Ministry of Environment and Energy
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PSSD

Planning System for Sustainable Development

The Methodical Report

NERI Technical Report No. 351

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Editor:
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Abstract:	PSSD - Planning System for Sustainable Development – is a part of the Baltic Sea Region's INTERREG II C program. The current report describes some theories, methods and tools developed under the PSSD project. First, the theoretical foundation of the project is described. Secondly, the role of indicators in sustainable development is discussed and a Web-based indicator generator is described. Thirdly, we describe a number of methods and tools, which support planning for sustainable development. Finally, some technical interface tools – especially a Web-based interface to the methods and tools, the so-called Planner's TOOLBOX, are described.
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Preface

The present report is a description of the theories, methods and tools developed as a part of the PSSD project. PSSD is an acronym for Planning System for Sustainable Development. This project was co-financed by the European Union as a part of Baltic Sea Region's INTERREG II C program. The participants of the project were regional councils and research institutes from Finland, Denmark and Germany.

The objectives of the project were to create a prototype for a transnational common GIS-based regional planning method in the Baltic Sea Region and a prototype for a computer aided tool for common use of the method. The idea behind the term prototype is that the first version of the common method would be created without any wider international need analysis. As the subtitle indicates, the current report only describes some theories, methods and tools, whereas the full contents of the PSSD project is available from the so-called Planner's TOOLBOX which can be found on the following Internet address: http://www.pssdtoolbox.net.

As indicated by the list of authors, more than 30 planners and scientists from 16 partner organisations have contributed to this report. Therefore, my first words of thanks should go to all authors of this methodological report of the PSSD project. Next, a special thank to Irmeli Harmaajärvi (VTT) and Jürgen Pietsch (TUHH) for their role in compiling documents to be edited as a part of the current report. Thank you also to Jukka Mikkonen (Regional Council of Päijät-Häme), Ann-Katrine Holme Christoffersen (NERI) and Hanne Bach (NERI) for their efforts in the final editorial work.

Finally, I will encourage readers of this report to visit the homepage of the Planner's TOOLBOX and read the following reports, also describing the PSSD project:

Summarised Experiences of the Project and the Programme (PSSD Summary Report)

Planner's TOOLBOX —A Technical Report

Henning Sten Hansen

Roskilde, February, 2001

Summary

The present report describes the most significant methodical results of the PSSD project - a part of Baltic Sea Region's INTERREG II C program. PSSD is an acronym for Planning System for Sustainable Development. The present report is a description of the theories, methods and tools developed as a part of the PSSD project. The objectives of the PSSD project are to create a prototype for the first common GIS-based regional planning method in the Baltic Sea Region and a computer aided tool for common use of the method. The idea behind the term prototype is that the first version of the common method would be created without any wider international need analysis.

First, the theoretical foundation of the project is described. Concepts of sustainability play a key role in a planning system for sustainable development. However, sustainability concepts are not easy to use in practical planning. Various approaches to sustainability assessment have been developed. The method of multiple qualitative and quantitative indicators has been chosen for the PSSD project. This approach is consistent with interpreting sustainability as the ability to meet a diverse set of goals where no single indicator exists. The cross-sectoral nature of spatial planning calls for a framework for structuring information on cause-effect relationships. Thus, the current project has adopted the DPSIR framework of the European Environment Agency. A planning system for sustainable development involves a wide range of different spatial data. Following the DPSIR framework, data describing the driving forces are often collected at municipal, county or even national level, but variables related to pressures and states often represent observation points. Trying to reconcile two sets of data, collected over different tessellations might be a difficult task. Therefore we decided to use grid cells as a common data model throughout the PSSD project.

Second, the role of indicators in sustainable development is discussed and a Web-based indicator generator is described. As a main part of the PSSD project, the Technical University of Hamburg-Harburg developed a Web-based Indicator Generator. Applying this tool, the user can create new indicators of regional sustainability and evaluate their quality. Thus, the Indicator Quality Check supports the evaluation of the quality and usability of an indicator by answering questions like "characteristics of future ability", "references of time and space" and "quality and availability of data". The subsequent discussion on indicators refers to healthy and sustainable cities as well as competitive capacity. In addition it is stressed that the state of environment not only reflects human influences but also natural processes and phenomena. Thus, geo-indicators describing processes, occurring at or near the Earth's surface can be used in the assessment of issues of importance to a sustainable society.

Next, we describe a lot of methods and tools, which might support planning for a sustainable development. One important aspect is concerned with the identification of regional sustainability. A lot of indi-

ces measuring the urban-rural transition zone are calculated for numerous urban regions in the Baltic Sea area. At a more detailed level, methods for calculating environmental indicators concerning biodiversity, aquifer sensitivity and construction suitability is presented. Various approaches to land-use classification are described and examples from Hämeenlinna and Copenhagen are presented. At the end of this chapter, some methods regarding socio-economic indicator creation are introduced. These methods are primarily concerned with the evaluation of urban costs and environmental impact assessment related to construction of buildings and roads, transportation and energy consumption. However, also a tool for estimating road traffic noise is included.

Finally, some technically interface tools – among others a Web-based interface to the methods and tools, the so-called Planner's TOOLBOX, are described. Information technology plays a key role in the PSSD project. As mentioned above the whole project is concerned with GIS based planning – primarily using the grid data model. Additionally, the methods and tools developed within this project were put into a Web based so-called Planner's TOOLBOX. Tools for aggregating and integration spatial data are developed, making data conversion into grid format easier. Basically the Internet has a wide support for dynamic visualisation compared to traditional papers. Therefore, techniques for making dynamic maps are presented. On the one side, a time-series animation of spatial data is presented, and on the other side it is shown how to use shareware components for making interactive maps on the Internet. Finally, Finnish Environment Institute describes the overall concepts and ideas behind the Planner's TOOLBOX.

1 Introduction

This report presents some of the most significant methodical results of the PSSD project. However, it is important to notice that at the moment of writing some of the partners co-projects were still not yet finished. Thus the main purpose of this report is to inspire reader to visit the project's public Internet web site at http://www.pssdtoolbox.net where the complete results can be found in the Planner's TOOLBOX - a common end product of the PSSD project. Also a lot of other basic information about the project is available there. To provide the reader with a general over view of the outline and the contents of the report this introduction briefly describes the purpose and the approach of the PSSD project.

The full name of the PSSD project is "PSSD — Planning System for Sustainable Development. GIS-based planning method, application and decision support system for promotion of sustainable spatial planning in the Baltic Sea Region". PSSD was one of the 45 projects implemented under the Baltic Sea Region's INTERREG II C program, co-financed by the European Union under its structural development funds. The PSSD project was targeted at realising the measure 7.2.1 ("Further development of spatial planning strategies and exchange of experience in the field of spatial planning") of the priority 2 ("Promotion of a spatial development approach in the Baltic Sea Region") of that program.

The PSSD project involved development of GIS-based computer aided tools to promote sustainable spatial planning and development in the Baltic Sea Region. Selection of indicators and analysis models and methods for GIS-based mapping was further improved so that it is now hopefully possible to take into account more effectively the natural environment and socio-economic factors including their combined effects during the various stages of regional development and spatial planning. The GIS-methods under development were mainly based on grid technology, which shows fresh potential again today. The project aimed at exemplifying this potential in spatial planning and development.

The objectives of the project were to create a prototype for the first common GIS-based regional planning method in the Baltic Sea Region and a computer aided tool for common use of the method. With these ambitious aims the PSSD partners wanted to call attention on the fact that at present it is almost impossible to produce comparable regional analyses on maps — especially at international level — because of lack of jointly agreed GI calculation methods. The other general argument of the PSSD was that spatial planning without maps is inadequate. The idea behind the term prototype was that the first version of the common method would be created without any wider international needs analysis. As experience shows there must be a base proposal before the real debate can start.

It goes without saying that a single project with limited time and resources is incapable of producing a totally new and widely accepted planning method at a first try. The integration of GI analysis methods in the PSSD remained uncompleted. Therefore, evaluating the results of this project, attention should be paid especially to the GI analysis methods chosen. Most of them are based on so-called grid techniques, selected as a hypothetical solution to the problem of data integration. The first question could be: are they appropriate for wider international use or not? The second question could be whether it would be possible to base some real-life joint spatial planning on them or not.

The project co-operation approach was based on user-producer relationship between the regional planning organisations and the national research institutes. The planners set up problems for the researchers, who tried to produce suitable GI tools for these purposes. A general copyright problem of the national GI data sets was one important reason for this approach. Actually the copyrights were so prohibitive that they nearly completely kept partners from exchanging data and prevented the internal co-operation in this field. The second cornerstone was every partner organisation's own co-project. The idea was to use as much grid techniques as reasonable in real-life spatial planning tasks of a partner. The international work groups — the third cornerstone — were set up to create a common framework for the co-projects and to work out some common methodical solutions from the partners' results.

Each of the nine involved partners contributed to the project by specific subtasks involving either development or testing of grid methods. In addition the partners had common tasks. The Finnish Environment Institute investigated bringing together GIS-data on the natural environment and socio-economic factors. The Geological Survey of Finland developed methods of utilising geological data in spatial planning. The Technical Research Centre of Finland produced evaluation methods to find environmentally sound, cost effective and competitive areas for construction. The Baltic Region Healthy Cities Office investigated, on the one hand, indicators of inhabitants' health and social well-being with reference to urban planning, and on the other, their visualisation on maps. A noise model was constructed in the test area. The Danish National Environmental Research Institute studied ways of visualising the spatio-temporal aspect using grid technology. The subtasks of the Danish Forest and Landscape Institute involved investigation into the potential recreational uses of the natural environment and their accessibility. The Technical University of Hamburg-Harburg developed testing and quality evaluation methods to be used in the study of indicators employed in spatial planning following the principles of sustainable development. They were used to assess the indicators used in the other project subtasks. Some methods, analysis models, and tools developed within this project were at the same time tested in practice in the spatial planning of the South Finland Regional Alliance (seven South Finland regions) as well as of the Danish region of North Jutland.

OpenGIS was more or less under discussion throughout the project. It is an international consortium that defines open application interfaces for GIS. OpenGIS together with Internet technologies may revolutionise the way GIS-products are made and sold. In the short run though there was no effect upon PSSD foreseen and that is why the OpenGIS principles were not stressed.

Finally though, it is necessary to stress the exemplifying nature of the methods presented in this report. They were found suitable for the target areas of this project and are hopefully useful for many other areas too. However, in general much more international discussion and demonstrations are needed before one method generally better than others can be pointed out.

2 Theoretical and methodical framework

The current chapter describes the basic theories and methods behind the PSSD project. Sustainability is one of the key concepts behind our planning system and below you will find a short introduction to the basic ideas concerning sustainability. In this context, indicators play an important role. The PSSD project is widely based on GI technology and this chapter explains some basic concepts concerning grid based spatial information.

