processes. What we should look for is an evaluation framework that would be at the same time normatively compelling (we do not want to throw money down the drain) and socially acceptable (sophisticated methods are of little use if not put into practice).

The main thesis in the paper is that both aspects should be kept in mind at the same time. Our intention is not to criticize CBA or EIA, but to underline that recent development in the area of transport evaluation cannot compensate for an insufficient attention to the structuring phase of the decision-making process.

After a presentation of the overall characteristics of CBA and EIA in Sections 2 and 3 respectively, some theoretical aspects related to structuring are analysed in Section 4. The activities involved in this process are described in Section 5. In Section 6 structuring is illustrated by an example on a public transport system in Brazil. Concluding remarks are presented in the last section.

2. Cost-benefit analysis

Cost-benefit analysis is based on welfare theory and is applied to determine the net social surplus of public investments or institutional decisions (Mishan, 1971, cited by Vreeker et al., 2002). In many countries, it is an obligation to evaluate projects using the principles of CBA. Several international organisations (e.g. OECD and the World Bank) also produce manuals for project evaluation based on the application of CBA (Bouyssou et. al, 2000).

The economic evaluation aims at providing the decision-makers with an estimate of economic costs and benefits over time of a given project compared with a reference situation (either the existing situation or a "do minimum" option).

In order to conduct a CBA study, initially the project is characterized by some alternatives. Then the effects of each alternative are identified and the monetary assessment is carried out.

The alternatives are proposed taking into account mainly the results of the engineering studies, such as traffic forecasting and other technical factors, and frequently reflect a particular value system (for example, the transport agency's values). The needs and concerns of the different actors interested in the decision do not always receive the necessary attention, which prevents them from effectively contributing to the formulation of the alternatives and the identification of their effects.

The effects of transport systems are typically grouped into the following general areas: transport and economic efficiency, safety, and environmental protection and improvement (PIARC, 1999a).

Transport efficiency includes travel time savings, vehicle operating costs, maintenance costs and investment costs. Safety mainly involves accident costs, while environmental protection encompasses effects such as noise nuisance, air pollution and visual intrusion.

In order to perform the monetary assessment, prices must be used to convert effects into monetary units.

The net present social value (NPSV) of a project can be computed as follows:

$$NPSV = \sum_{t=0}^{T} (B_t - C_t)(1+r)^{-t} \quad (1)$$

where B_t are the benefits in year t, C_t the costs in year t, T the evaluation period and r the social rate of discount. A project for which NPSV is positive (i.e. benefits are greater than costs) is interpreted as improving the welfare of society.

A study carried out by PIARC (2004) for road projects shows that the evaluation period ranges from 15 years to 60 years and the discount rate varies from 3% to 12%. According to Vreeker et al. (2002), the determination of these parameters is very difficult because they are the result of a social-political decision. This may explain the variety in values found in the PIARC study.

The evaluation can also be undertaken in terms of the internal rate of return (IRR) which is defined as the discount rate which would produce a NPSV equal to zero, and the benefit-cost ratio (B/C). A project is acceptable if B/C is equal to or greater than one.

However there are considerable difficulties in measuring all relevant effects of a project in monetary terms, associated with such factors as accuracy of information, distributional equity, compensatory payments, discount rate and lifetime of the project (Tsamboulas et al., 1999; Vreeker et al., 2002).

Table 1 provides an overview of the effects that are valued in monetary terms and those that cannot and hence are described qualitatively or quantified but not expressed in monetary units.

Table 1
Range of effects included in CBA

Effects valued in monetary terms	Effects described qualitatively
Travel time savings	Air quality (some components may be valued in monetary terms)
Accident costs	Cultural heritage and monuments
Investment costs	Disruption due to construction
Vehicle operating costs	Ecology and nature conservation
Maintenance costs	Landscape effects
Delay caused by maintenance work	Land use
Noise nuisance	Effects on pedestrians and cyclists
Local air pollution	Water quality and drainage
	Geology and soil
	Outdoor recreation

Source: PIARC (1999a)

On what concerns the environment, only some effects are valued in monetary terms and included in the analysis. For example, van Wee et al. (2003) present the results of the CBA carried out for the Zuider Zee line, a high-speed rail link in the Netherlands. The environmental effects expressed in monetary units were the emissions of some pollutants such as carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) which are seen as the most important indicators for all emissions.

CBA is considered a sound method which provides consistency in evaluating projects and establishing priorities but it has severe limitations. The emphasis on monetary assessment tends to reduce the range of effects to be taken into account in the analysis. Effects may be ignored not because they lack importance but because they cannot be valued in monetary terms.

More important than these classical limitations, which have been well documented in the literature, is the fact that CBA offers only very little guidance for the management of decision-making processes.

The response of economists to the classical limitations of CBA has been to sophisticate their tools (e.g. new methods for obtaining willingness to pay, experimental studies of biases, theoretical investigations on the foundations of CBA in order to cope with equity concerns and consequences highly dispersed in time, the emergence of "Ecological Economics", the economic models of climate change).

This increased sophistication has led to more complex and therefore less transparent models, leaving untouched this second problem.

