STRATEGIC ENVIRONMENTAL ASSESSMENT OF TRANSPORT INFRASTRUCTURE INVESTMENTS

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Abstract

The need for strategic environmental assessment (SEA) of transport infrastructure investments is widely acknowledged. Basic elements of SEA at the European level were developed in a study on bottlenecks in the European transport infrastructure. Corridors were identified in which further transport activities would lead to violations of sustainability goals. In the context of a recent project on the design of environmentally sustainable transport plans, an advanced SEA model was developed and applied in a case study for the German state of Baden-Württemberg. In the assessment approach, a bridge is built between SEA and cost-benefit analysis by deriving shadow prices from the network wide assessment.

INTRODUCTION

A prerequisite for the reduction of environmental impacts due to transport is the integration of environmental issues into transport policy as manifested in Article 130r(2)1993 of the Treaty on the European Union: "*environmental protection requirements must be integrated into the definition and implementation of other Community policies*". Environmental impact assessment (EIA) for transport infrastructure investments is mandatory at the project level (EU Directives 85/337/EEC, 97/11/EC). However, since environmental impacts of single projects might interact and other sources of pollution contribute to regional emissions, it is necessary to extend the scope of EIA to the level of policies, plans and programmes. In acknowledgement of this need, the European Commission has adopted a proposal for a Council Directive on the assessment of the effects of certain plans and programmes on the environment. Additionally, the Guidelines for Trans-European transport networks require that the Commission should develop instruments for strategic environmental assessment (SEA) of TENs (Article 8§2).

Starting from this background, an environmental bottleneck analysis at European network level has been presented by IWW et al. (1996). Despite poor statistical background with respect to environmental data, it was possible to identify corridors in which further transport activities would lead to a violation of sustainability goals. Although this study was meant as a status report on the present situation, the environmental approach developed can be used as a baseline for European SEA. The question arising from the above research is what a SEA could look like if there were no such severe data constraints. In a study for the German Environmental Agency, IWW et al. (1998) have developed a concept for planning an environmentally sustainable transport system. In the context of this overall framework, a SEA model has been developed which was tested based on data for the German state of Baden-Württemberg, where the data situation is comparatively good.

In section 2 of this paper we will describe the basic concepts of SEA which can start either from a forecasting or a backcasting approach. In section 3 it is shown what can presently be done on the European level to prepare a comprehensive assessment of network patterns. Section 4 is to develop a more detailed SEA concept that presently can be applied to regions and corridors while in a near future it will be possible to use the concept on a European level. Section 5 prepares the bridge between SEA and a project orientated cost-benefit analysis. It will be shown that shadow prices can be derived from SEA, which can be used for an economic evaluation of projects. Section 6 will summarise the findings and give some conclusions for the future development of SEA.

BASIC CONCEPTS

Though the need for SEA has been recognised in various political documents, there are few approaches to carry out SEA of transport infrastructure plans. A common assessment procedure does not exist yet, but there are studies on SEA from which conclusions can be derived. In the definition by Therivel et al. (1992), strategic environmental assessment is "*the formalised, systematic and comprehensive process of evaluating environmental impacts of a policy, plan or programme and its alternatives, including the preparation of a written report on the findings of that evaluation and using the findings in publicly accountable decision-making.*" This definition reveals that SEA addresses organisational, legislative and methodological issues. In this paper, methods for a network-wide and multi-modal environmental assessment of transport infrastructure plans are presented. Elements of SEA are derived from project-level assessment. These are (see also Bukold, Hey, 1997) the: screening process, scoping process, impact assessment, reporting and incorporation in decision-making, and reviewing by monitoring and feedback.

Screening process

In the screening process, the environmental relevance of a proposal for a policy, plan or programme is reviewed in order to decide whether SEA will be necessary. In Article 2 of the EC proposal for a SEA Directive, the characteristics of plans and programmes - policies are not addressed - which should be subject to SEA are described. It states that "*This definition includes plans and programmes in sectors such as transport (including transport corridors, port facilities and airports), [...], telecommunication and tourism.*" According to the proposal, strategic environmental assessment is needed for the Trans-European networks as well as for national transport investment and master plans, which are the case studies described in this paper.

Scoping process

In the scoping process, the general outline of the environmental assessment is set up. This comprises the identification of impacts to be evaluated, selection of suitable methods and definition of terms of reference for assessment such as the definition of object of investigation, time horizon, alternatives, geographical scale and procedural scope. The establishment of the scope of assessment will strongly influence the quality of results. Some requirements for the assessment of transport plans and programmes are the coverage of all transport modes, the inclusion of different policy and/or infrastructure options, and the consideration of indirect and cumulative effects.

A crucial point in the scoping process is the selection of environmental impacts that have to be assessed and the level of detail for the assessment that is appropriate at the relevant planning level. This selection starts with the definition of environmental objectives, which can be obtained from legislative documents and political agreements at European and national level. For the assessment of impacts, it is necessary to define measurable indicators that reflect the achievement of environmental objectives. The selection of indicators depends on the level of detail to which the proposed plan or programme is formulated and on the availability of data and assessment methods.