2.1 Sustainable development

The most widely sited definition of sustainable development was given in the 1987 report "Our Common Future" by the World Commission on Development and Environment:

> "Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCDE, 1987).

This definition is characterised by being expressed in broad philosophical terms defining a general political goal for the future development. The combination of the terms development and sustainable reflects the desire to ensure human welfare, prosperity and well-being (development) without destroying the environmental foundation (sustainability) for this development. Hence, spatial planning for sustainable development should promote economic and social development while simultaneously ensuring the protection and conservation of the natural environment and cultural heritage.

Generally, sustainable development can be defined in terms of three main components

- Ecological sustainability
- Economic sustainability
- Social/cultural sustainability

The components are to be considered as three interdependent dimensions of sustainability (fig. 2.1). Consequently, all three types of sustainability criteria must be met simultaneously.

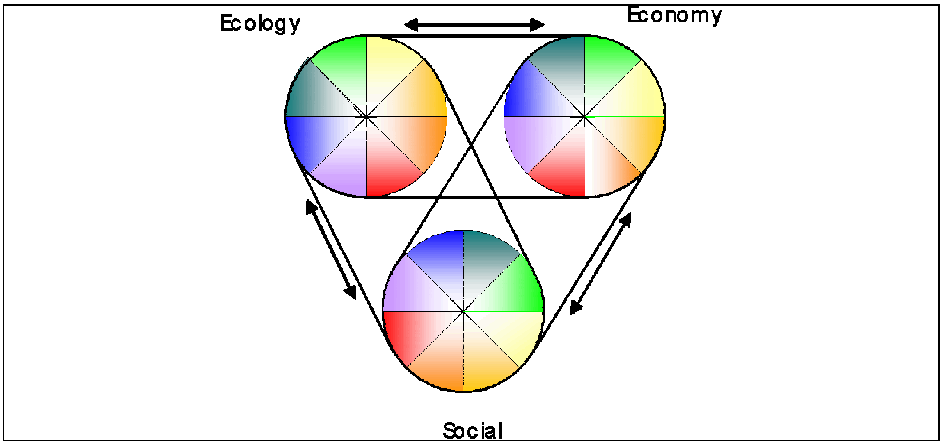


Figure 2.1. Three components of sustainable development (Teichert, 1998)

Various methodological approaches for sustainability assessment have been developed:

- Multiple qualitative and quantitative indicators
  This approach is consistent with interpreting sustainability as the ability to meet a diverse set of goals where no single indicator exists. Several system attributes believed to influence sustainability are identified and measurable indicators defined. A negative change in an individual indicator suggests that the development is unsustainable.

- Adherence to prescribed approaches
  This approach interprets sustainable development as the adoption of alternative ways of production, living etc. In this way, households are considered sustainable, if they reduce e.g. their water consumption.

- Time trends
  This approach assesses sustainability in terms of the direction and degree of measurable changes in system properties.

- Resilience and sensitivity
  Here sustainability is defined as the ability for a system to maintain its productivity when subject to stress.

The method of *multiple qualitative and quantitative indicators* has been chosen for the PSSD project. According to UNCSD (1999), indicators are signposts that can point the way to sustainable development. While there is still no precise definition of sustainable development, *indicators* can help us to show whether we are moving in the right direction – or not.

However the evaluation of sustainability by the use of indicators – as well as other methods – are complicated by the fact that:

- A clear answer to the question "What is sustainable development?" does not exists.

- The complexity of the system implies lack of knowledge of cause-effect relationships.

- The phenomena are working on various spatial scales.
- The phenomena are working on various time scales.
- Indicators differ in the directness of measurement - direct, proxy or indirect measures.

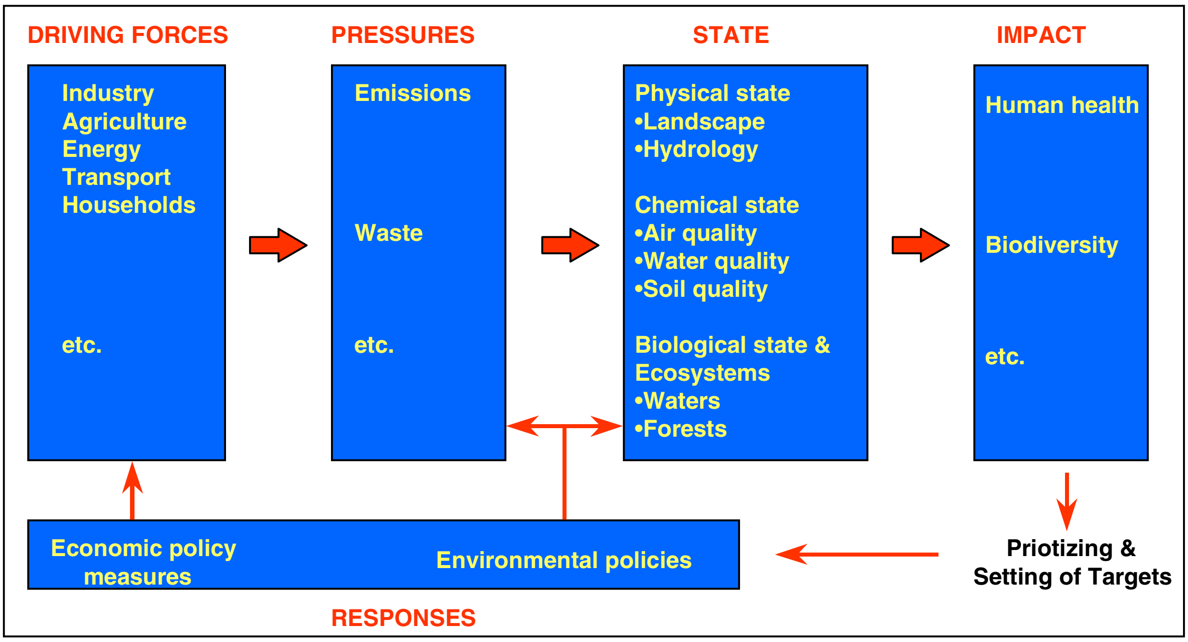


Figure 2.2. The DPSIR framework.

Spatial planning is related to space and directly related to the key issues of sustainable developments due to the cross-sectoral and integrated approach needed. This calls for a framework for structuring information in cause-effect relationships and related indicators. Thus, OECD uses a Pressure-State-Response model for organising environmental information. Human activities (pressures) exert a pressure on the environment, which result in the quality and quantity of natural resources (states). Society responds to these changes through policies (responses).

UNCSD has replaced the term Pressure with Driving Force. In the PSSD project the DPSIR framework of the European Environment Agency (NERI, 1995) has been adopted. According to this framework, a chain of causality exists from *Driving forces* over *Pressures* to environmental *States* and *Impacts* on human welfare, finally leading to political *Responses*. Figure 2.2 illustrates the DPSIR concept.

For the PSSD project the framework for assessment of sustainable development can be outlined as follows:

- A GIS based platform for assessment of spatial planning alternatives with respect to sustainable development,
- A mosaic approach is used – i.e. sustainability is evaluated in terms of both ecological, economic and social factors,

- The indicators support assessment of sustainability of planning alternatives in terms of compliance with the goals of regional / national / international action plans,

- The DPSIR framework is used to relate cause-effects relationships, i.e. organise information in relation to Driving forces, Pressures, State, Impact and Response.

<u>POPSI - a new approach for sustainability indicators</u>

POPSI means „Precaution Oriented Paths of Sustainable change towards Information societies land use“ and represents the planning theoretical approach for sustainable planning developed in Harburg (Germany). Sustainable planning is the new challenge in times of emerging metabolism. POPSI was required instead of DPSIR because in times of emerging metabolism this behavioural impulse-reaction-approach was not adequate in any way. Sustainability implicates provident acting not "fixing" things afterwards (fig. 2.3).

In comparison to POPSI, DPSIR does not represent a planning theoretical approach but a social respectively political scientific concept, which traces back to the Pressure-State-Response-Approach from the seventies. Consequently, the DPSIR framework responds quite well the longest obsolete first phase of the reacting environmental protection of the seventies. Furthermore, under the viewpoint of sustainability it is criticised that people do not act before situations deteriorate. Different phases of processes do not correspond with planning periods and societal patterns of reaction. The Environmental Impact Assessment (EIA) – since 1985, an EU-Directive – was precaution-oriented and thus further than DPSIR. The simple assessment of consequences goes already beyond. POPSI represents more than only an advancement of the assessment of consequences and precaution oriented prevention. It is about coming into methodical solutions producing sustainability and not only about preventing 'non-sustainable' situations.

New technologies are driving today's Information Society and offering many specific and attainable routes to sustainable development through their contributions to achieving greater economic well-being, reducing material consumption, supporting increased eco-efficiency, promoting more sustainable lifestyles, and improving democratic governance in modern society. The effects on the environment, the society, space etc. are quite different from those of the industrial society. For example, there is another kind of pollution, which doesn't seem to affect the environment as well as the society (health, living conditions etc.) as much as the smokestack industries did in former times. So we have to take these facts into consideration by examining present and new indicators for a sustainable development.

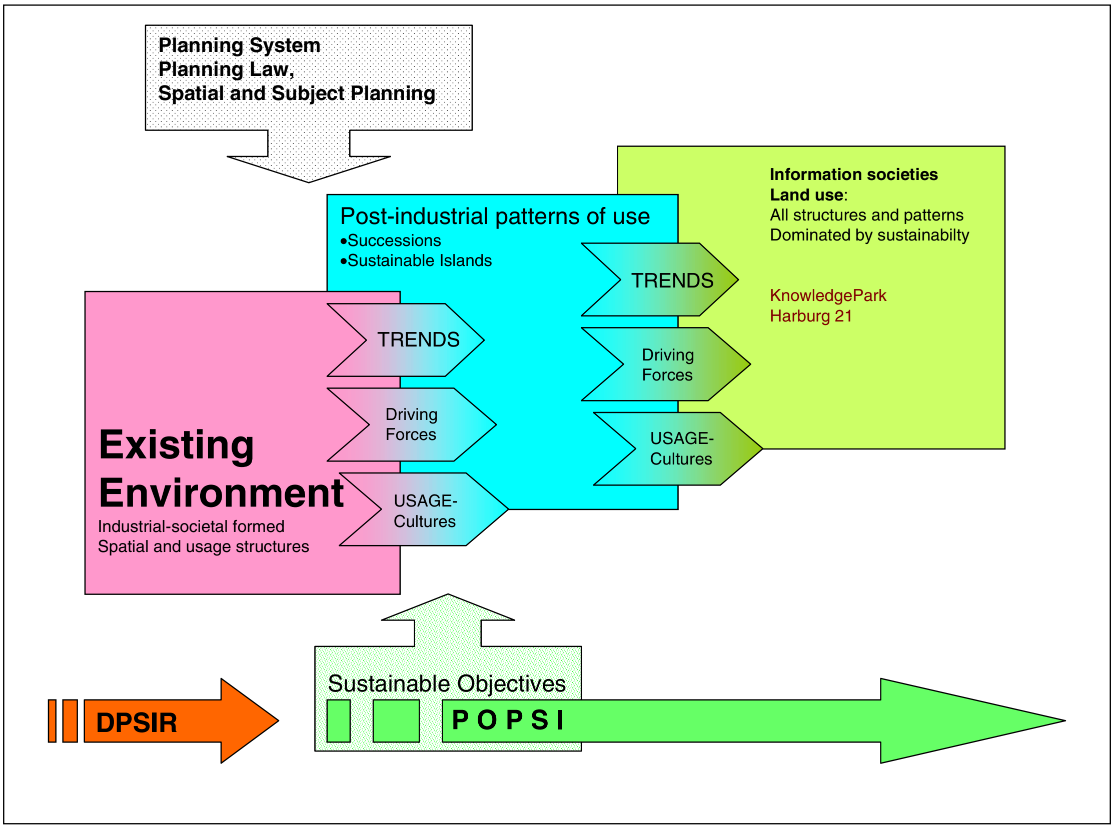


Figure 2.3. The POPSI Concept.