We argue that supporting decision-making processes is more than aiding to solve a problem or to choose one among many alternatives. As pointed out by Bouyssou et al. (2000, p. 87), "the determination of the "frontiers" of the study and of the various stakeholders, the modelling of their objectives, the invention of alternatives form an important - we tend to say a crucial - part of any decision/evaluation support study."

It should be noted however that we do not propose to replace CBA with "something else". Simply we want to draw the attention to some important aspects of the decision-making process that are not emphasized in CBA.

3. Environmental impact assessment

Environmental impact assessment is a systematic procedure to identify, predict and evaluate the environmental impacts of development actions. The results of an EIA study are usually presented in a report known as Environmental Impact Statement (EIS).

The EIA procedure consists of the following activities: environmental inventory; impact identification, prediction and evaluation; identification of mitigating measures and monitoring requirements; and communication of impact information. Similarly to CBA, an EIA study is usually conducted after the project and its alternatives (including the "no action" option) have been proposed.

The environmental inventory is supposed to be a complete description of the environmental setting in which the proposed action is to take place. This gives the baseline information against which identification and assessment can be made (Canter, 1977).

Impact identification refers to the need to determine those impacts requiring investigation. Although effects and impacts are often used interchangeably in EIA documents, there is an important difference between them. Development actions result in changes in the state of environmental variables (for example, increased pollutant concentrations in the air). These changes are effects. The predicted consequences of the environmental changes on humans, animals or plants are impacts (Bisset, 1985).

The confusion between effects and impacts is serious because, as will be explained in Section 5, effects represent means objectives while impacts characterize essential reasons for interest in a decision situation.

One of the main problems involved in impact identification has been a tendency to identify all possible impacts and to investigate them in depth. This has given rise to an activity known as scoping, which involves discussion between those implementing an EIA, those responsible for the project, government agencies and members of the public. The aim of scoping is to select those impacts which deserve further study.

Impact prediction consists of two stages. The first one is the estimation of the magnitude of changes in the state of environmental variables. For instance, mathematical models exist to allow predictions of the concentrations of chemicals in the air or in the water at varying distances from a source. The next stage is to determine the consequences of these effects (i.e. the impacts). Frequently experts can only make an estimate of the effects of a particular pollutant on organisms and populations. This is probably one of the most difficult activities within EIA (Bisset, 1985).

Impact evaluation refers to the need to determine the importance of the impacts. EIA constantly investigates a number of impacts which cannot be expressed in common units (e.g. money). Not all impacts will be considered to be of equal importance by decision-makers, environmental experts and members of the public. Judgements about the importance of the impacts can be done at all stages in EIA, but it usually occurs toward the end of the study when results are being collected for preparation of an EIS, or by decision-makers and members of the public after they have received copies of the EIS.

Once likely harmful impacts have been identified, mechanisms to mitigate them should be investigated and their ability to produce the desired results assessed. Communication of impact information refers to the presentation of quantitative data and qualitative information in a form that enables non-experts to come to conclusions on the merits and disadvantages of a proposed action.

Although originally intended to introduce environmental considerations into the decision-making process concerning development projects, plans, programmes and policies, EIA has been mostly applied to infrastructure projects such as highways, dams and harbours.

On what transport systems are concerned, the EIA procedure has had a major influence on consultation and public involvement. However public participation does not always include actual dialogue with the public. Moreover, the environment is usually taken into account in order to limit or mitigate harmful impacts, but seldom as a key factor in decisions on infrastructure development (PIARC, 1999b).

At European level, it has been recognized that environmental assessment should be developed as an integral part of the decision-making process for policies, plans and programmes (Tsamboulas and Mikroudis, 2000). Strategic environmental assessment (SEA) started in the 1990s to facilitate early and systematic consideration of potential environmental impacts in strategic decision-making.

Finnveden et al. (2003) identify the following steps in the SEA procedure: definition of objectives; formulation of alternatives; scenario analysis; environmental analysis; valuation; and conclusions. The authors recognize that some challenges need to be overcome for SEA to be an effective support to decision-making.

EIA and SEA emphasize the application of methods and techniques in order to approximate as closely as possible changes in the environment created by a new infrastructure. As already mentioned in Section 2, decision-making is not just a matter of evaluation methods.

Although some countries include the results of CBA in EIA (PIARC, 2004), environmental assessment remains disconnected from CBA. This has two main consequences: it is often neglected and it looses the strong normative appeal of CBA.

What is needed (but we do not offer that in the paper) would be a unified approach that would keep all of the strong normative appeal of CBA, fully integrating environmental issues, and oriented towards decision-making processes.

4. The meaning of structuring

Simon (1960, p.1) considers that the decision-making process “comprises three principal phases: finding occasions for making a decision; finding possible courses of action; and choosing among courses of action.” The author calls them respectively intelligence, design and choice, and relates these phases to the stages in problem solving described by Dewey (1910, cited by Simon, 1960): What is the problem? What are the alternatives? Which alternative is best?