Impact assessment

The initial step of the impact assessment is the compilation of a database on the current state of the environment and on the transport situation comprising environmental, geographical, socio-economic, transport, and infrastructure data. If data availability is poor, a bottleneck analysis is a possible means to determine focal points for which a more detailed analysis is necessary whereas for the remaining areas the impact assessment is performed at an aggregate level. In the second step, environmental impacts are predicted. This requires the preparation of scenario data for the proposed plans and projects, traffic forecasts for the relevant transport modes and the prediction of global and local environmental impacts. The results of the impact prediction can be presented in the form of tables, graphs or maps that depict the development of the indicators and possible environmental conflicts. The conclusive step of the impact assessment is the evaluation of the results. Generally, two different approaches can be selected: a forecasting approach or a backcasting approach. These approaches are briefly described in the following sections. The case studies presented later in this paper provide further information on the impact assessment procedure.

Forecasting approach

We start from the assumption that a set of environmental objectives has been defined based on the general issues mentioned previously and that these objectives have been transformed into specific indicators and targets. After the prediction of levels of the environmental indicators, an appraisal method is applied to transform physical impacts into comprehensive quality (utility) indices. The final step is based on general choice theory which offers a range of options. We present some of them very briefly. In the *risk cluster approach*, risk classes are defined for impacts, and projects are ranked according to their comparative risk of damage. The *target achievement approach* comprises a threshold analysis, in which the indicators for impacts are compared to target values that are defined in advance. The deviation between predicted and target values is as a basis for the impact judgement. *Multi-criteria analysis* (MCA) is often applied in project level EIAs. Planning alternatives are ranked according to a defined set of environmental targets. Each criterion can be assigned a specific weight. After the magnitude of environmental impacts has been calculated, the achievement of the different criteria is summarised into a single score using special aggregation rules. This score can be expressed either in qualitative terms (e.g. good, bad) or as a numerical value. *Cost-benefit analysis* (CBA) can be regarded as a special form of MCA, where the magnitude of impacts is not expressed according to different scales but is transformed into a common monetary equivalent. Consequently, negative and positive impacts (costs and benefits) can be aggregated.

Backcasting approach

While the forecasting approach directly follows the path of impacts from the source of emissions to the final impact or expected damage, the backcasting approach takes a converse approach to analysis. The first step consists of defining levels of environmental impacts that guarantee, based on present knowledge, sustainable development ('safe minimum standards'). The second step is to define sets of political instruments, including infrastructure expansion, which would achieve the safe minimum standards, and an impact prediction for these plans. And the third step is to select that action programme among these feasible sets that maximises the material welfare of the society subject to the environmental constraints. This means that the transport plan is the outcome and not the input of the assessment procedure. Different network configurations are finally assessed with respect to the material welfare losses which their realisation would induce (remember that costly resources have to be invested and transport demand might have to be restricted) to meet the safe minimum standards. The backcasting approach has recently been applied in some research studies, for instance in the EST (Environmental Sustainable Transportation) project of the OECD.

A backcasting approach is appropriate if the time horizon of impacts is very long. In this case, it is difficult to apply direct forecasting approaches for the impacts and the risks that are produced for future generations. Therefore, the indirect approach, based on clear specifications as to how the present generation is willing to manage the environmental risks for future generations, appears to be superior. There are, however, two caveats to be considered: firstly, safe minimum standards have to be defined based on expert knowledge and value judgements. This presupposes an interaction between experts and political decision-makers (some authors therefore fear a dictatorship of experts, but the forecasting approach embodies a similar risk). Secondly, the assessment is based on the assumed policy scenario and on cost estimations for single measures. A range of possible actions can be the result and double counting may occur in the sense that avoidance measures for one impact can also contribute to the reduction of others.

Reporting, incorporation in decision-making and reviewing

Based on the results of the impact assessment for investigated plans or programmes, recommendations should be made regarding preferred alternatives, mitigation measures, tiering with lower level assessments (e.g. corridor analysis, EIA of projects), and monitoring of impacts. The recommendations as well as the assessment results should be incorporated in a SEA report that is made available to decision-makers. Precautions should be taken to enforce the incorporation of the results into the final decisions. This can be enhanced, for example, by public involvement and by the integration of the SEA into a formal general assessment framework for plans and programmes. Reviewing the environmental impacts of a transport plan or programme after its implementation will provide information for further mitigation measures that might become necessary. Furthermore, better knowledge of the impacts on the environment can be gained, thus enhancing the information basis for future SEAs. For the monitoring of impacts, responsible institutions have to be identified.

