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Project

INTERNAT: Integrated Trans European Network Assessment

Partnership

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Information

This is the final report of the INTERNAT project. It represents the main results of the project and summarises a series of deliverables produced during the course of the project, which contain greater detail on various aspects of the project. Information on these deliverables can be obtained from the project coordinator or directly from the partners by following the references given in the table above.

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Executive summary

Introduction

The European Union decided in July 1996 that the Commission should develop appropriate methods of analysis for strategically evaluating the environmental impact of the whole network and corridors, covering all relevant transport modes in line with Article 8 of the Community guidelines for the development of the Trans European Transport Network.

Methods based on existing techniques and practices, have been jointly developed by the Commission and EEA through the co-ordination of relevant research activities, mainly in the 4th Framework for Strategic Transport Research. The development and refinement of methodologies is still in progress. The aim of INTERNAT was to identify priority research areas for the next Research Programme in view of the development and demonstration of improved methods and tools in order to integrate spatial impact analysis. INTERNAT was conducted partly by analysing the weaknesses of the state-of-the-art methods, tools and techniques but also by examining and assessing the potential of new approaches (landscape approach, life cycle assessment, cumulative impact assessment) and new technologies (remote sensing and GIS). The project provided a continuation of research in this field nourished by the findings of the COMMUTE[1] project, particularly in respect of:

- a methodology for strategic assessment of the environmental impacts of transport policy options;
- a framework for SEA including the basic methodological requirements for SEA of multi-modal transport actions and guidelines on integration.

The analysis of new approaches

Spatial environmental impacts including cumulative impacts

In order to make an assessment of spatial environmental impacts, it is necessary to initiate an analysis of the likely impacts to be addressed. This analysis can be represented by a carrousel of different interacting decisions and inputs. The overall purpose is to establish a well balanced information set concerning landscape units, landscape values and vulnerabilities, data-sources, associated functions, target profiles and impact profiles. Four issues/steps can be identified in this carrousel:

1. the identification of physical characteristics of landscapes;
2. the analysis of functions, corresponding to land uses and systems (referring to inputs, transformations and outputs, e.g. the hydrological systems);
3. sensitivity estimation, and;
4. the definition of target and impact profiles.

A landscape target profile refers more specifically to a goal of determining the optimal (ecologically sound, economically and socially beneficial) potential of landscapes. An impact profile describes the interactions of a certain landscape unit or landscape type. It is based on impact types likely to be caused by a development.

[1]COMMUTE: Common Methodology for Multimodal Transport Environmental Impact Assessment

Actually, the main problem in determining impacts is that standards as yet do not exist, certainly not at the European level: e.g. European landscape classifications are needed.

The key proposal in respect of the calculation of impacts on landscape in INTERNAT is based on the elaboration of ***landscape vulnerabilities***. The following assumptions can be made for value or vulnerability categories. The basic principle is that at strategic level, landscapes should be assessed preferentially in holistic frameworks incorporating appropriate classifications and typologies.

1. all landscapes have values, hence susceptibilities for impacts,
2. there are different value and vulnerability categories,
3. landscape valuation and vulnerability assessment is an integration of perceptual, ecological, cultural, social and economic aspects,
4. the generic value and vulnerability concept of integrity refers to any interpretation of wholeness, coherence, land use fitted to the natural conditions, historical continuity, legibility, typicality, etc. that can be assigned to a landscape unit or pattern. Integrity is both the key concept of a landscape unit itself, and its major criterion of value, function, and vulnerability.

The ***spatial environmental impacts*** discussed in INTERNAT are related to direct spatial impacts, indirect and cumulative impacts. The relevance of spatial impacts differs in absolute intensity and in spatial dimension, as well as between different modes and landscapes. INTERNAT determined a definition, setting out the availability and form of input data and the type and format of outputs for the following impacts: land take, noise, pollutant emissions, impacts on the vicinity of infrastructure and visual impacts. For each type of impact a set of indicators applicable for landscapes and landscape functions has been developed. These indicators have been chosen through conducting analyses of perceptual and ecological value. The issues analysed are:

1. policy relevance and utility for users,
2. analytical soundness,
3. measurability,
4. scale applicability determined by complexity of calculations
5. scale applicability determined by data availability.

In addition to the formerly mentioned spatial impacts the analysis of ***cumulative impacts*** has also been assessed. These are aggregated impacts resulting from the direct and indirect impacts, of background loads, natural and historical risks. These impacts can be additive, interactive and synergistic in time and space. Examples are global warming, forest die-off, peripheral spontaneous settlements caused by easier access to certain areas. Owing to the complexity of the subject there are no specific indicators. Therefore, the identification of suitable thresholds is central to the assessment of cumulative impacts.

INTERNAT evaluated several CIA-methods, their potential use and weakness, and consequently identified future research needed to improve the method:

1. Questionnaires, Interviews, Panels and Checklists
2. Matrices
3. Modelling
4. Trend Analysis
5. Carrying Capacity Analysis

6. New simulations exemplified as models to predict the sensitivity of wildlife species and fragmentation
7. GIS-modelling for the prediction of cumulative effects of land use planning
8. Cybernetic models
9. Integrated evaluation of cumulative effects with complex scenario techniques

The main principle of a CIA-concept is that for each specific resource, ecosystem and human community being affected by the TEN, the CIA should identify all other actions that may affect the resource and assess the cross- related nature and synergistic interaction of various impacts, i.e. the cumulative effects. A reliable assessment of cumulative impacts includes an analysis of land-use developments, in particular the analysis of future growth effects that might possibly be induced.

Life cycle assessment

INTERNAT analysed the possibilities to integrate the newly standardised life cycle assessment (LCA) method as one part of a methodological framework for SEA of transport corridors and explored the possibilities to extend or improve the method. The main problem is that LCA-methods initially were meant to be used in the product industry. Correspondingly, the standards have been primarily defined for this purpose. However, the possibilities to apply these standards for the SEA of transport infrastructure are evident.

Strategic environmental assessment typically compares different types of products in order to obtain an overview of their *long term* environmental impacts. For this purpose the LCA provides a good base by taking into account the whole life cycle of the product from the raw material acquisition through its production and use to the final disposal. Thus in a certain way also the *indirect* impacts caused by the production chains before the production of the actual product as well as after the production in the disposal of the product can be taken into account. Applying the LCA method means that besides construction, also operation, maintenance, renovation and destruction need to be considered as *separate* product systems. This may render the application procedure quite complicated and laborious. The method can be simplified by using average values, but at the same time the results become more uncertain and the method also less applicable for strategic considerations. However, by calculating beforehand certain *typical* cases it may be effective and illustrative to use these in the preliminary sketch phases of the planning.

The most severe weakness of the LCA method lies in its concentration on quantified issues only. The *qualitative* issues like landscape and townscape values, relations with nature etc. cannot be modelled as a product system. The question often involves issues that are highly interdependent, depending on cultural values and even varying in time. In this sense CIA tries to some extent even to take into account also these qualitative issues.

The analysis of new techniques

Remote sensing in GIS

Landscape characteristics and units correspond to geographical units mainly represented in maps, and spatial unit related data-sets. In this sense, techniques for data collection and processing in a spatial context are evidently necessary. While GIS concentrates on data management and spatial analysis functions, remote sensing puts emphasis on data generation aspects. One of the most important benefits of a GIS is considered to be the ability to spatially interrelate multiple types of information stemming from a range of sources. This powerful capacity has shown to have a major potential also when estimating the environmental impacts.

This estimation begins by considering a set of relevant indicators that were introduced at an early stage in the description of the landscape approach. In view of the integration of satellite remote sensing and GIS the aims of INTERNAT are to determine an overview of environmental indicators which can be derived through the use of these techniques and to evaluate how RS and GIS can contribute to a better interpretation of the GISCO database layers in order to estimate environmental indicators and generate secondary data sets (derived themes). The analysis included three steps:

1. a selection of indicators to be derived from satellite imagery or its classification;
2. the implementation of those indicators into a prototype software (GASSEAT) and;
3. the execution of pilot assessments at typical scale levels (through the use of GASSEAT).

The prototype developed during INTERNAT (GASSEAT) is designed to function as a research tool. In other words, it is not a market ready end-product. The prototype is meant to evolve in terms of sophistication and therefore is open as regards the input of new/other data sets, and algorithms to implement models that estimate impacts and new indicators.

Any ArcView compatible data set can be used as input to the prototype. The prototype is not a stand-alone software, but has been completely integrated in the commercial GIS-software package ArcView. GASSEAT is developed as a set of separate options of the default ArcView tools with a set of default data layers. However, any available data set in ArcView covering the same area can be combined with the data from GASSEAT. Models that simulate/estimate environmental impacts can be built-in. Such activity of course, requires ArcView Avenue language expertise in order to integrate new software codes. The same is true for new/additional indicators.

The analysis showed weaknesses of data availability, data quality, processing and classification techniques. Nevertheless, GASSEAT was applied to analyse some selected indicators: proximity of settlements, settlements touched, visibility, land cover heterogeneity, noise, historical sites touched, proximity to protection sites, number of protection sites touched, fragmentation of potential natural areas, degree of deforestation, connectivity and land take per land use class.

Integration of the TEN Gradient in the emission modelling

Another technique analysed in the context of INTERNAT was advanced emission modelling with respect to network link gradients in the context of SEA assessments. The objective was to examine the requirements, to assess available techniques and data models for linking GIS layers representing the TEN-T and Digital Terrain Models, and to estimate the impact of different resolutions of Digital Terrain Models on link gradients. As a result of the activity a method to derive TEN-T link gradients and its application to a study area has been developed and tested.

Based on the analysis of the linkage between Digital Elevation Models, Trans-European Transport Networks and the investigation of the identified emission models (EXTERNE Transport, STEEDS and TREMOD), it is possible to determine some conclusions as to which combinations of DEM and link representation are suitable for enhancing the quality of emission modelling in the context of SEA through the introduction of gradient factors. The selection depends primarily on the purpose, i.e. the spatial level of the SEA.

SEA and the concept of an integrated tool: conclusions of INTERNAT

An integrated tool within the INTERNAT-project is understood as a series of integrated processes for screening, scoping and actual measurement or estimation of environmental impacts specifically for the assessment of strategic environmental impacts. INTERNAT provides guidelines on procedures, methods and approaches in respect of the impacts to be addressed in a broad sense (spatial and cumulative impacts are included) and on the actual measurement or prediction of the environmental impact of an action and its alternatives.

The concrete steps within SEA identified in INTERNAT are as follows:

Screening and scoping	1. Baseline information on environment (divided into different structures / functions) 2. Valuation of the present environmental conditions (structures, functions), including preloads, background loads, environmental objectives and targets 3. Environmental impacts of the proposed action and its alternatives (possibly divided in product phases)
Carrying out of an SEA	4. Assessment of the (direct as well as cumulative) environmental risks, based on the connection / overlay of (2) and (3) 5. Results: comparing of risks of different alternatives

The assessment procedures identified in INTERNAT can mostly be categorised in four steps of SEA: scoping, assessment of loads, assessment of environmental impacts and strategic decision making.

As a conclusion of the spatial assessment of INTERNAT, landscapes should preferentially be assessed in holistic frameworks, in the first place appropriate *classifications* and *typologies*. Techniques such as remote sensing are helpful in feeding land classification exercises with objective data on land cover and landscape structure, directly related to the major impact classes: land take and fragmentation. The total impact quantification of SEA in large areas can substantially be facilitated through scientifically based land classifications.

For SEA, the determination of landscape units has different roles:

- differentiating the expected type of impacts of infrastructures between geographical landscape units. In certain areas Biodiversity values may be much more characteristic than visual qualities. In other areas, it will be the difference in scale of large infrastructures and the existing landscape pattern that will be important,
- following from the first role, differentiation of the choice and interpretation of evaluation, vulnerability and impact criteria, according to the different landscape units crossed,
- providing a stratification framework for sampling impacts that cannot be deduced directly from the general description of the units,
- extrapolation of impacts over the surface of the units, and quantifying total impacts of an infrastructure in terms of specific metrics of the landscape units (area, transact length, composition, etc.).

For the consistency of the procedures it is essential that the links between procedures are standardised. Research needs within the individual approaches and techniques have been identified. The main focus for the application of methods and for aggregating and desegregating data concerning individual environmental factors will be standardised. For the Biodiversity indicators a challenge for the future is to develop complex spatial Biodiversity models, which model key feature and populations, and which are causal and dynamic in space and time.
For the spatial analysis, the integration of remotely sensed data from satellites for the indicator estimation is an important objective of INTERNAT. Currently there is an intensive lack of GIS data on many environmental themes and other layers e.g. layers representing the TEN-T. GIS can also be used at the end phase of the implementation stage of an SEA. Decisions that take into account environmental issues are spatial and multi-criteria in nature and often require a mixture of quantitative and qualitative information. Given the integrating capacity of GIS it can, therefore, play a crucial role in multi-criteria analysis. In this case different environmental indicators together with other information on social and economic issues are combined to support a decision.

Recommendations for further research and actions

Priority research areas in INTERNAT have been identified through assessing the weaknesses of current methods and identifying potential of new approaches. This analysis resulted in a list of priority actions that can overcome shortcomings in a relatively short term and a list of priority future research topics.

Priority actions

1. More detailed land use/cover classification.
   INTERNAT directly demonstrated the need to establish a harmonised level 4 and 5 classification system for CORINE.
2. Implementation of quality control procedures:
   Consistency errors were encountered in the land use/cover database of GISCO.
3. Upgrade/Complete databases.
   Existing datasets on environmental topics such as biotopes, designated areas, and the NATURA2000 network, which should usually have an extensive attribute data set, would have more value if the geometric data were upgraded (from points to polygons).

4. Generate ‘value’ maps.
   More environment-related data sets containing information on values (soils, vegetation, landscapes, etc.) are needed in order to generate indicators and measure/predict sensitivities to certain human activities (pressures). Many of the databases analysed in INTERNAT proved to be digital, although some are only available in analogue format. Most of them cover the whole of Europe.

Priority research areas
The general problem of integrating an assessment of the spatial dimension of landscape values into an SEA of the TEN is the difference between the assessment scale and the spatial diversification and small scale characteristics of landscape values, which can hardly be represented directly on the relevant assessment scale. So the use of a generalised database is necessary (CORINE). Since the spatial quality (and vulnerability) is not directly measurable in detail, indicator driven concepts have to be used. The chosen indicators have to aim at a differentiated, reasonable, comprehensible and balanced view of the indicated values, to produce policy relevant results.
Generally a large gap exists between current scientific knowledge and current planning procedures. In this field, the state of science in Biodiversity is far behind other technical disciplines. The distance from the academic level and maximum scientific demand to normal planning procedures should be improved. To improve everyday planning, user-friendly and standardised methods are necessary.
The challenge for the future is to develop complex spatial Biodiversity models, which model key feature and populations, and which are causal and dynamic in space and time. Standardised use in practice depends on future availability of detailed basic information on relevant species to compile a database and to validate models. In order to gain that information more field-studies have to be carried out.

1. INTRODUCTION

In recent years the European transport scene has been subject to significant changes. Mobility has drastically increased and as a consequence congestion has also increased in almost all transport modes. At the same time the environmental burden of the transport sector far exceeds the carrying capacity of our environment and threatens ecological sustainability as advocated amongst others in the Brundtland Report (see World Commission on Environment and Development (WCED), 1987). In July 1996 the guidelines for the Trans-European transport network were adopted (Decision 1692/96/EC). These guidelines specify the objectives, priorities and broad lines of measures envisaged in the area of the Trans-European transport network (TEN-T). The need for environmental protection in the development of the TEN-T is explicitly underlined in the guidelines. Not only must existing environmental legislation be taken into account (article 8§1), also methods should be developed for strategic environmental assessment (SEA) of the network and individual corridors (article 8§2). Methods based on existing techniques and practices are being jointly developed by the Commission and EEA through the co-ordination of relevant research activities. This work consists of:

- pilot SEA of the overall TEN-T to forecast transport and emissions through the projects STREAMS, COMMUTE/MEET, SCENARIOS;
- pilot SEA of TEN-T for spatial impacts through EEA;
- pilot corridor assessments (in close co-operation with the Member States);
- the preparation of a SEA manual of transport networks and corridors.

Project INTERNAT is designed to identify priority research areas in the development and demonstration of improved methods and tools with special attention to the spatial component in impact analysis. INTERNAT assesses new technologies (i.e. remote sensing and GIS), other impact parameters (changes in land-use patterns, cumulative impacts) and impacts on biodiversity and spatial implication of emissions such as noise. It also analyses the introduction of new approaches such as lifecycle analysis or vulnerability analysis. A landscape approach has been a particular necessity in INTERNAT in order to scope both the spatial organisation as well as the ecological systems (soil system, water system,…).

The structure of this report is built on the following steps, firstly seeking to outline the further definition of spatial, environmental and cumulative impacts to be taken into consideration, then to examine the application of remote sensing and this in the analysis of spatial impacts. Subsequently impacts associated with emissions and energy consumption and the potential of life cycle assessment are explored.

In conclusion INTERNAT has defined priority research areas with the principal aim of establishing an Integrated Tool for Strategic Environmental Assessment of European wide transport network and corridors *(chapters 6 and 7)*. More specifically the project has:

- updated the "state of the art" methods and techniques and assessed the potential of new approaches (incl. cumulative impacts) and technologies *(chapters 2 to 5)*;
- enlarged the number of spatially oriented environmental themes, such as land use, landscape, biodiversity... in SEA *(chapter 2)*;
- harmonised the set of environmental issues and indicators on SEA *(chapter 2)*;
- introduced and explored the system approach of Life Cycle Analysis and Cumulative Impact Analysis and their relevance to SEA *(chapters 2 and 5)*;
- provided quantitative but also qualitative indicators to be applied in SEA *(chapters 2 to 4)*;
- described outlooks in terms of how remote sensing can enlarge the number and quality of data sets in addition to those already existing within the data banks of the Commission *(chapter 3)*.

2. SPATIAL ENVIRONMENTAL IMPACTS INCLUDING CUMULATIVE IMPACTS

2.1 Landscape analysis in the context of SEA

The general philosophy of this chapter is to complete the impact assessment as it is developed in the COMMUTE-project[2], by examining spatial indicators. The emphasis is placed on the interaction of infrastructures with the functional and spatial systems, which are covered or traversed. “Landscape” has a multiple and crucial role in SEA. This role becomes more important with the general increase of the socio-economic, ecological and strategic value of the landscape concept itself. Increased attention is paid to two important concepts which are often missing in impact studies on the strategic level:

- The spatial, formal or ‘landscape’ approach, in which the scale relation of infrastructure towards existing land, land use and observable structures is taken into consideration.
- The ‘system’ or function approach, in which landscapes are envisaged as functional entities such as river basins, ecological networks or agricultural units. Linkages and relations are more important than individual objects or separate components like soil, water, air, etc.

Both concepts will determine the relevant spatial environmental impacts to be addressed. This analysis can in a sense be represented by a carrousel of different interacting decisions and inputs (see *Figure 1*). The overall purpose is to establish a well balanced information set concerning landscape units, landscape values and vulnerabilities, data-sources, associated functions, target profiles, and impact profiles[3]. Four issues/steps can be identified in this carrousel:

1. Identify physical characteristics of landscape;
2. analyse functions and systems;
3. estimate sensitivity;
4. define target profiles.

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[2] COMMUTE: Common Methodology for Multimodal Transport Environmental Impact Assessment, a research project that ran from 1996 to 1999 within the Strategic Research stran of the European Commission Fourth Framework Transport RTD programme.

[3] A typology of the profiles is in Table 1, pg. 13.

The main problem in defining impacts and their importance is that standards as yet do not exist, certainly not at the European level. For instance, we cannot decide on a "successful" classification scheme, without taking into consideration issues such as infrastructure impact types or societal targets for specific landscapes. A protocol for assessment studies is dependent on establishing agreed European landscape classifications. Consequently, amendments can be made through the iterative development of other elements defined as contributing to the carrousel.

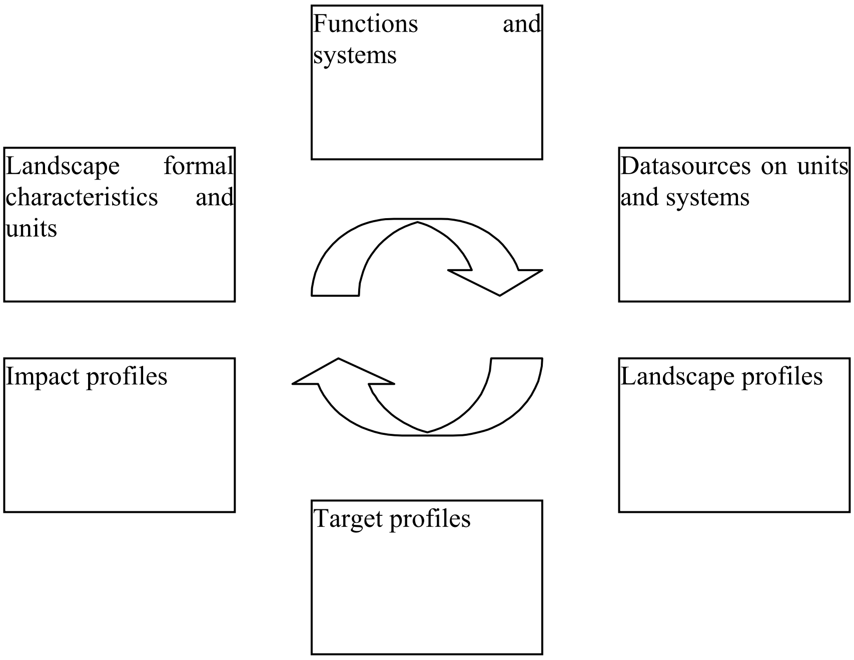


Figure 1: *The assessment of landscapes (the carrousel concept)*

In the carrousel the first step is the indification of the physical characteristics of the landscape. **Landscape characteristics and units** are geographical units of a certain uniformity or homogeneity and the emphasis in terms of their classification is on type and units. When following the second step, the'system' approach, it is also necessary to detect the functional linkages and relations within the landscape. **The functions** underlying landscapes refer principally to land use. Land use means much more than land cover, and includes next to visible cover types (e.g. vegetation) certain less directly observable aspects such as access conditions, etc.. The functioning can be translated into **systems** comprising inputs, transformations and outputs (e.g. hydrological systems). Each of the functions and characteristics can be assigned more concretely to the "landscape resources" (e.g. vegetation, water, built elements,…) for which the most appropriate integrity indicators can be optimally selected. They will be quantified or qualified using **data sources on units and systems** and correspond to e.g. maps on landscape/ geophysical characteristics and GIS data fed by remote sensing in orde to define the landscape profile.

Landscape profile is the result of a methodological analysis of the major physical, biotic, structural, cultural and land use properties of a landscape. From the profile the values and vulnerabilities of the landscapes can be assessed, and this refers to the third step: estimating the sensitivity.

In the frame of impact assessments it is useful to define target profiles for the areas of functions being affected. The **landscape target profile** has specific reference to a goal thus determining the optimal (ecologically sound, economically and socially beneficial) potential of landscapes. By determining statements or hypotheses in relation to potential impacts, the nature of these influences can be estimated. **An impact profile** describes the interactions of a certain landscape unit or landscape type. It is based on impact types likely to be caused by a development.

Examples:

- Start from assumptions concerning the interactions of transport infrastructures with the spatial configuration of landscapes and continue with establishing a European landscape classification based upon criteria that reflect these interactions
- Start from available (and standardised and area covering) data-sources concerning landscape (or components of landscape) and deduce zones of high landscape or ecological value and of specific vulnerability for fragmentation or disturbance
- Start from land use priorities throughout Europe, assess how they interact with transport infrastructure, and look consequently for data-sources that define landscapes with specific land use combinations and specific infrastructure interactions

In an expansion of Wascher et al. (1999) we can claim that a successful methodology for the assessment of impacts on landscapes is strongly dependent on the establishment of transparent and generally accepted reference values against which the measured criteria can be judged. For landscapes and biodiversity, such reference values may be defined for specific purposes at the regional or national level, but there is a lack of a coherent, operational and accepted landscape value system, especially at the international level.

