Evaluation of Externalities in Transport Projects

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The purpose of this paper is to illustrate the variety of issues and methods used to treat different types of externalities in transportation projects and to ask how these different approaches and values can affect project evaluation and ranking. Of special interest is the question whether the elimination of externalities and different procedures favor one type of transportation investment over the other, and specifically rail projects versus highway projects. To this point the paper mostly poses the questions with a focus on issues where bias can result.

The paper is based on a study conducted for the Ministry of National Infrastructure in Israel to improve the evaluation procedure of transportation projects in order to better account for externalities. This paper focuses on two main issues. First, we recommend approaches and methods of evaluation for different transport externalities, including the value of time savings. These evaluations are based on the international literature on these topics. Second, we suggest a methodology to better include externalities in the evaluation of transport *projects, including a quantitative and qualitative multicriteria analysis (MCA). The paper also discusses the implications of different methods and values for project evaluation.*

1. Introduction

Most transportation projects in Israel, both roads and public transport facilities, are evaluated ex ante by using a standardized procedure called the 'Nohal Prat'. This is essentially a cost-benefit analysis giving the profitability of a project to society. Two major deficiencies of the current procedure are:

- Externalities such as emissions, noise, and land use effects can only be included in a normative way; they do not influence the outcome of the cost-benefit analysis or the ranking of projects as derived through the formal procedure of the cost-benefit analysis.
- The value that is used to convert travel time savings into monetary units for travel for non-work purposes is arbitrarily set at 20% of the value of time spent on traveling for work purposes.

In a research conducted for the Israeli Ministry of National Infrastructures, a team led by the Hague Consulting Group (now Rand Europe) from the Netherlands produced recommendations to improve this procedure, focusing on the quantification of externalities and the values of travel time to be used. The recommended values, both for externalities and for timesaving, are mostly based on the international literature on these topics, adjusted, where possible, for Israeli conditions.

The area of externalities' evaluation of transport projects is well covered in the literature including a new book by Friedrich and Bickel (2001) and a new report by the Victoria Transport Policy Institute (2002). There is also a good coverage of appraisal methods including the review of project appraisal in European Union by Bristow and Nellthorp (2000) drawing from the EUNET project for the European Commission (DGVII) and a review of common sources of error and bias in transport project appraisal by Mackie and Preston (1998). The purpose of this paper is to illustrate the variety of issues and methods used for different externalities and to ask how these different approaches and values can affect project evaluation and ranking. Of special interest is the question whether the elimination of externalities and different procedures favor one type of transportation investments over the other, and specifically in comparing rail projects versus highway projects. To this point the paper mostly poses the questions with focus on those issues that can result in bias and recommend a methodology for the inclusion of as many externalities as possible in transport project evaluation. While the work presented in this paper is based on work done for the Israeli Ministry of Infrastructures, the issues, methods and recommendations discussed are general and should be useful for researchers and practitioners from other countries.

2. Evaluation Methods

The most important instruments for the evaluation of transport projects are:

- Cost-benefit analysis (CBA)
- Multicriteria analysis (MCA)
- Cost effectiveness analysis (CEA).

In CBA one tries to express all costs and benefits of a project in money units. In a social CBA in theory all impacts on society, also the externalities, are included. CBA is founded in welfare economics (for a good exposition see Mishan, 1988, Johansson, 1993 or Layard and Glaister, 1994). This means foremost that all impacts are measured in terms of changes in consumer surplus (sometimes also producer surplus). This change in the utility of households can be measured in two different ways (Johansson, 1993):

- The compensating variation: the maximum amount of money that a household is willing to pay to be just as well off as before the project;
- The equivalent variation: the minimum amount of money that must be given to the household to make it just as well off as it could have been, after the implementation of the project.

A common practical approximation of these methods used in transport project is the rule of a half.

In a MCA one does not try to express all effects in one dimension (money), but several dimensions are used at the same time. Criteria can be measured in monetary units, minutes, grams, decibels or even be qualitative (e.g. ranking of projects on a criterion). The overall assessment of a project or the ranking of different projects, using all the criteria, takes place by using criterion weights, which form an expression of political priorities. A good review can be found in Nijkamp, Rietveld and Voogd (1990), and some recent developments can be found in APAS (1997).

CEA is less common in transport projects and can take two forms (HCG, 1995): cost minimization (which alternative, for alternatives that have similar effects, can be implemented at the lowest costs) and effect maximization (which alternative, for alternatives with similar cost, yields the highest benefit to society).

3. The Role of Travel Demand Models

In order to evaluate most of the transport externalities, we need to know the travel demand and traffic conditions with and without the transportation project in question. This is usually the role of travel demand models that take as input information on regional growth trends, socio-economic changes, spatial patterns of development, and transportation infrastructure to produce estimates of trips by origin destination pairs, purpose, mode, and time of day. These trips are then assigned to a transportation network to produce speeds and vehicle kilometer of travel, by facility type and geography. These outputs from the travel demand models are necessary input to the evaluation of many of the externalities as will be described in later sections. There are a few issues and questions regarding the use of the output of these models for externalities evaluation.