SEA ON THE EUROPEAN LEVEL

There are some methodological exercises and case studies for SEA in Europe. An overview of these studies can e.g. be found in Lee, Hughes (1995). However, many of the studies listed only contain SEA elements. Even more limited is the number of studies dealing with transport infrastructure plans at the European level. In the following section, results of the project on "Bottlenecks in the European infrastructure" by IWW et al. (1996) are presented. The objective of the study, carried out on behalf of the European Centre for Infrastructure Studies (ECIS), was the identification of existing bottlenecks in the European transport infrastructure in order to determine priorities for future investments. An important part of the study was the environmental bottleneck concept, i.e. the identification of those critical areas where congestion problems coincide with environmentally sensitive areas or regions under severe strain. In these areas, additional transport activities or infrastructure will probably cause large detrimental effects on the environment.

The *scope* of the study is a network analysis of the transport situation in the year 1993, covering the main traffic flows in the EU. The selection of impacts was focused on local and regional impacts: effects on nature protection and conservation, effects on the population, and pollutant emissions. For the *impact assessment,* traffic flows for were acquired, based on which transport bottlenecks were identified by means of technical capacity and level-of-service criteria. These transport bottlenecks were subject to environmental assessment, which is presented in the following sections.

Effects on nature protection and conservation

For the assessment of adverse effects of transport on the earth's living natural resources, the sensitivity of flora and fauna to disturbances and the richness of the natural endowment within affected areas has to be identified. Based on the assumption that regions with these characteristics in many cases are put under legal protection, the 1993 United Nation's List of National Parks and Protected Areas has been used for this identification. The geographical information from the list is restricted to the size and the co-ordinates of a central point. This data has been transformed to a representation of the protected areas by circles of corresponding size around the central points. Then the road and rail networks have been overlaid with the protected areas' information. By means of GIS tools, those transport bottlenecks have been identified that intersect a 10 kilometre buffer one around the protected areas. As indicator for the severity of potential environmental impacts, the IUCN management status category of the affected protected area was assigned to the network segments.

Effects on the population

An indicator for noise disturbances is the number of inhabitants affected by noise above a threshold level. In a first step, a database the population densities of NUTS 2 regions in Europe 1992 was established, extended by NUTS 3 areas with high population densities (greater than 500 inhabitants/km^2). For the modelling of transport noise, a range of parameters has to be defined, e.g. traffic flows, traffic mix, average speed, road surface/track characteristics, vehicle operation phase, vehicle characteristics. In the case of road transport, traffic flows (average annual daily transport) and traffic mixes (share of freight vehicles) were taken from the traffic data. An approximation formula has been derived from noise simulation models to calculate the size of corridors around road links, where 65 dB(A) at daytime and 45 dB(A) at night-time are exceeded. These corridors have been estimated for the rail network as well, using the number of trains and maximum speeds. By overlaying these corridors with the regional data on the population densities, the number of inhabitants within the noise corridors were calculated by means of GIS-tools. All transport bottlenecks were then classified into six risk classes according to the number of inhabitants affected (see figure 1).

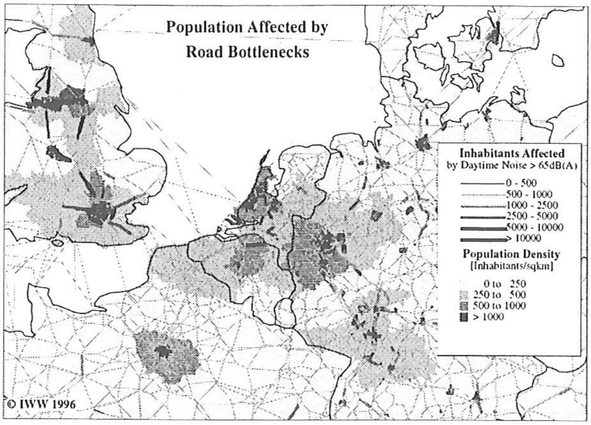

Figure 1: Population affected by road bottlenecks

Air pollution / transport emissions

Impairments from air pollution are encountered on the global, regional and local level. In the bottleneck approach, the focus is on local and regional effects on the corresponding transport emissions. The modelling of the air quality in a region has to take account of a range of factors: the existing concentration of air pollutants, meteorological as well as topographical parameters influencing the distribution and accumulation of air pollutants, and the amount of emissions carried into this region due to different sources. For most of these factors, sufficient data covering the area of the European Union is not yet available. Therefore, the modelling of air pollutant concentrations due to transport emissions was not feasible. Instead, we chose NO_x emissions from road transport as key indicator for air pollution. Though local air pollution is mainly relevant for road transport, in future assessments, emissions due all modes of transport have to be considered. Three steps were carried out to calculate the air pollution indicator: firstly, NO_x emissions were calculated for all transport bottlenecks by applying country specific emissions factors, differentiated by passenger and freight vehicles. In the second step, a database with total emissions was established. This database was obtained from CORINAIR summary tables the national emission totals for 1990. In order to use regions of equal size, an EMEP grid with a size of 50 km x 50 km has been applied. Thirdly, the calculated road transport emissions were assigned to the grid squares by means of GIS tools and the ratio of traffic and total emissions was calculated. A removal of emission sources in a square with a high share of transport emissions would contribute significantly to an improvement in local air quality.