2.2 Landscape typology and classification

The term "landscape" has a wide range of definitions, that not only results from to the very broad range of disciplines dealing with landscape, but also is due to the cultural and political differences within Europe. Therefore, and in order to give the term its practical role in SEA, a robust semantic framework should be adopted, with entries for each of the contributing disciplines and policies involved. At strategic level, landscapes should preferentially be assessed in holistic frameworks, in the first place through determining appropriate classifications and typologies

INTERNAT summarised different approaches to landscape synthesis that can be incorporated in SEA of TEN. For SEA, landscape classifications especially those based on robust and systematic survey and clustering techniques, are very helpful for the purposes of sampling the resulting classes in relation to specific impacts. Techniques such as remote sensing (*see chapter 3*) are helpful in feeding land classification exercises with objective data on land cover and landscape structure, directly related to the major impact classes of land take and fragmentation (*see 2.3 impacts on landscapes*). The total impact quantification of SEA in large areas can substantially be facilitated through scientifically based land classifications.
For SEA, the determination of landscape units fulfils different roles:

- Differentiating the expected type of impacts of infrastructures between geographical landscape units. In certain areas biodiversity values may be much more characteristic than visual qualities. In other areas, it will be the difference in scale of large infrastructures and the existing landscape pattern that will be important
- Enabling differentiation of the choice and interpretation of evaluation, vulnerability and impact criteria, according to the different landscape units crossed. This clearly follows from the first role mentioned.
- Providing a stratification framework for sampling impacts that cannot be deduced directly from the general description of the units.
- Allowing the extrapolation of impacts over the surface of the units, and quantifying total impacts of an infrastructure in terms of specific metrics of the landscape units (area, transect length, composition, etc.).

In landscape classification *sensu stricto*, the emphasis is on the class or type rather than on the area unit, although the distinction between typology and mapping is often blurred in practice. Landscape types can be assigned to different kinds of map units (pixels, polygons). Certain landscape typologies are qualitative and based on expert judgement such as the **Meeus typology of European landscapes** (Meeus et al. 1990). In *Table 1* a linkage is laid between the landscape types, their targets and likely impact targets.

Table 1: *The Meeus (1990) typology of European natural and rural landscapes, and their linkages to TEN impact profiles. Numbers under groups refer to the numbering code of the Meeus' types.*

LANDSCAPE TYPE GROUPS	LANDSCAPE PROFILE	TARGET PROFILE	TEN IMPACT PROFILE
Tundras (1-2)	Lowlands to hills covered by snow, bogs and fens; heathland	Protection against fire, grazing, dessication; CO2 sink	Very fragile soil and vegetation; barrier for arctic animal migration
Taigas (3-7)	From wetland plains to hilly; coniferous to mixed forests	Silvi- and agrocultural practices; high natural values	Fragmentation of forest belt
Uplands (8-9)	Rolling to mountainous, extensive use, forests and alpine vegetation	nature conservation, open air recreation, water reservoirs, panoramic landscapes	Disruption of integrity of landscapes, avalanche risks
Bocages (10-12)	Plains to rolling land; pastoral and hedgerow networks	extensive agriculture, protection of landscape and rural development	Disruption of integrity and scale inbalances, fragmentation of network
Openfields (13-19)	Plains to rolling land; arable crops, large scale landscapes	Continuation of arable farming, erosion control	Integration capacity because of scale
Steppic and arid landscapes (20-23)	dry to salt affected areas, grassland to sparse vegetation	Protection of nature, soil and water	Integration capacity because of scale
Regional landscapes (24-27)	Culturally determined specific landscape types, often intensively used	Protection of small scale intensive agricultural practices	Disruption of integrity and scale inbalances, fragmentation of structure; threat of unique conditions
Artificial landscapes (28-30)	Lowland landscapes like polders and deltas; intensive agriculture	Conservation of sustainable agriculture	Fragile soils, possible integration capacity, but threat of unique conditions

Strong changes in land use threaten the preservation of landscape heritage that is composed of relics of former land use types. The growing importance of the differentiation of European landscapes as major socio-economic assets of rural development has raised the awareness of the cultural landscape and its vulnerability in respect of the introduction of new features such as infrastructure. The Meeus' map of traditional landscapes can help in assessing the type of impacts of new infrastructures in relation to historical rural landscape characteristics. But a systematic map of the cultural heritage in SEA would be an important future task.

It is strongly advisable to develop **ad hoc landscape classifications** for Europe, based on the existing thematic datasources available within Europe, and specifically designed to categorize landscape profiles and impact profiles useful in SEA of TEN. The following suggestions should be further developed:

- Specific aggregations of the CORINE land cover database including, and in the first instance, the existing levels 1 and 2. Alternative aggregations may emphasize for example the spatial association of urban and agricultural areas, or the association of wetland and open water bodies.
- Specific syntheses of thematic data layers, such as the calculation of road density per $25km^2$, based on existing road databases, as an indicator of the existing degree of fragmentation
- Specific combinations of thematic data layers, such as land use and land quality, in order to assess functional landscape qualities

Table 2 gives an overview of possibilities. This should be further investigated, based on the overall analyses and conclusions of INTERNAT.

Table 2: *Inexhaustive checklist of useful ad hoc European landscape classifications/typologies in the frame of SEA of TEN*

Classification/ typology	Potential for development	Current availability
Urban / rural gradients	Yes, from CORINE land cover	virtually yes
Landform and Relief energy	Yes, from DEM[4] for Europe	yes, resolution
Biodiversity	Yes, from different CORINE & other data sources, problems with reliability and consistency	50 km resolution synthesis by Williams et al. (1998)
Degree of fragmentation by roads	Yes, from road databases ; road maps crossed with land use maps	coarsely, EEA SEA-TEN pilot study
Dominant landscape scale	Yes, from CORINE land cover, DEM, infrastructure maps and various statistics	No
Abiotic landscape	yes, from different maps (geology, landform, soils, climate, hydrography,…)	no, but separate approach in each country
Hydrographic basins	yes, from national and regional databases	Unknown
Ecoregions and districts	yes, from European to regional databases	DMEER[5]
Heritage values	Yes, based on various sources	Meeus map (very generalised) of traditional landscapes
Bioclimatology	Yes, based on climate, altitude & other stable categories	Partial, ITE based maps for some countries
Land cover	Yes	yes, CORINE land cover

[4] DEM: Digital Elevation Map, CORINE map on relief
[5] DMEER: Digital Map of European Ecological Regions

Landscape character	yes, based on existing thematic maps and remote sensing	no, only some countries
Quietness	yes, based on road map, land cover and data of specific acitivities (e.g. airports)	no, maps of tranquil areas for certain regions

In the framework of this project and as an essential part in the definition of European Landscapes an attempt was made to produce a checklist (Annex 1) of datasources directly or indirectly referring to „landscape entries“ throughout Europe.
Without pretending to be complete this checklist can serve as an inventory of which sources of relevant data are available for SEA, and in what format and through which channels in Europe. Not all datasources can exclusively be assigned to one of these 10 information source classes, for they cover more than one class. It should be stressed that the checklist is far from complete. Moreover one should be aware that this checklist should be updated at regular time intervals.

2.3 Impacts on landscapes

Within the system of assessing the environmental relevance of human activities the *concept of **impact*** is used in the sense of the *environmental relevant effect of the activities and elements of the assessed (Transport)system that causes environmental risks*. Thus "*impact*" with reference to the following implies broadly speaking the environmental consequences of the activities. ***Spatial impacts of transport infrastructure*** *are impacts, which occur in the vicinity of the relevant structure or activity and cause* ***environmental risks***. The types of impacts to be taken into account are further described in Figure 2.

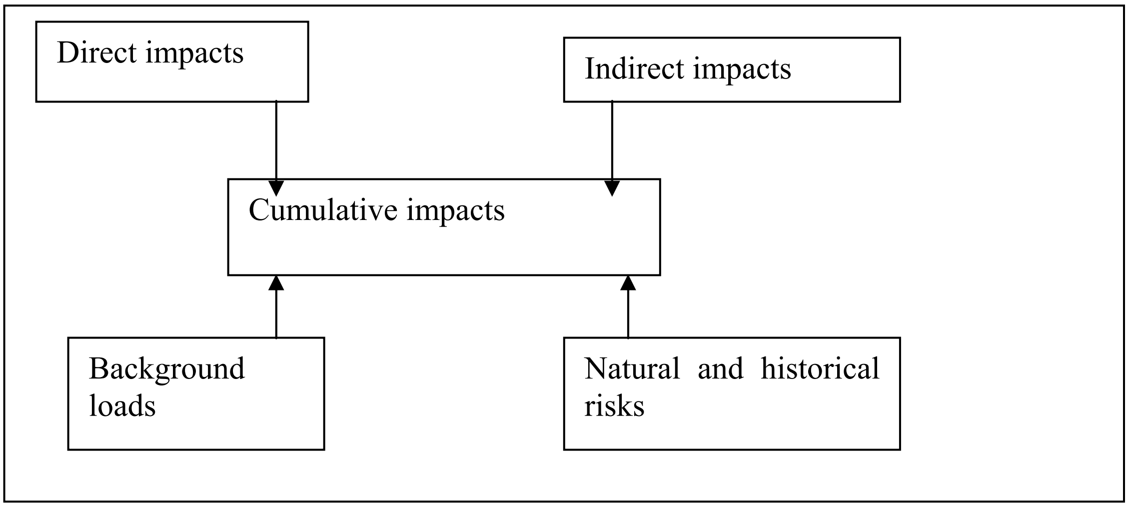


Figure 2: *Overview of impacts*

- Impacts that occur in the same place at the same time, and as a direct result of the action, are referred to as **Direct Impacts**.
- **Indirect impacts** can occur at a distance from the action, or the impacts of the action may appear some time after the action occurs. Indirect impacts usually refer to induced impacts as a result of changes in patterns of land use, population density or growth rate, activities development and related impacts on air and water and other natural systems, including ecosystems (Page & Parkins, 1997).

- **Cumulative impacts** result from the aggregate impacts of sometimes small, independent human actions, with different origins, and hence cannot be traced back to one single, or easily identifiable source(s). They occur in relation to the context of background loads and natural and historical risks.
- **Background loads** are loads that have been caused before the referred action.
- **Natural and historical risks** are, for example, storms, earthquakes, inundation, old waste dumps or old mining areas.

Any application 1) to determine impacts of major infrastructures and 2) to define of indicators for determining landscape functions and values is strongly linked to the question of spatial references for which such indicators can be considered as valid. The following table helps to select and apply sensitivity indicators for landscapes and landscape functions (Table 3). In conjunction with typological and statistical data, strategically significant conclusions can be drawn. The INTERNAT indicators have been chosen through conducting analyses of perceptual and ecological value. Analysed issues are 1) policy relevance and utility for users, 2) analytical soundness, 3) measurability, 4) scale applicability determined by complexity of calculations and 5) scale applicability determined by data availability. The selected group of indicators is used in the prototype application demonstrating the use of remote sensing (see chapter 3).

Table 3: *Interactions between resources, functions, impacts and indicators.*

RESOURCES	FUNCTIONS	IMPACTS	SENSITIVITY INDICATORS (of functions)
NATURAL VEGETATION & FOREST	• Biomass production • Soil protection • Climate regulation • Biodiversity regulation • Life quality	• Land take • Fragmentation • Impacts on the vicinity of infrastructure	• Proximity of planned infrastructures • Number and size of ecologically important areas cut, touched or cut through by the planned infrastructure • Nature reserves • Protection status • Degree of naturalness
CROPS	• Biomass production • Soil protection • (Climate regulation)	• Land take • Fragmentation • Impacts on the vicinity of infrastructure	• Agricultural productivity
WILDLIFE	• Biomass production • Biodiversity regulation • Life quality	• Fragmentation • Noise • Land take • Impacts on the vicinity of infrastructure	• Proximity of planned infrastructures • Number and size of ecologically important areas cut touched or cut through by the planned infrastructure • Nature reserves • Protection status • Target species
LIVESTOCK	• Biomass production • Life quality	• Land take • Fragmentation • Impacts on the vicinity of infrastructure	• Agricultural productivity

RESOURCES	FUNCTIONS	IMPACTS	SENSITIVITY INDICATORS (of functions)
WATER	• Biomass production • Climate regulation • Biodiversity regulation • Life quality	• Land take • Impacts on the vicinity of infrastructure	• Impact on surface water networks • Water quality • Ecological passibility and morphological values • Intergrity of the natural course of a river • River network density combined with geographical data • Protection status • Importance for retention • Number and size of stretches of water and ground water protection areas touched by transport infrastructure • Protection status
SOIL	• Biomass production • Water retention • Mineral resources (building material) • Pedological regulation functions • Biodiversity regulation • Life quality	• Land take • Impacts on the vicinity of infrastructure	• Soil quality before impact • Agricultural productivities • Buffering and filtering capacity • Number and area of valuable soil zones touched by planned transport infrastructures • Protection status
CLIMATE	• Biomass production • Life quality • Biodiversity regulation	• Impacts on the vicinity of infrastructure • Fragmentation • Global warming • Acidification • Air quality	• Emissions of CO_2 and other greenhouse gases • Emissions of SO_2 and No_x • Emissions of pollutants VOC, CO, SO_2, NO_x Particulates
PERCEPTUAL QUALITY	• Life quality	• Land take • Visual impact • Noise • Fragmentation	• Aesthetic value • Naturalness and diversity • Open space between settlements • Open space between forest and settlements • Number of people susceptible to noise disturbance • Area of land take in tranquil zones and type of observers • Landscape structure • Landscape readability
CULTURAL HERITAGE	• Life quality	• Land take • Visual impact • Fragmentation	• Number of visitors • Reference in travel guides • Number of designated landscapes touched or cut through by the planned infrastructure • Reference in travel guides

INTERNAT addresses a more in depth analysis in relation to the strategic character, the differentiation by mode, spatial scale, time scale and magnitude of impacts. It is important for SEA to analyse the relevant spatial impacts and their general magnitude as thoroughly as is possible with respect to the different modes/system-elements and basing this on the relevant compartments of TEN-links and the prognosis of the foreseen transport activities. Integration of spatial impacts in transport SEA has to be seen within the question of how this can put forward a differentiated view of the outstanding alternatives. So, depending on the integrated alternative strategic options, spatial impacts may (inter modal comparison) be included more on the level of the general characteristics of the relevant transport modes, or if spatial alternatives of routing are assessed, in a more detailed way, based on assessment of spatial sensitivities and concrete risks.

For the estimation of spatial impacts it is of further significance, whether the upgrading of existing infrastructure or the new construction of a link is in question. The analysis also integrates concepts used within concrete project related environmental impact assessments. It includes examples of concrete impact intensities from different case studies.

The main aim is to define impact classes with respect to possible SEA concepts, such as the assessment of overall magnitude, an assessment combined with information on spatial sensitivity. With respect to the need of generalisation in SEA different impacts are partially combined, according to their spatial characteristic. The following impacts (impact groups) are discussed: land take, impacts on the vicinity of infrastructure and visual impact, noise. For each of them a definition is given, an analysis of relevant databases, environmental targets and an approach to evaluate impact intensity. A selection of indicators is tested in the case studies during the prototype building and application for GIS/RS-integration (see chapter 3, 3.3 Impact analysis, selected indicators computed by GASSEAT and their output, page 31).

2.4 Cumulative impact analysis

Owing to the complexity of the subject there are no specific indicators for cumulative effects. Basically, a cumulative impact analysis (CIA) is necessary within the assessment process to identify whether or not thresholds are passed. Thresholds may be expressed in terms of targets, standards and guidelines, carrying capacity or limits of acceptable change, each term reflecting different combinations of scientific values (CEAA 1999). According to the COMMUTE report CIA methods can be grouped into the following categories: (i) those that describe or model the relevant cause-effect relationship; (ii) those that analyse the trends in impacts or resource change over time; (iii) and those that overlay landscape features to identify areas of sensitivity, value or past losses. The methods evaluated in INTERNAT have been summarised in Table 4.

Table 4: *Evaluated CIA methods in INTERNAT*

Method	Potential use	Weaknesses	Future research
Models, questionnaires, interviews, panels, checklists	First step in defining the basic scope of investigation		

Method	Potential use	Weaknesses	Future research
Matrices	Can be used during sceening and scoping	Based on expert opinion, time and space not taken into account, indirect, secondary, feedback events and socio-economic values are ignored, effects cannot be summed up	
Network and system diagram	Demonstrate a cause-effect correlation in a simple and clear manner	Time and space taken into account in a minor way	
Simulation modelling	Quantify the cause-effect relationships	Need of fundamental data, time, technical equipement and knowledge.	Data availability
Trend analysis	Additional tool for matrices, networks and system diagrams	Prediction can only be done under constant general conditions	
Carrying capacity analysis	Identification of thresholds on specified themes	Could be carried out at no larger scale than regional	
Overlay mapping and GIS	Analyses of landscape parameters, usefulls identifying areas where impacts will be greatest, in clarifying spatial networks or in analysing spatial and temporal environmental changes	It is not possible to visualise accumulations and the differentiation between additive and interactive processes is difficult	
New models to predict the sensitivity of wildlife species and fragmentation	Quantitative analyses and evaluation of dynamic processes	Insufficient data available, needs to be tested and developed	To develop complex spatial biodiversity models, which model key feature and population, and which are causal and dynamic in space and time
GIS modelling for the prediction of cumulative effects of land use planning	Quantify rates of regional resource loss by data layers of different years, develop empirical relationship between resource loss and environmental degradation	Data source, aerial photo interpretation and multivariate statistical analysis	
Cybernetic models	Can consider a large number of different factors	Type of effects and mutual impacts are not considered and thereby a valuation of impacts of sensitivity is not possible	
Integrated evaluation of cumulative effects with complex scenario technique	Detection of cumulative effects, enable the assessment of different combinations of options and different levels of investment	Information and databases are necessary, there is no tool to consider all the necessary inputs at once.	Improve datasets and tools

The analysis of cumulative impacts is a typical challenge to SEA, since the experiences demonstrate that indirect, synergistic, delayed, regional, trans-boundary or global effects are difficult to assess in project level EIA. The European Environment Agency describes Strategic Environmental Assessment as follows: "*SEA is generally considered as an objective-led process. It should evaluate to which extent objectives and targets for environmental protection are achieved by the strategic action. The comparison of alternatives forms the core of each SEA. The effects of each alternative are to be distinguished per transport mode, the potential modal shift and the effect of induced traffic. In the case of TEN, varying degrees of network extensions are to be discussed. Moreover SEA should identify potential conflict areas. The predefinition of environmental objectives and targets is essential for the evaluation of impact predictions*" (EEA 1998).

The general steps for SEA of TEN-T are defined in the COMMUTE assessment framework. Together with the basic steps for conducting a SEA as described by Harrop & Nixon (1999), the "Assessment Framework" of the CEAA (1999) for CIA, and the "Seven steps framework" of Clark (1994) for CIA they will lead to our framework for CIA in SEA for the TEN-T. In the following table (Table 5) steps and requirements to assess cumulative effects in SEA are set out, and questions that can be used as checklists are listed for each step.

Table 5: *Framework for CIA in SEA for the TEN-T*

Basic SEA Steps	Tasks to complete a CIA
1. List the **objectives and targets** of the policy, plan or programme, including the formal decisions that need to be taken, and identify the constraints.	• Stocktaking of the political environment concerning objectives and targets. • Identify any conflicts and trade-offs between them. • Indicate how binding the constraints are and whether they will change over time or be negotiable.
2. **Screening**	• Prepare a complete description of the proposed action in order to state the need for CIA in SEA.
3. **Scope** and analyse existing environmental issues, problems and protection objectives.	• Identify truly meaningful issues of concern (both negative and positive issues). • Use relevant environmental policies to list relevant environmental protection objectives for these issues/problems • Select appropriate resources, ecosystem components, and human communities. • Identify other actions (past, present, and future, as well as federal, non-federal, and private) that may affect the same ecosystem components. • Identify potential impacts due to actions and possible effects. • Identify thresholds • Identify spatial and temporal boundaries (use natural boundaries). • Identify thresholds.
4. **Analysis of effects** of the environmental impact of the action and its alternatives.	• Complete the collection of regional baseline data • Specify reasonable options for planning decisions and identify their environmental consequences • Assess effects of proposed actions on selected resources, ecosystem components, and human communities (do not disregard likely effects simply because they are not easily quantified).

Basic SEA Steps	Tasks to complete a CIA
	• Assess effects of all other identified actions on selected resources, ecosystem components, and human communities (address additive, countervailing, and synergistic effects, look beyond the life of the action) • Compare significant effects with thresholds.
5. Identify opportunities for **mitigating or compensating** impacts considered by stakeholders and assessors to be significant and suggest a preferred option.	• Focus on those impacts which are material to the decision • Compare these impacts with relevant environmental protection objectives and thresholds • Make a comparison of alternative options including the "without" proposal alternative • Test the sensitivity of the outcomes of the SEA to possible changes in conditions or to the use of different assumptions or development scenarios
6. Taking the **decision**	• There are no tasks for CIA in this step.
7. Establish a **monitoring programme** where necessary and decide when to evaluate the implemented policy, plan or programme.	• Identify further requirements for assessment where possible • Indicate how monitoring results of projects will be collected and used to evaluate the implementation of policy, plan or programme
8. Conduct **further environ-mental assessments**	• Specify any projects or other activities that may require project-level EIA

2.5 Landscape values and vulnerabilities

In the decision process on route selection and the decision on compensatory measures, inevitably, some valuation and vulnerability assessment of the landscapes and functions being traversed is of the order. Four assumptions can be made for value or vulnerability categories: (i) all landscapes have values, hence susceptibilities for impacts; (ii) there are different value and vulnerability categories; and (iii) landscape valuation and vulnerability assessment is an integration of perceptual, ecological, cultural, social and economic aspects. A further assumption (iv) concerns the generic value and vulnerability concept of **integrity**. Integrity refers to any interpretation of wholeness, coherence, land use fitted to the natural conditions, historical continuity, legibility, typicality etc. that can be assigned to a landscape unit or pattern. Integrity is both the key concept of a landscape unit itself, and its major criterion of value, function, and vulnerability.

Different meanings of "landscape values'" were provided during the Landscape Monograph study of EEA (EEA 1996, Wascher et al. 1999). This provides a useful framework for vulnerability assessment of different policies with spatial character such as CAP[6] and TEN. The generic value categories, as given in Table 6, should not only be interpreted with reference to specific interpretations of landscape, but also be interpreted differently in terms of the specific character of each landscape unit.