2.2 GIS in the planning process

Geographical Information Systems (GIS) and related computer-based information technologies are being used routinely in contemporary public planning and management. GIS, having a significant part of its methodological and theoretical background in the realm of the 'Quantitative revolution of geography', is often accused of being inherently chained to rationalism and positivism, and therefore not relevant for being used in the context of planning approaches more open than rational, synoptic model. As part of the PSSD project, the role of GIS in the planning process were investigated, especially in terms of non-rational approaches and phenomena's. As a framework for the discussion, the five approaches to planning included in the SITAR-model - Synoptic, Incremental, Transactive, Advocacy, and Radical planning are addressed.

The main motivation of the present work was to assess the way GIS is influencing physical planning at present and in the future. In a naive way it could be asked whether GIS is good or bad for planning - e.g. in terms of procedural efficiency, better steering, ability of coping with longer periods of time or more complex problems, or eventually as a democratic, communicative exercise. Further, it can be asked, whether GIS as a method ultimately will or should influence acknowledgement and perception of our surroundings.

It has often been claimed that planners and GIS-professionals do not speak the same 'language' (Geertman, 1999). What is the language of planners then? And what language is the GIS-people using? Is the lack of success in implementation of GIS in planning entirely a matter of discourse. At least part of the consideration of incompatibility of GIS and planning stems from the debate of GIS being an entirely positivistic discipline or method. On scientific theoretical grounds the issue - especially in the context of the use of scenarios - has been investigated. The matter can also be seen as a dimension of the general tendency of technologies to be idealised standardised attempts to copy, aid or fulfil human activities or desires.

The linkage of GIS and rationality and thereby the rational, synoptic planning-model often makes it inherit the claimed shortcomings of rational planning. Then the question will be if GIS is unavoidably chained to rational planning and, if not, how it can be discussed in terms of and applied to alternative planning traditions and theories.

Several counterpoint schools of planning, takes their point of departure in the shortcomings of the Synoptic planning tradition. The most important includes *Incremental planning, Transactive planning, Advocacy planning and Radical planning* (Hudson, 1979). The five planning traditions - commonly referred under the acronym SITAR - is an attempt to classify planning traditions, not to draw rigid demarcations between the traditions, but rather to understand the differences in theoretic background, goals, and means. It is not the idea of the SITAR-model that any of the five modes of planning could or should be played by it self. They should be applied alongside in the planning process, when found feasible.

As long as the activity is well within the limits of the technology and as long as it is possible to adapt the technology according to the changing needs, it is fine. But, when human needs change dramatically or when a technology has come to a closure, there will be a tendency of the technology setting the agenda of development rather than the human needs. Much of the present discussion on GIS and planning is to prevent GIS to come to a closure, sub-optimal to the needs of planners and the planning process.

When discussing planning theory, the point of departure will be whether the focus is on the ideological, normative theories behind our understanding of society, the theories *in* planning, whether it is the theories behind the methods used *for* planning, or whether the planning theories are addressing the processes and role in society - the theories *about* planning (Strand, 1989). Further on, Strand (1989) continues categorising the theories about planning into theories concerning the *role* of planning, its *procedures* and finally its *results*. Discussing GIS and planning, it is the *theories about the planning procedures* being in focus.

The discussion of GIS and planning has to a large extent focused on the technology as a facility to planning, i.e. theoretic considerations have been theories *for* planning. The resent development - of which the present text is an attempt - is analysing the role of GIS in the planning process - in other words the focal point is moving from GIS in the context of theories *for* planning to the context of theories *about* planning. Other recent examples are found in Geertman (1999) and Masser & Ottens (1999).

Loosing the inherited bonds between GIS and the rational planning approach would probably facilitate a larger extent of implementation of GIS in contemporary planning. But, as is acknowledged with rational planning, the GIS-developers have to relinquish some of the systematic and linearly process-orientated preoccupations. Software has to be open and flexible, supporting the processes of development and application.

Despite of the acknowledgement of the theoretic problems of objectivism and rationality, it is rare to find examples of reference to the very basic shortcoming of the use of GIS and multimedia in planning - the fact that only the issues and phenomena's that can be formulated in terms that is 'understood' by the computer can be included. There is no way that the feeling of being alive, family-relations, the sense of safety, fear of war etc. can be addressed. All together it is also true that if you expect a process that includes modelling a prediction of future situations, you have to accept a quantifiable, algorithmic point of departure of at least the phenomena under consideration. Baring this in mind, it becomes evident that no single media - GIS, multimedia or something else - can be too dominant in the planning process, and even less should there be a confusion of technology actually being planning itself. It is a facility, not a process.

2.3 Grid methods

A planning system for sustainable development involves a wide range of different spatial data, but integrating different kind of spatial data may often cause problems. Many data in the social and environmental sciences are collected for polygon units, but the systems of units often differ between the different data sets. Environmentally defined regions such as vegetation zones or watersheds will seldomly match the boundaries for officially defined zones like counties and municipalities. For example, air quality and traffic count data are collected and usually reported as point data, whereas land-use is reported as polygons. Population data is collected by points (households) but reported by region (parish or municipality) due to confidentiality requirements.

Following the DPSIR framework (fig. 2.2), data describing the driving forces are often collected at municipal, county or even national levels. However, variables related to pressures and states often represent observation points or internally homogenous polygons like land-use and soils. Spatial units defined for environmental data and the underlying data model is derived from the spatial variation itself - and therefore unique. Socio-economic units are nearly always the products of some political process - they are administrative units, and they are subject to change over time (Hansen, 2000).

Trying to reconcile two sets of data, collected over different tessellations, such as municipalities and watersheds, is a very difficult task. First, one must decide which layer will be the "standard" and which will be the one cut up to fit the other. Then you have to break up the regions of one layer and fit the pieces into the other layer (a very complex and time-consuming task for a GIS). Finally, one must partition the data values from the first layer into the second.

Instead of representing geographic features as polygon objects, space can be divided into discrete squares called cells, for which the values are stored. A cell is a uniform unit that represents a defined area of the earth, such as a square meter. Using this approach, points can be represented by one or a few contiguous cells. Lines can be represented by a series of cells that have a width of one or a few cells, whereas polygons can be represented by a range of cells (fig. 2.4).

Grid cells do not change over time in the same way as for example administrative units. Therefore, a cell-based system is better suited for different kind of change analysis. These cells can be encoded in raster or vector format, and in the present situation we will use vector based cells, but it is rather easy to convert data from vector to raster and vice versa.

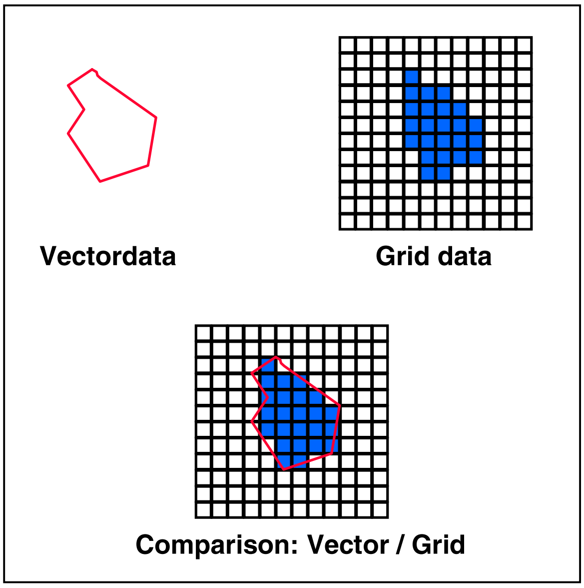


Figure 2.4. Cells versus ordinary polygons

The main advantage of using vector based grid cells compared with raster based grid cells is the possibility to assign multiple attributes to vector based grid cells. The most important disadvantage of the vector based grid cells is the lack of any compression technique. One difficult problem is to choose an appropriate grid cell size. Usually, you want the smallest possible grid cell size, but you have to consider some aspects pointing towards bigger cell sizes. First, it might be troublesome to handle data sets containing millions of grid cells, but this problem can be solved using raster based grid data sets with some kind of compression – for example run-length encoding. Secondly, some socio-economic data requires a minimum cell size due to confidentiality issues.

2.3.1 Map algebra

The analytical capabilities reflect the fundamental relationships between classes of spatial objects. In grid based systems the functionality is based on the map-algebra developed by Tomlin (1991). Map algebra is a spatial mathematics that uses sequential processing of mathematical primitives to perform complex map analysis. It is similar to traditional algebra operations, but in map algebra entire maps represent the variables. Map algebra includes most of the traditional mathematical capabilities (addition, subtraction, exponentiation) plus an extensive set of advanced map-processing primitives, based on the coincidence and juxtaposition of values among and within maps, e.g. masking, proximity and optimal paths (Berry, 1993). Following Tomlin (1991), the operators of map-algebra can be classified into local, focal, and zonal operations:

- *Local operations* compute a new value for each location (grid cell) as a function of one or more existing values associated with that location (fig. 2.5).

- *Focal operations* compute the new value of each location as a function of values, distance and / or directions of neighbouring locations on a specified map layer (fig. 2.5).

- *Zonal operations* computes a new value for each location as a function of the existing values from a specified grid layer which are associated not just with the location itself but with all locations that occur within its zone on another specified layer (fig. 2.5). Zones are sets of locations in a map layer with identical values.