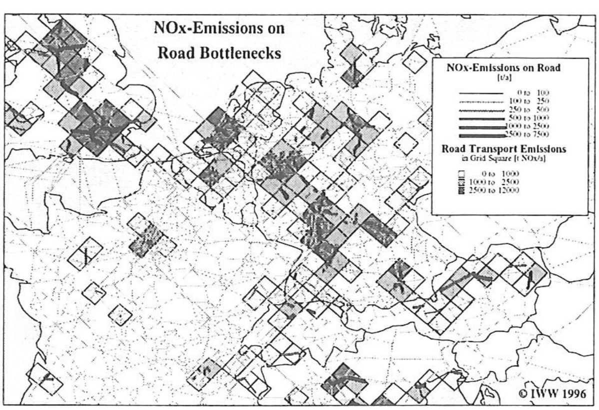

Figure 2: NO_x-emissions on road bottlenecks

Impact evaluation

In the conclusive step of the impact assessment, the results from the impact prediction were evaluated by means of a risk cluster approach (see section 2.3.1). For each indicator, six classes of environmental risk have been defined. In order to integrate the information from the impact assessment, an aggregate index was built by calculating the maximum value of classes of the single impact indicators. This approach is based on the precautionary principle, i.e. a high risk for one impact alone indicates a strong need for preventive or mitigation measures, independent of the values for other impacts. The application of the aggregate risk index reveals those transport bottlenecks that impose the highest risk on the environment, hence defined as 'environmental bottlenecks'.

About 3% of rail bottlenecks and 6% of road bottlenecks are identified as environmental bottlenecks. This means that they occur in critical regions and that their removal will require solutions other than infrastructure expansion or mitigation measures that lead to increasing infrastructure costs. As illustrated in figure 3, the majority of environmental bottlenecks in the road network occur in metropolitan regions. These are mainly the London area, the corridors from London to the Midlands and between Liverpool and Manchester, the Paris region, Madrid, Barcelona, the northern part of Benelux, the Rhine-Ruhr area, northern Italy, and Vienna. In these regions, the problems of traffic congestion, high emissions and noise disturbances compound one another. In the case of the rail network, environmental bottlenecks occur along a corridor from southern Britain via Benelux, Rhine-Ruhr, Rhine-Main, and the Alps to Vienna. These reflect the "blue banana"- regions that have been defined by Brunet. Further bottlenecks are encountered in the regions around Paris, Madrid, Naples, and Athens.

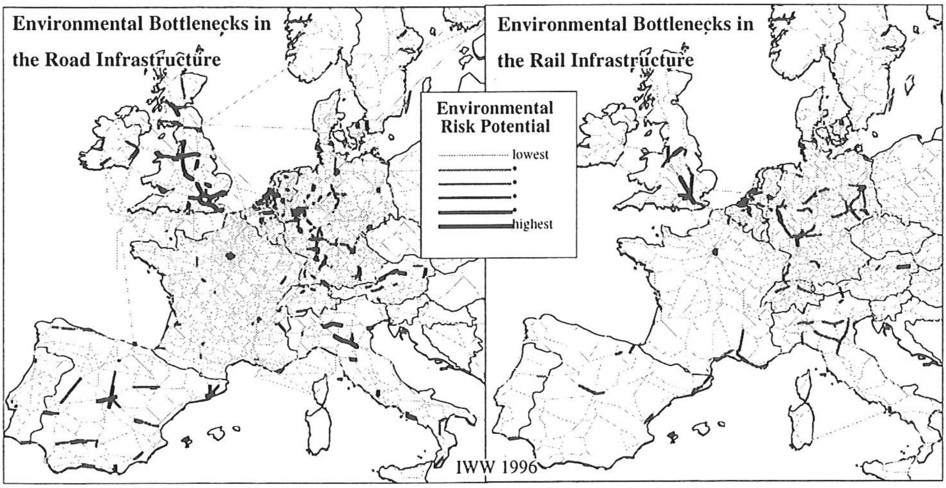

Figure 3: Environmental bottlenecks in the European road and rail infrastructure

SEA ON THE STATE'S LEVEL

The second case study on SEA was performed in the context of a project on behalf of the German environmental agency (Umweltbundesamt) (IWW et al., 1998). The objective of this project was to develop a methodology for an enhanced integration of environmental concerns into federal transport infrastructure planning. At present, project proposals for the federal infrastructure plan of Germany (Bundesverkehrswegeplan BVWP) are assessed by means of a cost-benefit analysis, which is supplemented by an ecological risk analysis for certain major road and rail projects. The research study had two major interests: firstly, the improvement of the monetary evaluation of environmental impacts in cost-benefit analysis; secondly, a procedure was developed that allows for an evaluation of the environmental impacts of transport in a multi-modal, network based and integrated assessment. The second project part corresponds with the development of SEA methodologies and therefore will be presented in the following text.