[6] CAP: Common Agriculture Policy

Table 6: *Expansion of value/vulnerability indicator classes and possible data sources (after Wascher et al. 1999).*

Indicator	Data sources
land cover diversity **Diversity**	Shannon index number of cover types/km^2 Coarse resolution: CORINE Finer resolution: land cover sets derived from high resolution satellite images Finest resolution: from airphotos, maps or field survey, including small landscape elements
architectural diversity **Diversity**	Number of construction styles/km^2 From field survey
colour diversity **Diversity**	Number of physiognomic vegetation types/km^2: from aerial photos, land cover maps, vegetation maps, etc Number of rock or soil types/km^2: from lithology/soil maps
seasonal diversity **Diversity**	Number of major phenological stages with distinct physiognomic expression: from climate map, land use map, vegetation map
morphographic diversity **Diversity**	Number of land form types/km^2 from geomorphology maps, satellite images, contour maps Relief energy as max altitude difference/km^2 from digital terrain model (DTM) or contour maps Number of basins of Nth order/km^2 from contour maps, stream maps
diversity of visual character zones **Diversity**	Number of distinct visual units from field survey or from aerial photos Number of transitions of character zones along roads Number of land use types from CORINE Number of remarkable focal elements of otherwise interesting visual features per km^2
size of open spaces **Quantitive spatial criteria**	Maximum view length from centre of km square Area comprised between visual barriers from detailed land cover map and specific spatial analysis software
size of biotopes **Quantitive spatial criteria**	Number of biotope objects in different size ranges Size of total area of valuable biotopes Total edge length of biotopes
aesthetic harmony indicators **Integrity**	Balance between prospect and refuge symbols (ratio) Presence of disturbing elements out of scale (yes/no) Harmony ranking from public preference photo sorting Expert judgement
Fragmentation **Quantitative spatial criteria, Integrity**	Length of major infrastructures per km^2 from road maps Shannon index applied to groups of mutually incompatible land uses from interpreted land use maps Number of topographic objects per km^2 from detailed land cover maps Land cover complexity index e.g. through radial analysis in land cover maps
purity of traditional land cover/use **Integrity**	% land occupied by traditional land use wholeness of traditional pattern as e.g. alpha or beta network index for hedgerow landscapes % abandoned land
Connectivity **Integrity**	Alpha and beta network indexes Mean distance between biotopes Inverse of fragmentation indexes

Indicator	Data sources
land use fit **Integrity**	Spatial correlation of land cover/soil type % unfitted land cover
water surfaces **Internal qualities**	Diversity of surface water bodies as Shannon index applied to classification of water bodies from topographic maps % area open water total shore length
water quality **Internal qualities**	Biotic index of water bodies Distribution of water bodies in different quality classes Contribution of unit area to groundwater recharge yes/no Natural water supportive to specific land uses yes/no
soil quality **Internal qualities**	% area covered by highly fertile soils presence of lithologic/geomorphologic/soil conditions important for nature conservation yes/no concentration of remarkable objects of “earth heritage” yes/no or objects/km2
protection status **Statutory value**	% area under protection rule number of protection rules applicable to unit area
land use stability **Internal qualities**	Economic indicators of stability of interesting landscapes e.g. agricultural succession safety, EC support, demography...
ecological disturbances **Internal qualities**	% area prone to fire or inundation risk size affected by forest die-back yes/no % area affected by desiccation or desertification
unique features **Unicity, rarity**	Presence of unique features, landmarks etc.

Values and vulnerabilities are also necessary elements for the evaluation of the significance of impacts on landscapes. The main question at network-wide level of TEN-T involves a general comparison of infrastructure modes and their global and network-wide effects on man and environment. At local or corridor level the main interest focuses on measures to avoid, reduce, mitigate, or compensate the effects of specific infrastructures, which are intended to be realised. After having taken the decision for a certain connection between nodes at network-wide level, the corridor has to be defined at regional level. Which corridor to take is a question of the integrity, for practical reasons reduced to the ‘development potential’ of landscape units. Besides ‘integrity’ the ‘sensitivity’of the resources and functions of a respective landscape unit, will be used as a major criterion for the evaluations of impacts on landscapes and functions..

The proposal in respect of the calculation of impacts on landscape in INTERNAT is based on an integration of sensitivity analysis and impact classification. Different examples of rules for the deduction of sensitivity and protection priorities have been developed: for air exchange, for surface water and local flood control, for ground water sensitivity, for filter and buffer capacity of soils, for biodiversity. The procedure to be followed after sensitivity analysis is the calculation of land cover changes of target species. An argumentative integrated evaluation of the modelling results should engage stakeholders in round table discussions. For instance it is clear that ecological modelling on the landscape scale is not a valid technique for project level impact assessment because of the roughness of the results.

Impact maps and sensitivity maps require to be overlaid by ecological modelling and the scenarios have to be compared with the target profile of the respective landscape unit. The results could be summarised in a matrix for each landscape unit, see Table 7.

By comparing the integrity matrices of different landscape units and comparing the effects on the diverse resources within these matrices, a ranking for impact prevention can be developed and the less harmful corridor may be detected. Whereas the abiotic controlling factors determine the natural conditions in the landscape unit, it is the condition of the living resources and the landcover which characterises the degree of human performance of the unit. The social qualities finally are a gauge for the social integration of the human performance. Their sensitivity can be evaluated (unconscious or in a mediation process) by the local, national or international society. The following diagram shows an example of a possible integrity matrix which could be applied.

Table 7: *Example of integrity matrix*

Landscape unit: ………………… ………………	**Resources**								
	Abiotic controlling factors			***Living resources and landcover***				***Social qualities***	
	WATER	***SOIL***	***CLIMATE***	***NATURAL VEGETATION & FOREST***	***WILDLIFE***	***CROPS***	***LIVESTOCK***	***PERCEPTUAL QUALITY***	***CULTURAL HERITAGE***
Characteristic functions and values									
Sensitivity (high/med/low)									
Target profile									
Foreseen infrastructure									
Impact profile									
Interference of development potential by impacts (high/med/low)									

2.6 Conclusions

This chapter described landscape approaches at different scale levels as well as methods to link functions to spatial systems. Also the types of impacts were discussed although this section will be developed further, in function of practical guidelines for the use of selected indicators, in the next chapter, 3. SPATIAL IMPACT ANALYSIS USING REMOTE SENSING AND GIS. The spatial environmental impacts discussed in INTERNAT are related to direct spatial impacts, indirect and cumulative impacts. The relevance of spatial impacts differs in absolute intensity and in spatial dimension, as well as between different modes and landscapes. INTERNAT elaborated a definition, the availability and form of input data and the type and format of outputs for the following impacts: land take, noise, pollutant emissions, impacts on the vicinity of infrastructure and visual impacts. For each type of impact a set of indicators applicable for landscapes and landscape functions has been developed.

In addition to the previously mentioned spatial impacts the analysis of cumulative impacts was also assessed, as well as the methods useful to execute cumulative impact analysis. The main principle of a CIA-concept is that for each specific resource, ecosystem and human community being affected by the TEN, the CIA should identify all other actions that may affect the resource and assess the cross- related nature and synergistic interaction of multiple impacts, i.e. the cumulative effects. A reliable assessment of cumulative impacts includes an analysis of land-use developments, in particular the analysis of future growth effects that might possibly be induced. . Because of the complexity of the subject there are no specific indicators. Therefore, the identification of suitable thresholds is central to the assessment of cumulative impacts.

This chapter demonstrated possibilities for evaluating sensitivity of landscapes and functions in confrontation with impacts with the objective of elaborating the definition of impact criteria. The main focus was laid on standardised rules for the application of methods and for aggregating and disintegrating data concerning individual environmental factors. The presented rules are to be seen as examples and are only valuable on strategic regional level.

3. SPATIAL IMPACT ANALYSIS USING REMOTE SENSING AND GIS

3.1 Introduction

Although most often used as a data storage and cartography tool, the main goal of a GIS is to function as a powerful spatial analysis tool. The number, form, and complexity of data analysis functions possible with a GIS are virtually limitless. The power of GIS becomes even clearer when it integrates remotely sensed data from satellites. While GIS concentrates on data management and spatial analysis functions, remote sensing puts the emphasis on data generation aspects. One of the most important benefits of a GIS is considered to be the ability to spatially interrelate multiple types of information stemming from a range of sources. This powerful characteristic has shown to have a major potential in estimating the environmental impacts as a consequence of human activities.

In INTERNAT considerable attention has been paid to the interaction of transport infrastructure with functional and spatial systems, which are covered or traversed, with reference to the two concepts discussed in the preceding chapter:

1) the spatial, formal or 'landscape' approach, in which the scale relation of infrastructure towards existing land, land use and observable structures is taken into consideration; and,

2) the system or 'function' approach, in which landscapes are envisaged as functional entities such as river basins, ecological networks or agricultural units.

Landscape valuation is an integration of perceptual, ecological, cultural and economical aspects. In order to estimate impacts of transport infrastructure on landscapes, either regarded as a collection of observable structures, or as a functional unit, it is a prerequisite to use a set of relevant indicators, which are:

1) indicators related to the perception component (cultural and scenic features using by criteria that relate to the acceptance of landscapes by the general public and individuals);

2) indicators related to the structure and functional component (ecological characteristics, in relation to the sustainability of biotic and abiotic features) and;

3) indicators related to the land use component (mainly socio-economic characteristics).

In chapter 2, Table 3, an overview of relevant indicators has been made. A selected group can be derived as control elements through the use of RS/GIS techniques. In this chapter an evaluation will be made of how RS and GIS can contribute to a better interpretation of the GISCO database layers in order to estimate environmental indicators and generate secondary data sets (derived themes) through the development and application of tests linked to a prototype software. The development of a prototype software originated initially as a result of the evaluation of recent literature and new evolutions in research experiences.

The compilation of the information was carried out through a review of the literature and a consultation of the research institutions at the leading edge of technical development in the fields of RS and GIS. A questionnaire was developed and sent to the following research centres: ESA, EUMETSAT, ASI (Italy), CNES (France), BNSC (UK), DLR (Germany), JRC (CEC), and SSC (Sweden). The following set of image data sources were analysed: SPOT (XS, vegetation, P), NOAA, Landsat TM, VHR images. In terms of GIS data sources GISCO, EUROSTAT, CORINE, DMEER and UNESCO World Heritage were consulted.

The reviewing and consultation activities revealed that the information on new approaches in respect of information extraction techniques using satellite data in order to estimate environmental impacts remains scarce. This is equally the case for examples of applications at a smaller scale than at EU level. The lack of complete and up to date information seems to be the main constraint determining the slow progress regarding indicator development through RS/GIS steered techniques. It is hoped this will become more efficient in the near future since the resolution of imagery is continuing to improve.

3.2 The INTERNAT prototype software: GASSEAT

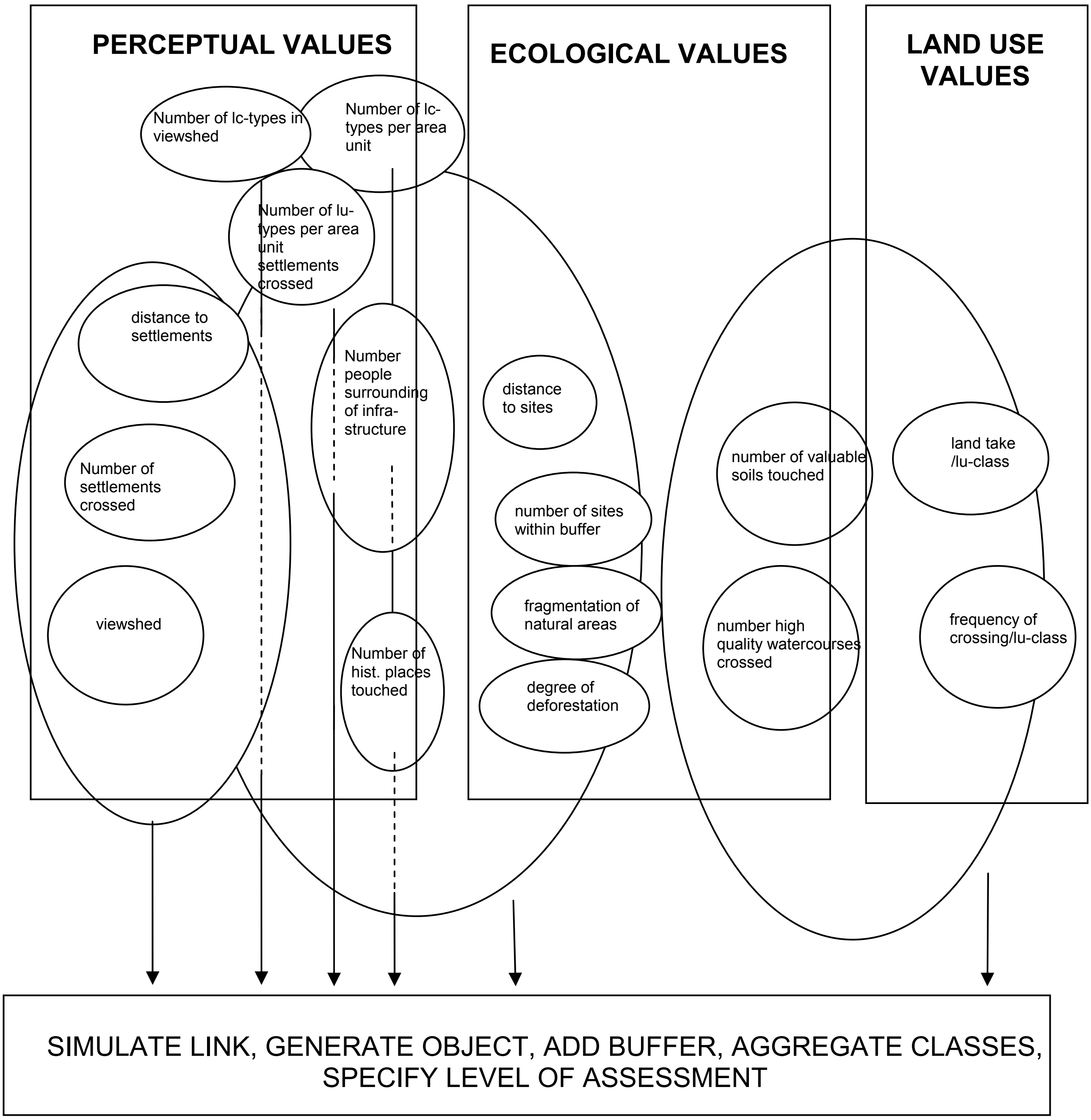
3.2.1 Functional qualifications and integration of GIS and remote sensing

The INTERNAT prototype will be referred to as the Geographic Analysis System for Strategic Environmental Assessment of the TEN (GASSEAT). The software aims to assist in the SEA of alternative plans for implementing the Trans-European Network on transportation. The conceptual model is illustrated in

Figure 3. There are 7 basic functional qualifications of the prototype, it has :

1. To enable the user to define alternative routes for the link under consideration as long as these alternative routes are located within the extent of the geographic database;
2. To allow the user to make a choice, at the beginning of the programme, about the kind of environmental values to be evaluated, these being: perceptual values, ecological values, land use values;
3. To enable the user to generate a geographic data layer expressing indicators for perceptual environmental values
4. To enable the user to generate a geographic data layer expressing indicators regarding ecological values:
5. To enable the user to generate a geographic data layer expressing indicators regarding land use values:
6. To allow the user to define geographic objects, aggregate classes, define buffer areas, and distances and directions for viewshed;
7. To allow the user to set the level of assessment where applicable.

Figure 3: ***Conceptual model of the prototype (GASSEAT)***



GIS and RS will be used in data collection, classification and indicator estimation. From the set of indicators proposed in chapter 2, Table 3: ***Interactions between resources, functions, impacts and indicators.***, 11 indicators were selected to be analysed by the use of GASSEAT (see 3.3). This selection aimed to include at least one indicator per resources group[7], thus presenting a fair possibility to be applicable at each scale level or having a strong potential for future research.

For reasons of user-friendliness, the availabilty/use of GIS software within the EC, and in order to limit the hard/software costs to implement the prototype, INTERNAT developed the prototypal software within one of the more commonly used GIS-software packages ArcView (from ESRI) for Personal Computer platforms. Besides the aforementioned arguments, ArcView offers very useful extensions (available separately from the main software component) to process satellite imagery (e.g. Image Analysis, Spatial Analyst). The only disadvantage of using this configuration for running the prototype is the long run times. These run times depend significantly on the resolution of the raster data sets (it takes more time to process picture elements with 20m than those with 1000m ground resolution, for instance).

3.2.2 The pilot studies

The prototype has been designed in such a way that it is transparently applicable on each of the three scale levels: EU (network), regional and local (corridor). The selection of the areas to be studied was strongly determined by the availability (within a short project time-scale) and the quality of relevant datasets.

The current land cover database of GISCO (also known as the CORINE database or CLC1990) has proven to be very useful for EU-wide and even regional assessment purposes. However, once more detail is required in order to perform local assessments, the aforementioned data set is not accurate enough. CLC1990 uses a three-level nomenclature and has a minimum mapping unit size of 25ha. Local assessments need higher level (level 4&5) division in land use/cover categories and a smaller mapping size unit. Land use/cover data sets with a higher level of detail than CLC1990 exist in many EU member states. However they cover small areas since they are usually compiled through the interpretation of large scale aerial photographs (which is an expensive task), and they do not use classification schemes harmonised according to CLC1990. In other words, it is usually very difficult (even impossible) to aggregate classes of local land use/cover databases in a way that they correspond to the CLC-classes.

For regional and local assessments, land use/cover data which are more detailed than the level 3 data are often necessary. Often these data do exist, however, a full coverage of the EU does not exist. Furthermore, locally established land use/cover databases use different types of land use/cover categories. Regional and local pilot studies were carried out only for Flanders since most of the data sets relevant to the environmental sector for Flanders are available at the Flemish Land Agency (VLM). The Flemish Region is crossed by the Trans-European Corridor n°2 HST-line PBKAL: Paris-Brussels-Köln-Amsterdam-London.

[7] natural vegetation & forests, crops, wildlife, livestock, water, soil, climate, perceptual quality, cultural heritage

Requests for local and regional data sets in other EU countries would not fit within the time frame of the INTERNAT project since this often requires long-term communication/discussion on data policy, legal issues and responsibilities.

During the reporting and evaluation period of the project (early 2000) it has become clear that suitable datasets could be made available by JRC for a more natural trans-border region in the Alpine area. It has been decided to accept additional project time to realize a second application of GASSEAT. The study area is a trans-border Alpine site between France and Italy, which is crossed by the Trans-European Corridor N°6 HST-line (passenger and freight transport): Lyon (France) – Trieste (Italy).

3.2.3 Input data

The following data sets are used in the prototype: EU national boundaries (ESRI), settlements (GISCO), designated areas (GISCO), biotopes (GISCO), Digital Elevation Model of Europe (GISCO), Roads (GISCO), Railroads (GISCO), Waterways (GISCO), Land use of Europe (GISCO), Land use map of Flanders (Flemish Land Agency), Biological Evaluation Map of Flanders (Institute for Nature Conservation), Forest map of Flanders (Department of Forestry, Ministry of the Flemish Government). Some of the data-layers are extracted from the Land cover of Europe (GISCO): the forestry map and the potential natural areas map. For the assessment of the Alpine site a land-use map has been used, deriving from CORINE land cover data (GISCO) up-dated using IRS-1C satellite data, at the JRC's Space Application Instititute.

A major limitation with respect to the availability of input data concerns the TEN data itself: GISCO faced a number of problems in exporting the TEN database to one of the more common GIS data exchange formats. Even more important, once imported into the ArcView system, crucial attribute information was missing. As an example, the fundamental data set incorporating the boundaries of the EU countries was not complete since fragments of boundaries of some countries were missing. Therefore, these data could not be used as a selection criteria to clip other databases according to nationality. An important number of data sets of GISCO have a point typology (designated areas and biotopes, data on settlements). The lack of geo-referenced data means that the available attribute information is not useful for GIS analysis. It is quite obvious that there is a highly significant and direct correlation between the quality of the input data and the reliability of the results of the impact modelling. Consistency errors were only detected in the land use/cover data set. Land use occasionally changes in an abrupt, apparently artificial, way. These errors are probably the result of inconsistent land use interpretation in different map sheets.

Quantification is compromised by the lack of diversification of the TEN segments constrained by attribute information. The only information that could be extracted was the distinction of whether the links were *planned* or *not planned* and information was available on certain projects to upgrade infrastructure. Information about the numbers of the projects was not available, which means that a particular TEN project could not be selected by its project number. The selection had to be done graphically by 'guessing' which transport links/modes were included in the project. For regional and local assessments it would be useful to have more detailed data on the exact location of the transport links.

Any data set that has an ArcView compatible data format can be used by the prototype. Besides, as is the case for all other GIS applications, data sets used in a GIS analysis must have been geo-referenced to the same projection system. Most of the data sets received from EUROSTAT were delivered in geographic co-ordinates (latitude/longitude) and were therefore not suitable for calculating distances and areas. The data sets had to be transformed to a common projection system, which allows metric operations.

To conclude, some data preparation activities (conversion to ArcView data format if necessary and conversion to a common projection system) are required before data can be used in the prototype. The actual response time (between official request and delivery of the data) was reasonable (1 month and 4 days). Not all data sets could be delivered in the requested format (export format, e00) since the volume of some data sets was too large, but since the VLM is using the same GIS-software, simply copying the original data rapidly solved the problem . However, other users, which are using a different type/version of software, would have run into exchange problems and/or data corruption/consistency problems at this point.

A detailed overview of data references and GIS/RS operations and techniques is given in Annex 2.

3.3 Impact analysis, selected indicators computed by GASSEAT and their output

Examples of the outputs of indicators are to be found in Figure 4, Figure 5, Figure 6 and Figure 7.

Table 8: *Overview of the indicators computed by GASSEAT by scale level*

Indicator	EU-level	Regional/local level	
		Flanders	Alpine site
Neighbourness to settlements	Long processing time	X	X
Settlements touched	X	X	X
Visibility	Not applicable	X	X
Land cover heterogeneity	X	X	-
Noise	Not applicable	X	X
Historical places touched	No data available	No data available	-
Neighbourness to protection sites	Long processing time	X	-
Number of protection sites touched	X	X	-
Fragmentation of potential natural areas	Long processing time	X	-
Degree of deforestation	X	X	-
Connectivity	X	X	-
Land take per land use class	X	X	-

Proximity to settlements

This indicator is useful to express a general impact in respect of distances to the settlements (i.e. urban areas) of the infrastructure. The prototype will generate a map with the transport link, which is coloured in different tones of red according to the proximity of the settlements. The redder the link, the higher the degree of proximity. Another type of map is a proximity map of the area under study. The redder a point on the map, the nearer the transport link is to that point. (see Figure 4). An index is generated which indicates the numerical expression of the proximity.

The proximity (neighbourness) values are determined as follows: a) for each settlement in the analysis the distance of each pixel to the settlement is calculated i.e. for each settlement a distance layer is generated; b) for each layer and for each pixel the distance value is substracted from the buffer value (distance at which the neighbourness is considered as being 0) with negative values set to 0; c) calculation of the sum of all corresponding pixels for the different settlement layers. The user will specify a buffer distance of the link to the settlements and their minimum size (surface) to select the settlements which have to be taken into consideration.

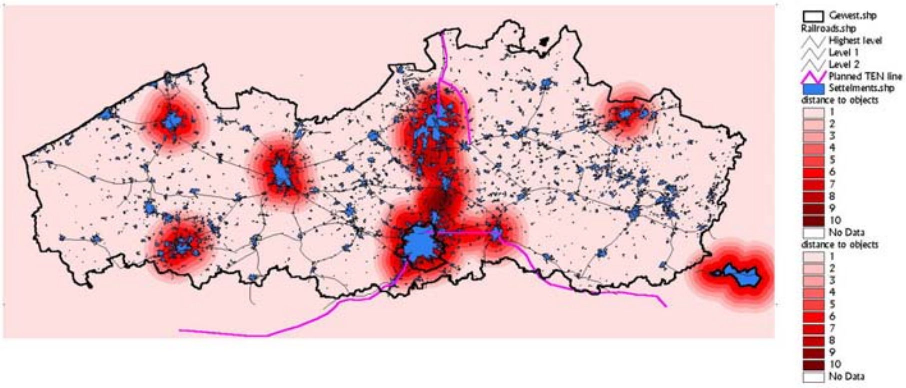
Information on the proximity of infrastructure is an important element in the analysis of ***the impact group related to the vicinity of infrastructure***. This impact group includes the different impacts resulting from the presence of transport infrastructure and its operation, which overlap and accumulate in the vicinity of the infrastructure to cause -single or cumulated- ecologically significant impacts. Relevant issues are:

- Direct impacts on spatial structures (relief and vegetation) with resulting indirect quantitative influence on groundwater and on local climate conditions and, accumulation, on biotopes (see also ***land cover heterogeneity, proximity to protection sites and number of protection sites touched, fragmentation of potential natural areas, degree of deforestation, connectivity and land use per land use class***)[8],
- Direct impacts on human settlements and life quality: ***settlements touched, visibility, land cover heterogeneity, land use per land use class, historical sites touched***,
- Transport activities, causing release of gaseous emissions, dust, and other substances and generating noise with impacts on life quality (see also chapter 4), also soil and water contamination or eutrophication characteristics, and effects related to artificial lighting and collisions with animals.