This classification represents a developer-oriented view on GIS capabilities. An alternative view is the user-oriented, which focus on input and output products. From this point of view, Berry (1993) identifies four functional groups:

- *Reclassification operations* assign a new value to each map feature on a single map based on the feature's position, initial value, size, shape, or contiguity.
- *Overlay operation* assign new values summarising the coincidence of map features from two or more maps based on a point-by-point, region-wide, or map-wide basis.
- *Distance measurements* assign map values based on simple or weighted connections among map features including distance, proximity, movement, and connectivity (e.g. optimal path).
- *Neighbourhood operations* assign map values that summarise conditions within the vicinity of map locations (roving windows) based on surface configuration or statistical summary.

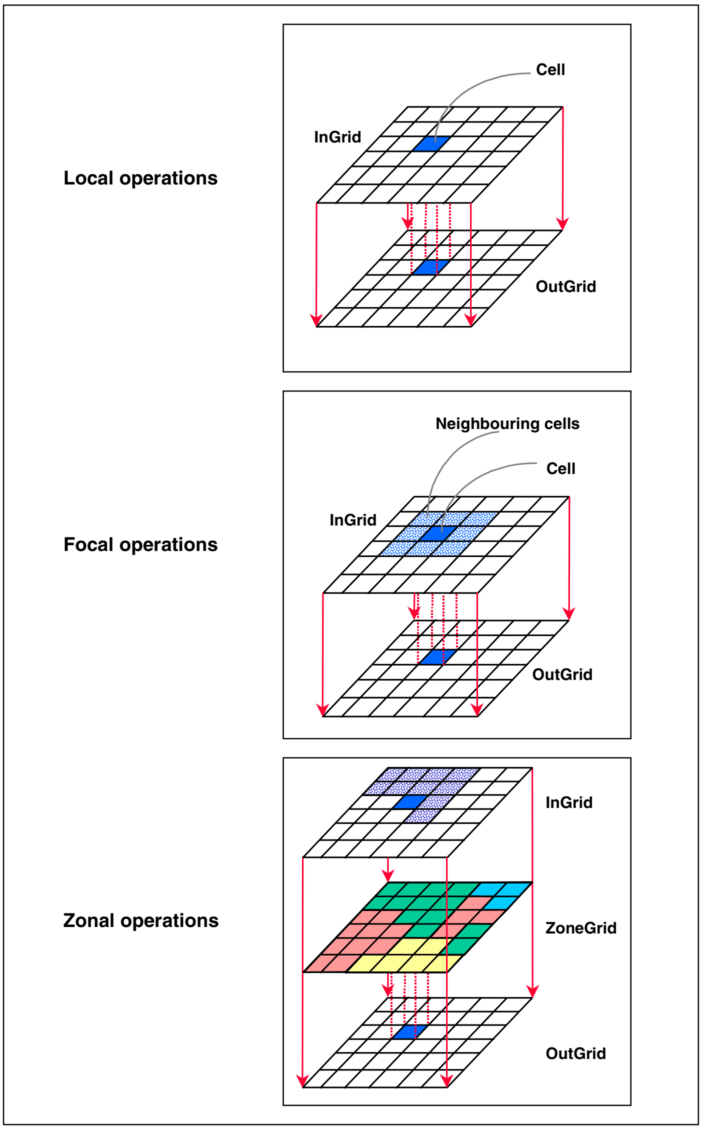


Figure 2.5. Operations on grid cells

2.3.2 Advantages and disadvantages using grids

Below some advantages and disadvantages using the grid data model are presented.

Advantages:

- Grids do not change over time, enabling temporal comparisons
- Fast management of huge collections of geographic information
- Due to the aggregation, grid data are generally cheaper than original point data
- Less privacy protection problems than for point data
- Easy to generalise to larger polygons
- Grid is a neutral unit
- Easy to transform from vector to raster and raster to vector

- Easy to produce time series, forecasts and models
- Grid generalises errors or pseudo accuracy of point data.

Disadvantages:

- The grid cell is an abstract unit without any association to the real world objects. Only an instrument to analyse GIS data,
- Not useful to produce strict boundaries at local level (e.g. cadastral boundaries),
- Networks are poorly represented by grids.

2.3.3 Using grids in geology

The geological mapping data (bedrock and superficial deposit maps) is usually in vector format. This data is, however, suitable for conversion to grid format. The geological surveys have also continuous-scale data, e.g. aero-geophysical and interpolated geo-chemical data. This raster data can be combined with vector mapping data, which has been converted to grid format in order to produce new data sets.

One of the aims when developing the GRID-method is to investigate the appropriate grid cell sizes to be used. The problem is how to combine socio-economic data, which often have coarse grid cell sizes with the environmental data that can be relatively detailed. Since geological environment in Finland is variable and detailed in comprehension with sedimentary bedrock areas elsewhere in Europe relevant data can be lost even in the case of using grid cell size as small as 100x100 meters. Appropriate generalisation of geological data requires knowledge on the geology in general, geological data in question and, what is also important, on the quality of this data. On the other hand the generalisation method depends on the results aimed for.

The reclassification of grid data is a basic operation in the processing of geological data for land-use purposes. The number of classes in the resulting grids and maps should be three to five at maximum. This viewpoint is based on previous experience and feedback, e.g. in the Finnish national EnviGrid-project (Geological Survey of Finland). The grid processing methods for reclassification and generalisation of geological data should be simple but not simplistic. This can only be achieved with the deep understanding of planning phenomena, geology and geological data. Feedback from the planners is vital in reaching the aim of delivering geological information for sustainable planning.

2.4 Framework for socio-economic indicator creation

2.4.1 Theory of spatio-temporal changes

Land-use changes are usually rather slow. It means that analysing the past or the future development we need data sets for long periods. There are two remarkable issues that we have to take into account:

- *The entity that we are analysing changes itself* (like bank offices). Bank offices were important local services in Finland 10 years ago. Nowadays, it is not so important to have these offices near by due the IT-techniques (e.g. on-line banking terminals). So what will be the future bank service?

- *Spatial and temporal comparability* means that we need areas and data sets that are made with the same method (criterion). The essential problem particularly with homogenous areas is that the phenomenon changes both temporally and spatially. This deviates from the normal statistics-based exploring, where geographical area is in general unaltered in relation to time (for example municipal units).

The figures 2.6 and 2.7 present three different ways of analysing spatial and temporal changes. The examples present past development of a densely built-up area between the years 1980-1995. Figure 2.6 illustrates three different ways of monitoring regions that change spatially and temporally:

- A - the extent of the region to be monitored is kept as it was in the initial situation.

- B – the extent of the region is allowed to change by the spatial change of the phenomena under observation.

- C – the extent of the region is set to the level as it has in the final situation. In the C1 case, the region in the final stage is projected on to starting point by the parts that fulfil the criteria given in the starting point. In the C2 case, the region in the final stage is projected on to the starting point as it is.

All the monitoring options can be justified. If the monitoring is an ongoing process options A and C are out of the question. Option A would before long lead to a region that would not match reality at all. Option C, on the other hand, is impossible when it comes to continuous monitoring, because the final stage is unknown. Under the circumstances, option B is the only possible basic system for the monitoring based on changing region.

2.4.2 Comprehensive planning

Regional planning has traditionally been mostly physical planning, but today we are concentrating on a more comprehensive planning, making plans for the overall development of the regions and local administrations.

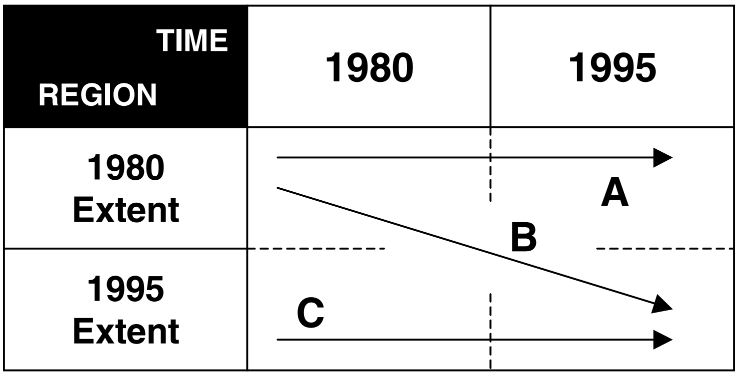


Figure 2.6. Alternative ways to monitor regions that changes spatially and temporally

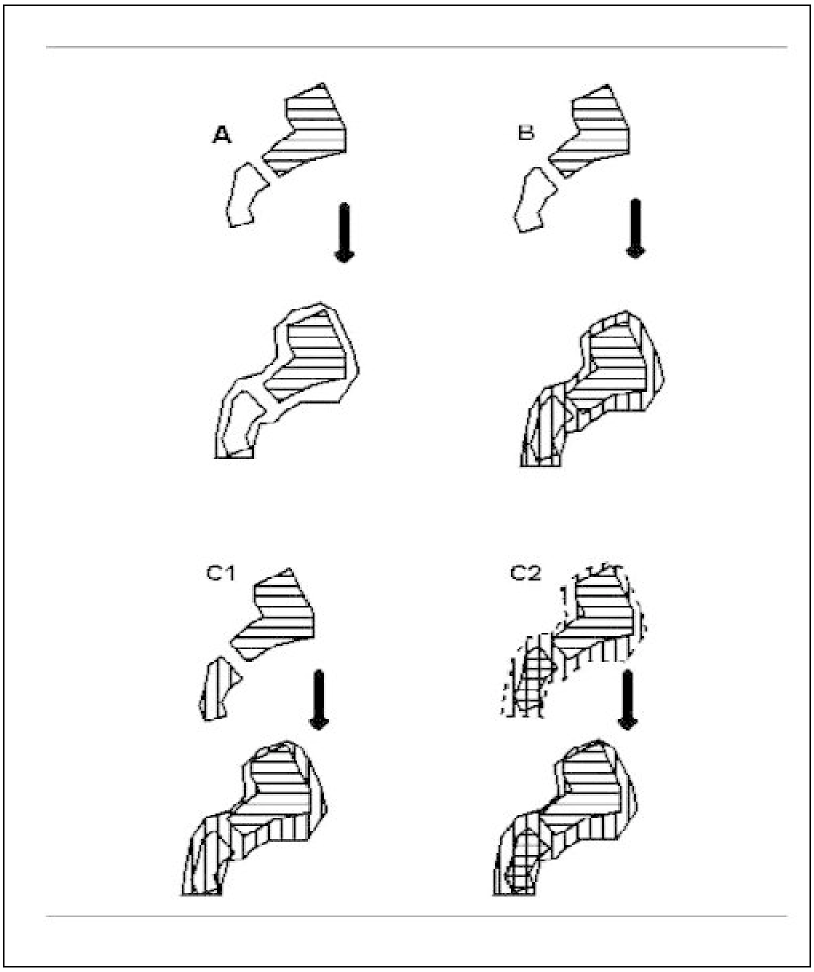


Figure 2.7. Options for the monitoring spatial structure.

