ASSESSING THE SOCIO ECONOMIC AND SPATIAL IMPACTS OF TRANSPORT INITIATIVES: THE EUNET PROJECT

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Abstract

The EUNET project develops and demonstrates a method for modelling and assessing the socio economic impacts of strategic transport initiatives.

There are three main areas of work. First, the development of a Regional Economic/Transport model, with a research emphasis on extending the Input-Output framework. Second, recommendations on costs, prices and values to feed into the assessment process. Third, production of an assessment tool, which can be linked to the regional economic/transport model. Three demonstration examples are used to validate the approach.

INTRODUCTION

The EUNET project is part of the European Union's Fourth Framework Programme of Research. It is being undertaken by a consortium of ten organisations from across the EU, led by Marcial Echenique and Partners Ltd of Cambridge, England. The project will be completed by Spring 1999.

The main objective of the project is the development of a comprehensive method for modelling and assessing the socio economic impacts of strategic transport initiatives.

Three papers have been produced; Beuthe *et al* (1998), Bristow *et al* (1998), and Jin (1998),which describe particular aspects of the work in more detail and these papers are to be presented at this conference. The aim of this paper is to give an overview of the EUNET project drawing on the three papers and also two earlier papers (Pearman *et al* 1997, Nellthorp *et al* 1997), while highlighting the main areas of innovative work.

BACKGROUND

The assessment of transport infrastructure projects and other transport initiatives such as road tolling has been of interest to the Commission for some time. The Commission provides finance to transport projects, and more generally there is a link between transport initiatives and the wider aims of the EU in areas such as regional development and social policy.

Over recent years the Commission has financed a number of research studies in the general area of assessment procedures. A key milestone was the EURET Concerted Action 1.1 which reviewed road infrastructure appraisal procedures across the (then) twelve member states (Mackie *et al* 1994). Two related areas of work then developed what EURET had begun. A series of studies under the APAS programme undertook reviews of assessment procedures in member states for rail and inland waterways, and a further APAS report (Beuthe *et al* 1995) extended the initial EURET work for ATT projects. Finally the TIE report (Bentzen *et al* 1995) provided a synthesis into a single recommended approach for all modes.

The EUNET project draws on this legacy from previous work, but seeks to demonstrate an operational approach, while simultaneously innovating in specific areas. Three demonstration examples are planned to show how the approach will work in practice.

There are three main strands to the project:

- the development of a Regional Economic/Transport modelling approach, with a research emphasis on extending the Input-Output framework which is at the heart of the Regional Economic Model (REM) and providing a possible method for using such a model for estimating employment/GDP gains from transport schemes;
- recommendations on costs, prices and values to feed into the assessment process;

- development of an assessment method, and prototype assessment software which can be linked to the demonstration regional economic/transport models, including the incorporation of accessibility analysis and a specific treatment of uncertainty.

The application of the model and assessment tool to three demonstration examples is also discussed to illustrate how the different elements of the research are bought together.

REGIONAL ECONOMIC/TRANSPORT MODELLING

Overall structure

Transport models forecast travel patterns and these travel patterns themselves derive from consumers travelling to buy goods, from firms trading with each other, from employees going to work. In short, they derive from the wider economy. A REM can represent the production and consumption and hence the trades from which these travel demands originate. In turn, a REM needs to be driven by macroeconomic forecasts. Given forecasts of how the main macro variables - GDP, imports and exports etc. - will change, a REM can disaggregate these changes between geographical areas and between industries.

Once this industrial change is known, a multi modal transport model can estimate modal split, travel times, outputs of pollutants and other useful policy inputs. The process is iterative. The changes in transport costs and congestion through time will gradually influence the spatial patterns of the location of industry and population.

So, by using an integrated system of macroeconomic forecasts, a REM and a transport model, the policy maker has a powerful tool for studying many strategic long term changes which are simply not captured by transport models alone.