First, there is the question of how accurate these models are. Much has been written on the problem of uncertainty of travel demand models (See for example: Skamris & Flybjerg, 1996; Walmsley and Pickett, 1992; Pickrell, 1990; Stopher, 1993; and Cambridge Systematics, 1996). The level of accuracy also depends on the type of project in question. Most of the models that are being used today are a variant of what is known as the four steps model that consists of trip generation, trip distribution, mode choice and assignment. These models that were initially developed in the 1950s and 60s to evaluate the need for new transportation infrastructure are not sufficient to evaluate new trends in transportation policy, such as travel demand measures mainly because our understanding of the consequences of such measure lags behind our understanding of the consequences of new transportation infrastructures projects. Sustainable transportation development calls for further investment in public transportation with accompanying travel demand management measures. The uncertainty in travel demand models is more significant for the evaluation of such schemes. While the travel demand model is only the first set of models in a chain of models to evaluate externalities, each of these models suffers from lack of accuracy and reliability, and the accuracy of one model is greatly dependent on the accuracy of the inputs it receives from the previous model in the chain and the linkages among these models are not nearly as strong as desired. The error in each model as well as the cumulative errors raises the question of the applicability of these models to sensitively determine externalities. The uncertainty in some of the models may significantly exceed the magnitude of the impact that is being evaluated. (Cambridge Systematics, 1997).

The second question with regard to the accuracy of travel demand models is how this inaccuracy affects the ranking of transportation projects. It is occasionally argued that as long as one uses a consistent set of assumptions and models to evaluate different projects, the bias will also be consistent and therefore may not affect the ranking of projects. While such an argument may be reasonable when comparing similar projects, like different alignments for a new highway, this argument is unacceptable when comparing different projects such as highway versus public transportation projects or in analyzing different transportation policies.

The third question related to accuracy is the question of how well these models deal with induced demand. This topic has also received a lot of attention in the literature, see also the discussion by Scott (in this issue). Most travel demand modeling practices assume that the total number of trips generated will not be affected by new transportation infrastructure, some of the practices assume that it will affect the distribution of these trips, and most consider potential changes only in mode and route choice. The assumption of fixed demand favors highway projects over transit projects. Expanding highways under a fixed demand assumption will relieve congestion, save travel time and reduce emissions. However, if induced demand is included, travel time savings per vehicle will be less than estimated, more vehicle kilometers will be driven on the highway and therefore emissions will increase. For transit projects, on the other hand, fewer passengers will enjoy the improved service and accessibility, and less revenue will be assumed for the transit operator.

The last question for this discussion is how sufficient is the output from these models for the evaluation of the different externalities. The output from most of these models as indicated above is volumes and average speeds for each segment of the highway system, in addition to ridership on the different segments of the public transportation system. While this output is sufficient to calculate savings in travel time, which is usually the largest benefit of transportation projects, it fails to provide the input needed for many of the externalities and particularly for the emission modeling. For good emission estimation one needs to know, in addition to the average speed, the speed profile, the vehicle mode of operation (cold start/hot start), and the type of vehicle and model. In some places, post processors are used to convert the information from the travel demand models to better input for emission modeling.

The major question with regards to all these questions is how these different issues affect the ranking of transportation projects. There is a need for further research on this topic.

New sets of travel demand models, activity-based models, are currently being developed and applied in major urban areas in Europe and the U.S. These models derive the demand for transportation from the demand for activities, therefore better understand the nature of travel and how people cope with activities and therefore have the potential to predict travel demand more accurately. Although the theory behind an activity-based travel-demand model is very attractive for obtaining the detailed accurate output needed for emission and air-quality analysis and other externalities, the development and application of such a model is very complicated. Shiftan (2000) showed that even advanced applications of such a model still lack many features that were simplified in order to make the model applicable. These simplifications lead one to obtain only some of the advantages of an ideal activity based model system. Much development is still needed to achieve the type of information needed for good air-quality and other externalities' analysis. However, activity-based modeling has important advantages for externalities' evaluation and is likely to continue to improve the input for externalities' evaluation.

4. The Evaluation of Externalities

4.1 Congestion

Congestion can be regarded as an external effect that travelers impose on each other. A traveler does not take into account the impact he or she has (together with the other travelers) on the travel times of other travelers. For a more detailed discussion of this issue see Scott (in this issue).

Two stages can be distinguished in evaluating congestion:

- The calculation of the travel times on the network.
- The conversion of the time losses in minutes to monetary units, using a value of time;

In theory it is also possible to omit the second step and insert the time losses due to congestion, measured in minutes, into a multicriteria analysis (MCA), but in all practical evaluation methods, time is converted into monetary units and included in the cost-benefit analysis (CBA).

Calculation of travel time

Most evaluation approaches for transportation projects simply calculate the total travel times for the situation with and without the project from the travel demand model. An example of this approach is the UK COBA method for the evaluation of trunk road schemes. The externality effect of congestion will be represented in this method by lower traffic speeds, which results when the volume/capacity ratio is high. The COBA method also uses a different way of calculating the speeds than that used in the assignment itself. Moreover, the demand is often fixed or only represented by a small set of elasticities (Department of Transport, 1997). Basically the same approach is followed in the evaluation frameworks for roads and transport telematics projects recommended for European Community projects (EVA, 1991; APAS, 1997).

Value of Time

The ‘value of travel time’, VOT, denotes the exchange rate at which a traveler is indifferent between marginal changes in the time and cost involved in travel. The VOT therefore is an output of a traveler’s decision-making process, not an input to this process.

Since the basic research carried out in the 1960’s and 1970’s demonstrated the value of time concept, VOT measures have frequently been used for economic evaluation of road infrastructure and public transport projects as part of the cost-benefit analysis. The travel time gains are originally in minutes or hours and the VOT is used to convert them into money terms. Because time saving is often the major benefit of transport projects the choice of value of time can significantly affect project evaluation.