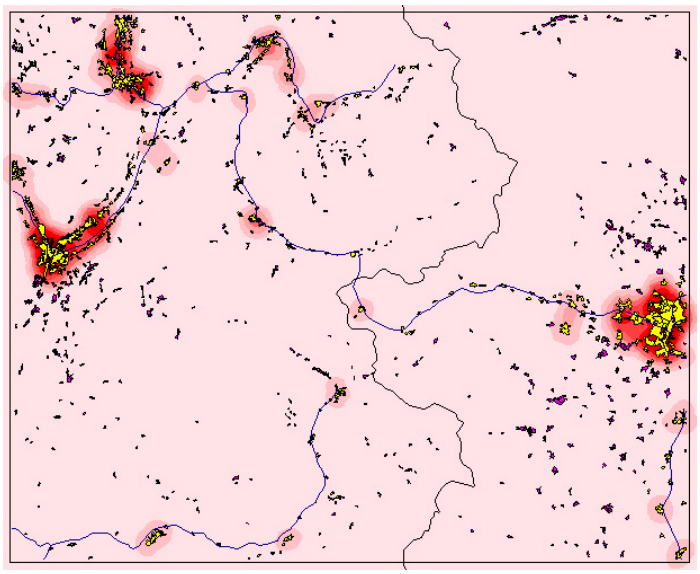
[8] indicators in '**bold**' and '*italic*' are computed by GASSEAT and commented in the following part of this section

Figure 4: *Maps indicating the proximity/neighbourness of transport links to settlements*

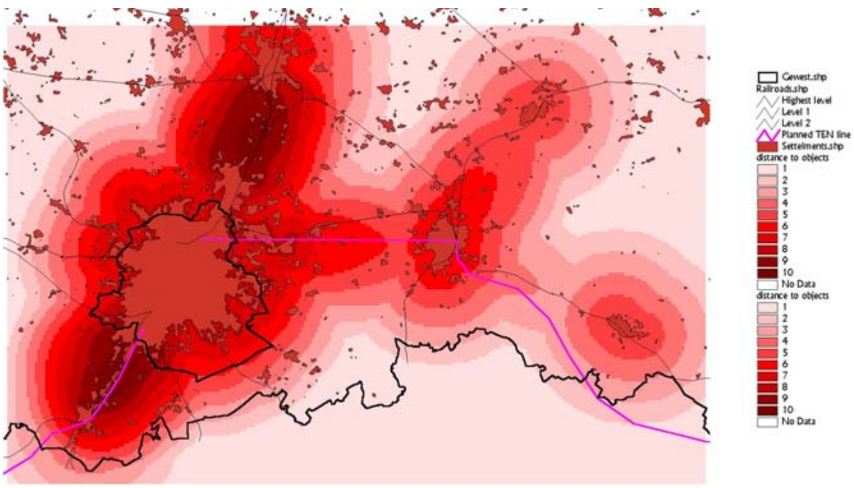
4a) at regional level: Flanders



4b) at regional level: the Alpine site



4c) at local level: Brussels and surroundings



In a research project for a SEA concept for the national German Transport Infrastructure Plan (IWW et al (1998)) the concept of a partial loss of the habitat value in the vicinity of infrastructure is seen as representative for different environmental risks. A generalised network assessment could operate with total impact magnitude, assessing relative losses of values for influenced areas (see Table 9)

Table 9: *Buffers and relative losses of values for areas affected by the vicinity of road- and rail infrastructure*

Distance	road: traffic intensity (DTV)				Railroad	
From the track	> 50.000	> 25.000	> 10.000	< 10.000	HST	convent.
Zone I : 5 - 25m	0,5	0,4	0,4	0,3	0,4	0,3
Zone II : 25 - 50m	0,3	0,3	0,2	0,1	0,2	0,1
Zone III 50 - 150m	0,1	0,1	0,1	0,05	0,1	0,05

Otherwise these impact types and buffers, because of their short distance reach, can only be integrated in corridor- oriented assessment if the assessment scale allows this. An example of how impact classes can be drawn from the above intensities is shown in *Table 10*. These can be used to estimate environmental risks e.g. for new constructed links in combination with information about the spatial sensitivity.

Table 10: *Buffers and impact intensity for the consideration of impacts in the vicinity of road and rail infrastructure*

Distance	Road: traffic intensity (DTV)				railroad	
from the track	> 50.000	> 25.000	> 10.000	< 10.000	HST	convent.
Zone I : 5 - 25m	very high	High	high	medium	high	medium
Zone II : 25 - 50m	medium	Medium	low	Low	low	Low
Zone III : 50 - 150m	low	Low	low	Not relevant	low	Not relevant

Settlements touched

This indicator reports on whether the transport link under consideration passes through settlements. This is examined in order to provide an indication as to the visibility of the transport link, the way a settlement is crossed, and the land taken within the settlements by the link. The more settlements crossed, the more visible the link is. The prototype generates a report, which indicates every settlement which is crossed by the transport link, the area of the settlement, how much land is taken by the transport link, and how many and how large the residual areas are.

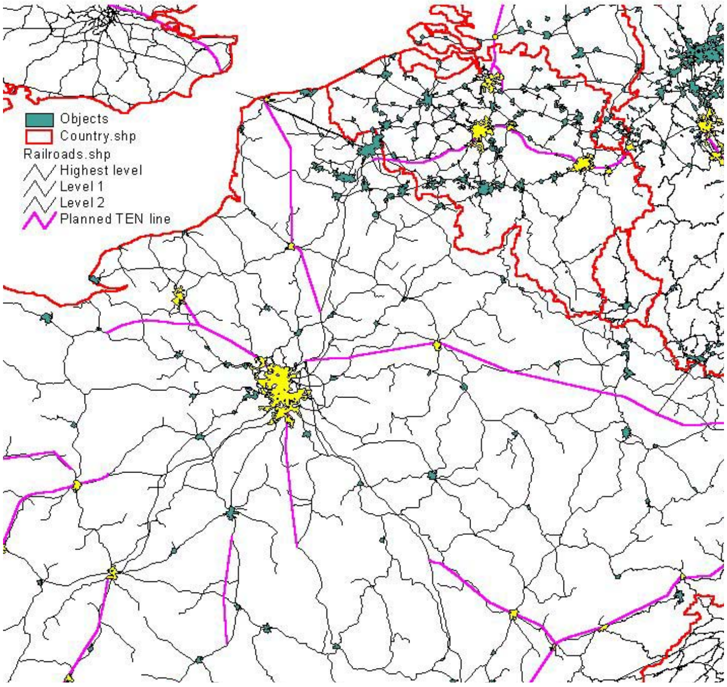
A second output consists of a map indicating the settlements touched and the residual areas of the settlements. An index indicates how many settlements are touched. Examples of such maps are given in Figure 5.

Visibility

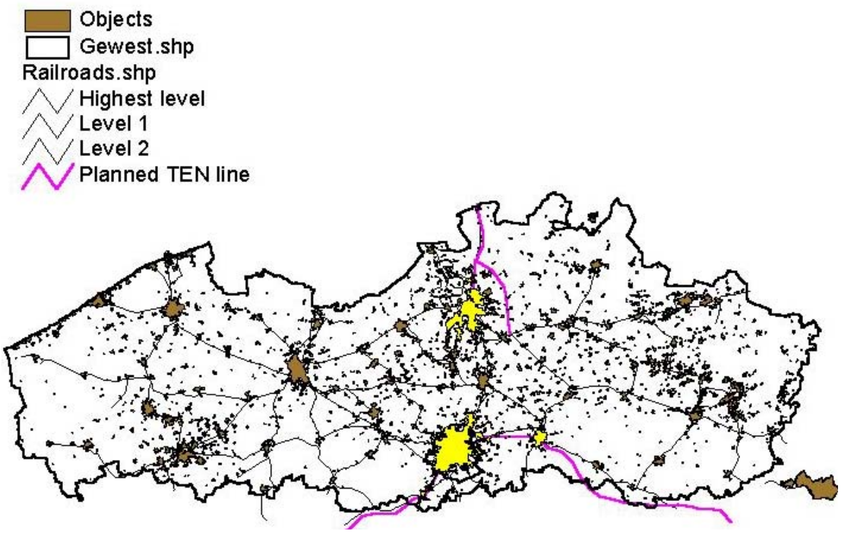
This indicator reports on how visible the considered transport link is from settlements taking into consideration the elevation of the area under consideration. Visual impacts refer to the aesthetic quality of a landscape and thus mainly its recreational function, its function as a home region for the inhabitants and as a component of the cultural heritage. The highest intensity of visual impact occurs in barren areas, be it of agricultural or natural character.

Figure 5: *Maps indicating the settlements touched and the residual areas of the settlements*

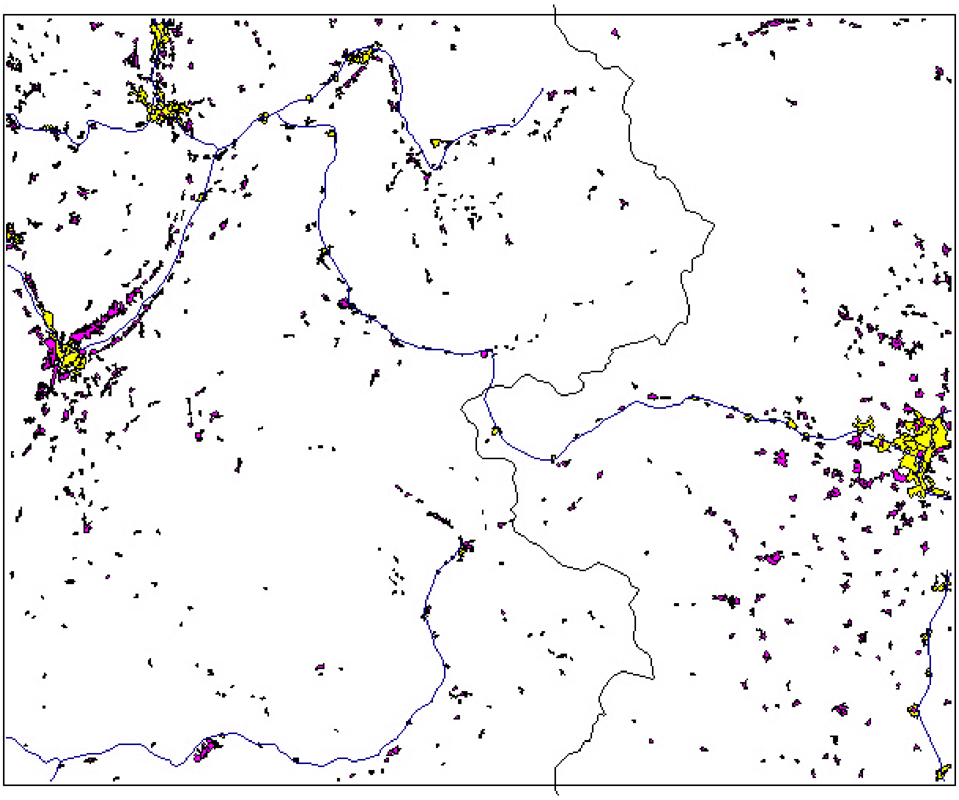
5.a) at EU-level: extract Northern France, Paris



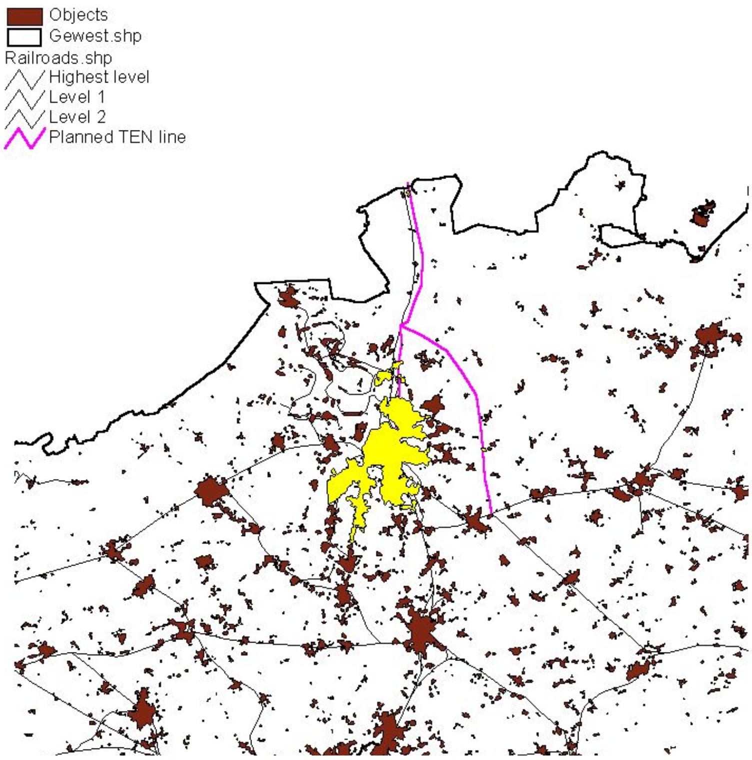
5 b) at regional level: Flanders



5 c) at regional level: Alpine site (fig. 6, JRC)



5 d) at local level: Flanders northern part



Hilly areas or rural (natural) areas with trees, bushes and small woods lead to a lower impact intensity in general. On the other hand they may be more sensitive in respect of visual impacts (e.g. the aspect of cultural heritage) than large scale rural areas.
The prototype provides a map, which indicates how visible the area, within the extent of the map under study, is from the settlements. Then it provides a map with the transport link coloured in red. The more red the transport link, the more visible the link is from the settlements, see Figure 6. The prototype generates also an index that expresses the visibility of the transport link. It is the sum of the values of the pixels that cover the link. Each pixel value is the number of settlements from which the pixel is visible.

Information about the general characteristic of the construction (civil engineering) together with basic information on the physical landscape, e.g. the relief is necessary to estimate the *impacts of the infrastructure* itself and their intensity. Information on the physical landscape is of interest especially for corridor assessments including analysis of the new construction of infrastructure.

The assessment of visual impacts is one of the themes that is regularly assigned to project orientated EIA, carried out at a stage, where both, localisation and technical specification of a track is already fixed. It is evident, that no detailed database on the technical specification of a track and its visual appearance is available at strategic level. The only information about the infrastructure that can be used to estimate visual impact, is based on the general characteristics of the relevant infrastructure type

Land cover heterogeneity

This indicator gives an idea about the heterogeneity of the land cover through which the transport link is passing. When there is a high heterogeneity, the transport link will attract less attention then in a low heterogeneous environment. The heterogeneity is calculated for a window moving through the area under study. The prototype generates a map with the heterogeneity of the area, defined by the user and a map with the link under consideration. An index will provide a numerical expression of the indicator. (see annex 3).

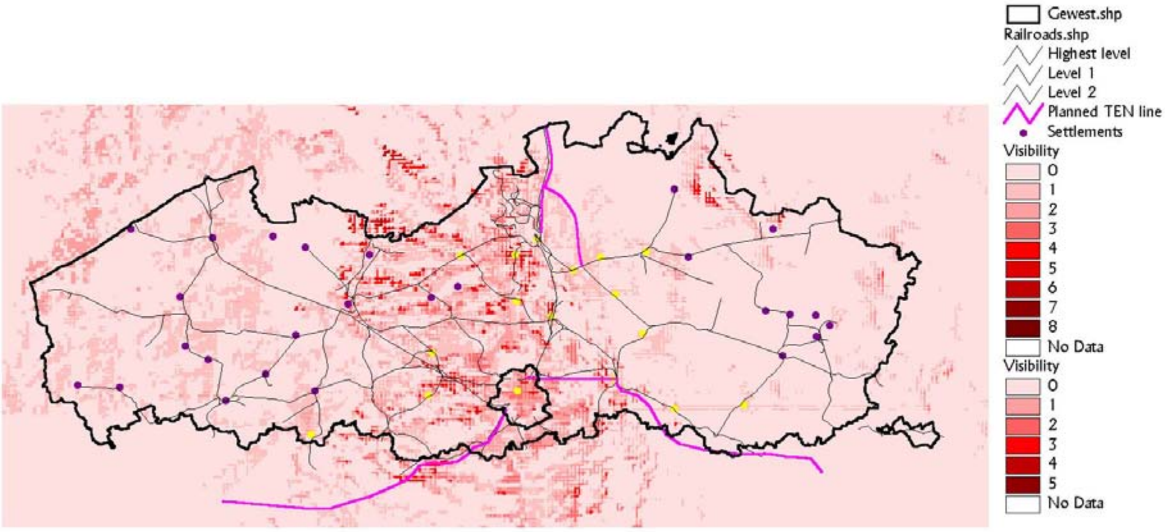
Noise

This indicator reports on the potential noise impact. It indicates how settlements are located with regard to the 65dBA, 60 dBA, 55 dBA, 50 dBA, and 35 dBA zones. The prototype shows a map with the noise contours and the location of the settlements in the contour (see **Figure 7**). Noise exposure of settled areas affects the quality of life and, at higher immission levels even human health (DHV 1998, UBA 1991). Noise exposure outside settlements influences the recreation function and also is discussed as a disturbing effect for specific fauna, e.g. birds (ILPÖ 1992).

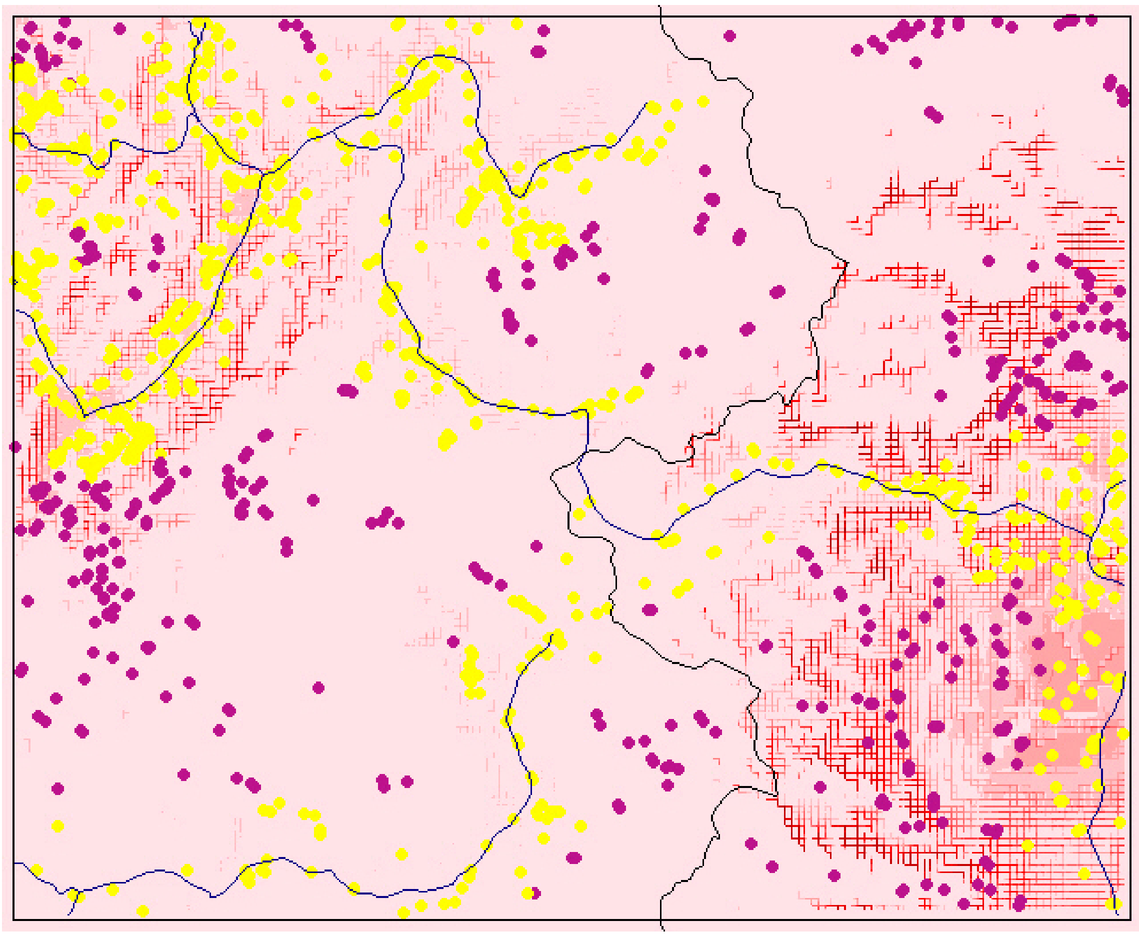
Figure 6 : Maps indicating the visibility of transport links

The more redder the transport link, the more visible the link is from the settlements.