The EUNET modelling approach has been conceived as a set of 'building blocks' and this concept is shown in Figure 1. The decision on which building blocks to include within a model for a specific study depends on balancing a set of issues, including the available resources, the status of the work (pre-feasibility, feasibility) and the spatial scale of the initiative.

The possible options are combined in various ways for the three demonstration examples.
For the Trans Pennine (North England) and Baltic examples the 'building blocks' used are shown in the diagram. The Trans Pennine example seeks to focus on the links with macroeconomic models, while the Baltic example looks more closely at the role of international trade in the overall approach

Building Blocks	Option A	Option B	Option C	Option D	Option E
I Modify macro-economic projections	Simple modification based on price elasticities TP	Partial equilibrium to predict changes to an export product	Partial equilibrium to predict changes in household consumption	How changes in export may affect levels of import	Full equilibrium between macro and regional models
II Convert macro data 'to regional data	Simple conversion based on past trend	Conversion based on constraints for domestic industries TP	Conversion based on constraints for imports and exports	Conversion based on constraints for consumptio n	Conversio n based on constraints for investment
III Computation of input-output matrix	Simple 25 sector IO model	40 sector IO model TP	Simple 25 sector IO model differentiating imports B	40 sector IO model differentiatin g imports	
IV Spatial distribution of industries, employment and households	Spatial distribution based on direct monetary transport costs	Incorporation of indirect logistic costs TP/B	Incorporation of producer cost savings from wider input choice TP	Incorporatio n of residual disutility to reflect historic trade links TP/B	
V Modal split	Single hierarchy TP/B	Nested	One day TP/B	Peak Non-peak	Multiple periods
VI Multi modal network assignment and capacity restraint	Minimum path	Multipath stochastic TP/B	One day TP/B	Peak Non-peak	Multiple periods

Note: TP = to be implemented for the Trans Pennine demonstration example
B = to be implemented in the Baltic demonstration example

Figure 1: EUNET modelling techniques: building blocks and options

A working model has been set up for the first demonstration example region, the 'Trans Pennine' area of England. This area extends from Liverpool in the west, to Hull in the east, incorporating the major urban centres of Manchester and Leeds. The Trans Pennine model consists of 127 zones, including 92 internal zones that comprise Great Britain and Northern Ireland, 31 external zones which represent the other countries of the EU and other European countries outside the EU and 4 external zones for the rest of the world indicating the direction from where the commodity flows enter or leave Europe. The strategic transport model is network based and multi modal, covering both passengers (slow modes, car, bus, coach, train and air) and freight (truck, rail, ship).

Work is also well advanced on the second demonstration example in the Baltic area using the 'building blocks' shown in the Figure. The third example (in Greece) will have the specific aim of demonstrating a 'EUNET light' approach, to address how the overall EUNET modelling and assessment method can be adapted to provide a less resource intensive approach.

The REM is at the core of the modelling approach and provides outputs to the assessment process as shown in Table 1. The multi modal transport model provides origin destination and generalised cost matrices by mode together with link loads and times.

Table 1: Output from the regional economic model

Variables	Data Type	Remarks
Industrial production in each zone by industry	Zonal	Measured in monetary value
Employees working in each zone by employee type	Zonal	in number of employees
Households residing in each zone by household type	Zonal	in number of households
Production costs of each industry in each zone	Zonal	i.e. average production cost by industry
Cost of living for each type of household in each zone	Zonal	i.e. average cost of consumer goods and travel
Sales prices for products from each industry in each zone	Zonal	
Wage rates for each type of labour in each zone	Zonal	
Matrices of trade of goods and services, and of people travelling between zones	Zone-pair	Trade being measured in monetary value, and people in trips per year

The REM will also form the main part of the experimental work to be carried out in EUNET. It will provide a platform for experiments in the two main areas of modelling research, on the Input-Output table and the treatment of employment/GDP gains from transport initiatives.