Following Simon's decision model, decision analysis can be divided into three main interacting phases: structuring the decision situation, evaluation of alternatives and recommendations. Structuring is viewed in this paper as encompassing the intelligence phase and part of the design phase (inventing and developing possible courses of action). Analysing possible courses of action and selecting a particular one correspond to the evaluation and recommendation phases, respectively (Fig. 1).

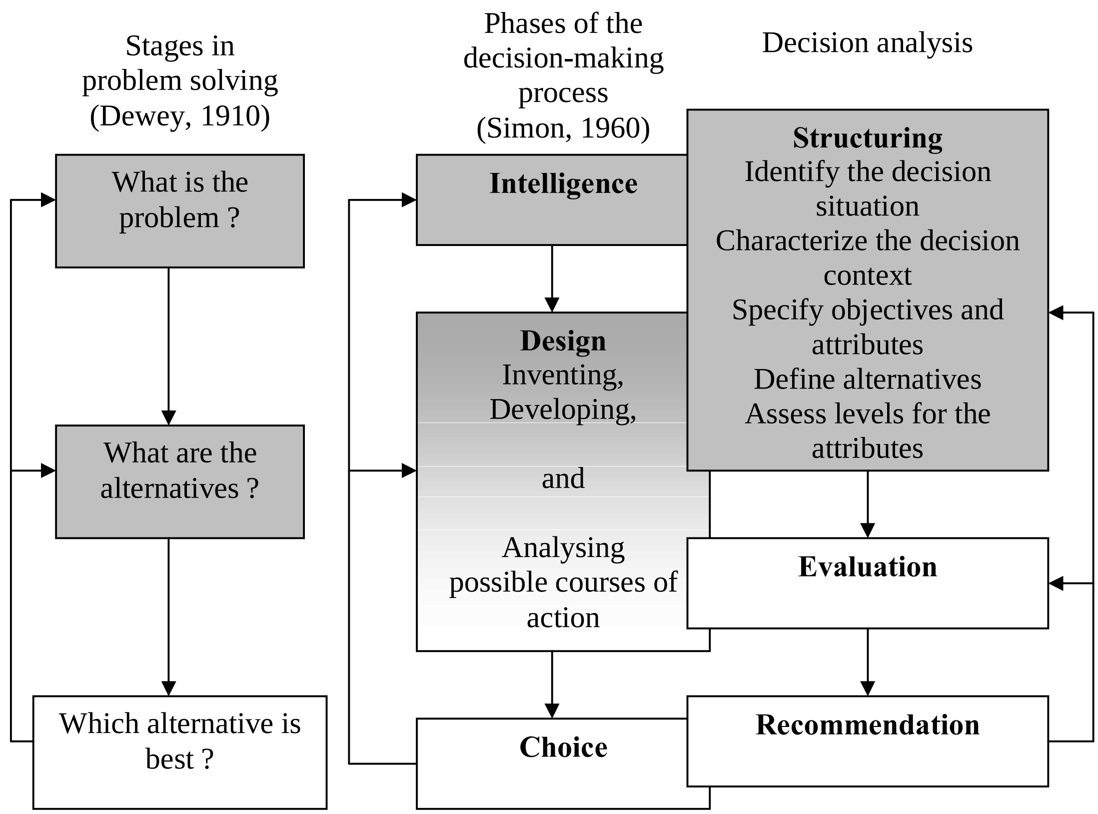

Fig. 1. Phases of decision analysis.
Source: Galves (2005).

Structuring is defined by von Winterfeldt (1980, p. 72) as "an imaginative and creative process of translating an initially ill-defined problem into a set of well-defined elements, relations, and operations."

The expression problem formulation can also be found in the literature. For French et al. (1998, p. 242), the problem formulation phase "takes place when an analyst and client explore a 'mess' of concerns and issues and structure these into a decision problem with several alternatives scored against several attributes/criteria."

According to Belton et al. (1997, p. 118), "the focus of work in the field of multiple criteria analysis has been predominantly on methods to support the process of evaluation and choice rather than on problem structuring". Practitioners and academics point out that greater attention needs to be paid to structuring (Bana e Costa et al., 1997; Belton et al., 1997), recognizing that if it is improved the quality of the decision outcome will be better (Henig and Buchanan, 1996; Corner et al., 2001).

This increasing interest in structuring may have been motivated by the difficulties which arise when applying multi-criteria methods to real-world problems. In fact, Guitouni and Martel (1998, p. 510) argue that "real applications revealed the weakness of the different MCDA methods to handle 'correctly' a DMS" (decision-making situation).

An important contribution to structuring is made by Keeney (1992), namely value-focused thinking. It is an approach that helps to understand and articulate values, and to use them to create alternatives and to identify decision opportunities. Values are what one cares about and they are made explicit with objectives.

Some authors interpret values as subjective components of a decision situation in opposition to objective components, such as alternatives (von Winterfeldt, 1980; Henig and Buchanan, 1996; Bana e Costa et al., 1997).

Wright and Goodwin (1999) propose what is termed future-focused thinking whereby scenario planning should be adopted prior to conventional decision analysis. For them, "scenario planning enables the construction of multiple frames of the future states of the external world and allows the testing of strategic options against these frames" (p. 320).