As mentioned earlier, the definitions of sustainable development should include three main factors: ecological sustainability, economic sustainability and social or community sustainability. The chosen indicators should reflect this division. Population health is an important part of social sustainability. The theoretical basis here is the conceptual model of Trevor Hancock (based on the ideas of Hancock in Hancock, T. & Duhl L. Promoting health in the urban context. Copenhagen FADL, 1988), who presents the three dimensions of sustainability: community, environment and economy (figure 2.8).

The figure showing the health gradient (figure 2.9) shows the background factors, or determinants for health. As indeed most of these factors are outside the sphere of influence of the individual or the health professionals, it becomes clear that they need to be taken into account in all regional, local and national plans for sustainable development, and the chosen indicators should reflect this fact.

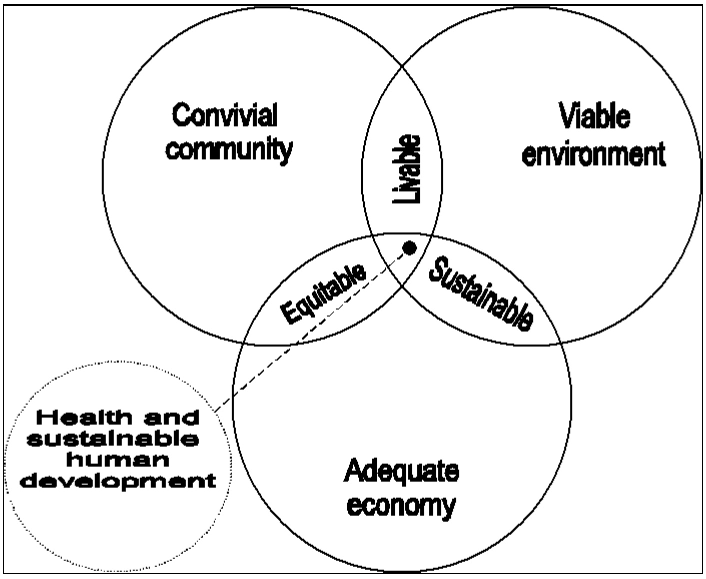


Figure 2.8. Conceptual model and planning tool (WHO Europe, 1997).

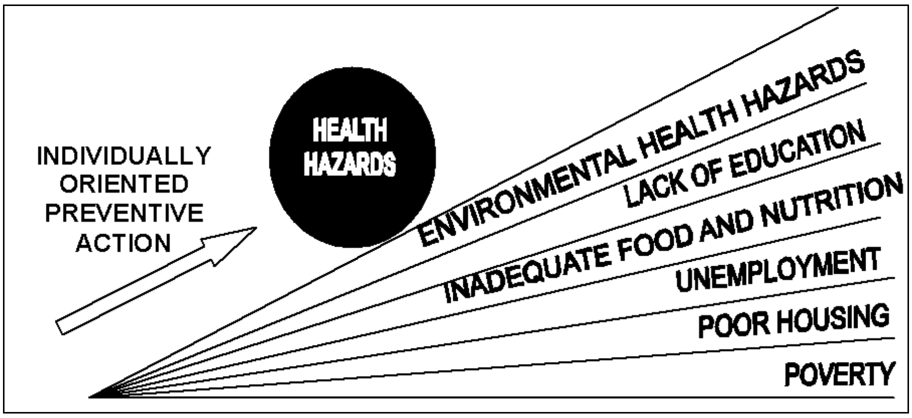


Figure 2.9. The health gradient (WHO Europe, 1997).

2.4.3 The choice of indicators

The choice of indicators depends on what we want to do with the indicator. The indicator can be used to demonstrate a point, to influence the decision-makers or the great public, or the media to monitor development and as a measure of what the organisation is doing. The indicator can be a strategic or a technical tool. To be useful the indicator does not have to be complicated or 'scientific' – we should bear in mind that what we call an indicator is often an image, a picture, a sign of what we are trying to describe.

The data should be readily available year after year to enable the planner to follow up the trends. The socio-economic indicators are used for all of these reasons, and a typical set of indicators comprises information on demography, income and education level of the population, health, public services and their use, economy of the city (tax collection, unemployment), housing, environment.

We should be looking at the planning phenomena from the point of view of overall sustainable development of the communities, not only physically but socially and economically, too.

3 Present and new indicators

Besides new methods for identifying the regional status quo and development paths there is still a need for the identification and management of indicators even though there are lots of already defined sets of indicators. Furthermore we need new methods for generating and assessing the indicators of regional sustainability (IRS) as well as for comparing different regions. The TUHH looked for new approaches and methods, which take sustainability into consideration in comparison to existing concepts.

Describing future development and expressing sustainable development by sets of new indicators requires an approach, which does not describe only the status quo. On the contrary, we need indicators which describe the metabolism and impacts of an information society and their implemented development patterns because very different social structures can emerge from the development of the information society depending on pattern of technology use and collective mind sets. For monitoring the development of patterns of settlement, energy and material flows and their forces it is necessary to differentiate between society requirements and various usage in space and time. Using development stages a long-term development trend can be deduced (fig. 3.1).

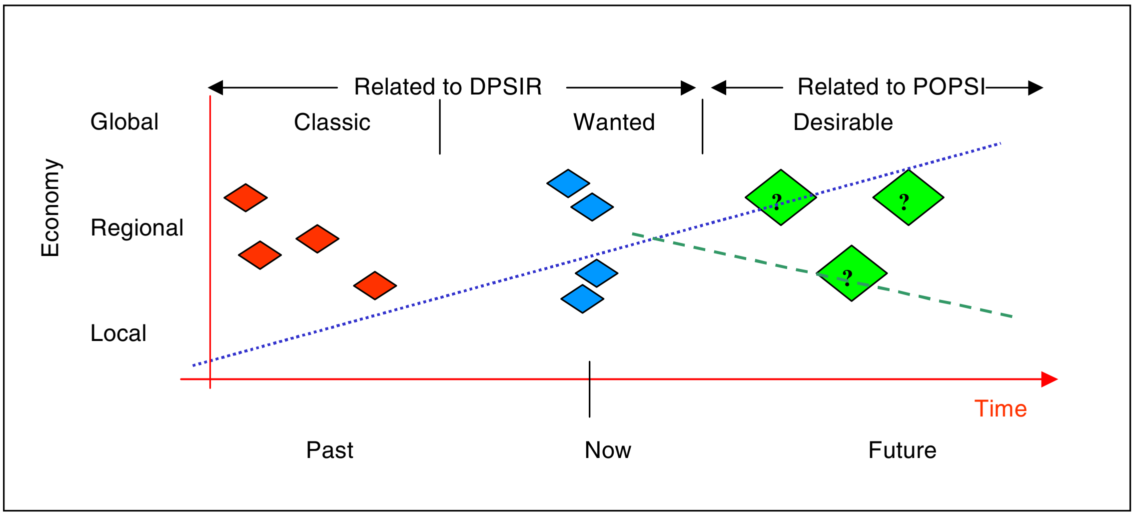


Figure 3.1. Force of expression of indicators

The new information society, which differ from former ones, has its own metabolism with its own impacts on development and is leading to new kinds of development patterns. This is also cited in another project of the European Commission called ASIS (Alliance for a Sustainable Information Society). "The new technologies of the Information Society, and the changes they facilitate and induce in society, provide unique opportunities to help achieving Sustainability, but is not always clear how to capitalise on these opportunities. The objective (...) for a Sustainable Information Society is to demonstrate how best the objectives of sustainability can be supported by inducing an appropriate direction to the development of the Information Society. (...) This society may be seen as the next step along the path towards a fair, fulfilling, prosperous and sustainable world" (European Commission, 2000).

3.1 Identification and Management of indicators

The generation of a sustainable indicator set by the Indicator Generator and the assessment of it with the Quality Check tool are both following the syndrome concept and the metabolism approach.

The development of regions is based on a life-cycle concept of successions of use, whose products influence again further developments. The development lines, bifurcation and basic patterns of succession make possible their own culture of use, changing types of use, processes and speed. To be able to attune to post-industrial metabolism, pre-industrial metabolism of material flows and energy levels must be overcome as well as the still existing dependency on pattern of thought of the agrarian phase.

3.1.1 Requirements for sustainability indicators

The development of indicators of regional sustainability always leads to the question of quality. A first approach is to define, which requirements have to be fulfilled to evaluate an indicator as a good one:

- *Global / regional / local*. Our aim is to develop *Indicators of Regional Sustainability*. However, global and regional objectives of a sustainable development should not contradict. Therefore it is important to evaluate, if the chosen indicator works on a global, regional or local level and if predications on a regional level are possible.

- *Ecological / social / economic aspect*. Sustainable development requires looking at social, environmental and economic aspects in an integrated way, and to consider inter linkages between these three aspects. We decided not to require the definition if an indicator is an ecological, economic or social indicator, because sometimes indicators cannot be categorised unequivocally. Developers of new indicators are asked to decide, if an indicator has something to do with resource use, infrastructure or society needs or if these aspects are combined.

- *Spatial reference*. The selection of sustainability indicators requires the consideration of different spatial structures. Indicators and evaluation criteria should be assigned to their spatial reference. If possible, the spatial reference of an indicator should be named and visualised.

- *Temporary reference*. Sustainable development is a long-term concept. Indicators should not only describe the present status but also visions and future objectives (time series data must consider future prognosis). Set of indicators should point to long-term and trend-setting solutions. Sometimes a short-term success conceals long-term developments. The evaluation of indicator data requires the development of evaluation criteria. The evaluation criteria should be comprehensible and logic.

- *Data*. If data is available, it is necessary to document methods of data survey. Time series data allows predications about (sustainable) developments. Therefore time series data should be preferred. It is less expensive to use data that already exists. Maybe it is possible to use established and reliable data sources.

- *Expandability*. It should be possible to expand sets of sustainability indicators. They should be open for further development.

- *Regional comparability*. Usually it is of interest to compare different regions. A set of Indicators of Regional Sustainability should contain some indicators that consider local specialities.

3.1.2 The Indicator Generator

After the determination of the requirements for indicators of regional sustainability, the TUHH developed a Web-based Indicator Generator tool for creating and identifying sustainable indicators following these requirements. Registered users have the possibility to use the tool to create new indicators of regional sustainability and to evaluate the quality of their own indicators. With this Quality Check tool we would like to support the development of suitable indicators of regional sustainability. The objective of the tool is to visualise the evaluation of a single indicator and to clarify, if something has to be done to improve its quality. Both, the Indicator Generator and the Indicator Quality Profile give some guidelines to develop suitable indicators of regional sustainability.