The UK Input-Output Table

At the heart of the regional economic model there is a national Input-Output Table for the UK. This IO Table links industrial production, trade, and employment and consumers so that the impact of transport changes can be estimated with the multiplier effects being taken into account. But the way I-O tables are currently applied needed to be improved to meet the requirement of EUNET (see Jin 1998) to assess the socio economic impact of transport initiatives, i.e the impact on industries, employment and the population.

In turn, this has led the EUNET modelling research to focus on incorporating households and employment in the IO structure, linking employment and consumers and introducing modelled transport costs

Incorporating households in the IO structure

In a standard IO Table, household consumption is defined as the total demand for output from each industry measured as a sum of money. It does not relate to the actual number of households. To include actual households as consumers it is necessary to replace the total sum of monetary demand by (a) the number of households and (b) average consumption of each household.
The product of (a) and (b) will be equal to the original sum in the IO Table. However, households can be introduced in this manner by socio-economic group, so that in a given future year the marginal changes in goods prices due to transport may be reflected in the cost of living of each socio-economic group.

Incorporating employment in the IO structure

A conventional IO Table represents employment by total gross salaries and wages as part of the value added. In order to estimate the changes of labour demand in terms of the number of employees (with part-timers converted into full-time equivalents) it is necessary to replace the monetary value. Also it is preferable to introduce employment by type, such that the changes can be analysed in detail.

Linking employment and consumers

The standard IO Table does not have a link between the final consumers and the supply of labour. In other words, a change of labour demand does not affect the level of consumption. Yet in practice, households play the dual role of the consumer and labour. The extended IO structure in the EUNET model will provide such a connection, so that employment changes imply changes in final consumer demand, and cost of living is reflected in the salary costs. This means that a coefficient matrix needs to be developed which combines households of different income groups with households that supply labour to different branches of industries.

Introducing modelled transport costs

The IO structure used by the regional economic model represents the transport sector by mode (road, rail, inland waterways, shipping, air and auxiliary services). A typical IO structure assumes that transport cost is a constant input to industries wherever they are located. Such an aspatial assumption may be avoided in the regional economic model by introducing the transport costs estimated by the multimodal transport model. In other words, the transport model will calculate by mode for each type of passenger or freight originating in each zone the travel costs it incurs, and these costs are passed on to the IO calculations in the regional economic model so that industries and consumers in different geographical areas have different expenditures in transport.

The contribution of transport initiatives to the economy

The European Commission (and national Governments) have shown an ongoing interest in the contribution of transport development to the national or regional economy measured in terms of GDP growth or net employment gains. In order to provide a better understanding of the linkages between transport initiatives and economic development, the EUNET modelling research is looking at linking the Regional Economic Model with the cost/output relationships inherent in a macroeconomic model. The aim is to demonstrate this approach using the Trans Pennine demonstration model.

The current version of the model takes all components of the GDP as given. In other words, the model assumes that the total national GDP does not change with different transport policy/projects alternatives.

The model however gives an indication on potential changes of costs to industries and households that result from a change in transport. For example, a reduction of freight tariff on a certain mode on a certain part of the network causes the costs of outputs to decrease in the model. Because in the model the income of households is index-linked to the prices of goods, this results in a lower cost to provide the same standard of living, which in turn leads to lower labour costs. The model is capable of considering all the multiplier effects in the system consistently, based on a matrix of fixed coefficients. As the model reaches equilibrium it outputs a new set of (lower) costs and prices.

Such cost reductions could potentially be used as an indicator for factors such as strengthened competitiveness of certain products for the external market, through reduced export prices, or increased opportunities for inward investment due to reduced production costs in certain areas.

Such effects could bring a marginal, net increase of GDP in comparison with a macroeconomic Base Forecast. The model could then take into account the multiplier effects, such as how increased labour income would stimulate further consumer demand and saving. Ongoing work is now adapting the model to allow it to take into account these wider effects.

Needless to say, there are many intervening processes that are going on between, say, a reduction of export prices and the actually achievable increase of export for a given industry. Medium to long term growth forecast models have established a wide range of such relationships. By linking the REM with macroeconomic model 'elasticities', it is hoped that new insights can be offered into the transmission mechanisms by which transport supply affects a national economy.