In a planning procedure it is preferable that possible negative impacts of a proposed plan are identified and prevented at the earliest planning level as possible. This means, that incompatibilities of plans with environmental goals should be identified and reported to the decision-makers before a plan is approved. Therefore, the starting point of the proposed procedure for a design of environmentally oriented transport plans is the definition of environmental targets (see figure 4). On this basis, scenarios for different sets of transport policy measures ('transport policy scenarios') are designed which would achieve the environmental targets. Subsequently, a transport forecast and environmental impact prediction are carried out for each transport policy scenario. If more than one scenario achieves the environmental targets, economic assessment methods are applied to identify the least-cost scenario. Based on this scenario it is possible to estimate shadow prices for environmental impacts. These shadow prices can be reintroduced into the cost-benefit analysis of projects. In the following sections we will present the elements of the assessment procedure and the results from a case study for the proposed methodology.

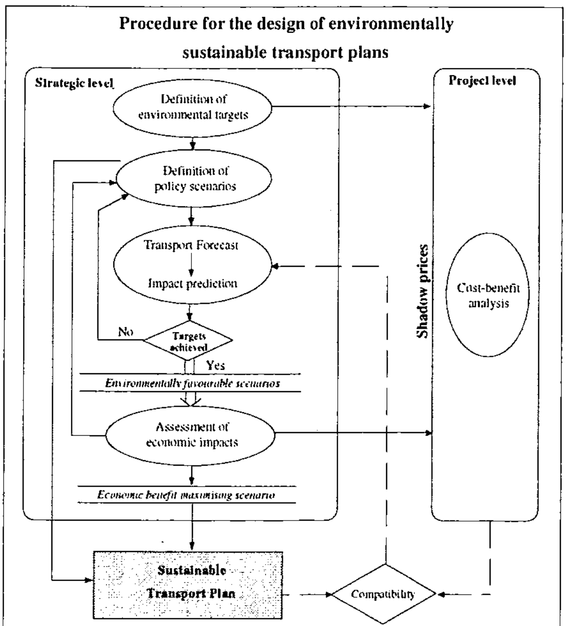

Figure 4: Procedure for the design of environmentally sustainable transport plans

Definition of environmental targets

The objective of designing environmentally oriented transport plans is to contribute to sustainable transportation. For the use in SEA, the concept of sustainability has to be transformed into measurable indicators that describe the state of the environment and into target values for these indicators. The following table summarises indicators and environmental targets used in this project. These environmental targets were derived from lists of environmental criteria for sustainable transport by the German environmental agency (UBA 1997). They represent safe minimum standards to prevent irreversible environmental damage.

Table 1: Indicators and target values for environmental impacts

Environmental Impact	Indicator		Environmental Target 1992 - 2010
Global warming	CO_2 emissions from transport		-30%
Tropospheric ozone	transport emissions of	NO_x VOC	-80% -70%
Atmospheric pollution	ambient concentration of	benzene particulate matter	2.5 µg/m3 1.5 µg/m3
Noise	daytime level of noise exposure of inhabitants		≤ 65 dB(A)
Nature protection	further fragmentation of restricted areas further sealing		not allowed not allowed

Definition of transport policy scenarios

A crucial point in the development of environmentally sustainable transport plans is the selection and combination of transport policy measures. Not only environmental, but also economic and social requirements for an efficient transport system have to be taken into consideration. The task is to assemble catalogues of measures, termed "framework scenarios" in this project, that are efficient, consistent, and operational. These can consist of all types of transport related measures such as infrastructure investments, regulatory or financial instruments. Based on the results of the impact assessment, the framework scenarios might have to be modified in order to achieve environmental targets or to improve economic efficiency. The cycle of defining and modifying policy scenarios is performed until at least one transport policy scenario is found that achieves the environmental goals.

For our case study, three different transport policy scenarios were defined for 2010: a trend scenario based assumptions of the BVWP '92, framework scenario 1 that consists of restrictive policy instruments such as infrastructure prising, strict emission limits and raised fuel taxes, and framework scenario 2 with less regulatory measures but assumptions on organisational improvements in the transport sector. A strict measure that has been used in both scenarios is an fleet average for fuel consumption of 5 l/100km for cars. The transport network for the trend scenario and for framework scenario 1 is composed the present German infrastructure plus approved projects of the BVWP '92. Based on the results from the transport forecast for these scenarios, new projects with only small transport flows have been taken out of the networks in framework scenario 2.