6 a): at regional level: Flanders



6 b) at regional level: Alpine site



6 c) at local level

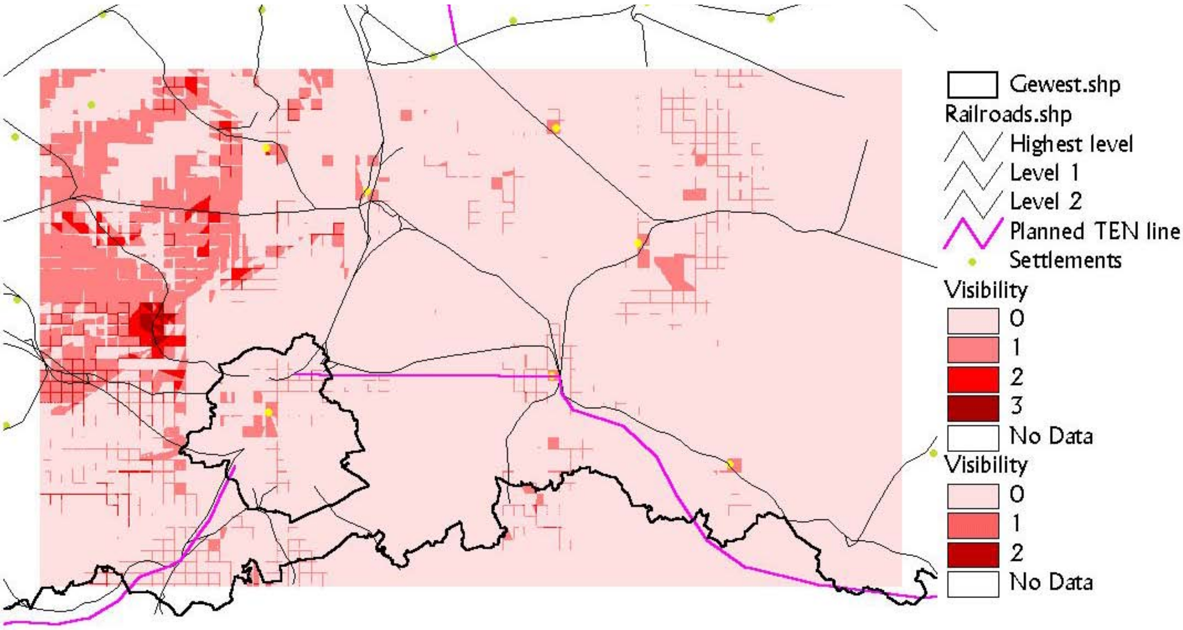
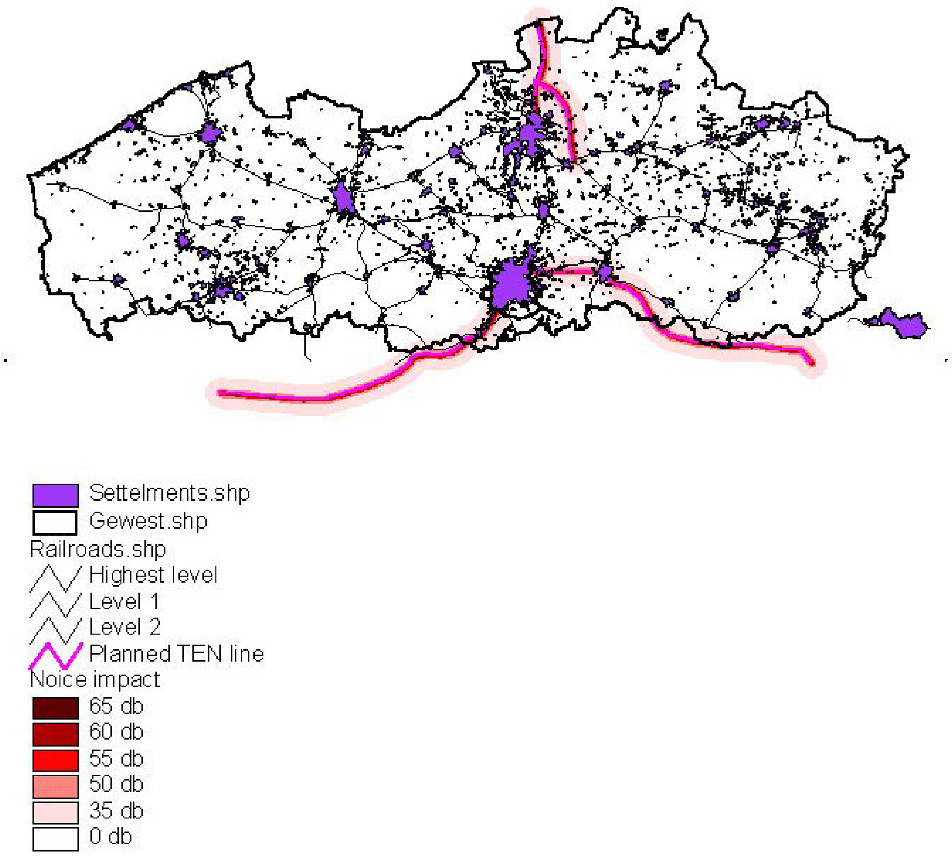
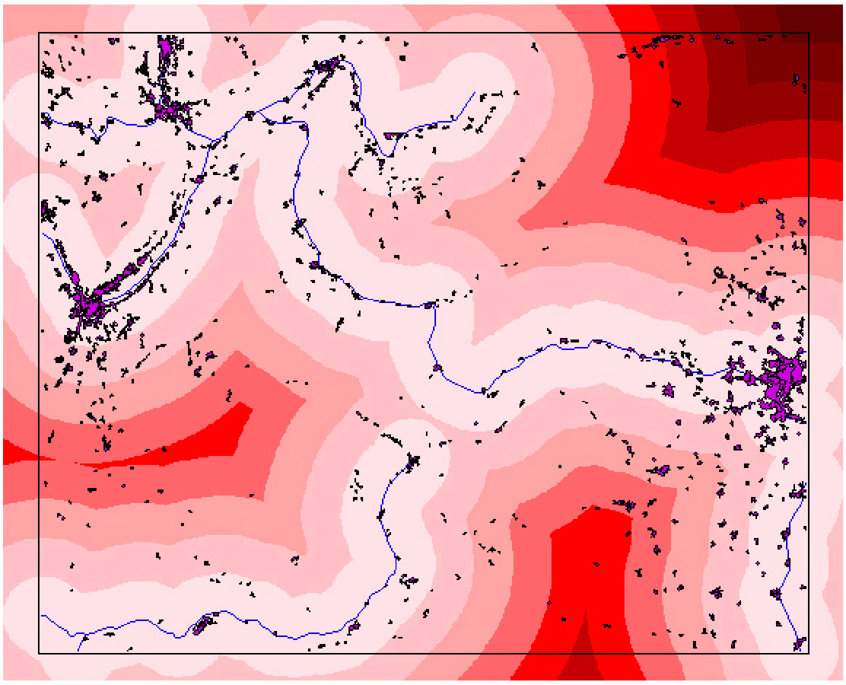


Figure 7: Maps indicating noise buffers

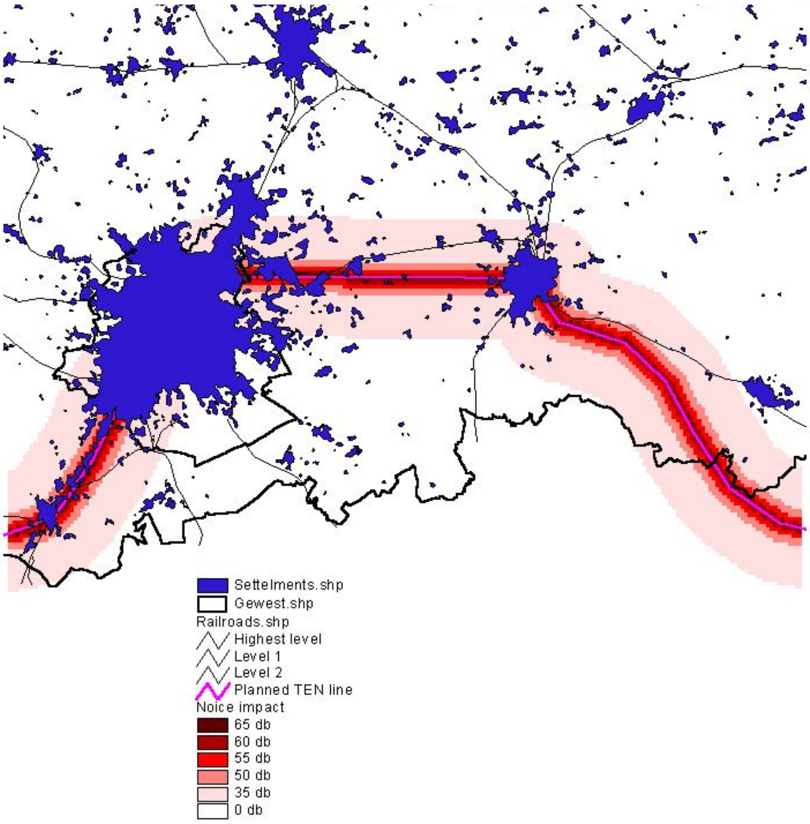
7a) at regional level: Flanders



7b) at regional level: the Alpine site



7c) at local level: Flanders



The COMMUTE tool integrates a detailed method for the calculation of noise emission at the source for road- and rail transport and also can be used to estimate noise immission referring to different immission levels and based on traffic forecasts. If there is no adequate traffic forecast available, an assessment of the noise immission can instead be based on assumptions about the traffic intensity, referring to the general characteristic of noise emission of the different transport systems. For an assessment of noise immission on the strategic level the manner of operating is to compare relative intensities. This means, that although the level of detail may be limited, it has to be ensured, that different modes or scenarios are assessed on a comparable level.

The amount of emission will be influenced by the characteristics of the landscape. Relief has an important impact. The possibilities for integrating this aspect in the approach for spatial impact analysis of emissions will be discussed in chapter 4.

Noise is part of ***a larger direct impact group related to emissions generated by transport activities***. Transport is a major source for gaseous pollutants and of particulates. The majority of emissions will be emitted at ground level. To estimate *impacts of transport activities* a transport prognosis and information about the emission characteristic is a precondition. Additionally to be mentioned are scientific prediction models for the extension of some of these impacts (e.g. for the spatial extension of emitted gaseous substances from road transport in Germany: MLuS 1996). These kind of models have been developed for application in concrete project orientated assessments. An application in strategic assessments is also possible, but has to be decided taking account of the scale level and objectives of the assessment (particularly for corridor assessments) Otherwise more generalised impact estimations should be used. The COMMUTE model comprises a database for the calculation of emission from transport activities (not including the local spatial distribution of emissions in the analysed version).

Historical sites touched

This indicator reports about the potential impact on the cultural identity of the area through which the link passes. It verifies whether the transport link under consideration touches historical sites. At the time of demonstration no data about historical places in the EU was available. The prototype generates a report, which indicates every historical site that is crossed by the transport link and the total number of sites crossed (see annex 3).

Proximity to protection sites

This indicator aims to express the proximity of protection sites to a transport link by taking into account the distance to the protection sites. The prototype will generate a map with the transport link, which is coloured in different tones of red according to the proximity of the protection sites. The redder the link, the higher the level of proximity. Once again, a general proximity map is generated for the areal extent, which was defined by the user. The latter can be superimposed with transport links, which gives the same result as the road-proximity map. An index is generated and expresses a numerical indication of the proximity (see annex 3).

Number of protection sites touched

This indicator reports on whether the transport link under consideration touches protected areas. The aim is to analyse how much land is taken within the protection sites and consequently provides an indication of the impact on the bio-diversity of the area in question. The prototype generates a report, which indicates each protection site that is crossed by the transport link, the area of the protection site, how much land is taken by the transport link, and how many and how large the residual areas are. A second output consists of a map indicating the protection sites touched and their residual areas. The index gives the total number of areas touched (see annex 3).

Fragmentation of potential natural areas

The prototype calculates the fragmentation of potential natural areas making use of a partitioning process in relation to forests, inland wetlands and maritime wetlands. Quality of the areas is taken into consideration through the combination of data on the designated areas and biotopes for the EU level, along with the data on the biological value of vegetation units of Flanders for regional and local assessment level. The prototype generates a report, which indicates the size of each area that is crossed by the transport link, the area of the protection site, how much land is taken by the transport link, and how many and how large the residual areas are. A second output consists of a map indicating the areas touched and their residual areas (see annex 3).

Degree of deforestation

This indicator identifies about how much forest area is taken by the transport link. The prototype generates bar charts per forest category indicating how many pixels have disappeared, and shows a map with the route of the link demonstrating where forests disappeared (see annex 3).

Connectivity

The prototype determines whether virtual networks exist between biotopes located within potential natural areas and whether these networks are crossed by planned TEN-links (see annex 3).

Land take per land use class

This impact is looking to assess the direct land take caused by the infrastructure. The dimension of land take is not only dependent on the technical specification of the transport infrastructure, but also influenced by relevant spatial structures that are crossed by infrastructure. An EU–wide assessment could try to estimate classes of land use depending on the infrastructure classes if the analysis of cases allows significant classification. Concerning regional and corridor assessments, it is suggested to apply a *case to case concept*, to allow the integration of the specific local conditions.

The following *Table 11* gives a comprehensive intermodal overview reflecting on the *magnitude of land take* for different transport modes and infrastructure types. The compilation derives from recent approaches adopted (e.g. M+R 1993, EEA 1998, DHV 1998). It could serve as a basis for a more detailed overall calculation of land-take in network oriented SEA as well as for the assessment of corridors. Additional data on topography and on population density is needed.

Table 11: *Average land take of transport infrastructure.*

Infrastructure Category	**Track areas Cross Section (m)**	**Additional areas (m)**	**Area depending supplement on additional areas (%)**		
			Conurba-tions	**hilly areas**	**mountainous areas**
Road transport					
Motorway with 8 lanes	45 – 50	35-40	100	50 - 100	100 - 150
Motorway with 6 lanes	35 – 40	35	100	50 - 100	100 - 150
Motorway with 4 lanes	25 – 30	30	100	50 - 100	100 - 150
Other roads with 2-3 lanes	10 – 20	20	50	25 - 50	50 - 100
Rail transport					
HST	20	25	50	150 - 250	250 - 350
Upgraded Conventional	15	20	50	100 - 200	200 - 300
Speed Adapted Upgraded	15	20	50	75 - 150	75 - 150
Conventional	15	15	50	50 - 100	50 - 100
Inland waterways					
Artificial channels	50	50	25 / 12,5	100 / 50	-
Damming/sluices of rivers	10 - 20 (changes of water levels)	20 (bankzones)	0	-	-
Shortcuts of river-courses	50 (only for concerned sections)	50	-	-	-
Changes of the freeflowing river	-	20 (bankzones)	0	-	-

The prototype reports the land take per land use class in relation to the number of pixels disappearing. The prototype generates bar charts per land use category indicating how many pixels which disappear, and shows a map with the route of the link where land use categories have disappeared (see annex 3).

3.4 Conclusions

The prototype developed during INTERNAT is designed to function as a research tool. In other words, it is not a market ready end product. The prototype is meant to evolve in terms of sophistication and therefore is open regarding the input of new/other data sets, algorithms to implement models which estimate impacts and new indicators.
Any ArcView compatible data set can be used as input to the prototype. The prototype is not a stand-alone software, but has been completely integrated in the commercial GIS-software package ArcView. The prototype is developed as a set of separate options of the default ArcView tools with a set of default data layers. However, any available data set in ArcView covering the same area can be combined with the data from the prototype.
Models that simulate/estimate environmental impacts can be built-in. Such activity of course requires ArcView Avenue language expertise in order to integrate new software code. The same is true for new/additional indicators.

Although in-depth application of the prototype is beyond the scope of this project, the example applications as performed in this project and described above, indicate the potential and boundary conditions of GIS and RS for the 3 levels of SEA:

- The prototype has been designed in such a way that it is transparently applicable on each of the 3 scale levels identified for the SEA of the TEN (network, region, corridor). However, the price for this flexibility is the fact that the user has to evaluate very carefully which data layers may be combined with each other on each scale level. Further recommendations on this topic are developed in Chapter 6.
- Although the availability of basic input data should not be too problematic, it still remains a topic of concern, for which recommendations are given in Chapter 7. Specific attention is given to data compatibility of regional datasets throughout EU member states in terms of data dictionnary and data quality sensu lato.
- The engines or basic algorithms comprised in the prototype are environmental themes. In case the propagation process itself, or the observation method are comparable, it is basically a matter of parameter tuning to be able to run the prototype for these themes.

4. IMPACTS ASSOCIATED WITH EMISSIONS AND ENERGY CONSUMPTION

4.1 Review of existing methods and models

This chapter deals mainly with methods and models for the assessment of emission, energy and noise from multimodal transport as they are required to function as input for SEA. The focus in INTERNAT is on methods and approaches on the strategic level. All models and approaches considered in this context have to be applicable to the network- and corridor level.

In the framework of the COMMUTE project a methodology for Strategic Assessment of the Environmental impacts (SEA) of transport policy options and methods for the assessment of environmental, noise and safety impacts of the Trans European Transport Network (TEN-T) have been developed. The methodology is primarily applicable to policy decision-making at European level and covers road, rail air and waterborne transport modes. Computer software (COMMUTE tool) that embodies the main aspects of the methodology has been developed and demonstrated within the project.

The demonstration has been done by sensitivity tests and by the application of the COMMUTE tool to assess the impacts on energy consumption, primary pollutant emission and safety of TEN-T for different scenarios within the framework of the Commissions workplan for a pilot SEA. This pilot SEA is performed within the context of the TEN-T Guidelines. In the course of the pilot SEA the COMMUTE method and model has proved to be applicable on the network level for the assessment of emission, energy and safety aspects. COMMUTE includes also a Noise model for road, rail and airborne transport.

COMMUTE is network oriented and is combined with a GIS for the spatial evaluation and presentation of results. COMMUTE is therefore capable of operating both on network- and at corridor level. The end user defines through the input data the spatial scope within which the COMMUTE model performs the impact assessment. For all spatial scales the same assessment methods for each of the links and nodes comprising the transport network will be applied. The results are available for each of the links and nodes considered. Since this approach calls for a considerable amount of input and model data COMMUTE provides a wide variety of default data (emission factors, fleet compositions, default speeds etc.) to support the use of the model in cases where input data are lacking (e.g. network and national level). On the other hand all default data may be modified by the end user in case more up-to-date data are available or data reflecting the characteristics of a specific transport corridor can be obtained.

On the basis of these considerations INTERNAT was aimed at identifying new approaches and models which could provide an added value to the TEN-T assessment. Approaches and models identified have been identified through contact with the circle of the EU wide modelling society and through a search in the www. Among these the three models ExterneE Transport, STEEDS and TREMOD have been selected for further investigation.

As outlined above one of the major prerequisites for appropriate tools in the context of the TEN-T is the applicability on the network and corridor level together with the capability for a spatial analysis of the results. The identified models have been screened according to the above feature. It was found that none of the models was designed to support the detailed spatial evaluation of model results and that the application on network- and corridor level would be limited. It was agreed not to review these models in detail but to concentrate on approaches integrating spatial characteristics in emission modelling. Both the recent projects MEET and COMMUTE present conclusions on the fact that slope has an important impact on the amount of emission.

4.2 Improvement of the TEN-representation to model the slope effects on emissions

4.2.1 Availability of Digital Elevation Models (DEM)

This chapter addresses data issues and possible ways of incorporating GIS-based calculations of gradient factors for emission models. Additional emissions for driving uphill are not fully compensated by a corresponding reduction when driving downhill. It is proposed to use correction factors to calculate the positive or negative impact of slope on the amount of emissions. Such speed-dependent correction factors are called gradient factors.

There is a wide range of digital elevation data available for Europe. The databases can be divided into two groups: digital elevation data available as seamless datasets for pan-Europe and digital elevation data available for single countries or regions. Six digital elevation models covering the European territory have been identified (see *Table 12*). The underlying data models are either contour lines or grids.

Table 12: *Available digital elevation data for pan-Europe.*

Name	Data model	Resolution	Cost	Provider
Digital Chart of the World (DCW) - Hypsography	Contours plus spot heights	1:1,000,000 (1,000 feet contour lines)	130 Euro	Chadwyck-Healey Ltd, Cambridge, UK; also distributed with ArcInfo
Bartholomews	Contours	1:1,000,000	225-320 Euro per country	Bartholomews Data Sales Support, Glasgow, UK

Name	Data model	Resolution	Cost	Provider
GTOPO30	Grid	30" (approximately 1 km)	free	U.S: Geological Survey's Eros Data Center, Xioux Falls, USA
GETECH - Europe DTM 2.5	Grid	2.5' (4 km)	1560 Euro	Geophysical Exploration Technology (GETECH), University of Leeds, UK
GISCO - Digital Terrain Model Pan-Europe 20 million	Grid	5' (1:20,000,000)	Only available with GISCO data set (2,500 Euro)	EUROSTAT
GISCO - Digital Terrain Model Pan-Europe 3 million	Grid	1:3,000,000	restricted access to data	EUROSTAT

(Sources: ESRI, 1997; Gittings, 1997; MIMAS, 1997; EUROSTAT, 1999; GETECH, 1999; USGS, 1999)

Looking at individual countries data availability for DEM is fairly good. All member countries of the European Union do have high-resolution elevation data for their territory. For nearly all countries grid models are available, the distance between grid points is between 20 m (Italy, Portugal) and 200 m (Spain). For Greece, only contour lines at 20 m equidistance are obtainable. There is a wide cost range for the elevation data. Higher data resolution typically leads to higher costs, but there are exceptions in both directions. To cost ofpurchase or license the DEM for all member countries of the EU can be estimated at more than 4 million Euro not taking into account possible quantity discounts.

4.2.2 Concept for Empirical Testing

A test study area was selected and a test procedure was developed to assess the impact of different resolutions of Digital Elevation Models on link gradients in the context of the requirements of emission models within SEA of trans-European transport networks. As a case study for the empirical analysis, a section of the existing Motorway A45 in Germany has been chosen. The motorway section has a length of 54 km and runs through a low mountain range between Hagen and Olpe in North-Rhine Westphalia. The relief of the study region can be considered as typical for most hilly parts of the European Union with the exception of the Alps.

The objective of the empirical analysis was to assess the accuracy of several combinations of different DEM and different road link representations. For this, road elevation at 100 m intervals and road gradients for those 100 m segments were modelled and checked against a reference data set derived from elevation survey data for the particular motorway section which has been made available by the road construction agency of the state of North-Rhine Westphalia. Subsequently, gradient factors for the emission model were modelled and compared with gradient factors based on the survey data.

For the representation of the motorway section two data sets have been analysed, a digitisation at high resolution specifically created for this purpose and a digitisation at lower resolution available in the EUROSTAT GISCO road network data set (see *Table 13*).

Table 13. *Network link representations analysed.*

Code	Resolution of source map	Description
A	1:25,000	High resolution digitisation of road link
B	1:500,000	Medium resolution digitisation of road link (GISCO)

For the representation of terrain elevation five Digital Elevation Models with different resolution and precision have been used (see *Table 14*).

Table 14. *Digital Elevation Models tested.*

Code	Type	Resolution	Description
A	Grid	50 x 50 m	German elevation model 1:25,000
B	Grid	600 x 900 m	GTOPO30, 30 arc seconds
C	Grid	1,000 x 1,000 m	GISCO - Digital Terrain Model Pan-Europe 1:3,000,000
D	Contour	1:1,000,000	Elevation model of the Digital Chart of the World
E	Grid	9,000 x 15,000 m	GISCO - Digital Terrain Model Pan-Europe 1:20,000,000

The road link data and the DEM were linked by standard routines available in commercial GIS (e.g. SURFACE-PROFILE command in ArcInfo) in order to arrive at elevation information for selected points of the road. All possible combinations of road and elevation data have been tested. A visual presentation of the DEM with contour lines and the derived relief map overlayed by the motorway section under study can be found in *Annex 4: Results of empirical testing of Digital Elevation Modelling.* After a visual plausibility check based on this presentation, DEM E was excluded from further analysis.

4.2.3 Modelled Elevation and Gradients

Results of the empirical testing are first presented in terms of accuracy of modelled road elevations and gradients for the different combinations (*Table 15*). All statistical measures have been calculated on the basis of 100 m segments of the motorway section. The quality of DEM is usually measured as root mean square error (RMSE) expressed in metres. Looking at modelled elevation it becomes obvious that only the high-resolution DEM A in combination with the high-resolution link representation A can reproduce reality to a high degree whereas the other DEM's lead to larger deviations of between 25 and 35 metres. A similar precision of the DEM/link combination A/A can be found for gradients. However, here the error of DEM B and C in terms of percent slope is much less than for elevation.

Finally, the modelled gradients are aggregated to the seven gradient classes required by the emission models (Hassel and Weber, 1997) and correlated with the reference data. At first, the high-resolution DEM/link combination A/A perfectly reproduces the percentages of the reference gradient classes. However, linking DEM A with the low-resolution road representation B results in no correlation at all. This is because the lower precision of the road representation leads to a path in the DEM which goes over the mountain tops and the valleys instead of using the clefts and bridges as link A does. On the other hand the lower resolution DEM C leads to satisfactory results and to a certain degree this is also true for DEM B. This is because the RMSE for elevation and gradient is measured at exact location whereas the gradient classes are aggregated for the whole link. That means that these DEM sufficiently reproduce the overall characteristics of the road elevation profile, but that there is some deviation in the exact location of elevations and gradients. The performance of DEM D is not satisfactory at all.

Table 15: ***Accuracy of modelled road elevation and gradient.***

DEM	Link representation (scale)	Elevation RMSE (metre)	Gradient RMSE (% slope)	Gradient classes Correlation with reference (r^2)
A Grid (50 x 50 m)	A 1:25,000	0.69	0.64	0.99
B Grid (600 x 900 m)	A 1:25,000	25.00	3.29	0.48
C Grid (1,000 x 1,000 m)	A 1:25,000	27.13	2.78	0.86
D Contour (1:1,000,000)	A 1:25,000	33.34	11.14	0.10
A Grid (50 x 50 m)	B 1:500,000	12.70	7.71	0.00
B Grid (600 x 900 m)	B 1:500,000	24.65	3.56	0.69
C Grid (1,000 x 1,000 m)	B 1:500,000	27.40	2.89	0.85
D Contour (1:1,000,000)	B 1:500,000	33.61	11.45	0.11

4.2.4 Modelled Gradient Factors

The provision of the gradient class as previously described comprises the input required by the emission model. However, in order to go one step further in the assessment of different DEM and road representations it must be asked, how the gradient classes translate into gradient factors for the sample link under study. This is done in two ways, aggregate gradient factors for the whole link and disaggregated gradient factors for small segments of the link, both differentiated by driving direction. To recap, a gradient factor is a multiplier for the amount of emission calculated by assuming a flat link.