COSTS, VALUES AND PRICES IN APPRAISAL

The aim of this area of work is to provide a full set of values for the EUNET appraisal tool. It is described in more detail in Bristow *et al* (1998). Impacts which are being considered include direct impacts, environmental impacts, and socio-economic impacts, as shown in Table 2.

Table 2: Recommended EUNET impacts

Impact	
Direct	Investment Costs System operating/maintenance costs Vehicle operating costs Revenues Time Safety Service Quality
Environmental	Noise Local Air Pollution Regional Air Pollution Global Air Pollution Landscape Land Take Land Amenity Special Sites Severance Water Pollution
Indirect	Output Employment Land Use Strategic Mobility Other Policy Synergy

There have been two main tasks on appraisal values, and a third task to construct a database of transport costs, as follows:

- to review current appraisal practice for major transport projects across member states. Information on member states' current use of formal cba and mca methods was gathered by the project partners and recorded in a series of Country Reports.
- to prepare for each impact a common definition, units of measurement and accompanying monetary values where appropriate, using the information gathered through the Country Reports;
- to obtain operating cost data, by mode for each member state where available and develop a vehicle operating cost database.

The first key finding from the Country Reports was that virtually all member states use cba for at least one mode in the transport infrastructure planning process. In many countries the overall appraisal embraced not only the cba result but also some form of qualitative appraisal of the social, economic and environmental effects. In four countries, the cba result was input to a multi-criteria framework.

It was decided that a European value set and a Country-Specific value set are necessary in EUNET. Although it could be argued that the philosophy underlying cba implied the need to use local values (the values for the people actually affected by a project), projects of European significance will need to be appraised within a common framework for European Institutions to determine funding allocation issues. On the other hand, member states may wish to appraise projects using a similar framework, though with values relating to country-specific objectives.

Within this approach, several technical issues then arise. The first is the wide variation in the appraisal values used at national level for some impacts. Why do these differ and can they be reconciled for the purposes of deriving a European value set? Clearly, cultural differences in tastes and preferences may be a factor, but variation in real incomes, the definition of impacts, methods of empirical estimation or foreign exchange issues may also be important.

This point can be illustrated with the example of accident costs. There are a number of components to any accident costs figure. The EUNET project has looked at the 'value of a fatality' and defined it for comparative purposes as the casualty related costs of each fatality. Even with this standard definition there are considerable differences in the values across the EU. Factors influencing this could include (i) remaining definitional differences, (ii) variations in income per capita between member states (which would impact on individuals' ability to pay for safety) (iii) cultural differences in attitudes to risk and to loss of life and (iv) the nature of the measurement methods used - eg. problems of bias in willingness to pay measures.

Given the information in the Country Reports, some adjustment can be made to values to take into account the inclusion/exclusion of human costs (and the factors raised in (i) and (iv)). The EU value, based on a weighted average of country values by population (see below), overcomes the second factor.

However, it is also argued that cost-benefit analysis should respect differences in the preferences of groups of individuals where possible, since these affect total willingness-to-pay. For this reason, a residual variation in the Country Specific values seems logical, reflecting differences in risk aversion.

Two previous approaches to the task of generating European values were identified, in the EVA Manual (EVA consortium 1991), and the EURET road study (Mackie *et al* 1994). The EUNET study builds on these approaches, using the method described above.

For the fourth main task, to produce a complete database of transport costs for the implementation of the demonstration examples, operating costs functions are needed for each mode, vehicle type and country for each relevant type of infrastructure. The transport model needs operating costs in terms of overhead, distance related, time related and speed related components. Data are needed for base and forecast years.

In order to produce this database, considerable effort has been put into collecting data from each member state. Not surprisingly, data availability varied across mode and country. Road vehicle operating costs were more readily available than rail operating costs and tariff data where there are issues of commercial confidentiality. Furthermore there were considerable problems of definitional differences when comparing data across countries. Work is now in progress to complete the database of operating costs and tariffs.