Corner et al. (2001) consider that approaches to structuring address the creation of objectives and alternatives in a static way. They advocate the dynamic decision problem structuring, which implies that thinking about alternatives helps generate objectives and *vice versa*.

These are also important and complementary contributions to structuring. As a crucial phase of the decision-making process, the aim of structuring is to facilitate actors' learning about and understanding of a decision situation. As mentioned by Belton and Stewart (2002, p. 35), " a problem well structured is a problem half solved". Indeed, structuring prepares the evaluation phase by identifying the actors interested in the decision, specifying their values and creating desirable alternatives. On the other hand, the process of evaluation contributes to clarify the meaning of these objectives and to identify new objectives and alternatives. Belton et al. (1997) show that it is possible to combine structuring and evaluation methods to provide useful decision-making support. The main activities involved in structuring are described in the next section.

5. Activities in structuring

In this paper structuring encompasses the following interrelated activities: identifying the decision situation, characterizing the decision context, specifying objectives and attributes, defining alternatives and assessing their performances on the attributes.

It should be stressed that the content of this section is a review of a trend and illustrates the shift in the field of decision analysis from evaluation methods to structuring and robustness issues.

5.1. The decision situation and its context

A decision situation may be a decision problem or a decision opportunity (Keeney, 1992). A decision problem occurs when there is a need to do something about a situation which is found unsatisfactory in some way (Belton and Stewart, 2002). A decision opportunity is identified and defined by the decision-maker rather than precipitated by external parties or events. A decision situation may be very unstructured (e.g. "How can we reduce traffic congestion in the city?") or reasonably well defined (e.g. "The location of a new airport").

Once the decision situation has been identified, it is necessary to characterize the decision context, by specifying its components and understanding how they interact. In fact, the decision situation and its context are closely related. The decision context helps define the decision situation more carefully and clearly.

When characterizing the decision context, it is important to specify such components as the system boundaries, the actors, the existing characteristics of the decision-making process and the type of problematic.

Geographical and time boundaries are frequently associated with the activity under consideration. However Finnveden et al. (2003) point out that system boundaries can exist not only for the activity but also for the emissions and use of the resources, for the impacts and related activities. The authors consider that the definition of these boundaries involve political choices and, in view of the importance of environmental protection, they claim for broad system boundaries at least as a starting point.

Since the decision is the result of interactions among the actors, it is crucial to understand who the actors are, what role each one plays and what they expect from the decision-making process. An actor is any participant in this process, such as the decision-maker, the analyst or facilitator (an actor who supports the decision-maker) and any individual or group interested in or affected by the decision.

The actors typically involved in transport decision-making are the transport agency and other governmental agencies (e.g. environmental and planning agencies), community groups, environmental groups, business community, travellers and the general public.

The consideration of the values and needs of the different actors is seen as a cornerstone of transport decisions. Indeed, if the actors facing a decision problem do not identify and express their values, it will probably be very difficult for them to evaluate alternatives in a meaningful way.

However the successful integration of the various interests is greatly influenced by the quality of the communication between the parties, the socio-political powers and the institutional structures within which they operate (PIARC, 2003).

For Keeney (1992), the actors should be involved early in the decision-making process because this increases their willingness to cooperate, since it lets them see that the decision has not already been made.

Many times a decision process has already a "history" at the moment decision aiding takes place. Characteristics such as existing alternatives, different points of view and conflicts among the actors form an important component of the decision context. As an example, Bana e Costa et al. (2001) describe a decision situation concerning a new railway link in which the decision had been postponed many times because of a conflict between public institutions.

The decision context is also characterized by the corresponding problematic. Roy and Bouyssou (1993) distinguish four types of problematic (*problématiques de référence*), i.e. broad categories of problem: choice, sorting, ranking and description. In transport problems, most of the decision contexts can be described by the choice or the ranking problematic. The type of problematic is important not only to specify the decision context but also to help select the method for the evaluation of the alternatives.

5.2. Objectives, criteria and attributes

An objective is a statement of something that one desires to achieve. Keeney (1992) distinguishes between the fundamental objectives and the means objectives. For example, two environmental objectives for a transport decision situation could be to minimize pollutant concentrations in the air and to minimize health impacts. The first objective is a means to the achievement of the second one. Minimizing health impacts expresses an essential reason for interest in the decision situation and therefore can be considered as a fundamental objective.

As the means objectives are associated with the effects of a project and the fundamental objectives represent the impacts, it is very important to separate them.

Objectives can be structured in a fundamental objectives hierarchy and a means-ends objectives network. The set of fundamental objectives should possess the following properties: essential, controllable, complete, measurable, operational, decomposable, non-redundant, concise and understandable.

Fundamental objectives associated with transport systems should reflect the key concerns of the actors and may be structured by type of impact, such as environmental, social, economic and political. With multiple actors, the crucial role of the fundamental objectives hierarchy is to provide a constructive mechanism for communication (Keeney, 1992).

In order to help the structuring of objectives, Belton et al. (1997) propose the use of cognitive mapping (Eden, 1988), which aims to represent a given situation as each actor perceives it and is usually generated using a one-to-one discussion.