The literature contains many VOT studies. National VOT studies were recently conducted, amongst others, in the Netherlands (HCG, 1990; Gunn, 1996), the UK (Accent and HCG, 1995; Gunn, Bradley and Rohr, 1996) Scandinavia (e.g. Algers et al, 1996 for Sweden) and Chile (Ortuzar, 1996). Figure 1 presents results from the TRACE project carried out by HCG and others for the European Commission (DGVII) regarding recent national VOT values. All values in national currencies were converted into January 1998 ECU/hour. While in most studies a distinction was made in VOT’s by mode and trip purpose, Figure 1 presents only values that do not distinguish between purposes. The labels in Figure 1 refer to each specific country and reference. Car (vehicle) and car driver VOT’s are generally higher than VOT’s of public transport users. Most VOT outcomes for cars are around 5 ECU/hour, whereas for public transport the VOTs from these studies are all between 0 and 5 ECU/hour, except for one study in France. This difference is partly a ‘selection’ effect: a person with a high value of time tends to choose fast modes. Studies by trip purpose show that VOTs for travel on employer’s business are higher than for all other purposes, also if the chosen mode is public transport. For car, many studies find a value close to 20 ECU/hour. For public transport the value is somewhat lower (between 10 and 20 ECU/hour) and for car passengers the average VOT is between that of car driver and public transport. The commuting VOTs are lower than the business trip VOTs but higher than for other purposes. Many studies yield a value of time for commuting which is close to 5 ECU/hour. The differences in VOT between the modes are more divergent for specific purposes compared with those shown in Figure 1 for all purposes together.

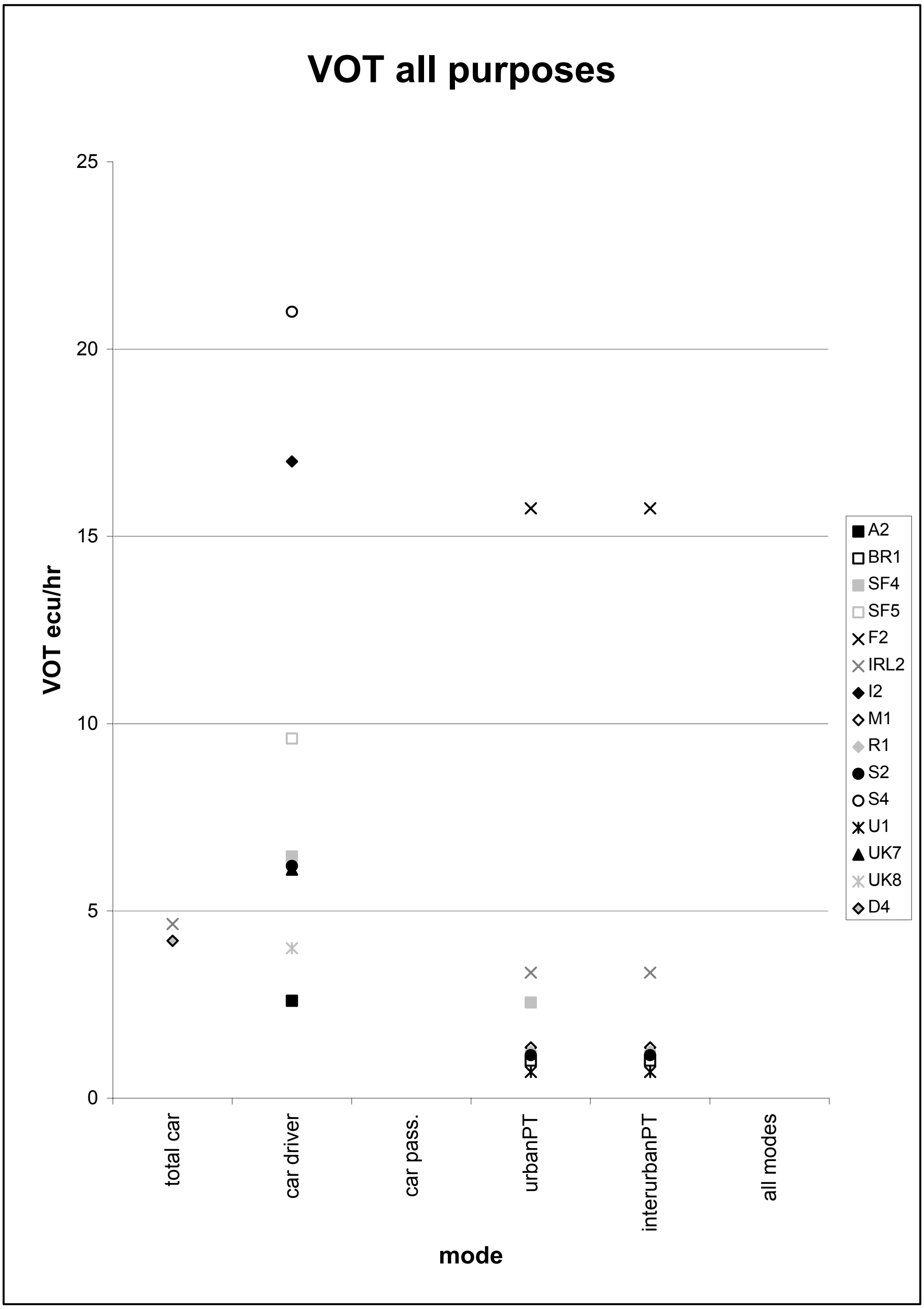

Figure 1: Value of Time Values for All Purposes from Different Studies.