ASSESSMENT FRAMEWORK

Introduction

The assessment methodology developed within the EUNET project is expected to be innovative, but also to provide a functioning and practical product within the three years of the project. EUNET's work in this area is described in more detail in Beuthe *et al* (1998).

In essence, the chosen approach combines cba and mca methods. This decision to implement a dual cba and mca structure raises a series of issues. Most obviously there is the question of how double counting can be avoided or at least minimised. For example, impacts such as accessibility which may appear in the mca will inevitably overlap to an extent with cba impacts. Pearman *et al* (1997) suggested a possible compromise which will be followed in EUNET.

The proposed assessment methodology has four main steps within the overall framework (shown in Figure 2):

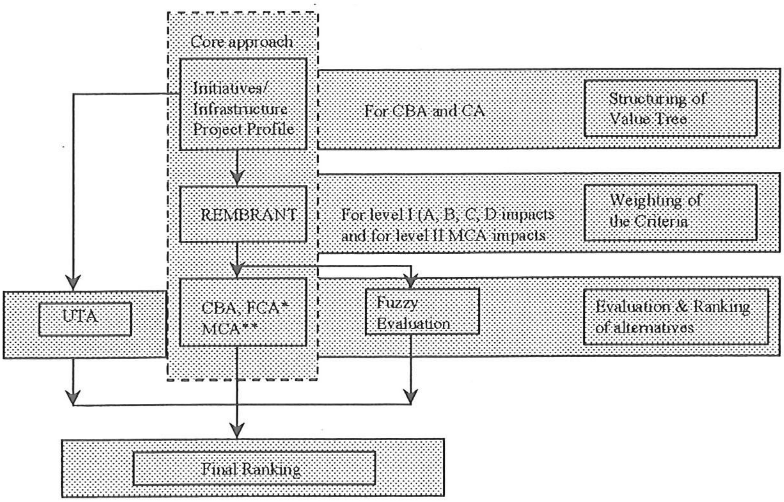
- *Decision tree:*
  a. *Objectives*: definition of basic goal(s) and/or objective(s)
  b. *Criteria*: description of the appraisal variables and their corresponding functions
  c. *Structure*: definition of how the criteria are related

- *Weighting:* prioritisation of the criteria in the appraisal

- *Evaluation and ranking:* utilisation of criteria, weights and structure to meet the objectives

- *Presentation of results:* analytical, monetary output, graphical representation, etc.

The overall presentation of the results should also include 'explanatory' material such as basic transport indicators (such as change in mode split) to provide a context for interpreting the assessment results.



*Financial Analysis
** Linear Additive Aggregation function

Figure 2: The proposed general methodological framework

Decision Tree

The first step is to define the objectives and the assessment criteria of the problem. The precise choice of assessment criteria will always depend on context of the assessment, so the approach in EUNET has been to develop a checklist of criteria (profiles) for each main mode.

In the proposed methodology, the hierarchy is structured in four levels; (A) core impacts, (B) non-core, non-strategic impacts; (C) strategic, territorial impacts and (D) strategic, non-territorial impacts

Core impacts would include operating and time costs savings, while driver convenience would be an example of a non core non strategic impact. Strategic territorial impacts would include strategic mobility and environmental issues such as accessibility and the level of pollutants. Strategic non territorial impacts would include factors such as conformity to wider planing objectives.

Accessibility analysis is also included within the overall assessment framework. 'Accessibility' is constructed from two functions, one representing the activities or opportunities to be reached and the other representing the time or cost to reach them. Two main possible measures have been discussed - an equity measure and a cohesion measure. In the equity measure the accessibility of any zone is calculated as a function of the zonal populations and travel times. To compute an aggregate equity indicator a weight is given to each of the zones, according to factors such as its economic development and degree of peripherality. Less well developed zones would be given a higher weight and policies to improve accessibility to less favoured regions would thus score relatively highly.