The authors consider that the process of building a value tree (a fundamental objectives hierarchy) has much in common with that of building a cognitive map. However they draw the attention to the fact that translating a cognitive map to a value tree is not a straightforward task, because they have different structures. Examples of application of cognitive mapping to structuring in the context of MCDA can be found in Bana e Costa et al. (1999), Ensslin et al. (2000) and Ülengin et al. (2001).

Cognitive mapping is one of the problem structuring methods stemming from the fields of Operational Research and Systems which are collectively referred to as “Soft OR” (Rosenhead, 1989). These methods include the strategic choice approach (Friend and Hickling, 1987) and soft systems analysis (Checkland, 1981; Checkland and Scholes, 1990).

Specifying an attribute for each of the lowest-level fundamental objectives corresponds to measure the achievement of objectives. An attribute is a measure of the degree to which an objective is met by various alternatives (Keeney and Raiffa, 1976). The term attribute is mostly associated with multi-attribute utility theory and therefore is not universally used. For Keeney (1992) terms such as measure of effectiveness, measure of performance and criterion have been used to define an attribute.

However there is no consensual definition of what is meant by a criterion in the MCDA literature.

According to Roy and Bouyssou (1993), a criterion is a function of real numbers defined on the set of potential actions in such a way that it is possible to consider or to describe the result of comparing two actions a and b on the basis of two numbers g(a) and g(b). For these authors, to conceive a criterion is, first of all, to isolate certain aspects of the consequences of the actions in order to make comparisons which reflect specific points of view. They consider that a coherent family of criteria should be exhaustive, cohesive and non-redundant, and discuss the importance of some independence conditions.

Some authors use criterion in the sense of objective (Henig and Buchanan, 1996; Belton et al., 1997; Corner et al., 2001). In order to avoid ambiguity, the term attribute is preferably used in this paper.

There are basically three types of attributes: natural, constructed and proxy attributes (Keeney, 1992). Natural attributes are those in general use that have a common interpretation to everyone. Constructed attributes are developed specifically for a given decision context. In general, a constructed attribute involves the description of several distinct levels of impact that directly indicate the degree to which the associated objective is achieved. If no natural or constructed attribute is available, it may be necessary to utilize an indirect measure or a proxy attribute.

It is essential that an attribute is unambiguous which means that every level of achievement indicated by the attribute should have a clear meaning to all individuals concerned about a given decision.

Roy and Bouyssou (1993) point out that the quality of data, which concerns uncertainty and/or imprecision of data, must be taken into account when choosing a criterion. French (1995) identifies different sources of uncertainty and discusses the modelling of uncertainty within an analysis. Belton and Stewart (2002) differentiate between internal uncertainty, relating to the decision-making process, and external uncertainty, regarding the lack of knowledge about the consequences of a particular choice. They recognize that uncertainty can be reduced but not eliminated.

5.3. Alternatives and their performances

In the traditional framework used to evaluate transport systems, the alternatives are defined at the beginning of the decision-making process. This is frequently an important source of conflict because the proposed alternatives usually reflect a particular value system (for example, the transport agency's values).

When the objectives and concerns of the different actors are expressed and structured, alternatives can be created taking into account the significant aspects of the decision context. Fundamental objectives, attributes, means objectives and existing alternatives can be used to generate alternatives (Keeney, 1992).

In transport systems, the characteristics of the alternatives depend on the decision-making level. For example, at the policy level alternatives involve mainly transport modes and corridors while for projects they consist of such elements as routes, technical and operational features of the infrastructure and the vehicles.

Once the set of alternatives has been defined, the last activity in structuring a decision situation, according to what is proposed in this paper, is the assessment of the performances of each alternative. This means that, on each attribute, a level on a scale that may be qualitative or quantitative, is assigned to each alternative.

A simple example of hypothetical performances of three alternatives for a new road is given by Nijkamp and Blaas (1994) and presented in Table 2. The authors do not indicate the measurement scales in the table but costs are usually expressed in monetary units, travel time savings may be measured in time units (e.g. minute), loss of natural area in units of area (e.g. hectare) and reduction in traffic accidents in percentage.

Table 2
Performances of the alternatives

Alternative Attribute	A1	A2	A3
Costs	40	60	80
Travel time savings	25	30	20
Loss of natural area	2	1.5	1.75
Reduction in traffic accidents	4	5	10

Source: Nijkamp and Blaas (1994).

The fundamental objectives and the corresponding attributes, the alternatives and their performances are the results of a constructive process which prepares the evaluation phase. In this phase, sources of uncertainty or imprecision concerning the parameters of the evaluation model come into play. For example, if CBA is used, these parameters are the social discount rate, the evaluation period and the prices chosen to convert effects into monetary units.

If the evaluation is performed by means of a multi-criteria method, these parameters take the form of weights, aspiration levels, thresholds, etc. There are different plausible values for the parameters and their choice will determine the evaluation of the alternatives on the different criteria (Dias et al., 2002).

A study concerning the impact of acceptable combinations of values for the parameters on the results obtained by the application of an evaluation method is called robustness analysis.