4.2 Air Pollution and Noise

The emissions of air pollutants from traffic mainly consist of exhaust emissions, but there are also impacts of fuel that evaporates from the fuel system and emissions that result from the contact between the tires and the road surface. Some of the emissions have purely local impacts; others contribute to effects working on a regional or even global scale. This is represented in Table 1. Generally speaking, the impacts on a larger geographical scale also take more time than those at a smaller geographical scale. Emissions vary by type of vehicle (e.g., truck vs. private cars, engine size, model) and fuel (diesel vs. gasoline).

Table 1: Air pollution and geographical scale

Pollutant/effect	Local	Regional	Global
Carbon monoxide (CO)	Health effects		
Hydrocarbons (HC or C_xH_y)	Health effects	Summer smog	
Particles (PM)	Health effects	Winter smog	
Oxides of nitrogen (NO_x)	Health effects	Summer smog Winter smog Acidification	
Sulphur dioxide (SO_2)	Health effects	Winter smog Acidification	
Carbon dioxide (CO_2)			Greenhouse effect

Two types of traffic noise can be distinguished (Department of Transport, 1993):

- Low frequency noise: this type is caused by the engine, the exhaust system and transmission, particularly of heavy vehicles; it dominates when traffic is not in free-flow conditions;
- High frequency noise: this type is caused by the interaction of tires with the road surface; it dominates under free-flow conditions.

Evaluation of Air Pollution and Noise Impact

In order to include impacts on air quality and noise in the evaluation of transport projects the following steps need to be taken:

- Estimate (if possible quantitatively) the impacts of the project on emissions of pollutants and noise (e.g. in terms of kg for different pollutants and dB for noise, also at this level we usually estimate emissions in terms of gram per mile or per hour that together with the travel data can provide better input for the next step), based on the available traffic model forecasts;
- Calculate the quantitative impact of these emissions on humans, animals, plants and buildings. These effects include health effects, the effects of summer and winter smog and acidification, and the greenhouse effect. The valuation of the change in emissions can then be based on these impacts. In studies that try to reach quantification, these relationships are called exposure-response relationships or sometimes also dose-response relationships. This work includes modeling how pollutants spread (dispersion models), take part in chemical reactions and lead to primary and secondary effects. Establishing these relationships is notoriously difficult and the outcomes are often highly unreliable.
- Derive a monetary measure for these effects to include them in a cost-benefit analysis (CBA) of the transport project. As part of the monetary evaluation of these effects there is

a wide discussion of methods and values for the value of life, some of this discussion is covered in the next section regarding the cost of accidents. Alternatively the impacts (quantitatively or qualitatively) can be inserted into a multicriteria analysis (MCA), which does not call for a conversion into monetary units.

For the evaluation of a transport project, dispersion and exposure-response model simulations are usually not carried out. Instead of this, the results of more general exposure-response studies are used (e.g. by adopting their results in terms of money units per gram) or one directly goes from emission (in grams) to evaluation. Examples of the latter approach are methods of monetarisation that do not use the exposure-response relationships, such as hedonic pricing, abatement or reduction cost and some forms of contingent valuation. Another example of not using exposure-response relationships is the use of roadside emissions (in grams) directly in MCA evaluation (though the weights of these criteria could be based on some knowledge about the effects on humans, animals, plants and buildings).

For noise, similarly to air pollution, a relationship can be formulated which links people with the physical level of the external effect. In the case of noise, this is not a matter of pure health effects: noise from traffic is generally not regarded as a source of damage to human health. Noise does however produce nuisance. Questionnaire surveys have attempted to measure the nuisance effect and relate the annoyance expressed by the respondents to some physical measurement of the noise. An important outcome of such surveys is that there exists a large variation between individuals in their sensitivity to noise. Practical research therefore has since moved to establish an average or community annoyance rating for each noise level. In the UK assessment method for road projects, all areas where existing traffic is likely to be increased or reduced by at least 25% (equivalent to a change in noise level of 1dB(A)) should be identified. Nuisance (percentage of people bothered very much or quite a lot) is derived from a graph of the relation between nuisance and noise or change in noise.

Monetary Valuation of Traffic Exhaust and Noise

The air pollution effects of transport projects can only be included in a CBA if they are converted into money units. Since these external effects are not traded on the market, we cannot use preferences revealed at the market of these ‘goods’. Other, less direct methods have to be used to derive monetary expressions. These methods can be classified in several ways (e.g. EVA, 1991, Hausman, 1993, Johansson, 1993, Button, 1994, Verhoef, 1994, IOO, 1995, APAS, 1997, Quinet, 1994, 1998). We tried to synthesize all this material and arrived at the following classification:

- Equation of external cost with the cost of repair, avoidance or prevention or with the cost to achieve pre-determined emission targets;
- Asking respondents questions about hypothetical situations (stated preference methods);
- Open-ended Contingent Valuation (CV);
- Closed-ended CV;
- Conjoint analysis;
- Looking at related markets (revealed preference methods);
- Travel cost method or housing demand/utility functions (or household production functions); and
- Hedonic pricing.

Some of these methods could start from the emission levels (e.g. avoidance cost, hedonic pricing); other methods should preferably follow exposure-response calculations (e.g. better informed answers can be obtained from a CV asking persons for the willingness to accept certain health risks compared to asking for the willingness to be compensated for certain emission levels).

Overviews of results of monetary valuation studies can be found in Verhoef (1994), Quinet (1994) and Quinet (1998). These studies provide a monetary cost of traffic exhaust emissions per vehicle or passenger kilometer or per amount of emission and show that values vary from country to country and from study to study.

4.3 Cost of Accidents

Valuing the economic loss of traffic accidents is based on cost elements, which are categorized into two main types:

1. Cost to the injured person including costs of treatment and cure, hospitalization, insurance, administration and judgment. These also include indirect costs such as economic loss to the injured person's place of work.
2. Accident cost including damage to the car and other property, time loss, congestion cost, administrative costs and damage to the environment.