Impact Assessment

The general scope of the impact assessment has been set up in the previous steps with the definition of environmental goals and indicators and with the specification of transport policy scenarios. The geographical scope of the assessment depends on the region for which a transport plan is designed, in our case study the federal state of Baden-Württemberg, located in south-western Germany. The first step of the impact assessment is a traffic forecast. For this task, a multi-modal transport model covering generation, distribution, modal split, and traffic assignment was applied. By means of GIS-tools, traffic data and spatial characteristics were then assigned to the squares of a 5 km x 5 km grid based on the EMEP grid. Spatial characteristics, which have been used in the case study, are protected areas, wind velocities, and population densities. Several models have been developed to predict environmental impacts based on this data. These comprise models for forecasting emissions, ambient concentrations, noise exposure, and effects on nature and landscape. Finally, the results of the impact prediction were compared with the environmental targets defined in advance.

Modelling transport emissions

For the estimation of emissions due to transport activities, data on traffic flows and emission factors are applied. For the forecast of *road* transport emissions, the following differentiation for the emission factors was applied: 6 air pollutants (CO_2, NO_x, CO, VOC, benzene, diesel soot particles), 2 kinds of fuels (gasoline, diesel), 4 vehicle categories (cars/two-wheelers, light goods ≤ 3.5t, heavy goods > 3.5 t, buses), 4 road categories (motorways, other rural, main urban, other urban), 3 congestion classes (not congested, 5% congested, 10% congested), and 3 gradient classes (≤ -6%, -5% to +5%, ≥6%). Additionally, average factors for cold start emissions in Germany are estimated. Evaporative VOC emissions were calculated for Germany and assigned to the grid squares proportional to population densities. The calculation of *rail* transport emissions is based on average energy consumption values specified for different train classes (passenger/freight trains, diesel/electric engine, high speed/non-high speed trains). Emission factors were determined for direct emissions from diesel engines and for emissions of power generation due to rail transport. For inland waterway shipping, average emission rates per ship type were applied. In figure 5, the case study results for transport emissions are presented. It can be concluded that the modal shifts and technical measures assumed in the framework scenarios contribute significantly to the reduction of gaseous emissions, mainly by reductions achieved in road transport.

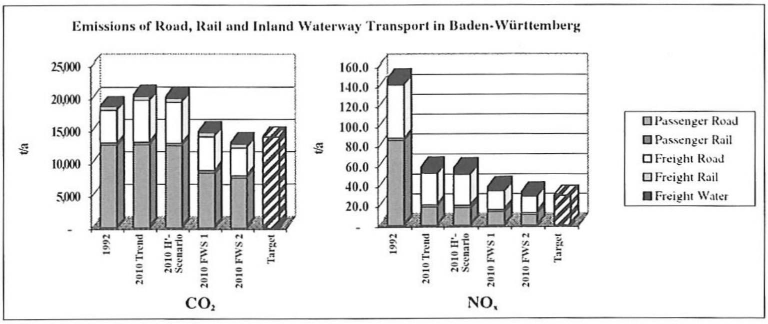

Figure 5: Emissions of road, rail and inland waterway transport in Baden-Württemberg

Modelling ambient concentrations of air pollutants

The environmental targets for benzene and diesel particles are provided as maximum concentration values. Therefore, a prediction model for the dispersion of air pollutants has been developed. The forecast of concentrations at a given location is composed of a forecast of the background concentration and of the excess concentration due to emissions from transport. Present background concentration values for different types of regions can be derived from literature. To forecast future values, the grid squares are grouped according to region types. For each region type, the change of emissions between the base year 1992 and 2010 is calculated, and the background concentration is decreased proportionally. For the prediction of the excess concentration from road transport, several models with different aggregation levels are described in the literature. At the level of national transport infrastructure planning, screening models have to be applied that require an acceptable number of input parameters and limited computing power. In our project, the ambient concentration along rural roads is predicted using the MLuS-92 approach (FGSV, 1996). For roads in urban areas a model is applied that is based on an approach developed by Lohmeyer (1996). Input variables of the derived model are standardised concentration values for different road classes, average values for wind velocities and emission densities per road that are calculated in the emission prediction model.

In the case study, the maximum of all concentration levels in each grid square is calculated as an indicator for the air pollution in this area. The target value for the concentration of particulate matter is exceeded by these peak values in the base year 1992 in 100%, in framework scenario 2 in 3% of the grid squares. In the case of benzene, these values are 98% for 1992 and 0.2 % for framework scenario 2. This means that though air quality will increase significantly under the assumed measures, additional action is necessary to achieve the environmental targets.