Roy (2004) explains that the word robustness refers not only to solutions, but also to conclusions (see Roy and Bouyssou, 1993) and methods (see Vincke, 1999). Wong and Rosenhead (2000) relate robustness to the structuring components of a decision situation and not to the parameters of the evaluation model.

It is not the purpose of the paper to deepen the discussion on this topic, but to underline that robustness and structuring represent an important shift in the field of decision analysis which may also be profitable in the area of transport evaluation.

In the context of supporting and managing decision-making processes related to transport systems, structuring can contribute to:

- Improving communication and facilitating negotiation among the actors;
- Promoting the integration of the technical, economic and environmental issues into the decision-making process;
- Creating meaningful alternatives by considering the relevant aspects of the decision situation and its context;
- Preparing the evaluation of the alternatives on the basis of an agreed set of objectives and corresponding attributes.

Underestimating the importance of structuring can lead to public opposition to proposed transport systems, additional work and costly delays (consider, for example, the case of the 3rd Paris Airport as described by Damart and Roy (2005)).

6. Structuring in practice: the Curitiba high-capacity rail system

In order to illustrate how structuring may be conducted in practice, this section analyses the high-capacity rail system planned for the city of Curitiba, Brazil. After a short description of the project, the framework used to its evaluation is presented. Then some possible structuring elements of this decision situation are proposed and discussed. The text that follows is based on the information presented by Milléo (2001). None of the authors participated in the studies concerning this project.

6.1. Curitiba high-capacity rail system

Curitiba is the capital of the State of Paraná, in the southern region of Brazil, with 1 600 000 inhabitants. Curitiba is known for the sensible manner in which it became a major city without losing a comfortable life-style. It derives its economic prosperity from its role as commercial and processing centre for the expanding agricultural and ranch areas in the interior of the state.

The city has a notably efficient transport system, which includes lanes on major streets devoted to express buses. The buses stop at tube-shaped stations designed for protection from the weather and for quick bus entry and exit. Disabled access is also provided (http://en.wikipedia.org/wiki/Curitiba).

The development of Curitiba's transport system began in the late 1960s, early 1970s. The urban planners decided to integrate transportation, land use and road systems in order to promote the development of the city. Separating traffic types and establishing exclusive bus lanes on the city's predominant arteries helped to define two important characteristics of the city's transport system: a safe, reliable, and efficient bus service operating without the hazards and delays inherent to a mixed-traffic bus service; and densification of development along the bus routes.

However, due to the growing demand for public transport in Curitiba's metropolitan area, a high-capacity rail system has been proposed. This system will be integrated to the bus network, linking the southern metropolitan area to the city centre (Milléo, 2001).

6.2. The evaluation framework

6.2.1. Feasibility study

The agency responsible for operating the transport network in Curitiba commissioned a feasibility study for the high-capacity rail system (TC/BR, 2000, cited by Milléo, 2001) which included cost-benefit analysis and impact assessment.

The feasibility study took into account a specific layout which resulted mainly from engineering studies. The proposed rail system is 13.9 km long and will operate on an elevated concrete structure, serving 9 stations. Its capacity is 30 000 passengers per hour in each direction.

The benefits considered in CBA were travel time savings and reduction in operating costs for a period of evaluation of 30 years. Time savings correspond to the difference between travel time without the rail system and travel time after the implementation of this project. In order to convert time savings into monetary units, the average hourly salary of the system's passengers was used.

Reduction in operating costs was obtained by comparing operating costs without the project with those estimated for the rail system. If the system is not implemented, the passenger demand will have to be satisfied by the bus network and private cars, resulting in increasing operating costs.

Investment costs for the rail system encompass infrastructure, vehicles and equipment costs. Additional investment costs for the situation without the project were also estimated and subtracted from the investment costs for the system. The final value corresponds to financial costs and was converted into economic costs for Brazilian conditions.

The results of the CBA show that benefits largely exceed costs, the most important benefits being those related to reduction in operating costs (Table 3).

Table 3
Results of the CBA (US$ thousand)

Time savings expressed in monetary terms	Reduction in operating costs	Investment costs	NPSV
88.89	1 108.75	324.44	810.79

Source: Milléo (2001)

The following environmental effects were identified: local air pollution, contribution to the greenhouse effect, noise nuisance, impacts on water quality and drainage, visual intrusion (proximity of an elevated concrete structure to existing buildings), impacts on cultural-historical buildings in the city centre and land use modifications.

According to the feasibility study, the rail system will contribute to reduce the emissions of some pollutants such as carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur oxides (SO_x). The maximum noise level of 76 dB at 70 km/h was estimated and the construction of a screen was recommended in order to reduce noise nuisance. The study also considered that the elevated structure will not cause important changes on water quality and drainage. Cultural-historical buildings in the city centre will not be affected by project which is also expected to play an important role on the renewal of the urban zone where it will be located. None of these effects were included in the CBA.

6.2.2. Comments on the evaluation framework

The evaluation of the effects of a given project is subject to uncertainty and inaccurate determination (Bouyssou et al., 2000; Vreeker et al., 2002; van Wee et al., 2003). This also applies to the CBA for the rail system under consideration.