The users must decide for what purpose they want to use their sustainability indicators. For all users it is very important that sustainability objectives are defined and that regional or local objectives do not contradict with national or international objectives. Usability criteria might be important for users who want to use the indicator immediately. In this case it is important that data is easily available. If he or she wants to make comparisons between different regions, then it is necessary to have comparative data. If the indicator isn't usable because the necessary data is not available, this is not necessarily an argument against the quality of an indicator. Maybe a lot of work has to be done to get reliable data.

The generator is used as a uniform scheme to create new indicators on a tuned approach through the input of our partners. In accordance with the requirements defined above, the indicators are assigned attributes, which seems relevant:

- Indicator spectrum (resources, infrastructure, society), DPSIR, thematic field, usability, possible influences of indicator data.

- Spatial references: reference area (international, national...), areas of effects, relations beyond the reference areas, name of investigated area, common general validity.

- Time reference: time for realisation, life cycle phase, character of indicator.
- Linkages to other existing indicators: aggregation level of indicators (from highly aggregated to basic).
- Sources and availability of indicator data.
- Evaluation criteria from very high significance to without significance.

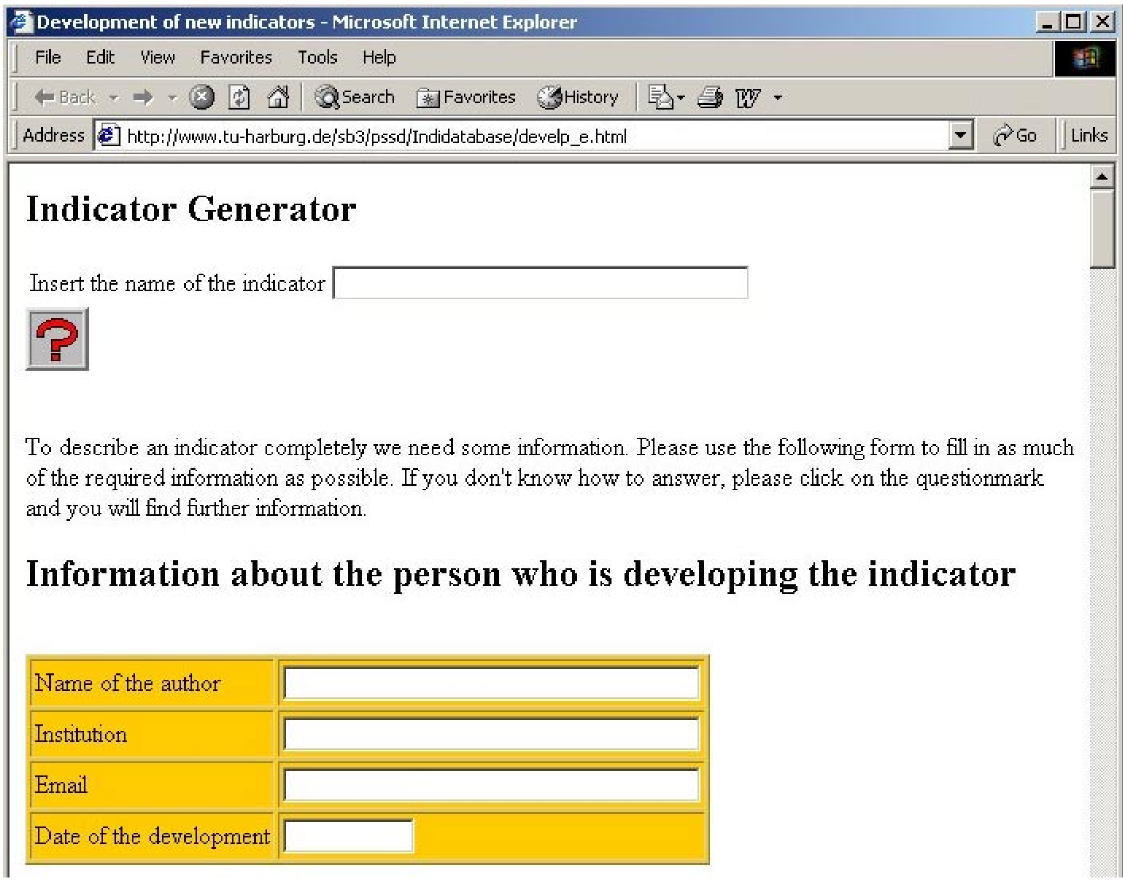


Figure 3.2. The Indicator Generator

3.1.3 The Indicator Quality Check

The Web-based Indicator Quality Check supports the evaluation of the quality and usability of a sustainability indicator by answering the questions in the sections “Characteristic of future ability”, “References of time and space” and “Quality and availability of data”. These categories circumscribe the desired requirements, which an indicator of regional sustainability shall meet. The user respectively author of an indicator can check its usability using the Indicator Quality Check from the TUHH. The user has the possibility to evaluate the practicability of an indicator by answering every single question and giving it weak or strong marks between “not qualified”, “partly qualified”, “qualified” and “well qualified”.

The Quality is described by sustainability objectives, spatial references, time references. The usability of an indicator is made up of data availability and flexibility (fig. 3.3). All proposed indicators from our partners, which were generated by the Indicator Generator and added to the Planner's Toolbox, were tested by the new modified Quality Check. The indicators are listed below and also presented in the Internet by the TUHH WebPages. The results of the checked indicators are also available in the Planner's Toolbox. The proposed indicators will be tested in the target areas in case studies with regard to their planning availability. August 2000 the list of indicators is as follows:

Accessibility potential	Nutrient effects of bedrock
Permeability of different soil types	Solar radiation index
Construction suitability	Groundwater sensitivity
Soil fertility	Soil moisture
Fragmentation of open space	Undissected landscape areas
Proportion of protected areas	Exposure to high traffic noise
Silent areas	EcoBox
Households by car ownership	Traffic by modes
Unemployment allowances	Households by socio-economic groups
Workplaces by sectors	Amount of traffic areas
Competivity	Distance mature forest
Flying squirrel	Forest patches
Health care	Loss biodiversity
Pollution	Rare species
Social service	Species hotspots
Traffic accidents	Undisturbed areas
Vascular plat species	

The indicators can be assigned to various sectors - resources, infrastructure and society. Some of them can not be assigned to one single sector, standing in the intersection of these three sectors.

3.1.4 Indicator evaluation - an example

The given example shows for each field of the Quality Check a special result. The result depends on the definition and objective of the indicator. Results may differ by the particular user of the Quality Check. The check of all indicators show that there is a lack of information, the usability and the quality of nearly any indicator in the sense of sustainability. That means that most of the generated indicators do not fulfil the requirements for indicators of regional sustainability (IRS).

3.1.5 The spatial dimension of indicators

The use of GIS technology assumes that an indicator has spatial characteristics and that a specific scale is associated as well. The scale plays an important role and restricts decisive the application of an indicator. Using an indicator in a spatial analysis context requires the space to be defined as a reference area. Most often indicators refer to administrative borders (e.g. counties) - more rarely to physical borders (e.g. watersheds). Beyond it, there are indicators who refer to arbitrary space units like biodiversity. In the latter case the use of the GRID-method (see chapter 2.5) is the most useful one. Finally, it is quite difficult to define the areas of many environmental problems. For example, the emission of carbon dioxide has a global dimension whereas noise has a local one. Therefore, the information about spatial references is of prime importance for the use of any indicator.

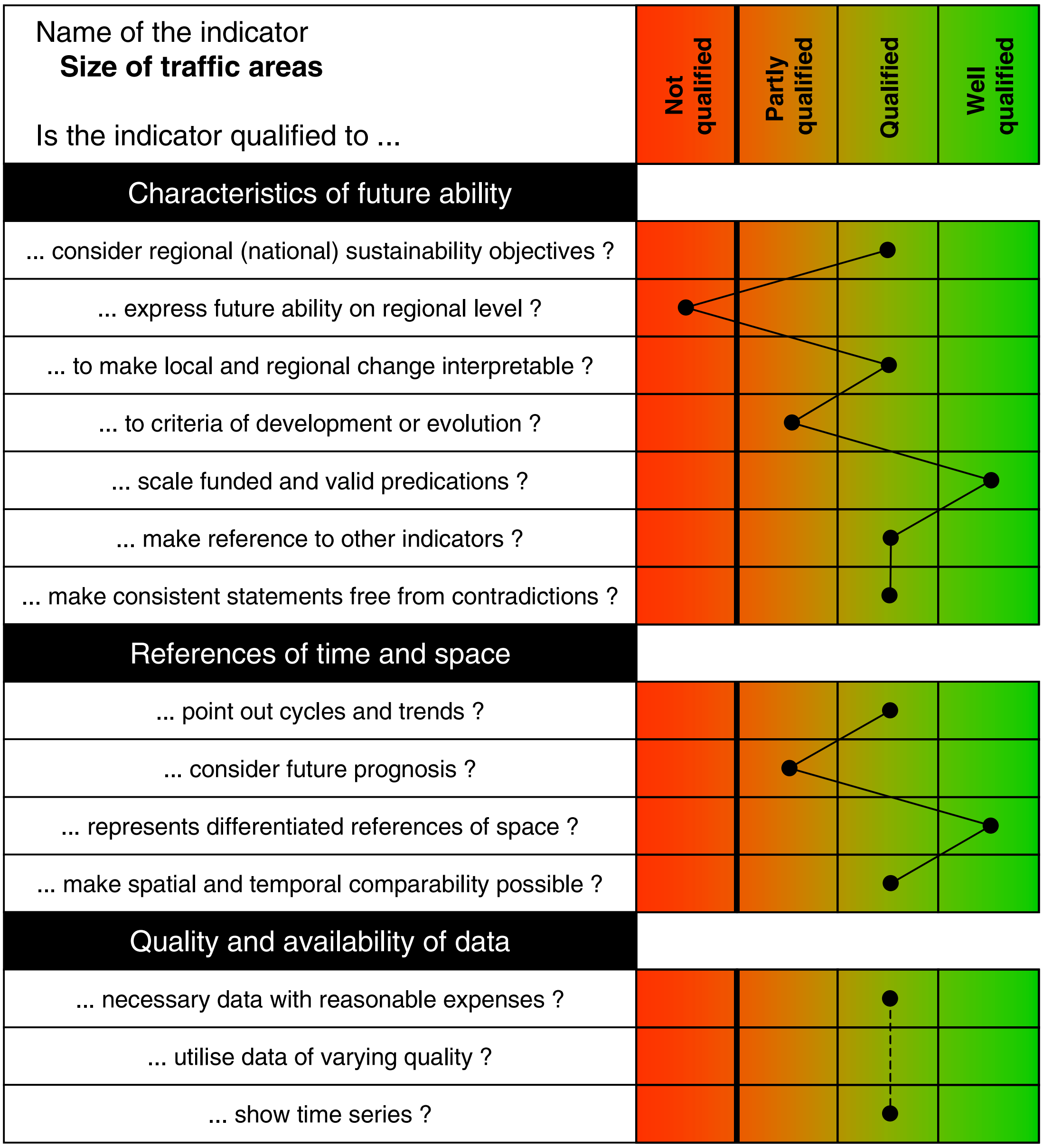


Figure 3.3. Indicator Quality Check – an example (TUHH, 2000)

3.2 Geo-indicators

The condition of environment at any time reflects not only human influences but also natural processes and phenomena, which may cause changes whether or not people are involved. Geo-indicators are measures of geological processes and phenomena occurring at or near the Earth's surface. They measure both catastrophic events and those that are more gradual, but evident within a human life span. Geo-indicators describe processes and environmental parameters that are capable of changing without human interference, though human activities can accelerate, slow or divert natural changes. They can be used in the assessment of a number of environmental processes and issues of importance to a sustainable society. (Berger & Iams, 1996).