Modelling noise disturbance

As in the case of air pollution, the prediction of noise disturbance at the network level can be performed by the use of screening models. Such models have been established in our project for road and rail noise. In a first step, the reference noise level along *roads* is calculated according to the noise protection manual for roads in Germany RLS-90 (Bundesminister für Verkehr, 1990). This approach has been enhanced by the incorporation of the traffic mix from the transport models and by the inclusion of reflections via the assignment of typical housing structures to road classes. The number of inhabitants that are exposed to noise above a threshold level are calculated by means of the typical housing structures and corresponding inhabitant densities (Heusch-Boesefeldt, 1997). For the case study, a target level for daytime noise of 65 dB(A) has been applied. In total, about 10% of the population are exposed to road noise above the target level (see figure 6). In the case of *rail* noise, the prediction model is based on German noise legislation. Noise values along tracks are calculated based on traffic flows and on parameters describing the train characteristics such as train length, maximum speed, type of breaks and share of trains operating during night time for different train classes. For each network section a corridor is determined in which a defined noise level is exceeded. By using the population densities of the affected region, the number of inhabitants in this corridor is estimated. The case study show that about 2% of the population in Baden-Württemberg are exposed to daytime noise levels above 65 dB(A) due to rail transport.

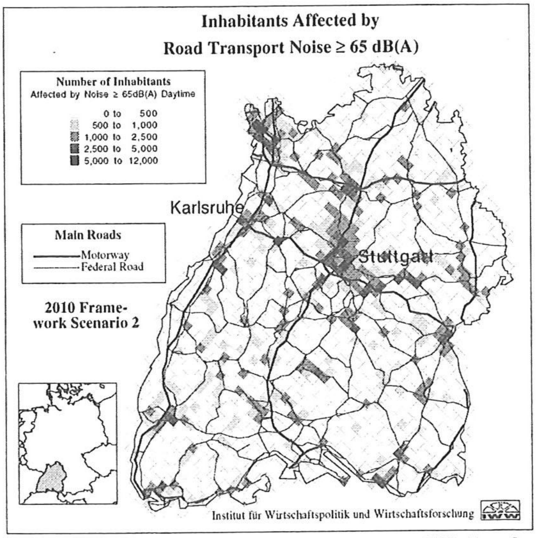

Figure 6: Inhabitants effected by road transport noise in Baden-Württemberg

Modelling impacts on nature and landscape conservation

The impact of the transport infrastructure on nature and landscape conservation can be predicted at the network-wide level by using the following impact indicators: lengths and land take by networks, division of conservation areas and impacts of infrastructure construction on exclusion areas. The first two indicators are calculated by extracting data from the transport network models. The division of conservation areas is determined by overlaying transport networks and spatial data on conservation areas. "Exclusion areas" are areas where further infrastructure construction is not allowed in order to achieve environmental targets. Areas of such environmental importance are, for example, nature protection areas, national parks, the core areas of nature parks, and protection areas of European significance (e.g. Important Bird Areas). In our project, nature protection areas are used in further assessment. For all grid squares, the percentage of nature protection areas of the total area is calculated. Grid squares with 25% to 50% share of nature protection areas are assigned to risk class 3, those with a share of more than 50% to risk class 4. These two classes are regarded as exclusion areas. If a new infrastructure alignment intersects one of these areas when following a direct route then an alternative variant has to be chosen which bypasses the exclusion area. If there is a plan to upgrade existing infrastructure within an exclusion areas, supplementary mitigation measures will be necessary. In total, this leads to additional infrastructure investment and operation costs of 80 Mio DM / year in framework scenario 1, respectively 40 Mio DM / year in framework scenario 2.

Evaluation of environmental impacts

In our project, the backcasting approach was applied. Hence, the results of the impact prediction for a range of transport policy scenarios are compared to environmental targets defined in advance. The evaluation of the scenarios used in our case study has revealed that the trend development in transport will lead to serious conflicts with environmental goals. In particular, the reduction targets for CO_2 and NO_x and for the noise exposure of the population are exceeded. In framework scenario 1 the environmental impacts of the transport sector can be lowered considerably, but it remains the case that the environmental targets cannot be reached. In framework scenario 2, most of the environmental targets are fulfilled. Some local adjustments of the assumed measures will provide an environmentally sustainable transport policy scenario.

STRATEGIC ASSESSMENT AS A BASE FOR SHADOW PRICING

In the backcasting approach, the SEA procedure is integrated into a general assessment framework for all relevant impacts of transport infrastructure plans. Therefore, in the following step an economic assessment of all environmentally favourable transport policy scenarios is performed. Subsequently, the scenario that bears the maximum economic benefit is selected. If economic benefits of all scenarios are regarded insufficient, the procedure of defining and assessing policy scenarios is repeated until an acceptable scenario is found.

When a transport infrastructure plan is developed, a large number of alternative projects is proposed. Theoretically it is conceivable to assess each possible combination of projects separately, and then select the environmentally and economically most beneficial scenario. In reality, however, this will be impractical due to the immense number of possible combinations. On the other hand, the assessment of single projects is necessary, for example for the ranking in order to take investment decisions. At this point, the application of shadow prices for externalities offers a solution to the problem. If a transport policy scenario of maximum economic benefit which achieves the environmental targets is found it is possible to derive shadow prices for the fulfilment of these targets using the results from the environmental and the economic assessment. These shadow prices can be described as follows: if a transport infrastructure project leads to a violation of an environmental target by one unit, new policy measures have to be taken. These measures will lower the economic benefit of the whole transport plan by a certain amount - the shadow price of the target. The economic background for the shadow-price approach is briefly described in section 5.1, the methodology for the calculation of shadow prices based on the scenario assessment is presented in section 5.2.