Table 16 presents gradient factors for the A45 section taking passenger and light duty vehicles with regulated catalytic converter as example. The gradient factor for the reference data in north-south driving direction with an average speed of 100 km/h is 1.22, thus reflecting that the motorway in that direction is mainly climbing up the mountains. The gradient factor is 0.98 for the opposite direction, thus demonstrating that even large parts of driving downhill cannot reduce emissions compared to a flat road because of the presence a few upward sections. Looking at the correlation with the reference for all speeds, again, the DEM/link combination A/A leads to perfectly modelled gradient factors and the combination C/A and C/B have an overall good performance for aggregate, i.e. link based results.

Table 16: *Gradient factors (NO_x) for A45 section for passenger and light duty vehicles with regulated catalytic converter.*

Digital Elevation Model	**Link representation (scale)**	**north -> south**		**south -> north**	
		Gradient factors (100 km/h)	**Correlation (r^2) with reference (all speeds)**	**Gradient factors (100 km/h)**	**Correlation (r^2) with reference (all speeds)**
Reference Survey data	A 1:25,000	1.22	1.00	0.98	1.00
A Grid (50 x 50 m)	A 1:25,000	1.23	1.00	0.98	1.00
B Grid (600 x 900 m)	A 1:25,000	1.30	0.84	1.07	0.78
C Grid (1,000 x 1,000 m)	A 1:25,000	1.25	0.93	1.06	0.92
D Contour (1:1,000,000)	A 1:25,000	1.10	0.67	1.03	0.63
A Grid (50 x 50 m)	B 1:500,000	1.30	0.81	1.14	0.77
B Grid (600 x 900 m)	B 1:500,000	1.30	0.86	1.06	0.81
C Grid (1,000 x 1,000 m)	B 1:500,000	1.26	0.93	1.06	0.92
D Contour (1:1,000,000)	B 1:500,000	1.09	0.66	1.02	0.68

This result is graphically confirmed by

Figure 8 that presents gradient factors for the same vehicle category as in *Table 16* for different average speeds. DEM/link combination A/A provides a perfect fit for all speeds, DEM C is slightly worse having a constantly higher gradient factor than the reference case. Other combinations clearly represent worse performances, in particular, the DEM D based on contour lines but also the combination of a high-resolution DEM with a low-resolution link representation A/B results in misleading gradient factors.

It should be noted that all DEM/link combinations except A/A are giving a wrong, i.e. larger than one, gradient factor for the south-north driving direction which is mainly downhill. This is in line with the overall picture that these DEM/link combinations lead to too high gradient factors. This has to be seen as some kind of error propagation, because these DEM/link combinations allocate a small percentage of the total link in the extreme gradient classes of +/- 6 percent which do not exist in the reference data set.

The GIS-based calculation of gradient factors allows the provision of these correction factors also for any segment of a transport link. *Figure 9* shows localised gradient factors of the A45 section under study for the different combinations of DEM and road representation (in north-south direction). The gradient factors displayed are calculated for segments of 100 m length. Gradient factors can easily be aggregated to any other segment length. Through simple GIS-operations it is also possible to transform the gradient factors from link segments to raster cells of any size to match the grid input data structure of many emission models. In this way it is possible not only to calculate the amount of total emission but also to link the emission model with air dispersion models to calculate the local and regional air quality along the transport links by having a precise description of the place of emission.

A visual comparison of the modelled gradient factors with the reference case clearly shows the correspondingly high accuracy of the high-resolution DEM/link combination A/A and the deviation of other combinations. DEM B and C lead at many places to an exaggeration of gradient factors both positively and negatively. DEM D considers the link, for many parts of the section, as being flat, i.e. a gradient factor of 1. Also, the consequence of mismatching resolutions of DEM and link representation (A/B) are visible: the localised gradient factors have hardly anything in common with the reference case.

The visual evaluation is confirmed by the correlation of the modelled localised gradient factors with the reference case. Only the DEM/link combination A/A results in a high correlation, all other combinations are very low thus not suitable for providing localised gradient factors.

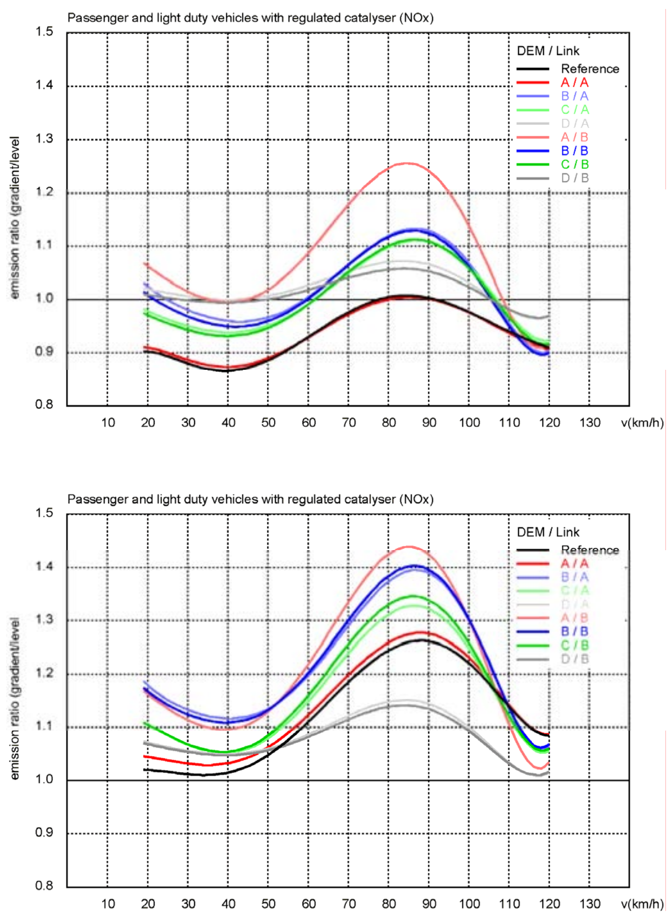


Figure 8. *Average speed related gradient factors for A45 section, north-south (top), south-north (bottom).*

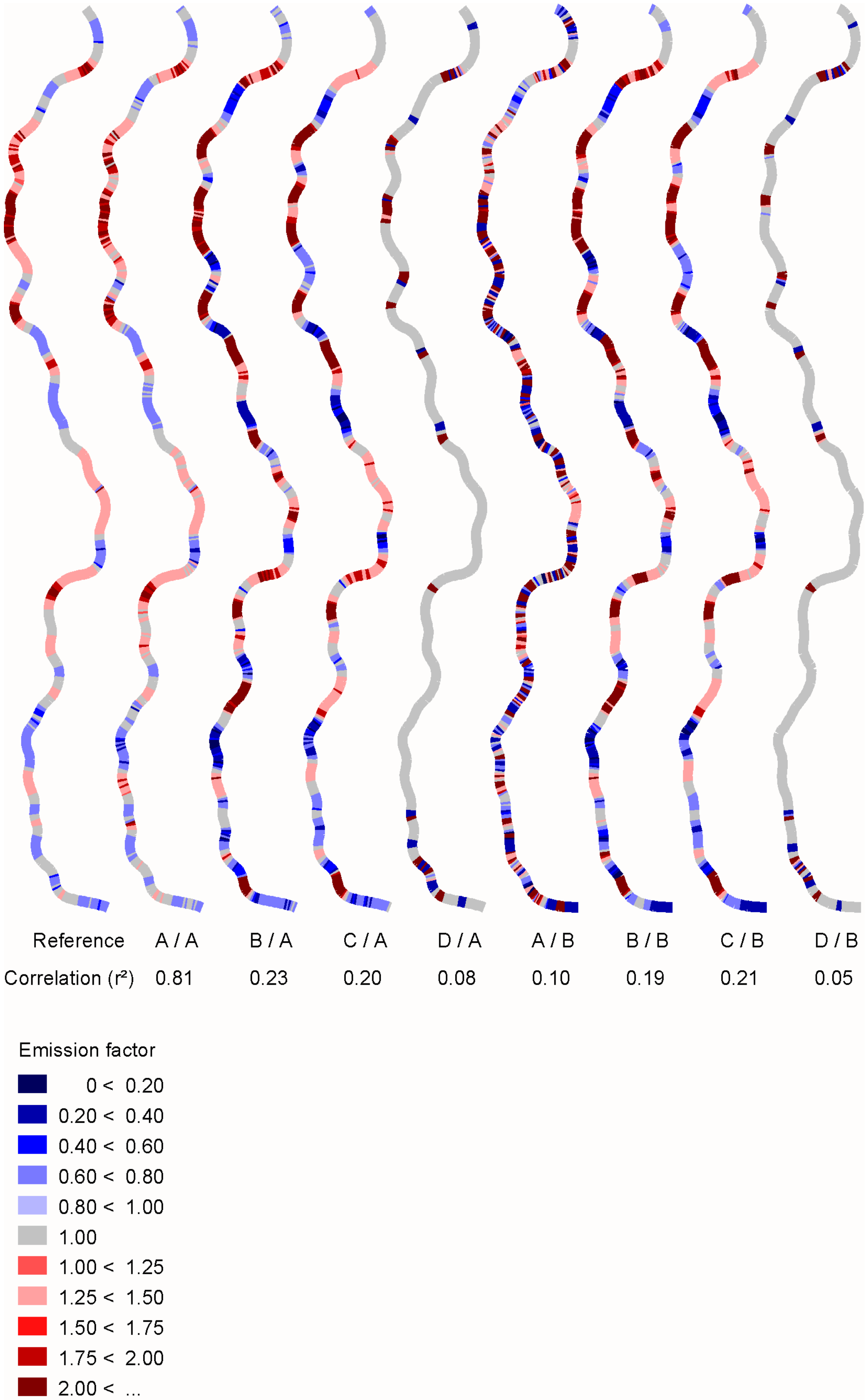


Figure 9. *Localised gradient factors for different DEM and network representations and correlation (passenger and light duty vehicles) with reference (north-south direction).*

4.3 Conclusions

Based on the analysis of the linkage between Digital Elevation Models, Trans-European Transport Networks and emission models (Spiekermann et al., 2000) which has been summarised in this section, it is possible to elaborate some recommendations on which combinations of DEM and link representation is suitable for enhancing the quality of emission modelling in the context of SEA through the introduction of gradient factors. The selection depends primarily on the purpose, i.e. the spatial level of the SEA :

- *Network level.* If the focus is on European-wide emission modelling at the network level then it is reasonable to use a DEM and a network representation with medium resolution. The analysis has shown that a combination of two datasets available from EUROSTAT, the GISCO Digital Terrain Model Pan-Europe 3 million and the GISCO Transport network leads to satisfactory results. Gradient factors for links based on this combination match to a high degree the reference case.
- *Regional level.* It is hardly possible to give a clear recommendation for the regional level because there is a lack of DEM matching the proposed scale for this level. It depends very much on what will be the purpose of emission modelling at that level. If the objective is to calculate emissions only the DEM/link combination of the network level might be sufficient. If the objective is to feed a regional air dispersion model with the emission data, higher resolution DEM and link data as proposed for the corridor level have to be processed.
- *Corridor level.* If the focus is on corridor studies and at the same time not only on emission but also on air quality, a high-resolution DEM is indispensable to achieve a proper localisation of the points of emission and the gradient factors at those points in order to get a precise input to air dispersion models. It could be shown that using a DEM with regularly spaced elevation points in a 50 m grid in combination with a high-resolution representation of the transport network leads to a very precise description of the slope characteristics along the transport links. Thus it is possible to obtain exact gradient factors for rather small segments of the transport links.

5. LYFE CYCLE ASSESSMENT

5.1 LCA applied to the transport infrastructure

INTERNAT analysed the possibilities to integrate the newly standardised life cycle assessment (LCA) method as one part of a methodological framework for SEA of transport corridors and explored the possibilities to extend or improve the method. The main problem is that LCA-methods initially were meant to be used in the product industry. Correspondingly, the standards have been primarily defined for this purpose. However, the possibilities to apply these standards for the SEA of transport infrastructure are evident. The first final texts on life cycle assessment were approved by the International Organization of Strandardisation (the ISO 14040-series) in 1997. The ISO 14040 standard describes the principles and framework for conducting and reporting LCA studies, and includes certain minimal requirements.

In the SEA of transport infrastructure the goal is normally to compare different alternatives for corridor lining, different alternatives of the transport mode and different alternatives of the infrastructure construction itself. The description of the proper product system of transport infrastructures should be started with its *functional* description, because this should be equal in all the alternatives. This means, for example, the definition of the traffic carrying capacity of the planned road. After defining the alternatives for the considered infrastructure the initial description of their *product systems* should be made. Product systems and their unit processes of transport infrastructure need to be considered as a structure. A comparison should be made with the product systems of built structures in general.

The product systems of the basic processes of a structure can be defined according to the following procedure:

1. divide the structure into appropriate components;
2. determine for each component its average lifespan and the average period of its renovations;
3. define the basic processes of each component with their inputs, outputs and internal functions linking outputs with inputs;
4. complement the basic processes with appropriate product chains in order to encompass their whole life cycles;
5. make the inventory model of each component and process with a proper tool and;

6. test and adjust the models.

The consideration of structures and their life cycles is a significant supplement to the normal product oriented LCA framework, which concentrates merely on the production of a product.

It is obvious that the building of product systems according to the principles above can be a very complicated and tedious process. Thus, it must be simplified to correspond to the significance and accuracy of the whole consideration. Firstly, many of the chains from raw material acquisition to the basic process can be roughly summarised as unit impacts. Another simplification of the system can be made by considering the continuous and periodic operation and maintenance processes as average yearly processes. Even the occasional renovation processes can be estimated using average periods. After determining the average lifespan of a component and the average period of its renovation, it is now easy to compare all its basis processes on the yearly base by dividing the consequences of construction and destruction by its lifespan and the consequences of renovation by the average renovation period and by adding these to the yearly consequences of maintenance. Table 17 gives the example of infrastructure classification to be used for defining product systems of TEN infrastructures.

Table 17: *Infrastructure classification.*

Mode	Infrastructure type	Additional associated areas
Terrestrial routes		
Roads	Motorway, 8 lanes Motorway, 6 lanes Motorway, 4 lanes 2-lane roads	Embankments, fillings and cuttings, tunnels, crossings, bridges, junctions, slip roads, noise barriers, barrier areas, rest stops, service facilities
Railroad	HST-track HST-track / upgraded Conventional speed adapted upgraded conventional track conventional track g<1,25%	Embankments, fillings and cuttings, tunnels, crossings, bridges, electric power lines, perimeters, service and safety facilities
Inland waterways		
Artificial inland Waterways	Canal Locks/sluices	Embankments, bridges, dams, water management systems, service facilities, bank zones
Natural inland waterways	Rivers Lakes	Embankments, bank zones, dredging, buoyage, leading marks, beacons, bridges, quays
Infrastructure for air transport (airports without buildings)		
International Community connecting	runways	Perimeters, fences, lights, beacons, radars, service areas, safety facilities
Regional Accessibility points	heliport	

The most difficult task in the inventory analysis is, certainly, the collection of proper data. There are not yet any comprehensive databases for life cycle assessments of transport infrastructures available. Thus, one has to collect the data from various sources. Because of the complexity of the product systems of the transport infrastructures, it will be highly advisable to use some commercial tools to define them. Depending on the situation one can, of course, also use normal spreadsheets to achieve this. The following tables shows examples of basic data that could be used for the construction of a 2-lane main road.

Table 18. *Material requirements for constructing 1 km of a 2-lane main road*

Material	Amount	Unit
Asphalt	230	t/km
Limestone	180	t/km
Gravel	8400	t/km
Sand (fine)	17290	t/km
Sand (var.)	10400	t/km
Crushed stone	9900	t/km
Water	760	t/km

Table 19. *Energy and fuel consumption of the construction machines as well as their atmospheric emissions according to the work phases.*

	Energy MWh/km	Fuel l/km	CO_2 t/km	CO kg/km	NO_x kg/km	SO_2 kg/km	VOC kg/km	Particl. kg/km
Preprocessing and loading	800	41700	279	283	2090	428	610	173
Transport	340	33700	89	487	1150	16	168	124
Laying	20	4500	12	62	200	14	21	17
Total	1160	79900	380	832	3440	458	799	314

Table 20. *Energy and fuel consumption of the construction machines as well as their atmospheric emissions according to the road components.*

	Energy MWh/km	Fuel l/km	CO_2 t/km	CO kg/km	NO_x kg/km	SO_2 kg/km	VOC kg/km	Particl. kg/km
Surface layers	785	32000	256	159	1650	393	568	137
Road base	44	11400	27	143	440	30	50	37
Sub-base	79	8700	23	126	320	8	43	33
Blanket course	90	9900	26	144	370	10	49	38
Bank	162	17900	48	260	660	17	89	69
Total	1160	79900	380	832	3440	458	799	314

Table 21. *Dust (2-40 µm) as well as noise-time (dBA*h) within 7 m distance of the source produced by the construction machines.*

	Dust Kg/km	Noise-time dBA*h/km
Surface layers	0	Not available
Road base	9700	56000
Sub-base	1000	45000
Blanket course	1200	52000
Bank	2100	93000
Total	14000	246000

5.2 Advantages and limitations of the LCA method

A clear benefit of using the LCA method is that in this way the whole life cycle of the products, and thus in a certain way also the *indirect* impacts caused by the production chains *before* the production of the actual product as well as also *after* the production, that is to say in the disposal of the product, can be taken into account. However, in applying the LCA method for large scale infrastructures the normal method has to be extended by considering besides the production of the structure (i.e. its construction) also its operation, maintenance, renovation and destruction as *separate* product systems. This may render the application procedure quite complicated and laborious. The method can be simplified by using average values, but at the same time the results become more uncertain and the method also less applicable for strategic considerations. However, by calculating beforehand certain *typical* cases it may be effective and illustrative to use these in the preliminary sketch phases of the planning.

The LCA method does not function well for assessing the impacts of the actual traffic. In principle it could be used for that too, but the main causes for the variation of the impacts of traffic are elsewhere. For that purpose estimations of the actual traffic have to be made by considering how it depends on the whole transport network, the urbanisation pattern, capacities of the routes in relation to traffic needs etc. The impacts of vehicle production, maintenance, repair and disposal, which can be assessed by the LCA method, are not the actual issues here, because they cannot be allocated to certain routes. However, such considerations could well complement the considerations of the impacts of the actual traffic on the routes.

According to the ISO 14040 standard (see 5.1, LCA applied to the transport infrastructure, pg. 54) the inventory analysis in the LCA shall be complemented with an impact assessment.and finally with an interpretation phase. This is mainly carried out with reference to the assessment of impact *potentials*, which would still require the assessment of the actual impacts. However, there are difficulties to "translate" the elementary flows of the inventory analysis or even the impact potentials through to actual environmental impacts. This should be done by first assessing the local and global pollution *contents* and after that the *exposure* of the living environment to these contents. This, in turn, would require models for estimating the dispersion and condensation of pollutants as well as models of the ecosystem, living conditions, environmental impacts on human health etc. The cumulative impact assessment (CIA) can be a natural extension to the LCA by considering the impacts from the receiver's (end point) point of view. In this way especially, the pollution content and the exposure to it can be assessed (see Figure 10).

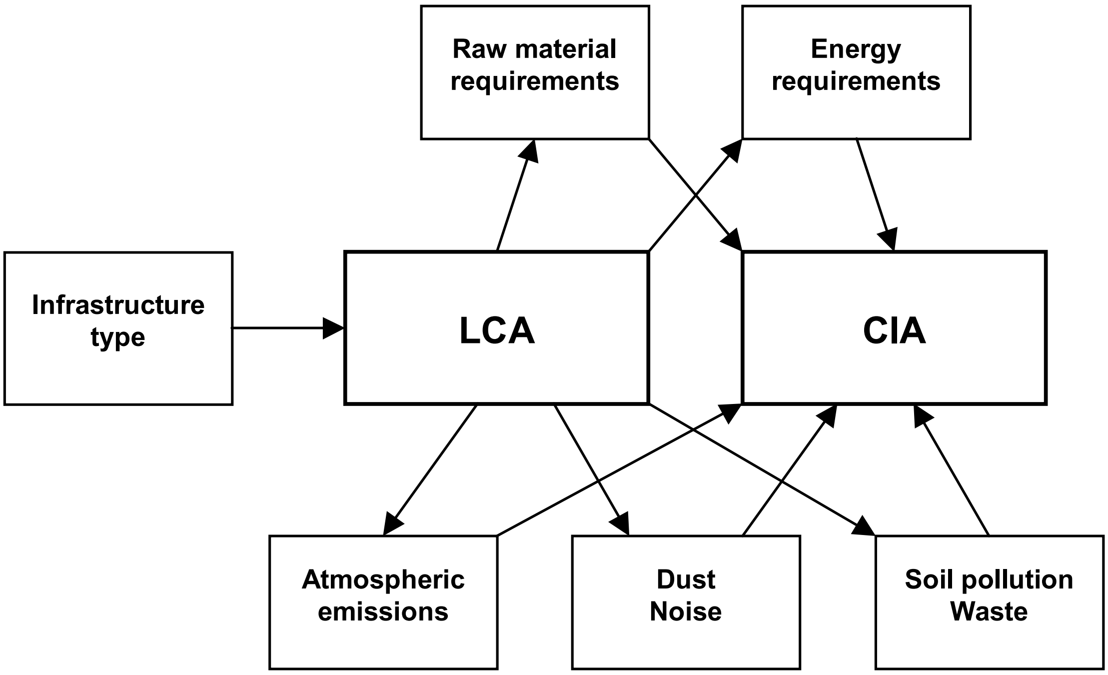


Figure 10: *LCA as an input to CIA*

The most severe weakness of the LCA method is its concentration on quantified issues only. The *qualitative* issues like landscape and townscape values, relations with nature etc. cannot be modelled as a product system. The question involves issues which are highly interdependent, depending on cultural values and even varying in time. CIA attempts at least to some extent to take into account also these qualitative issues.

Also such indirect consequences of the choices of transport infrastructure such as their impact on social and the economic life of cities and countryside in the future, cannot easily be considered through the process of LCA. It may be possible to create some rough models to address these elements by using e.g. statistical methods. However, they are not basically products but simply changes to the present situation and are better described, for example, by certain simulation models.

5.3 Conclusions

From the assessment of LCA within INTERNAT conclusions are based on the consideration of two basic ways of applying LCA in the strategic assessment of transport infrastructure. The first way is to directly assess the environmental loads of certain specific infrastructure options. The alternative is to apply it, beforehand, to certain *typical* infrastructure cross-sections in some typical situations.

It is important to underline that the findings still remain theoretical and that in relation to achieving a comprehensive assessment it is still necessary that this be complemented by other additional procedures. The approach remains complex and is aggravated by the excess of rigour in relation to most practical needs. At the moment it is still too early to integrate the approach in the overall framework. However, because it requires lot of toilsome work it should be used only for very limited systems and complemented with other methods.

6. STRATEGIC ENVIRONMENTAL ASSESSMENT AND THE CONCEPT OF AN INTEGRATED TOOL: conclusions of INTERNAT

6.1 Strategic Environmental Assessment (SEA) in relation to the TEN

Strategic Environmental Assessment is the term used to describe the environmental assessment process for strategic actions (policies, plans and programmes) to be approved earlier in the planning process than the authorisation of the individual projects. The SEA process can vary depending on the level of strategic action, the sector, and the planning procedures. The principle aim of SEA is to help decision making on the evaluation of environmental effects. The relationships between SEA and general assessment methodology are still under development. Furthermore, what happens in the transport sector will also be influenced by the development of SEA procedures in other sectors. All the assessments within INTERNAT have been conducted specifically in view of the basic principles related to SEA. This is because the main goal has been to define priority research areas in view of the development of an integrated tool for SEA.