There is a variation in the items included in the evaluation of these costs in different countries and in the available data to support these evaluations. In order to include impacts on accident cost in the evaluation of transport projects the following steps need to be taken:

- The risk of accidents, i.e., the numbers of fatalities, severe and slight casualties and damage-only accidents has to be predicted first (with and without the project). This needs to be done on the basis of the traffic forecasts, preferably by mode and road type.
- Evaluate the cost of each type of accident and casualty, and the value of life.

Valuing risk levels for accidents

Various methods for the assessment of risk levels for accidents have been developed. The levels of risk are derived from the effects of different kinds of parameters on the number and severity of accidents. Such parameters are for example: type of road, number of injuries on a road section, time of driving on a specific road (day/night) etc. One such approach is the safety performance function (SPF) describing the relationship between the traffic volume (AADT) on a highway, and the safety of the highway, which is defined as the collision frequency expected on the highway in a time period (or per period of time and length of section) (Hauer & Persaud, 1996).

It is recommended to use local studies for such relationships. Western European (e.g. Dutch) averages for the numbers of fatalities, casualties and accidents cannot be used in Israel for example, as the frequency and severity of accidents in Israel is quite different.

Various cost assessment methods

One of the main elements in accident costs is the value of life. There are various assessment methods for the value of life (for a good discussion of these various approaches see for example Mishan (1975)) and various studies show that different methods and values are used in different countries. See for example a comparison by Elvik (1991) that included 20

European countries. Costs for a fatality were found to be up to 2.5 Million dollars (according to 1994 exchange rate). Life loss assessment has the largest weight in the calculations and lost productive capacity also has a major role. Both significantly diverge among countries. The value of lost quality of life has been estimated by means of different methods in different countries. In Great Britain, New Zealand, Sweden and the USA, the value of lost quality of life is based on estimates of road user willingness to pay for reduced risk of fatality. In Denmark, Finland and Switzerland, the value of lost quality of life is based on implicit values derived from public decision-making concerning health and safety. In Belgium, France, Italy, Luxembourg and Spain, the value of lost quality of life is based on the courts' judgments approach. Many countries did not estimate the value of lost quality of life.

Values can be used from other countries if they are adjusted for GDP. For Israel, for example we recommended a value of 4 Million NIS per fatality, which is the value obtained from the UK Department of Transport values minus 30 percent (which is the difference in GDP between the two countries) and also coincides with the 1 Million EURO value accepted in the EU some years ago (which again reflects a certain average between the values adopted by the various EU countries.). However, this adjustment doesn't consider differences in demographic and other characteristics between these countries. A recent comprehensive study conducted within the framework of the European project UNITE (Nellthorp et al., 2001), suggests a value of 1.5 million Euro measured as a "consumer value" of the value of a statistical life, based on the willingness-to-pay method.

4.4 Land Use Effects

We can distinguish four main categories of land use effects:

1. The visual impact of the transport change.
2. Other direct local effects, such as severance.
3. Land values and property rights.
4. Effects that are induced partly or wholly through the changes in accessibility resulting from the transport project. This is a major benefit of transport projects that contributes to economic growth.

Methods to Evaluate Land Use Effects

We focus here on the effects through changes in accessibility. Methods to evaluate land-use effects fall into two groups: the first one, which relies on personal judgments, and the second, which involves formal mathematical models. Judgment-based methods vary from individual judgment, to informal use of group judgment and formal analysis of group judgment that ranges from taking an average of several opinions to formalized Delphi surveys.

Predictive land use models can be classified into static models representing a single point in time, and dynamic models running for a series of time periods, with transport changes generally taking one or more such periods to have an impact on land-use. Many of the current models fall into the category of quasi-dynamic models, which could be classified into three main categories (European Commission, 1996):

1. Entropy-based models pioneered by Wilson (1970); this group has almost completely disappeared from current practice.

2. Spatial economics models based primarily upon the integration into a spatial form of separately developed economic models such as a multi-area input-output model. Practical applications of these approaches are discussed in Hunt and Simmonds (1993), and are currently represented by the MEPLAN and TRANUS packages.
3. Activity-based models based primarily upon representation of the different processes affecting the different types of activities considered. Highly developed examples of this class are the IRPUD model developed by Professor Wegener at the University of Dortmund, Germany and the one presented by Hunt (in this issue) including elements of agent-based micro-simulation

A detailed review of some of the current operational urban land-use transport modeling frameworks is provided by Hunt et al (2001). See also the review of recent research projects relevant to the integration of transport, land use planning and environment policy by Geerlings and Stead (in this issue), the review and discussion by Van Wee et al. (in this issue) regarding the impact of land use on mobility and the development of sketch planning models to assess land-use transport policies by Pfaffenbichler and Shepherd (in this issue).

Application of methods

So far as we are aware, none of these methods is a formal requirement anywhere. There is however a growing requirement that one or other of these methods should be used to examine the expected land-use impacts of at least major transport proposals. There is also an emerging requirement that this should be done whether or not the land-use impacts of transport change are considered desirable; there is evidence that the supposed “regeneration” effects of new transport infrastructure have been quoted in support of schemes where additional benefits were needed to support the justification, but that undesirable effects (such as increased pressures for development in areas where policy is to resist development) are being ignored where conventional transport benefits were sufficient.

It has to be recognized that all of the formal, quantified methods listed above require analysis over larger areas than are often required for the analysis of transport benefits. This poses major problems in developing a formal method for consideration of land-use impacts, which can be implemented, for individual schemes without greatly multiplying the expense on modeling. Whether this should actually be attempted remains an issue for debate.