Travel time savings were obtained by estimating passenger numbers which depend on many factors such as population growth and land use changes. Although the project is intended to contribute to the renewal of the urban zone where it will be located, the influence of land use developments on passenger demand was not taken into account. The choice of the average hourly salary of the system's passengers seems to be arbitrary because salaries are different and the value of time may differ according to the type the journey (e. g. work or leisure).

Uncertainty on the evaluation of the reduction in operating costs is related to the number of passengers that will take buses or cars if the project is not implemented, to operating costs for buses and cars, and for the rail system.

Despite all the factors of uncertainty and inaccurate determination, sensitivity analyses with respect to model parameters were not conducted. The results should then be seen as indications of these effects.

It should be pointed out that sensitivity analysis is often restricted to studying the impact of the variation of a few parameters on the NPSV, one parameter varying at a time (Bouyssou et al., 2000). Therefore sensitivity analysis is not a substitute for robustness analysis. In decision-making processes with conflicting values and/or data of poor quality, it is very important to look for robust conclusions.

The general framework used to evaluate the high-capacity rail system followed the traditional pattern, i.e. the project was defined *a priori*, hence without the participation of the different actors interested in the decision, costs and benefits were estimated, and the environmental effects were identified but not integrated into the analysis. A different way to address the same situation is presented in the next section.

6.3. Structuring the transport system problem

Some structuring elements of the decision situation concerning the high-capacity system planned for Curitiba are explored in this section. The aim is to show how the various effects of the project, especially environmental ones, can be considered in order to support the decision-making process.

The necessity of providing a high-capacity system resulted from the increasing demand for public transport in Curitiba. In the feasibility study, the decision context was restricted to comparing the proposed rail link with the situation without this project.

However structuring should foster creative thinking and build a shared language among the actors. The decision context could then be broadened and formulated in terms of searching for desirable alternatives to improve public transport between the southern metropolitan area and the city centre.

Some of the actors directly involved in this context are the passengers, the institute for urban planning, the agency in charge of operating the transport system, the environmental agency and the Curitiba Municipality. As the institute for urban planning is responsible for land use development and extension of the transport system, it is assumed to be the decision-maker.

Each actor has specific objectives with respect to this transport problem which will be taken into account by the decision-maker. The passengers are certainly concerned with travel time, fare costs and safety. The decision-maker wants to promote the renewal of the zone where the project will be located. The agency responsible for operating the transport is interested in reducing maintenance and operating costs. The environmental agency is concerned with the potential impacts of the project on the urban environment. Safety is also an important issue for the Curitiba Municipality but it is mostly interested in investment costs.

Once the objectives of the different actors are identified, the “Why is it important?” test suggested by Keeney (1992) would be applied, in order to separate the fundamental from the means objectives. In this example, it is supposed that the objectives mentioned above express essential reasons for interest in the project. Therefore they may be considered as candidates for fundamental objectives. Fig. 2 illustrates a simplified fundamental objectives hierarchy for the problem.