INTERNAT concentrated on transport infrastructure and travel, as these are spatially the most relevant parts of the TEN-T. Nevertheless, at a network-wide level basic modal decisions also have to take into account vehicle manufacture, maintenance and disposal, because these are essential parts of the cumulative impacts of the modes of TEN-T. Furthermore, for the preparation of an SEA of TEN-T, links between the results of the INTERNAT-Project and other projects of the Strategic Transport Research Programme are to be established (e.g. COMMUTE, SCENARIOS, STREAMS, POSSUM, STEMM, ECPOAC, EUNET, ECONOMETRIST, FANTASIE, COST 341).

The research topics for INTERNAT were derived from the issues identified during the COMMUTE project. The main objectives of COMMUTE were as follows:

- To define a methodology for strategic assessment of the environmental impacts of transport policy options, to support transport policy decision making at the European level.
- To develop computer software that embodied the main aspects of the methodology and could represent the results to users.

- To demonstrate the use of the main aspects of the methodology and the computer software; in particular impacts on energy consumption, primary pollutant emissions and safety.

The report COMMUTE Framework for SEA (COMMUTE, 1998) provides guidelines for the carrying out of an SEA. It provides on one hand general procedural and methodological requirements for the application of SEA in the transport sector and on the other hand guidelines on integration methods.

The following general steps within the process of an SEA have been identified on a general level in COMMUTE (the main issues considered in INTERNAT are in bold):

1. **Setting of Objectives and Targets (Stocktaking of the Political Environment)**
2. **Screening to determine the need for SEA at this stage of the planning process**
3. **Scoping: identification of:**
   - the physical/regional limits;
   - the impacts to be addressed;
   - the alternative actions that need to be assessed.
4. **Carrying out of the SEA:**
   - Measuring/predicting the environmental impact of the action and its alternatives;
   - Evaluating the significance of the impact (e.g. through comparison with environmental objectives)
   - Proposing recommendations: preferred alternative, mitigation and monitoring measures.
5. Preparation of the decision
6. Taking the decision
7. Making arrangements for monitoring and follow-up
8. Conducting further environmental assessments (at later stages of planning process, e.g. project EIA)

The integration of approaches and methods were also identified within COMMUTE. INTERNAT has analysed additional procedural and methodological requirements in relation to scoping and the carrying out of phases of SEA (Figure 11).

An SEA should be opened by setting specified environmental *objectives and targets*. In the following step, *Screening*, a decision is to be taken on whether the need for SEA can be established or whether the Programme, Policy or Plan (PPP's) should be rejected or exempted. Should the need for an SEA be established by screening the subsequent step is *scoping*. Scoping includes the definition of relevant environmental impacts and indicators, delineation of the study area, fixing of the time horizon, choice and composition of suitable tools and methods, as well as the definition of alternatives to be assessed. The task "identifying spatial impacts " in INTERNAT responds to the first three steps of an SEA as it's aim has been to identify relevant environmental impacts to be considered within an SEA.

The next step is the assessment of single impacts identified as relevant. For this actual *carrying out of an SEA* a broad range of *methods and tools* has proven to be applicable. In COMMUTE a distinction was made between assessment, aggregation and other methods. The assessment methods like Geographical Information Systems (GIS) and the COMMUTE tool focus on the measurement of single impacts, while aggregation methods like Cost-Benefit-Analysis (CBA) and Multi-Criteria-Analysis (MCA) are capable of aggregating single measurement results into overall indicators. Among the other methods viz. Life-Cycle-Analysis (LCA), Cumulative Impact Analysis (CIA) and Strategic Sustainability Appraisal

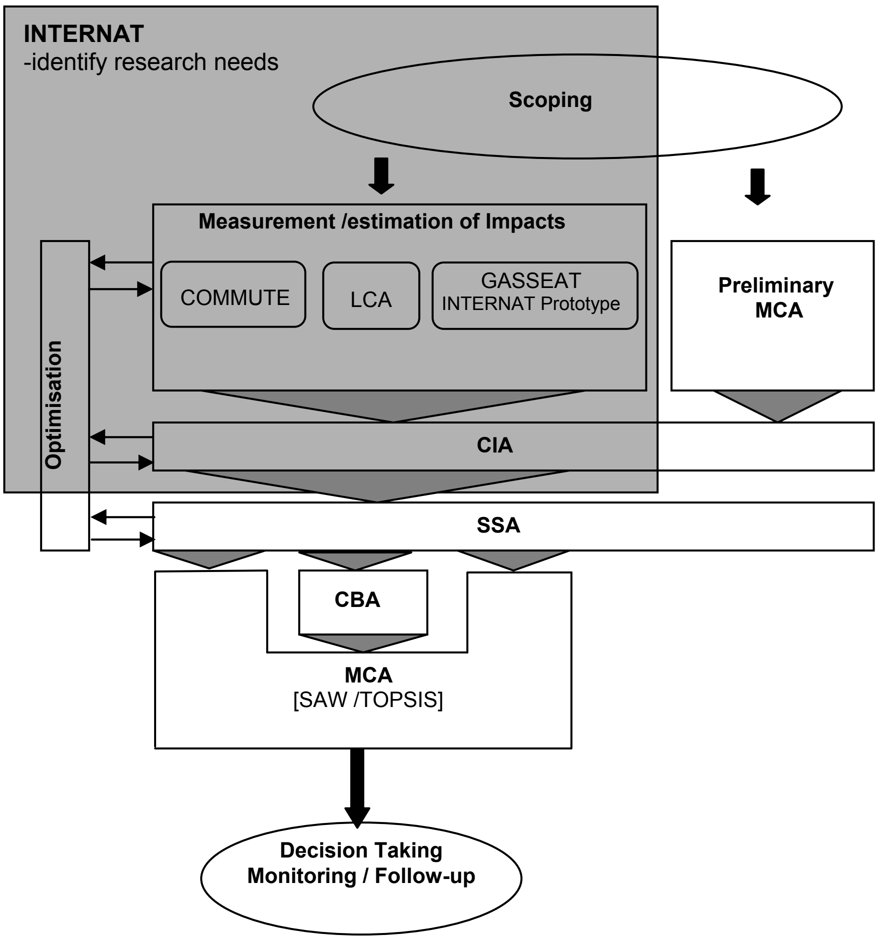


Figure 11: *The integration of SEA approaches and methods.*

(SSA), complementary innovative approaches are presented which, if they are integrated into the carrying out of an SEA, can enrich the SEA by life-cycle, cumulative impact and sustainability aspects. (cp.Figure 11) The tasks of INTERNAT on this execution phase concentrate on the adoption of new methods like satellite systems, improvement in theories for the measurement of air pollutant emissions and other methods like CIA and LCA.

The relevant impacts can be assessed through the COMMUTE tool (air pollution emissions), or through integrated GIS and remote sensing methods like the INTERNAT prototype, LCA and CIA. The COMMUTE tool is applicable to the modelling of impacts in key areas of energy use, emissions, safety and noise. It could be expanded to address other environmental impacts in the future such as land use and biodiversity. These environmental impacts have an important spatial dimension. They have been specified in INTERNAT and a reseach prototype for the assessment of these impacts has been introduced. Within the measurement, CIA and SSA phases of SEA optimisation should be conducted through identifying mitigation measures. The new inputs and effects should be fed back into the assessment of single impacts. Having passed SSA, the single impacts need to be aggregated through MCA. Indicators, which are suitable for monetisation, can be monetised through CBA. However, since not all of the impacts can be monetised, CBA alone cannot be used as an overall aggregation technique. Therefore also the impacts which have been monetised through CBA need to be fed into MCA in order to be aggregated with the other indicators. The results of the aggregation of impacts through MCA will form the basis for decision making. The results of the carrying out of the SEA in its core sense should then be incorporated into an *SEA report*.

In order to ensure that an SEA is a well-considered process to enhance environmental benefits and contribute to environmental sustainability, *follow-up and monitoring* should also form an integral part of an SEA.

6.2 Integrating procedures identified by INTERNAT

6.2.1 The INTERNAT approach

Following the *general SEA-process* as developed further in COMMUTE, INTERNAT has analysed additional procedural and methodological requirements in the following steps:

Screening and scoping	1. Baseline information on environment (divided into different structures / functions) 2. Valuation of the present environmental conditions (structures, functions), including preloads, background loads, environmental objectives and targets 3. Environmental impacts of the proposed action and its alternatives (possibly divided in product phases)
Carrying out of an SEA	4. Assessment of the (direct as well as cumulative) environmental risks, based on the connection / overlay of (2) and (3) 5. Results: comparison of risks of different alternatives

The assessment procedures identified in INTERNAT can mostly be categorised in four steps of SEA: scoping, assessment of loads, assessment of environmental impacts and strategic decision making. Each of these themes is discussed in the following section. A simplified sequential breakdown of the SEA process highlighting the implementation phases using the INTERNAT approach as a framework for an integrated process (tool) is shown in ***Figure 12***

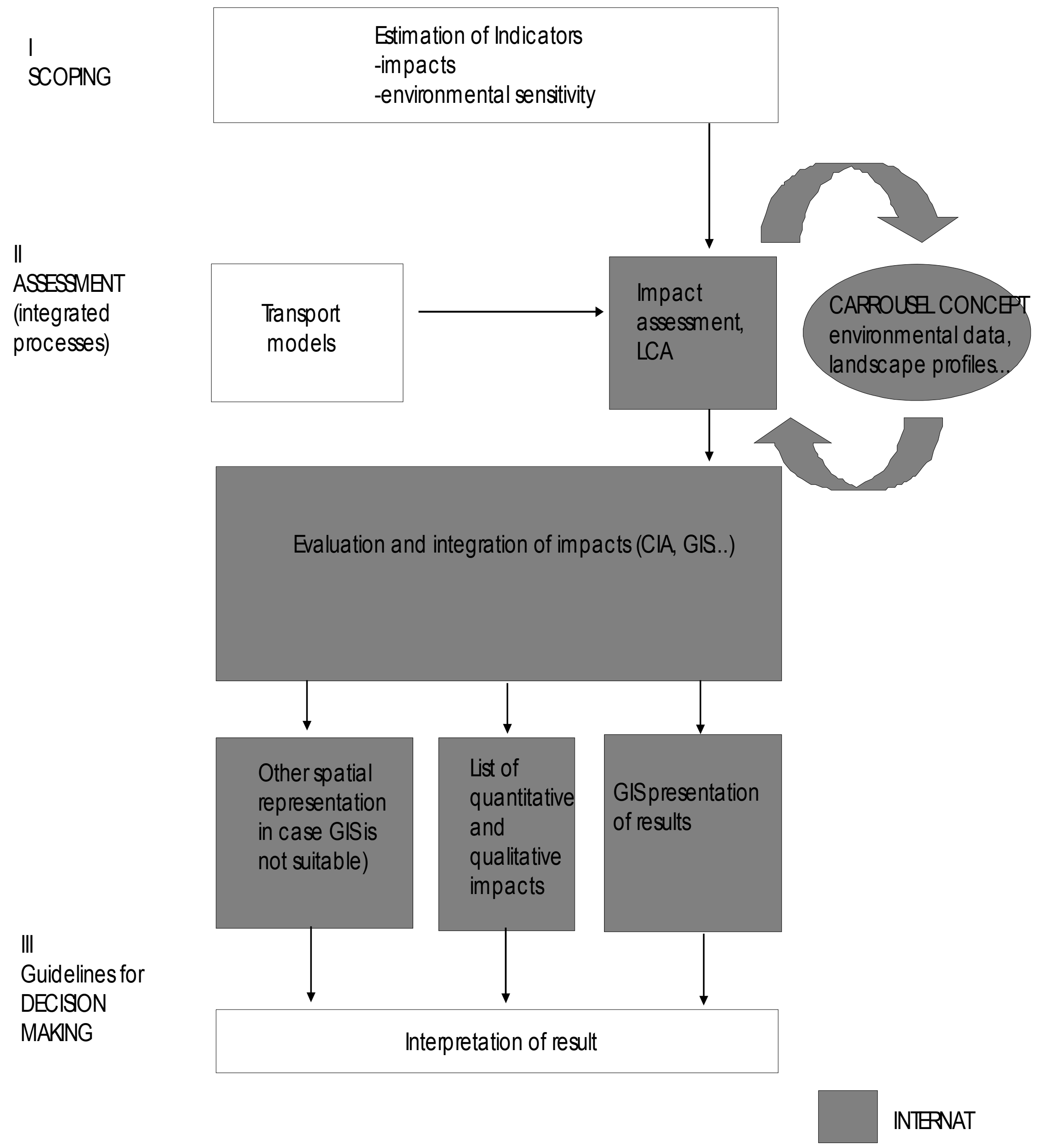


Figure 12. *Simplified flowchart of INTERNAT processes*

The procedures of SEA defined in INTERNAT are by definition clearly linked together. Environmental data and other data which is needed for the calculation and evaluation of impacts is collected. This contributes to the selection of indicators and some of the indicators can be achieved directly through integrating data and GIS. The data is then fed into different models and approaches. After the evaluation of indicators and their significance, the indicators are listed and if possible also presented through application of GIS (see Figure 13). The process as it is described in the diagram is general for all tiers but not all impacts can or need to be calculated at each tier level.

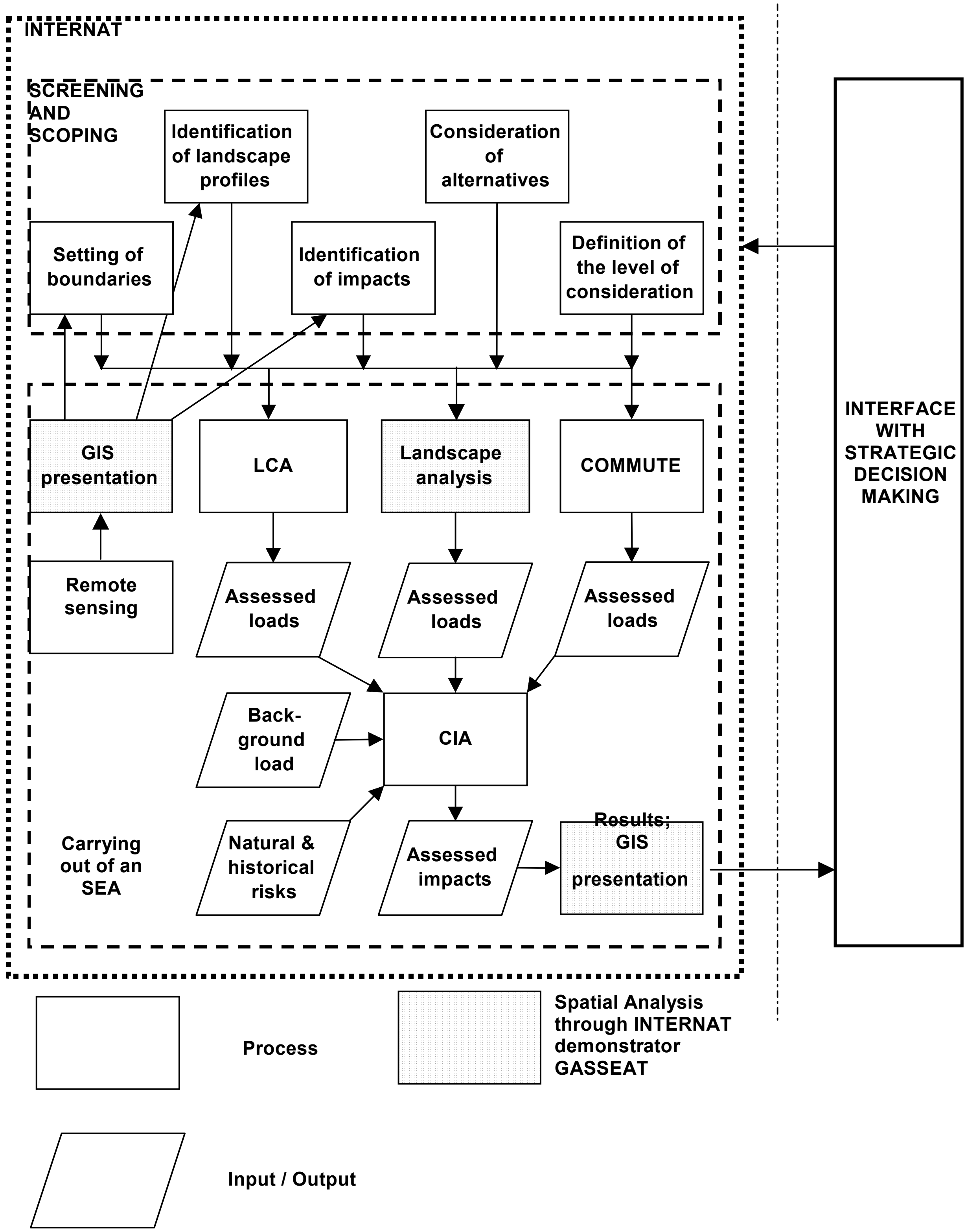


Figure 13: *Inputs and outputs of the scoping phase and calculation and estimation phase of SEA.*

6.2.2 The assessment process according to the INTERNAT approach

Screening and scoping

The whole SEA of the alternatives starts with the scoping process. The key elements of the scoping process are:

- setting geographical and time frame boundaries for the assessment;
- identification of landscape profiles to be considered;
- identification of impacts to be considered;
- consideration of alternatives and;
- definition of the level of consideration.

Setting geographical and time frame boundaries for the assessment underlines the importance of spatial scale and time scale. Remote sensing with GIS presentation can be used for the setting of boundaries and for identifying relevant landscape profiles and impact categories.

INTERNAT concentrated on the assessment of strategic environmental impacts. The structure, the contents and the methods of SEA depend more or less on the structure/the tiering of the decision process. In the case of TEN the description of a network-wide, a regional and a corridor level represents in some way a possible tiered decision process. Not all impacts are equally relevant at different levels. The impacts on climate change, acidification and energy use do not have a specific spatial character and are not strongly spatially influenced for example. In general one can say that the lower the level of the assessment to be considered, the more precise the spatial location should be, and the more spatial is the character of the indicators.

Fixed dimensions to be applied for the definition of the areal extent of corridors might not be appropriate. The corridor study area should be variable depending on conditions and infrastructure to be provided. Another constraint is how to tackle the interaction across the frontiers of member states. Obviously the availability of data is important but also in a purely practical sense the problems of reconciling different types of GIS layers and different nomenclatures is and remains real in arriving at a more global approach. It will be important to define the quality of all data levels and their validation for the level of areas to be studied.

The second topic is related to the temporal scale. Strategic assessments concern environmental impacts over different time scales. This means that during the project a whole range of environmental effects were considered and that is also why LCA and CIA took an important place in the project. Identified CIA methodologies for this step include the use of questionnaires, interviews, panels, checklists, matrices, network and system diagrams and trend analysis.

Assessment

The assessment of environmental impacts will follow the carrousel concept whereby a well balanced information set should be established considering landscape units, landscape values and vulnerabilities, data-sources, associated functions, target profiles, and impact profiles.

At the European scale level, attention should be given to the different cultural and semantic differences concerning landscapes and landscape values. The intensity with which landscape resources are being investigated in different countries and regions differs considerably. Even the most global European data-sets (such as CORINE) suffer from these discrepancies.

Both in a formal and functional approach, integrity is the major criterion of value and vulnerability in relation to TEN-impacts. The way this integrity should be defined cannot be standardised. Any index of value, vulnerability or impact should therefore be interpreted taking into consideration the specific character of areas and the specific functions. Broadly speaking "Character" can be equated with the "landscape profile", while the function corresponds to the "target profile".

Practically, the suggestion can be made that at each level of assessment (global, network, corridor). The area should be divided first into geographical character units and appointed functional targets. It is desirable that both can be integrated as much as possible, so as to obtain a robust spatial framework for the impact assessment. The definition of impact profiles and of specific impact indicators should be carried out for each character/function areal unit separately. Alternatively, standard impact indicators applied over large areas should be interpreted differentially for these character/function units.

Europe wide definition of character zones is an important future task. Formal approaches as developed in several countries (such as the ITE land classification system, or the German physiographical map) are inspiring examples, however of ad hoc developments, of Europe wide neo-classifications of landscapes. Also, remote sensing and GIS techniques can be very helpful in this respect.

The relevant spatial impacts and their general magnitude with respect to the different modes / system-elements should be analysed as far as possible, based on relevant compartments of TEN- links and the prognosis of the foreseen transport activities. Integration of spatial impacts in transport SEA has to be seen within the question of if and how this can be put forward in a differentiated view of the outstanding alternatives. So, depending on the integrated alternative strategic options spatial impacts may (inter modal comparison) be included more on the level of the general characteristics of the relevant transport modes, or if spatial alternatives of routing are assessed, in a more detailed way, based on assessment of spatial sensitivities and concrete risks.

For the estimation of spatial impacts it is further of significance, whether the upgrading of existing infrastructure or the new construction of a link is in question. The analysis also integrates concepts used within concrete project related environmental impact assessments. It includes examples of concrete impact intensities from different case studies.

A holistic framework

As a conclusion of the spatial assessment of INTERNAT, landscapes should preferentially be assessed in holistic frameworks, in the first place with the aid of appropriate *classifications* and *typologies*. Techniques such as remote sensing are helpful in feeding land classification exercises with objective data on land cover and landscape structure, directly related to the major impact classes: land take and fragmentation. The total impact quantification of SEA in large areas can substantially be facilitated through scientifically based land classifications.

For SEA, the determination of landscape units has different roles:

- differentiating the expected type of impacts of infrastructures between geographical landscape units. In certain areas Biodiversity values may be much more characteristic than visual qualities. In other areas, it will be the difference in scale of large infrastructures and the existing landscape pattern that will be important,
- the second: following from the first role, is the differentiation of the choice and interpretation of evaluation, vulnerability and impact criteria, according to the different landscape units crossed,
- thirdly: providing a stratification framework for sampling impacts that cannot be deduced directly from the general description of the units,
- and finally: extrapolation of impacts over the surface of the units, and quantifying total impacts of an infrastructure in terms of specific metrics of the landscape units (area, transact length, composition, etc.).

For the consistency of the procedures it is essential that the links between procedures are standardised. Research needs within the individual approaches and techniques have been identified. The main focus for the application of methods and for aggregating and disaggregating data concerning individual environmental factors will be standardised. For the Biodiversity indicators a challenge for the future is to develop complex spatial Biodiversity models, which model key feature and populations, and which are causal and dynamic in space and time.

The possible use of LCA and CIA

LCA can be used in the strategic environmental assessment of transport infrastructures in two basic ways. In order to achieve a comprehensive assessment it still has to be complemented with other procedures.

The first straightforward way to use LCA is to directly assess the environmental loads of certain specific infrastructure alternatives. This requires, however, a lot of basic data and becomes thus easily very laborious and time consuming. Nevertheless, if the required data are easily available, the calculations themselves don't cause any problems. It is actually possible to use the same spreadsheet, for example for various assessments, by merely changing certain data values within it. As an example, to assess different road cross-sections at the same place, it suffices only to change the amounts of the different materials required for one unit of the cross-section in question. All the other data concerning, i.e. the production and transport of material, can be kept unchanged. On the other hand, if the cross-section is the same, but the site will be changed, the demand of material does not change, but the systems of production and transport of materials will change accordingly.

The other way to use LCA is to apply it, beforehand, to certain *typical* infrastructure cross-sections in some typical situations. Thus it could be possible to achieve for these cross-sections specific *normal values* of environmental loads, which then can be corrected to fit to actual situations by proper *correction factors*. These simple "modules" instead of complicated calculations can then be utilized in the actual assessments of the transport infrastructures. This way to use LCA is not as flexible as the former one, but it is much simpler and very easy to comprehend, because the typical cases show at once the basic levels of the expected environmental loads and can be handled "manually" in the *first strategic considerations* when considering various alternative solutions. Thus, the procedure would be to use at first these normal cases during the preliminary phases and subsequently apply the direct LCA models for assessing closer and more precisely the environmental loads of the chosen alternatives.

An integrated assessment method for LCA, taking into account all the consequences of route infrastructure choices should include:

1. The LCA method for assessing the quantitative elementary flows and impact potentials of the infrastructure itself,
2. The CIA method for extending the considerations to the actual environmental impacts and to take into account also certain qualitative issues,
3. Transport model for assessing the impacts of the actual traffic and
4. Simulation models for assessing the future indirect impacts of the choices in respect of community life as a whole.