Accessibility

Sophisticated land-use/transport modeling such as described above is time-consuming and expensive, and is not necessarily a practical option. It is therefore common to use accessibility, which is a key input from transport models to land-use models in some state-of-the-art modeling approach as a proxy for the transport effects on land use.

Accessibility can be broadly defined as "the ease of reaching" a set of opportunities, or "the ease of being reached" by a set of contacts (such as clients or customers) and can be calculated from the output of the transport modeling. In general, it is taken as referring to possible or potential movements, and hence as reflecting the scope for interactions which may or may not result in actual travel or transport.

There are many measures of accessibility and there have been a few reviews of these measures. See for example Jones (1981) and Geurs and Ritsema Van Eck (2001). The choice of accessibility measure may depend on the policy objective of the project in consideration.

Geurs and Ritsema Van Eck (2001) recommend activity-based accessibility measures to further improve the assessment of accessibility impacts.

5. Recommended Evaluation Methodology

This section described the recommended evaluation methodology developed for the Israeli Ministry of National Infrastructure. However, the methodology is quite general and the general framework is recommended for other places as well. The methodology consists of three steps:

1. The cost-benefit analysis (CBA), which includes all factors that can reliably be converted into monetary units;
2. A quantitative multicriteria analysis (MCA) for all the effects that cannot at the moment be reliably converted into monetary units but can be quantified, including the outcome of the CBA as one of the criteria;
3. A qualitative MCA for further non-quantifiable factors.

The qualitative MCA depends on the ranking of several projects with regards to each of the relevant criteria. This cannot be done on the basis of one project alone (this also goes for the quantitative MCA: MCA is by definition a method for comparing alternatives).

5.1 The cost-benefit analysis

The CBA should include the following factors (all for the difference between the future year with the project and the future year without the project; effectively all the factors are in terms of changes):

- Investment cost
- Operating and maintenance cost
- Public transport revenues
- Travel cost for the travelers
- Travel times for the travelers
- Cost of accidents.
- Cost of health effects of air pollution
- Cost of noise

The first 4 items are by definition in monetary units. Of course discount rates need to be used to get annual figures and figures for a total project lifetime on the same basis. The change in the revenues for public transport companies by definition should be equal to the change in the cost for public transport travelers, so that in the social CBA these effects will cancel out.

5.2 The quantitative multicriteria analysis (MCA1)

The first stage MCA has a purely quantitative nature. Table 2 presents the criteria that are part of MCA1.

Table 2. Criteria in MCA1

Criteria
Net present value from the CBA
Accessibility index (or indices)
Acidification (emission of NOx and SO_2 in acid equivalents)
Contribution to greenhouse effect (emission of CO_2)
Consumption of land (in acres; will partly be included in investment cost)
Energy use (in joules; will partly be included in fuel cost; also depletion of natural resource stock)

As described above the accessibility criteria are a proxy for the impact on the future regional growth in houses and jobs (land use effects). The cost of emissions in the CBA only includes the health effects (particles and ozone), not the acidification and greenhouse effect. The latter two effects are therefore included in MCA1. Examples of the emission factors to calculate the scores for these criteria for Israel are presented in Table 3. Table 3 also contains the average energy consumption factors in mega joules per vehicle kilometer. Energy consumption (at the prices actually paid) is part of the travel cost for private modes and of the operating cost for public transport, but an extra weight can be given to this criterion, because of concern for the depletion of the existing stock of natural resources.

Table 3. Emission factors for acidification, greenhouse effect, and energy consumption

Segment	Acid equivalents/ vehicle km	CO_2 in G/vehicle km	Energy consumption in mega joules/vehicle km
Passenger car	0.019	143	1.9
Lorry	0.290	800	8.4
Diesel bus	0.316	1175	12.3
Tram	0.328	4450	46.7
Train	0.820	9700	101.8

The investment cost is already included in the CBA and these will probably include the cost of the land being used for the project. However, this is likely to be an underestimate of the true opportunity cost of the land in places like Israel where this is not a competitive market and the government is a major landowner. The consumption of land is therefore included in the quantitative MCA as well, to express the scarcity, which is not properly expressed in the prices and in the investment cost. It can be measured in acres, based on the planned layout of the project (e.g. a new railway line).

The overall outcome of MCA1 can simply be found by standardization and weighted summation. For standardization we recommend that every score on a criterion be divided by the highest value that is observed among the projects to be compared, for that specific criterion. Consequently all the values in the MCA will be between 0 and 1.

A simple MCA method has been chosen here, instead of more complicated methods such as AHP (analytic hierarchy process), to facilitate the use of the MCA for all projects to be evaluated. The qualitative MCA can only be carried out by using sophisticated MCA methods. The MCA1 can only be carried out if several projects are compared. If there is only one project, no standardization can be performed, and it is not possible to conduct a sensible MCA.

After this, the overall MCA1 score of a project can be found by multiplying the weights (if quantitative weights are available; examples are given below) by the criterion scores and adding or subtracting the results over all criteria. The net present value and the accessibility index ('good' things for society) should be added, the other criteria ('bad' things for society) should be subtracted.

The weights for the 6 criteria in MCA1 can be determined by the policy makers. Instead of using a single set of 6 weights, multiple sets (e.g. a 'green' set with a high weight for the environmental aspects and a 'regional growth' set with a high weight for accessibility and a 'financial' set with a high weight for the CBA outcome) can be used, and the sensitivity of the outcome for changes in the weights can be analyzed. The weights' sets could for example be as those listed in Table 4. The standard set is loosely based on the Dutch standard set for the evaluation of public transport projects of the Ministry of Transport.