Economic background of the shadow price approach

Two different lines of thought exist on the notion of costs. In the first line of thoughts, costs are regarded as "expenditure costs", i.e. costs arise when entrepreneurial decisions lead to payment transactions. In the second line of thoughts, costs are defined as "costs of capital". These reflect the valued consumption of resources for the production of goods or services. Thus, calculated interest or personal remuneration of sole trader are part of the costs. In the model of an enterprise, the cost of capital is derived by formulating the limitations to resources as constraints to an optimisation problem and calculating the effect of loosening the constraints by one unit. Thus, the shadow prices characterise the scarcity of resources in decision situations. The costs of capital are therefore closely connected to goals and constraints. In this line of thought, true costs that are independent of the enterprise, place and time do not exist. Instead, the value of a good depends on the value judgement of the decision-maker, which again is measured by his economic goals.

A central problem in the application of the shadow-price approach to transport infrastructure planning is the definition of environmental targets. Their value influences the total benefits of activities and therefore the optimal transport plan as well as the shadow prices that are derived. If the costs of environmental losses were known, an optimal value for the resource consumption could be determined by maximising the economic benefits minus the environmental costs. The solution of this optimisation problem is the same whether the 'correct' damage cost values are applied or the 'correct' environmental targets. This means that the determination of the economic costs of environmental impacts and their application in cost-benefit analysis as well as the definition of environmental targets and the determination of shadow prices are valid approaches in impact evaluation. In the planning practice, however, the definition of environmental targets will be more easily understandable to the decision - makers than the translation of environmental quality into monetary terms.

Methodology for the calculation of shadow prices

The calculation of shadow prices is based on the economic assessment of transport policy scenarios, which concentrates on mandatory impacts as defined in CEC (1996), i.e. construction costs, maintenance costs, operating costs, revenues, generalised costs, and traffic safety. The quantification of costs is performed by means of standard methods taken from transport infrastructure planning in Germany. The costs of prevention technologies are estimated based on a study by ECN et al. (1996). For each scenario, the aggregated sum of economic costs is then calculated. These scenario costs are assigned to the environmental impacts, for which the target is not achieved in the trend scenario. First, these impacts are weighted according to the difference between the results of the trend scenario and their target values. The costs of framework scenario 2 are assigned to the impacts in the ranking order and according to their weights. If the target value for an impact is not achieved in framework scenario 2, additional measures are assumed following a least-cost principle until the targets are achieved. The costs of these measures are assessed and assigned to the impact.

The shadow prices can be applied in cost-benefit analysis for assessment of transport infrastructure projects. To consider risks of damage that remain below environmental targets, direct and indirect approaches are linked. While the shadow-price approach is applied for target breaches, impacts below the fixed standards are valued by means of damage cost or willingness-to-pay approaches. Here, the results from the enhancement of the monetary evaluation of environmental effects in the cost-benefit analysis for single projects, are applicable. This approach leads to cost functions for environmental impacts that are differentiated by the sensitivity of regions and by transport mode.

CONCLUSIONS

In the previous sections, two different approaches for the development of SEA for transport infrastructure investments have been presented. The aim of the European bottleneck study was to identify corridors in which further expansion of transport activities would lead to severe conflicts with sustainability goals. The environmental assessment approach developed can be used as a baseline for a European SEA. Several SEA elements are already incorporated in the approach: the selection of relevant local impact indicators, the modelling of regional environmental impacts, a multi-modal approach, a large data base containing transport and environmental information, and the consideration of environmental sensitivities. For future SEA of European transport networks, the approach has to be enhanced by the development and assessment of alternative scenarios, global impacts indicators, and improved databases. In the context of the study for the Umweltbundesamt, a SEA model was developed which shows that a detailed impact prediction and evaluation is feasible when the data situation is comparatively good. The general approach of the study satisfies the requirements for SEA that have been defined in section 2. The concept of shadow prices for externalities provides an instrument for tiering strategic and project-level assessments. In near future, when environmental and transport data will be available at the European level, it will be possible to use the concept for the assessment of European transport programmes as well. Therefore, the improvement of the databases is a major task in the enhancement of future possibilities for SEA.

The further development of SEA will have to focus on two aspects: the procedural scope and the selection of environmental goals and indicators. The procedural scope of SEA determines its success in political decision making. Therefore, legislative and organisational requirements have to be formulated for the integration of SEA into a formal general assessment procedure for plans and programmes. As shown in section 5, the definition of environmental targets determines the assessment results. Therefore, it is necessary to define internationally acknowledged sustainability goals and environmental targets that reflect the allowable contribution of transport to environmental conditions. The strengthening of SEA will improve the integration of environmental issues into transport policy at the national and international level.

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