In INTERNAT evaluated CIA-methods and their potential use in the assessment process are given in Table 22.

Table 22: *Evaluated CIA methods in INTERNAT*

Method	Potential use
Network and system diagram	Demostrate a cause-effect correlation in a simple and clear manner
Simulation models	Quantify the cause-effect relationships
Trend analysis	Additional tool for matrices, networks and system diagrams
Carrying capacity analysis	Identification of thresholds on specified themes
Overlay mapping and GIS	Analyses landscape parameters, in identifying areas where impacts will be greatest, in clarifying spatial networks or in analysing spatial and temporal environmental changes
New models to predict the sensitivity of wildlife species and fragmentation	Quantitative analyses and evaluation of dynamic processes
GIS modelling for the prediction of cumulative effects of land use planning	Quantify rates of regional resource loss by data layers of different years, develop empirical relationship between resource loss and environmental degradation
Cybernetic models	Can consider a lot of different factors
Integrated evaluation of cumulative effects with complex scenario technique	Detect cumulative effects, enable the assessment of different combinations of options and different levels of investment

Integration of GIS/RS

Political decisions concerning the environment are supposed to be supported by results of scientific research. Most of the time, the results of scientific research must be summarised and simplified in order to be useful and understandable for decision-makers. As GIS is a data integration and analysis tool, GIS experts often act as intermediary between decision-makers and sector scientists. The decision situation determines the need and the nature of the information required. To this end it is useful to distinguish between “hard” and “soft” information. Hard information is derived from reported facts, quantitative estimates, and systematic opinion surveys (e.g. census data, remotely sensed data etc.). Soft information represents the preferences, priorities and judgements of the decision makers. This type of information is used because social, economical, and political values and considerations are taken into account.

GIS can be used as a spatial analysis tool at several stages in SEA. In other words, GIS often helps to generate hard and soft information. The type and amount of information needed for investigating a decision problem is related to the decision situation complexity. The latter is a function of the number of alternatives, the evaluation criteria, and the interest groups. Decisions which take into account environmental issues are spatial and multi-criteria in nature and often require a mixture of quantitative and qualitative information. Given the integrating capacity of GIS, it can, therefore, play a crucial role in multi-criteria analysis. In this situation different environmental indicators together with other information on social and economic issues are combined to support a decision. In this case, GIS is used at the end of the SEA.

Sometimes GIS experts work more at the scientific level in order to use the GIS analysis capacity to come up with hard information (e.g. useful indicators). This was the case for INTERNAT where the role of GIS and RS in SEA was applied to issues of data collection through RS, classification, and indicator estimation. Environmental impacts must be measured and estimated before they are entered into the comprehensive assessment method. In this case, GIS is used at the early stages of the SEA.

7. FUTURE RESEARCH NEEDS

In this chapter different research needs, that may be regarded as significant to optimise and develop transport SEA are described. To judge their relevance for an SEA of the TEN, the tasks of the possible assessment have to be defined. SEA is part of a decision process. Concept, contents and level of detail of the assessment strongly depend on the decisions to be aimed at. So as a basis for making concrete statements on future research needs it has to become clear, if the assessment aims

- at a description of possible environmental problems caused by the TEN and the different projects (red flag approach)
- furthermore at the objective of providing an aid for controlling modal and / or regional investment of the EC in transport infrastructure, or
- at a more detailed assessment of proposed projects to allow a comparative view

Priority research areas in INTERNAT have been identified through assessing the weaknesses of current methods and identifying potential of new approaches. This analysis resulted in a list of priority actions which can overcome shortcomings in the relative short term and a list of priority future research topics.

7.1 Priority actions

7.1.1 More detailed land use/cover classification

In order to use effective up-scaling and down-scaling functions for consistent assessment at three levels (EU, regional, corridor), more detailed information on land use/cover is needed. Priority action for this topic should concentrate on the following fundamental components:

- establishment of a harmonised level 4 and 5 classification system. Concepts for integration of the national propositions for the extension of the CLC (Corine Land Cover) level 4 and 5 have been proposed by the ETC/LC (European Topic Centre for Land Cover).
- the potential of the very high-resolution imagery which has recently become available (IKONOS) with regard to 1) the generation of level 4 and 5 land use/cover information; 2) the possibility to update existing databases; and, 3) the assessment of the quality of

existing databases. A major bottleneck for using this very high-resolution imagery will be its high financial cost price;

- development of data aggregation guidelines. Up-scaling and down-scaling assessment techniques will require a set of rules to generate accurate and consistent land use/cover information layers at different scales.

7.1.2 Implementation of quality control procedures

The format, incompleteness and inconsistency of data sets cause difficulties in assessment processes and errors in evaluations. As mentioned before consistency errors were encountered in the land use/cover database of GISCO. With the start of the development of CLC2000, it is useful to review the existing quality control procedures and to formulate even more stringent customised quality control procedures in order to prevent such types of errors (land use changes across national boundaries, mapsheet boundaries etc.).

7.1.3 Upgrade/Complete databases

Existing data sets on environmental topics such as biotopes, designated areas, and the NATURA2000 network, which usually should have an extensive attribute data set, would have more value if the geometric data were upgraded (from points to polygons).

7.1.4 Generate 'value'maps

More environment-related data sets containing information on values (soils, vegetation, landscapes, etc.) are required in order to generate indicators and measure/predict sensitivities to certain human activities (pressures).

A lot of the databases analysed in INTERNAT proved to be digital, some are only available in analogue format, most of them cover the whole of Europe. The need for specific data bases will depend on the type of indicators used and the geographic extent of the site. Actually, many methods are biased towards the existing maps or databases of 'pre-valued' landscapes and land uses. It is dangerous to adopt these pre-values exclusively since the sensitivity of landscapes will not only depend on the type but also on the area in which it is situated. The only exact attitude is to judge each landscape in terms of its own character and societal use

Indicators for impacts on biodiversity are at present only very rough or exhibit a lack of data sources (EUROSTAT 1999). EUROSTAT for example defines area loss, damage and fragmentation of nature conservation sites within 10 km or less of a TEN infrastructure and fragmentation of landscape units larger than 1000 km² as indicators for the loss of biodiversity. Concerning biodiversity, and especially concerning wildlife species, there is a great need to build up the bank of data sources.

Equally for the prediction of cumulative effects by models, as well as for the development of different scenarios, extensive information and data are necessary. Not only status (upgrades, new links) and location of the planned infrastructure links or estimates on the predicted magnitude of traffic impacts on the links, but also information on the average daily traffic and number of motorway lanes or rail tracks incorporated in the existing infrastructures is necessary. Also maps or statistics on population density or growth rate, activities, developments, environmental loads (emissions, old waste dumps, old mining areas), storms, earthquakes or inundations are necessary. Beyond this socio-economic topics have to be taken into account with respect to data like cultural heritage and traditional cultural activities, social structures and values, amenity and economical structures.

7.2 Priority research areas

This section will describe priority research areas in view of the development and demonstration of improved methods on spatial environmental impacts. Detailed research needs are detected and listed in deliverable 3 of the project.

7.2.1 Research needs related to principles of strategic assessment

One main problem in assessing spatial impacts of TEN is, that the location of the infrastructure is not fixed, as far as new construction of infrastructure is concerned. Assessment on the basis of assumed lines or polygons may produce misleading results, since possibilities of minimising impact or even avoidance in later stages of the planning procedure are disregarded. This leads to the research question, how can anticipated avoidance of environmental risks at later stages of the planning be integrated.
A case study could compare different concepts (e.g. assessment of direct lines, of a hypothetical polygon, assessment of different alternative polygons, assessment based on the characteristics of the whole possible area related to the infrastructure, ...). Another element is the difference in the relevance of spatial impacts (resulting risks) between new construction projects and upgrading projects, where the relevant spatial impacts already exist, being influenced by the project. The location in these cases is mostly precisely determined, so that the structures and functions subject to influence can be estimated (if the assessment scale allows this). To allow a differentiated assessment and a comparative view with regard to new construction options, the relevant preload (caused by existing transport infrastructure, but also by other sources) has to be integrated. The further assessment should allow a comparative view on projects independent of their absolute dimension (length). This implies results being estimated according to length - units.

Impacts differ in an important way between the modes and actually the knowledge and experience on particular issues for inland waterways and harbours and airports remains very scarce. Additional case study analyses would be useful to broaden the empirical base.

7.2.2 Research needs related to the landscape approach and the use of GIS/RS

The general problem of integrating an assessment of the spatial dimension of landscape values into an SEA of the TEN is the difference between the assessment scale and the spatial diversification and small scale characteristics of landscape values, which can hardly be represented directly on the relevant assessment scale. So the use of a generalised database is necessary (CORINE). Since the spatial quality (and vulnerability) is not directly measurable in detail, indicator driven concepts have to be used. The chosen indicators have to aim at a differentiated, reasonable, comprehensible and balanced view of the indicated values, in order to produce policy relevant results.

The strength of the landscape concept for impact studies at all tiers is often underestimated. The landscape concept has the following "strengths":

- It enables the stratification of the areal context of TEN into spatial units of a certain uniformity (land use, relief, ecology,…), so as to direct in a rational way the environmental assessment and to extrapolate point observations over larger areas
- It enables guidance to be provided with regard to the spatial interpretation of the land use and environmental functions (basins, ecological networks,…) and helps to study the latter within a system approach (pathways of emissions, emissions etc.)
- It helps to link the "rational and objective" scientific approaches to environmental impacts, to examine the inclusion of rather subjective and societal interpretations of the environment.

Generally a large gap exists between current scientific knowledge and current planning procedures. For example, the state of science in Biodiversity is far behind other technical disciplines. The distance from the academic level and maximum scientific demand to normal planning procedures should be improved. To improve everyday planning, user-friendly and standardised methods are necessary. The search for a balance of landscape interpretations throughout tier, regions, countries, etc. is one focal point in new approaches.

The strategic impact assessment can be driven primordially by accommodating different "entrances": the availability of spatial data, the existence or absence of environmental policy, regional experience with infrastructure impacts etc. Therefore it is advisable to start with a screening of the available inputs, experiences, policies across Europe. From this screening guidance can be given in order to obtain the best possible assessment angle, which may be different for particular regions, scale levels etc.

Certain landscape and land use frameworks that maximally integrate impact profiles are important and should be developed at EU level, as they exhibit promising potential: the ITE land classification, and the UK landscape character approach for instance. Such frameworks provide consistency in environmental descriptions across large areas and allow for stratification in sampling areas for infrastructure impacts.

The challenge for the future is to develop complex spatial Biodiversity models, which model key feature and populations, and which are causal and dynamic in space and time. Standardised use in practice depends on future availability of detailed basic information on relevant species for example to compile a database and to validate models. In order to gain that information more field-studies have to be carried out.

Concerning the qualifications of data sets, it is important to mention that some of the already existing natural resources data sets, such as biogeographical zones and landscapes, can be useful when considered as weight factors in certain evaluations. For this however, expert judgement is needed to either assign weights to the different classes of the theme, or to define the experts rules (criteria) which are part of the evaluation process. It is important to have a clear definition of what the information is standing for and to have knowledge on the aggregation techniques used or to develop aggregation guidelines.

Scientists often need detailed data (high resolution), but this is not what decision-makers need for policy and planning issues. Decision-makers need information, which enhances the quality of the decision. There is a need for research to investigate whether a general procedure can be developed which guarantees sound consistent multi-level (from scientific to policy level) information.

7.2.3 Research needs on cumulative impact analysis

To date complex cumulative effects, which encroach on different resources and have a temporal and spatial dimension, can’t be reproduced sufficiently by the available methods. There is a lack of scientific safeguarding for these complex processes. Usually scientific evidence is only available for individual effect paths. This leads to the claim to stimulate interdisciplinary research concerning complex cumulative effects, such as interactive or synergistic effects, which cover different resources.

Furthermore approaches to quantify cumulative effects are necessary within the near future. These require improved modelling, defining of commonly avowed thresholds and the definition of indicators (i.e. contamination levels, percentage of habitat loss, degrees of degradation).

Complex scenario techniques are necessary to fathom network-wide cumulative effects of all activities and for all resources. They should enable the assessment of different combinations of options and different levels of investment. Relative environmental impacts of each scenario should be identified, assessed, and evaluated. An example for regional scenarios of a river basin is given by Hulse et al. (1997). An assessment of alternatives has to be conducted, in which either an originally chosen set of options is selected or a new mix of land-use planning, fiscal control and technological developments deemed to have the least environmental impact is recommended (for a comparable concept to use in the transport sector see IWW et al. 1999, linked to the German Transport Infrastructure Plan).

Environmental impacts have different time scales. It will also be important to develop a method to unify and compare different time scales of the different methods used in the assessment procedure, e.g. LCA and cross-sectional analysis.

7.2.4 Research needs related to life cycle assessment

On the *quantitative* side the LCA procedure of route infrastructures could be considerably improved by extending the considerations from the emissions and impact potentials to actual impacts on the environment. This can be achieved by assessing the *pollution contents* of the air and soil at various places on the route and in its surroundings, estimating the dispersion of the pollution and their accumulation. This is not an easy task, because the dispersion of emissions depends on winds as well as on land profile, vegetation and built structure surrounding the route. Finally, the considerations should be complemented with methods for assessing the *exposure* to the impacts. This could be undertaken by starting from the end points, e.g. with certain indicators of the impacts.

The only way to simplify the method for the purposes of strategic assessments is to use average data and larger unit processes. As stated before, the larger unit processes can be achieved by first making inventory analyses for smaller scale product systems in certain standard situations and then treating them as unit processes with the achieved elementary flows as their inputs and outputs. However, attention has to be paid to the scope of applicability in using average data and unit processes. Average values may hide the real and most important issues which should be brought to attention by the comparisons. Because of this, the used data and unit processes must be as transparent as possible in order to reveal their true scope of applicability.

The improvement of the *qualitative* side of the considerations could be handled in two ways. One way is to try to quantify the qualitative issues. For example, some of the subjective qualitative values of people can more or less be quantified by enquiries and interviews and their statistical analysis. However, this is not a very reliable way, because many value questions are highly interdependent and can considerably vary in time. The other way is to consider all the quantitative issues by using the LCA method and complement them with a separate consideration of quality issues. In this case, however, the qualitative issues must not be underestimated just because they cannot be handled as systematically as quantitative ones.

In order to arrive at a comprehensive impact assessment besides the direct impacts, also the cumulative and indirect impacts as well as the impact interactions, should be taken into account. However, these latter impact categories make the whole system very complicated and diffuse. Because of this they can be considered only on a very general level.

7.3 Conclusions

The research topics for INTERNAT were derived from the issues identified during the COMMUTE project. The COMMUTE methodology provides a Framework for SEA including the basic methodological requirements for SEA of multimodal transport actions and guidelines on integration. In addition, a software tool comprising assessment of air pollution emissions, energy consumption, noise and safety has been designed. It could be expanded to include other environmental impacts like land use, biodiversity and landscape in the future. These types of impacts have an important spatial dimension and are isntrumental in INTERNAT research project whose purpose was the further development of SEA in this way. The COMMUTE methodology envisages also integrating different SEA approaches and tools.

INTERNAT has investigated these issues more in-depth by theoretical and methodological research on the one hand and on the other hand through a more practical investigation developing and testing a prototype in order to define the weaknesses of current methods and the potential of new approaches and the integration of spatial environmental indicators.

Finally, the project team defined, as it was intended, in as detailed a way as possible the priority research areas for the further development of an integrated tool.

The INTERNAT project confirmed the potential for future exploitation of the methodological framework on the different spatial levels. Within COMMUTE, the pilot SEA of plans for the Trans-European Transport Network (TEN-T), and INTERNAT it has been demonstrated that the framework is suitable and its potential can be fairly easily confirmable. However, it has to be concluded that further work on classification and definition of data on the one hand, and further research in a number of areas would be necessary. Some weaknesses and shortcomings, especially in existing databases, which should be easily able to be resolved, could already help to demonstrate a broader application of the software tool GASSEAT, its integration with the COMMUTE tool and the different approaches assessed within INTERNAT.

The project team suggests therefore to develop and apply the framework in the future in an incremental way. One can commence by making use of a simplified tool based on the experiences of the COMMUTE tool and GASSEAT and it can be developed to a more elaborated tool once future research areas have been successfully addressed. For example INTERNAT proved that especially the application of new and rather complex approaches such as Cumulative Impact Analysis and Life Cycle Analysis still requires further methodological research, for practical application although their theoretical potential is clear.

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List of presentations

- The European Transport Research Conference: "Paving the way for Sustainable Mobility", 8 and 9 November 1999, Lille
- Workshop on COMMUTE/INTERNAT, 20th of March 2000, DG TREN and EEA
- EC Congres on GI and DIS, 28-30 June 2000, Lyon

List of Acronyms

4th FP	Fourth Framework Programme
5th EAP	Fifth Environmental Action Programme
CIA	Cumulative Impact Analysis
CLC	Corine Land Cover
CODE-TEN	Strategic Assessment of Corridor Developments, TEN Improvements: research project
COMMUTE	Commun Methodology for Multimodal Transport Environmental Impact Assessment: RTD-project ST-96-SC0203
CORINE	CoORdination of INformation on the Environment
COST	European cooperation in the field of scientific and technical research
CTP	Common Transport Policy
DEM	Digital Elevation Model
DGVII	European Commission Directorate General VII: Transport
DGXI	European Commission Directorate General XI: Environment, nuclear safety and civil protection
DMEER	Digital Map of European Ecological Regions
EC	1) European Commission// 2) European Communities
ECMT	European Conference of Ministers of Transport, a co-operation organisation for European transport ministers
EEA	1) European Environment Agency// 2) European Economic Area
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (of the United States)
ERA	Ecological Risk Analysis
ETC/LC	European Topic Centre on Land Cover
EU	European Union
EURET	European Research on Transport Programmeof the 2nd Framework Programme
EUROSTAT	Statistical Office of the European Communities
GIS	Geographic Information System
GISCO	Geographic Information System of Eurostat
GLP	Generic Landscape Profiles
HST	High Speed Train
INTERNAT	INtegrated Trans-European Network Assessment Techniques
LCA	Life-Cycle Analysis
LCIA	Life-Cycle Impact Assessment
LCSEA	Life-Cycle Stressor-Efects Assessment
MCA	Multi-Criteria Analysis
MEET	Methodologies for Estimating air-pollutant Emissions from Transport: RTD-project ST-96-SC0204
PPP	Policies, Plans and Programmes
RS	Remote Sensing
RTD	Research and Technical Development
SAMI	Strategic Assessment of the Interaction of CTP instruments - research project ST-97-SC1176
SCENARIOS	Scenarios for Trans-European Network: research project ST-96-AM0104
SEA	Strategic Environmental Assessment
SRD	Software Requirements Document

SSA	Strategic Sustainability Appraisal
STREAMS	Strategic Transport Research for European Member States: research project ST-96-AM0105
TEN	Trans-European Network
TEN-T	Trans-European Transport Network

Glossary

accessibility	time and cost needed for passengers and freight to move from origins to destinations, and general quality of the transport connection
action	(any project or activity of human origin)
activity	(any action that is not physical work, activities do not involve the construction of an object and may lead to an environmental effect (e.g. highway=action, traffic=activity)
Agenda 21	The action programme for the 21st century agreed to work for a long-range sustainable development of society by 185 countries, which signed the Rio Declaration, United Nations Conference on Environment and Development in Rio de Janeiro 1992.
baseline data	a minimum of reliable and readily available data, which are necessary to realise an impact assessment
Birds and Habitats Directives	the Community legislative framework for protecting Europe's wildlife and habitats
Brundtland Report	Report of the World Commission on Environment and Development (1987): Our Common Future. This report launched worldwide the principles of sustainable development
corridor	the area between two urban centres, airports, ports or other fixed poles of traffic attraction (e.g. border crossings), between which traffic flows occur
draft Directive on SEA	a proposal for a Directive on the assessment of the effects of certain plans and programmes on the environment COM(96)511
effect	(any response by an environmental or social component to an action's impact)
environmental standards	levels of environmental impacts which have to be implemented through national legislation, used as criteria to evaluate infrastructure projects
ESPOO Convention	Convention on Transboundary Impacts
EU-Directive on EIA	Directive 85/337/EEC on the requirement of an EIA for most infrastructure development projects (amended by Directive 97/11/EC)
fifth environmental action programme	This document provides a framework for Community policy 'Towards Sustainability' (COM(92) 23 final). The programme is strategic in character and puts its main emphasis on the integration of environmental considerations into economic and sectoral policies.
fourth framework programme	This programme, adopted by the Council Decision of 1/12/1994, sets out all the activities of the Community in the area of research and technical development (1994-1998).
fragmentation	severance
geographic information system	GIS- data management and analysis
green paper	Green Paper of 20/12/1995 on 'Towards Fair and Efficient Pricing in Transport' Policy options for internalising the external costs of transport in the European Union COM(95)624
guidance	official or frequently used documents explaining how transport infrastructure plans or policies should be interpreted
impact assessment	to assess the impacts of a proposed policy, plan, programme or project
indicator	forecastable quantitative or qualitative variable which symbolises environmental or other impacts of transport infrastructure plans (including ordinal scale: e.g. low, medium, high)
induced traffic	traffic which would not be generated in the absence of new transport infrastructure
long term	25-30 years

mitigation measures	measures to reduce or ameliorate the unavoidable impacts of transport infrastructure development, remedial measures
mode	a form of transport (such as road, rail, air, inland water shipping, marine shipping, pipeline, bicycle)
monitoring	mechanism for correcting unacceptable aspects of implementation
multi-criteria analysis	technique to aggregate separate indicators (qualitative and quantitative) by making use of weighting
network	a number of interconnected corridors, either multi-modal or uni-modal
node	a location where two transport corridors are connected to one another, enabling transfer from one corridor to the other
pole	a fixed location which generates or attracts traffic, either as origin or as destination (e.g. urban centres, industrial areas) or because it is a fixed point where traffic flows need to pass (e.g. a port, border crossing);
process review	to ensure that all the relevant impacts have been properly assessed, defining appropriate corrective actions
project-level environmental impact assessment	a process which provides information about the environmental impacts of the project
region	(any area in which it is suspected or known that effects due to the action under review may interact with effects from other actions. How far the area extends will vary greatly depending on the nature of the cause-effect relationship involved)
remote sensing	RS, mainly by use of satellites - data collection by use of satellited
scoping	to determine the issues to be included in the SEA
screening	to determine whether an environmental asessment is necessary
severence	fragmentation
stocktaking of the political environment	define the environmental objectives and target values of the different policies (transport and environment)
strategic environmental assessment	a process which provides information about the environmental consequences of decisions about policies, plans and programmes
strategic transport research programme	part of the 2nd Framework Programme (EURET)
synergetic	synergistic - this effect arises when the resulting environmental impact is greater than the sum of constituent inputs
TEN-Guidelines	Community Guidelines for the Development of the Trans-European Transport Network (Decision N°1692/96/EC) of the European Parliament and of the Council 23/7/1996. Identifies potential transport infrastructure developments and the need for SEA.
tiering	distinguishing different transport infrastructure plans or other policies, plans or programmes which are prepared consecutively, and which influence one another
traffic flows	passengers and freight moving from origins to destinations, and characteristics such as transport mode, speed, time of the day, number of vehicles
transport infrastructure development	making changes to the transport infrastructure network
transport infrastructure plan	a plan, or programme, proposing changes to the transport infrastructure network and setting a framework for more detailed project decisions
white paper	White Paper on the Future Development of the Common Transport Policy: a global approach to the construction of a Community Framework for Sustainable Mobility COM(92)494

Annexes

Annex 1: Data references to landscape typologies

Annex 2: Data references and GIS/RS operations/techniques for indicators for estimating environmental impacts

Annex 3: Examples of assessment through the use of the prototype GASSEAT

Annex 4: Results of empirical testing of Digital Elevation Modelling