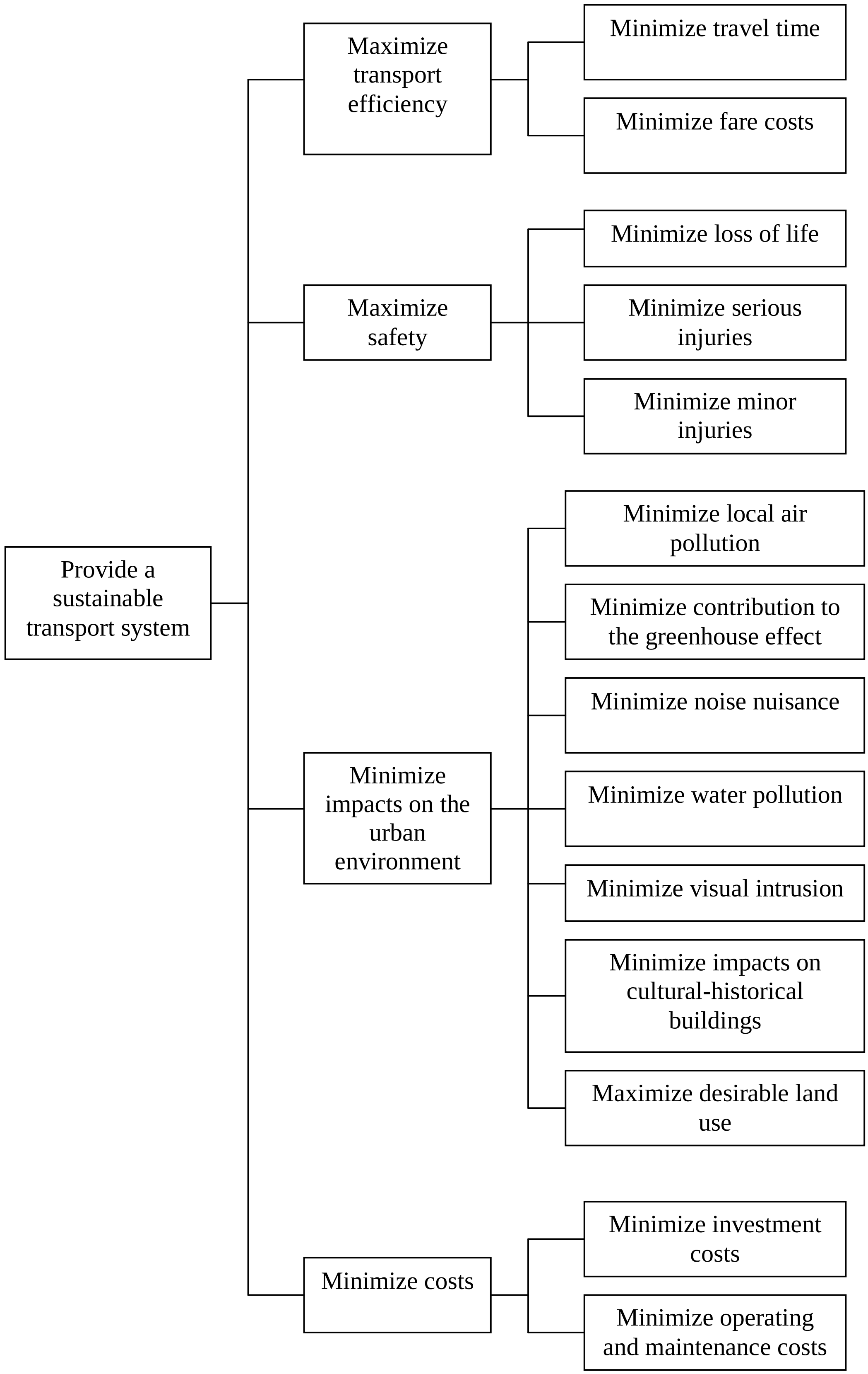

Fig. 2. A fundamental objectives hierarchy for the transport system problem.

An overall objective for the problem under consideration could be to provide a sustainable public transport system. The four objectives immediately under the overall objective specify its meaning. Therefore a sustainable system should maximize transport efficiency and safety, and minimize environmental impacts and costs.

Transport efficiency is specified as travel time and fare costs. The important aspects of safety are loss of life, serious injuries and minor injuries.

Potential impacts on the urban environment are specified according to the environmental assessment undertaken as part of the feasibility study.

It could be argued that minimizing health impacts might be more appropriate as a fundamental objective than minimizing local air pollution. These impacts, like other ones, are not included in the hierarchy because they were not mentioned in the environmental assessment. Further identification of fundamental objectives and development of a means-ends objectives network for the fundamental objectives would certainly have improved the knowledge about the environmental impacts of the project.

Finally costs are broken into investment costs, operating and maintenance costs.

The results of the CBA could have been included in the objectives hierarchy, as proposed in some multi-criteria methodologies (Tsamboulas and Mikroudis, 2000; Vreeker et al., 2002). However in this example, it was decided to keep the elements of the calculations in the CBA separate (e. g. travel time, investment costs, operating and maintenance costs), in order to clearly identify each objective of the hierarchy. Moreover this avoids double counting between the CBA and the structuring components.

The resulting hierarchy encompasses the actors' main concerns and indicates the set of objectives over which attributes should be defined.

Some of the lowest-level objectives in Fig. 2 can be represented by natural attributes (e.g. travel time, fare costs, serious injuries and costs) while for other objectives indirect attributes may be necessary (e. g. local air pollution, noise nuisance and water pollution).

Constructed attributes might be necessary to represent such impacts as visual intrusion, impacts on cultural-historical buildings and land use. Attributes of this type are intended to measure precisely what the fundamental objectives are meant to address. Therefore it is very important that each level of a constructed attribute is carefully defined and clearly described.

Specifying attributes is not a simple task, even when natural attributes seem obvious, because it involves consideration on context-dependent factors such as value judgements, system characteristics within the geographical boundaries (e.g. environmental, social and economic ones) and the time period over which attributes will be assessed. The available information for this example on the rail system does not allow for the proposition of an appropriate set of attributes.

The fundamental objectives and the corresponding attributes provide the basis for learning about the decision situation and creating alternatives. In this example, alternatives other than the proposed one could be created in order to better achieve the fundamental objectives associated with a sustainable transport system.

7. Concluding remarks

The motivation for this paper is the authors' belief that decision aiding is more than aiding to choose. In other words, supporting decision-making processes is not just a matter of evaluation methods and more methods cannot compensate for poor structuring.

The aim of structuring is to facilitate actors' learning about and understanding of the decision situation. Underestimating the importance of structuring can lead to public opposition to proposed transport systems, additional work and costly delays.

In this paper structuring encompasses the following interrelated activities: identifying the decision situation, characterizing the decision context, specifying objectives and attributes, defining alternatives and assessing their performances.

As an illustration, structuring of the high-capacity rail system planned for Curitiba was developed. Some of the actors directly involved in the decision-making process were identified as well as their main concerns. Fundamental objectives were grouped into four areas (i.e., transport efficiency, safety, impacts on the urban environment and costs), and a possible hierarchy for these objectives was proposed.

A structuring framework adapted to transport evaluation would be badly needed. The purpose of this paper was not to solve this problem but to mention that recent advances in decision analysis should not be overlooked.

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