Table 4. Examples of sets of weights for MCA1.

Criterion	Standard	Green	Regional growth	Financial
NPV	**83**	**78**	**79**	**88**
Accessibility	**8**	**8**	**12**	**6**
Acidification	**2**	**4**	**2**	**1**
Greenhouse effect	**2**	**4**	**2**	**1**
Consumption of land	**4**	**4**	**4**	**3**
Energy use	**1**	**2**	**1**	**1**

5.3 The qualitative multicriteria analysis (MCA2)

The MCA2 should be regarded as a worked out extension, to be added to the methodology consisting of steps 1 and 2 after experience has been gained in the practical application of steps 1 and 2. Table 5 presents the criteria to be included in the MCA2 with an example of a potential set of weights.

Table 5. Criteria in MCA2; example of a set of weights

Criteria	Example of a set of weights
Overall outcome of MCA1	**93**
Water pollution	**1**
Soil pollution	**1**
Effects on cultural heritage	**1**
Landscape and other visual effects	**1**
Severance effects in ecosystems	**1**
Barrier effects	**1**
Visibility effect	**1**

These criteria, with the exception of the outcome of MCA1, can only be defined in an ordinal way. The user should rank the projects that are compared (or the alternatives within a project) on each criterion (e.g. 'better than' or 'as good as'). Because of the qualitative nature of the criteria, an overall outcome should not be calculated by weighted summation. The recommended method to get an overall outcome is the dominant regime method, which is also used in The Netherlands for the evaluation of public transport projects. This method can handle either quantitative or ordinal weights. A possible set of weights would be 93 for the first criterion and 1 for each of the 7 other criteria.

The dominant regime method relies on comparing pairs of alternatives. For each pair, the regime is a row of +1 or –1 values indicating whether the first alternative of the pair is better or worse than the second for a particular criterion. The final outcome of the MCA is derived by combining the weights with the regimes. In simple cases the final outcome can be found analytically. For more complicate cases, numbers will be drawn from a uniform distribution, which are in accordance with the ranking information on the weights and criteria. For every combination of draws an outcome in terms of a ranking of alternatives is calculated. Summation over all sets of draws (e.g. drawing 1000 times) gives the final ranking of alternatives and probabilities that an alternative will be better than the others. This method can be used for situations in which some of the criteria are quantitative and some qualitative (mixed problem), as we have here for MCA2. The weights can be quantitative or ordinal as well (Hinloopen and Nijkamp, 1990). For application of this method, or other methods that can handle similar problems, specialized software is needed.

6. Conclusions

This paper first reviews, discusses and recommends methods and values for the different externalities including value of time savings for congested evaluations based on the international literature. Second, a methodology to better include externalities in the evaluation of transportation projects is suggested including adding a quantitative and qualitative multicriteria analysis (MCA) to the evaluation procedure.

By including the outcome of the cost-benefit analysis in the multicriteria analysis, we can make sure that the two-step procedure does not produce two different rankings of projects (one from the cost-befit analysis and another from the multicriteria analysis), but one final ranking of projects based on all criteria in the cost-benefit and the multicriteria analyses.

There is much literature on different methods to evaluate transport externalities and on the estimation of different related values such as value of time and value of life. This literature shows that there is wide variability in the methods used in different places and in the estimate of these values in different countries and among different studies.

The MCA is sometimes criticized as being much less objective than assigning monetary values to benefits, and subjective to political pressure. However, given the high uncertainty, complex evaluation, and the high variability in these values, these values are often also political choices. We therefore recommend the MCA as a supplement to the CBA for externalities that are difficult to convert to monetary values. In this way the decision criteria is at least transparent and as suggested, several sets of weights among the criteria would add some sensitivity analysis. More transparent and flexible analysis tools will be more useful for policy makers.

Despite all the literature there is still a need for further research on the implications of the different approaches on policy and decision-making. In other words, how much the use of different approaches and values affect the ranking of projects. It is suspected that some of the current practice and lack of fully accounting for externalities favor less sustainable transport alternatives. This is also an issue of great importance for future research. There is a growing need to develop methods to combine mobility and sustainability measures as also discussed by Black (in this issue) regarding the development of a single index that measures both sustainable transport and potential mobility, and by Banister and Stead (in this issue) regarding adding a measure of transport efficiency to the measurement of transport intensity. The next section identifies some of the key issues with regard to this question that require further research.

6.1 Key Research Issues

The main research question arising from this paper is what is the effect of using different evaluation methods and values on the ranking of transportation projects. In other words how sensitive is project evaluation to the evaluation method and value. There are many related questions to this main one that should be addressed in future research. These include (with no prioritization):

- Further improvement of evaluation methods;
- Further analysis of uncertainties in the different models used in evaluation and further improvement of these models (such as travel demand and emission models);
- How accurate evaluation methods are and what is the potential to make them more accurate?
- The role of travel demand and how the use of different models and assumptions may affect the evaluation of different projects?
- The role of other models including emission modeling, dose-response modeling, noise models, safety performance models, and land use models. Are they achieving their goals? Are current improvements to these models likely to provide the required output?
- How well is the process of assigning monetary values for different externalities?
- Which externalities should be converted to monetary value and included in the CBA and which externalities should be included in a multicriteria analysis?
- The decision making process and how it affects the ranking of projects? This should be addressed both from a normative point of view and a positive point of view;
- At what level are decisions being made? At what level should they be made? And how is this affecting the decision-making itself?
- Who is doing the evaluation and for whom? And how does it affect the results? Who should do the evaluation?
- How definitions of study areas, variants and alternatives considered including the reference variant might bias the analysis?
- The role of politics and public involvement in decision-making. What is it? How should it be? And how does it affect decision-making?
- The issue of double counting of costs and benefits;
- The planning horizon and the assumptions about the project lifetime and how it affects the evaluation?
- Equity issues. This paper only discussed efficiency. Equity can enter as a separate item in MCA; however, quantifying it in CBA requires specification of a social welfare function that extends beyond simple aggregation of benefits and costs. What is the impact of equity on project evaluation and what should be this impact? Rosenbloom and Stahl (in this issue) discuss mobility for the elderly; are we given a fair value for the benefits of this segment of the population?