The cohesion measure would measure the improved potential for interaction between people in different parts of the EU. The basic principle would be to calculate how many people could be reached from any particular zone within a certain threshold travel time. To compute the aggregate indicator a population weight would be given to each of the zones.

Weighting

After analysing available techniques it was concluded that the most efficient weighting method for the scope and needs of EUNET is *pairwise comparisons* (Saaty 1990). This method is well-established and is practical, operationally efficient and reliable, and likely to be acceptable to the decision-maker (in terms of being relatively easy to understand).

One of the best known methods using pairwise comparisons is the Analytic Hierarchy Process (AHP). AHP is relatively simple to use though somewhat controversial, for example because of problems about illogical reversals of the ranking of alternatives following apparently irrelevant changes to the list of projects being ranked.

There are, however, a series of variations on the basic AHP theme, which appear to be superior on theoretical grounds. One of these, *REMBRANDT*, has been adopted for EUNET.

Evaluation and Ranking

The next step requires the integration of the previous steps for the selection among competing alternatives.

At this stage the proposed methodology consists of a core evaluation method with a series of alternative or additional procedures "bolted on" to the side of the core process. The core is relatively straightforward and it provides a fallback position. In addition, a set of innovative and/or supplementary procedures are introduced, namely:

- *UTA:* a utility-based evaluation procedure which could use CBA as a criterion and, in principle, put both the CBA and MCA into a single framework.

- *Fuzzy evaluation:* an alternative which represents impacts as fuzzy quantities, rather than as crisp numbers with associated degree of elasticity.

UTA/fuzzy evaluation

The UTA method constructs a non-linear additive utility function from a preference weak order defined by the user on a subset of reference alternatives (Jacquet-Lagrèze E., *et al*, 1982). The construction, based on the principle of ordinal regression, consists of solving a small linear programming (LP) problem where the objective function is the sum of approximation errors and the decision variables are the co-ordinates of the breakpoints of the marginal utility functions.

With the fuzzy evaluation option the proposed methodology allows for representing impacts as fuzzy quantities rather than as crisp numbers. The method being used can be seen as an extension of NAIADE (Munda, 1995), which uses criteria weights instead of evaluating on equal basis as originally proposed by Munda. It is a discrete multicriteria method. The impact (or evaluation) matrix may include either crisp, stochastic or fuzzy measurements of the performance of an alternative with respect to a judgement criterion.

Uncertainty

Sensitivity testing will be used to address uncertainty in the assessment, but alternative ways of approaching uncertainty and imprecision, especially within the MCA part of the analysis, are offered by the alternative evaluation models, UTA and fuzzy modelling:

UTA can estimate a non-linear utility function, which can be used in the context of the expected utility theory of uncertainty. This methodology can provide a complete treatment of uncertainty (either stochastic or imprecision) in the appraisal. It does however require some knowledge of the distributions of the different scores. It is proposed to elicit the necessary information on the assumption that the distributions are either triangular, rectangular, or simply discrete.

As far as fuzzy evaluation is concerned, the method can be particularly useful in the case of uncertain data or forecasts. Since the REM provides forecasts without any associated probability distributions, risk analysis could be used to build a range of uncertainty around some central set forecasts. Then, these uncertain forecasts with the associated variation could be represented as fuzzy numbers allowing for the computation of the degree of truth that a particular ranking is correct.

SUMMARY

A substantial amount of innovative work is in progress, concentrated in the areas of:

- extending the Input-Output approach to make it more applicable for regional economic and transport modelling and linking regional economic and macroeconomic models to estimate 'real' employment/GDP gains from transport initiatives;
- new approaches to measuring and valuing the impacts of transport initiatives;
- development of combined cba/mca assessment methods, including new approaches such as fuzzy evaluation, leading to a better treatment of uncertainty;

- the linking together of each area of work in an operational system, based on regional economic/transport models, assessment software, and a database of transport costs.

These broad themes are now being brought together within the demonstration examples.

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