Geo-indicators are usually designed for use in environmental and ecological monitoring, reporting the state of the environment, and assessing environmental sustainability on local, national and international scales. Following Berger & Satkûnas (1999) they help to answer questions like:

- What is happening to the environment? - conditions and trends
- Why is it happening? - causes, links between human influences and natural processes
- Why is it significant? - ecological, economic and health effects
- What are we doing about it? - implications for planning and policy

The Wuppertal Institute has developed an indicator concept for measuring the material intensity of products and services, reflecting the eco-efficiency of products. (Wiggering, 1997) During the PSSD-project, the examples developed by GTK are exemplified by the possible aggregate use of bedrock areas and suitable construction conditions. In addition the use of groundwater resources represents the material use.

The framework chosen by the GTK aims at refining basic geological information for the sustainable planning. The aquifer protection helps to provide good quality water - also in the future. Planning for future healthy environment should be based also on geology e.g. recognising areas with naturally occurring high concentrations of heavy metals and arsenic in superficial deposits, bedrock and groundwater. There is often conflict between the use of geological resources and geological protection. Objective information on the possible exploitative geological resources and natural, scientific and educational values of different "geotopes" is needed to settle down the conflicts. Investigations of scenic values and biodiversity require also knowledge on geology.

3.2.1 Framework for geological indicator creation

Geology is of primary consideration in all land-use development and management. The aim of this study is to investigate the general concepts and methodology when processing geological data for land-use planning. The geological resources comprise e.g. geological raw materials such as groundwater and construction materials as well as lithology and formations of bedrock and superficial deposits. Geological information can be evaluated for specific environmental and economic purposes:

- Locating and protecting groundwater resources
- Extraction of sand, gravel and hard rock deposits for buildings, roadways etc.
- Site selection for waste disposal or treatment facilities
- Developing and maintaining residential, commercial, industrial and agricultural areas
- Creating or restoring parks, reserves and natural areas
- Assessing the risk of geologic hazards, for example landslides.

3.2.2 Geology in sustainable planning

Sustainable planning from the holistic point of view includes geological factors, which form part of the boundary conditions for natural resources consumption, construction conditions, potential biodiversity and pollution susceptibility.

The geological indicators that were chosen for this study describe the state of the environment. Natural geological processes and changes usually have a relatively long time-scale. Short-term environmental changes caused by human activity are often difficult to investigate due to lack of relevant spatio-temporal data. The indicators dealing with the geological state of environment are for example:

- Aquifer sensitivity.
- Natural soil contamination.
- Soil fertility.
- Nutrient effect of bedrock.

The geological themes or indicators are classified according to planning issues:

Basic needs, health aspect
- Protection of aquifers, aquifer vulnerability.
- Natural risks (geo-chemical).

Environmental and protection aspect
- Protection of geo-diversity and geology influencing bio-diversity.

Economical aspect
- Construction suitability.

Special theme combining resources, environmental and economical factors
- Land-use of bedrock areas.

3.3 Healthy and sustainable cities – discussion on indicators

Community health assessments are becoming an integral to processes ranging from providing easier access to local level health and other services to improving transportation systems. Too often the planning systems are making plans for the people in a top-down fashion, instead of developing planning systems, which would promote social change and sustainability. Hancock & Duhl have presented a widely accepted definition of a healthy community for the World Health Organisation, which is based on a definition from 1986 and thus quite a long time ago. They propose the following 11 elements as key parameters for cities, communities and towns:

- A clean, safe physical environment of high quality
- An ecosystem that is stable now and sustainable in the long term
- A strong, mutually supportive and non-exploitative community
- A high degree of participation and control by the public over the decisions affecting their lives, health and well being

- The meeting of basic needs for food, water, shelter, income, safety and work for all the city's people
- Access to a wide variety of experiences and resources, with the chance for a wide variety of contact, interaction and communication
- A diverse, vital and innovative economy
- The encouragement of connectedness with the past, with the cultural and biological heritage of city dwellers and with other groups and individuals
- A form that is compatible with and enhances the preceding characteristics
- An optimum level of appropriate public health and sick cares services accessible to all
- High health status – high levels of positive health and low levels of diseases

Obviously these criteria are negating the realty. They do not indistinctive apply to the different stages of developments within the Baltic Sea region.

3.3.1 Use of Indicators in Sub-regional Planning

The Healthy Cities network has agreed to prepare a local *health profile* to collect information on the health and health determinants in the cities. The health profiles are targeted at the great public as well as the elected decision-makers and the urban planners. The question raises why only cities and not sub-urban areas are taken into account within this profile to a sustainable and healthy development.

The issue of appropriate indicators has been debated over and over again. The validity of an indicator, the evidence base behind an indicator, the feasibility and accessibility, and the overall concept of indicator is vague. To complicate things further, the concept of sustainability has been linked to existing indicators as another facet of general well being. By definition "an indicator on sustainable development shows if the community, region or population is developing in a way, which can be sustained also in the future". This implies that we should be able to observe the direction of change over time.

The WHO Healthy Cities Project has collected and reported a set of indicators from the member cities twice - the first time during the second phase of the project in 1992 – 1997 and the second time when the cities filled their application forms to join the third phase beginning in 1998. Turku has been a member of the Healthy Cities network since the 1987, and Stakes, a national research centre for health and social fields, co-ordinates a National Network in Finland. The nine member cities of the National Network have been the test areas for different indicators. The starting point has been that health is the outcome of various determinants of health. Thus the lists of indicators reflect different fields of life although 'traditional' health indicators have a role to play, too. The result of the questionnaires - both to information management experts and to local level health professionals - are presented below.

Proposed indicators to be included in a local Health Profile by the Finnish National Network of Healthy Cities according to a survey made by the Baltic Region Healthy Cities are:

- The Most expedient Indicators

  Mortality by age groups
  Cause of death - 12 different groups
  Survey data on peoples' health behaviours
  Regularly smoking
  Subjectively felt good health
  Percentage of population living in sub-standard dwellings
  Unemployment percentage
  Percentage of population on income benefit
  Total income benefit per client in FIM
  Children taken into care
  Level of education - all categories

- New indicators needed

  Percentage of working age people on disability pension
  Days of sick leave (in relation to the total number of people between 16 and 64 years)
  Truancy from school – how many days and how many pupils each day
  Proportion of people in Mental Health Care as compared with total population
  Percentage of population on medication for psychological problems
  Survey on self-reported feeling of safety
  Over 75-years olds in long-term institutional care
  Survey on social support
  Survey on the quality of living environment
  Survey on loneliness
  Percentage of population entitled for refundable medication – age standardised data.

The general feeling was that data should be readily and economically available. They should be quite recent, and different municipalities should make their own health profiles using the same indicators to allow comparison between municipalities. As such, the Health Profiles were considered an excellent tool for monitoring as well as planning health determinants. It is notable that the used indicators do not take into consideration spatial dimensions – no more than the 'traditional' spatial indicators take into account the community perspective. An indicator for *migration* for instance, does not tell us from where and / or to where the people move.

3.4 Indicators of competitive capacity

Most of driving forces in land-use development is out of planner's control. Almost any land use change cannot happen without permission of the planning authorities. Concerning a sustainable view of planning, this is annoying. Regional planning authorities are making plans and decisions without being convinced that the development is sustainable. The driving forces of development represent the general demand of different land-use purposes and should therefore be known by planners. They should also be sensitive for changes in driving forces, especially in the spatial distribution.

Regional planning has no influence on the general growth of GNP, but competitiveness affects the land-use in a wide extent. Accessibility of certain attractions represents competitiveness and should therefore be taken into consideration in regional planning. At least planners should state the following questions: What is causing the pressure and what is steering the land use development and in which directions? Attractions and their accessibility seem to prove why some areas grow and some others decline. By studying the future attractions, we may predict the coming migration patterns. Furthermore, by knowing the driving forces and pressures, we can direct the structural policy to the right target and planning efforts as well.

Competivity mechanisms

- Speculation of investors
  - Growth expectations
  - Guessing the winner
  - Betting the winner
  - Gaining profit
- Location benefit
  - Nearness
  - Accessibility
  - Price
  - Available infrastructure
- Nature resources
  - Shoreline
  - Hiking areas
  - Recreation areas
- Competitors
  - Municipalities rivalry for good taxpayers
  - Companies rivalry for skilled labour
  - Inhabitants preferences for attractive housing environments
- Land-use pressure
  - Environmental restrictions
  - Need of potential construction areas
  - Realisable land-use

Indicators describing development

- Low average age indicates new settlement
- High average age indicates migration
- The age of buildings show the development phases of urban settlement
- The rate of incomes describe just competivity
- Commuting distances describe the gravity of working places
- Some indicators explain development
- Changes in accessibility
- High average age means depopulation