- The different effects of all these issues on different types of transportation investments, specifically on highway investments versus public transport investments.

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References

Accent and Hague Consulting Group (1995); *The value of travel time on UK roads* - 1994; Final report; Report for Department of Transport; Accent and HCG, London/The Hague.

Algers, S., J. Lindqvist Dillén and S. Widlert (1996); *The national Swedish value of time study*; Paper for the Course and Seminar on Value of Time; Easthampstead, Berkshire, England.

APAS ROAD/3 (1997); *Transport Research – APAS – Evaluation*; European Commission, Directorate-General Transport; Office for Official Publications of the European Communities, Luxembourg.

Black (in this issue). *Sustainable Transport and Potential Mobility.*

Banister and Stead (in this issue). *Decoupling Transport.*

Bristow, A. L. and Nellthorp, J. (2000) Transport project appraisal in the European Union. *Transport Policy*, 7, 51-60.

Button, K. (1994*); Overview of internalizing the social costs of transport; in ECMT*: *Internalizing the social cost of transport*; ECMT/OECD, Paris

Cambridge Systematics, (1996). Uncertainty in Quantifying Air Quality and Other Benefits of Transportation Control Measures. In *Task 3: Analysis Framework, Quantifying Air Quality and Other Benefits and Costs of Transportation Control Measure*. Prepared for the U.S. Environmental Protection Agency, Washington, D.C.

Cambridge Systematics, (1997). Changes in Air Quality and Transportation Associated with the 1996 Atlanta Summer Olympics. *Draft report of NCHRP Project 8-33 prepared for the National Cooperative Highway Research Program.*

Department of Transport (1993); *Design Manual for Roads and Bridges,* Volume 11: Environmental Assessment; DOT, London.

Elvik R (1991). "An Analysis of Official Economic Valuations of Traffic Accident Fatalities In 20 Motorized Countries". *Accident Annual and Prevention* Vol. 27 No. 2.

EVA-consortium (1991); Evaluation process for road transport informatics, *EVA-Manual;* EVA-Consortium, Munich.

European Commission (1996): *Transport research – APAS – modelling of urban transport*. Office for Official Publications, Luxembourg.

Friedrich, R. and P. Bickel (2001), *Environmental External Costs of Transport*. Springer, Heidelberg, Germany

Geerlings H. and D. Stead (in this issue*). Integrating Transport, Land Use Planning and Environment Policy in European Countries.*

Geurs, K.T. and J.R. Ritsema Van Eck (2001), *Accessibility Measures: Review and Application.* RIVM, The National Institute of Public Health and the Environment,

Gunn, H.F. (1996); *Research into the value of travel time savings and losses; The Netherlands 1985 to 1996;* Paper for the Course and Seminar on Value of Time; Easthampstead, Berkshire, England.

Gunn, H.F., M.A. Bradley and C.L. Rohr (1996); *The 1994 national value of time study of road traffic in England;* Paper for the Course and Seminar on Value of Time; Easthampstead, Berkshire, England.

Hague Consulting Group (1990*); The Netherlands' "Value of Time" Study: Final Report;* Report for Dienst Verkeerskunde, Rijkswaterstaat; HCG, The Hague.

Hague Consulting Group (1995); *Openbaar vervoertechnieken voor middelgrote stedelijke agglomeraties*, Inventarisatie en toetsingskader; HCG-report 484-1; HCG, The Hague.

Hauer,E., Persaud,B. (1996); *Safety analysis of roadway geometry and ancillary features;* Research Report, transportation Association of Canada, Ottawa, canada

Hausman, J.A. (Ed.) (1993); *Contingent Valuation, A critical assessment*; Contributions to economic analysis 220; North Holland, Amsterdam.

Hinloopen and Nijkamp, (1990), Qualitative multiple criteria choice analysis: The Dominant Regime Method; *Quality & Quantity*; Vol. 24, pp. 37-56, 1990.

Hunt J.D. (This issue) *Questions About Agent Behavior and its Representation Arising with the Micro-simulation of Urban Systems.*

Hunt, J.D., D.S. Kriger, & E.J. Miller, (2001) A Review of Current Operational Urban Land-Use Transport Modeling Frameworks. Paper submitted for consideration for publication in *Transport Reviews.*

Hunt, J.D. and D.C. Simmonds (1993): Theory and application of an integrated land-use and transport modeling framework. *Environment & Planning B,* Vol 20, pp. 221-244.

IOO: Institute for Research on Public Expenditure (1995); *The price of mobility in the Netherlands*; IOO, The Hague.

Johansson, P.-O. (1993); *Cost-benefit analysis of environmental change*; Cambridge University Press, Cambridge.

Jones, S R (1981) *Accessibility measures: - a literature review.* TRRL LR 967. Crowthorne, TRRL.

Layard, R. and S. Glaister (1994); *Cost-Benefit Analysis;* Cambridge University Press, Cambridge.