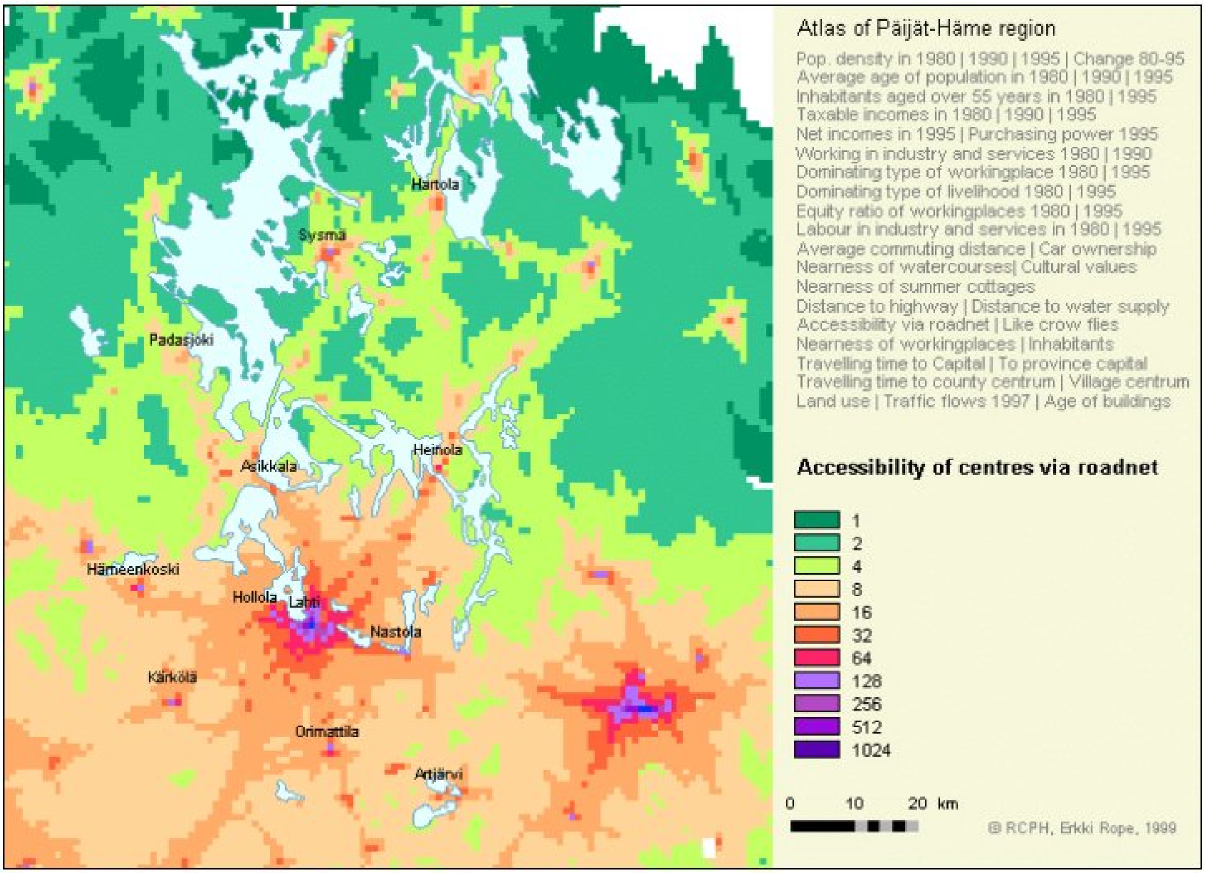


Figure 3.4. Accessibility potential of Päijät-Häme region

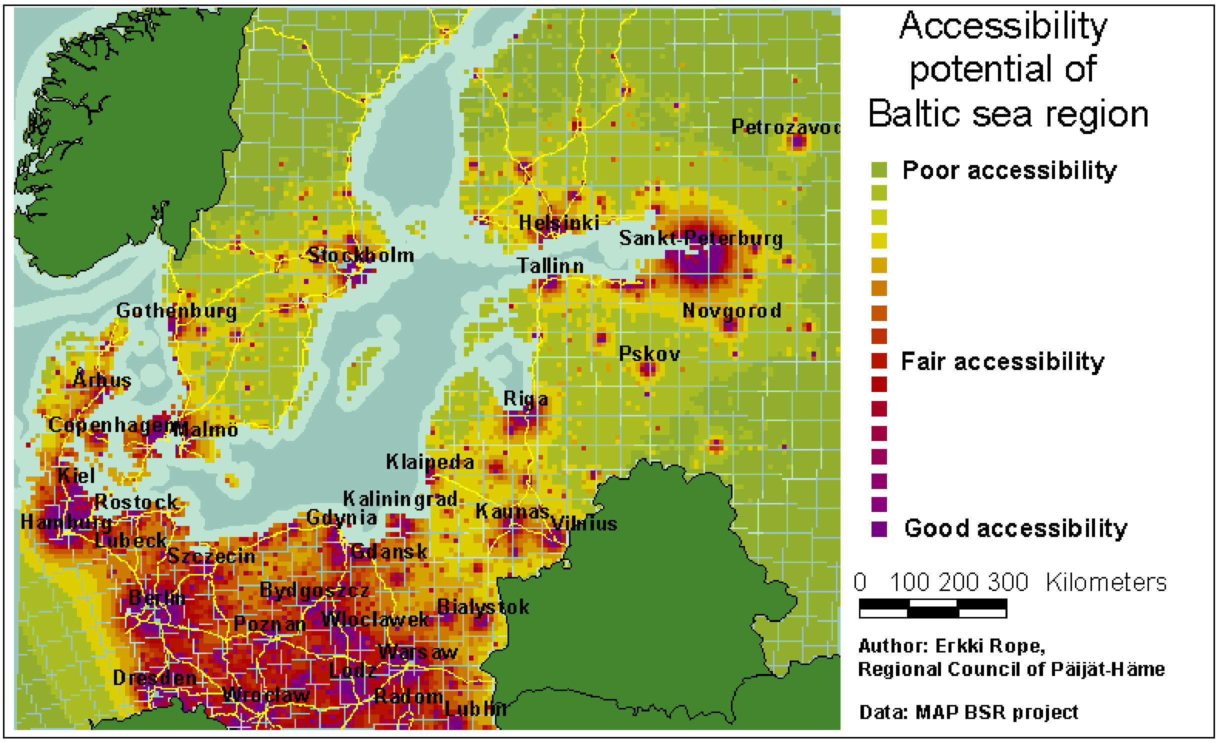


Figure 3.5. Accessibility of Baltic Sea region

- A few indicators predict development
- High average age of population predicts change in purpose of use of houses
- Accessibility of working places

The accessibility of Päijät-Häme is calculated by measuring travelling time from each grid cell to nearest centre of four different size categories and then summarising the separate.

Based on the BSR Map population data of centres accessibility potential of all centres to a synthetic grid of 10-km grid cells is calculated. The centres consisted of several shapes of which all had same name and same population. In order to handle each centre just once the extra items were removed judging by perimeter. The co-ordinates were also converted to Gauss-Krüger rectangular projection where the gravity calculations were made (fig.3.5).

In the last diagram (Fig. 3.6) we show how the Accessibility Potential of the Baltic Sea Region and the Regional Council of Päijät-Häme are composed of various data and how they are aggregated.

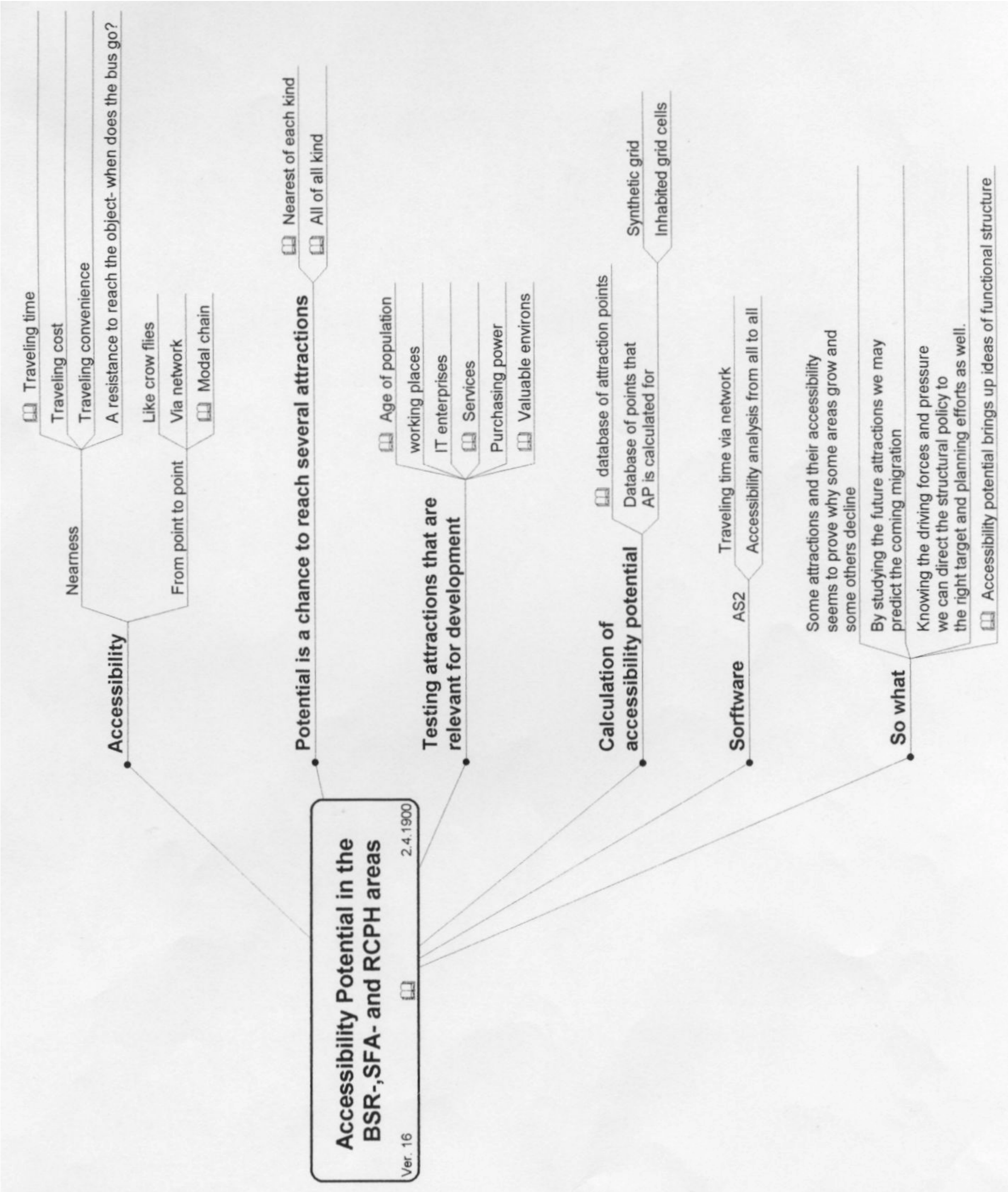


Figure 3.6. Computing the accessibility potential

4 Methods and tools

During the PSSD project, a lot of methods and tools concerning sustainable development have been developed. Strictly speaking, there is only a few real tools - meaning for example AML programs or Avenue scripts. However, in the Planner's Toolbox some AML programs or Avenue scripts have been uploaded together with the description of the method, but most often the Toolbox only contains descriptions how to use a method.

4.1 Identifying regional sustainability

To identify the regional sustainability, it is important to make some basic analyses of the land-use structure. As a result, we can measure the degree of impact of the human being on the environment. To make comparative analyses, CORINE land-use data were used, because these data are available for all three countries.

Urbanisation has been one of the most significant ways for the transformation of societies over the last century. Urbanisation, as it is traditionally defined, is bound up with a movement of population from rural to urban areas. But meanwhile the urbanisation path has changed dramatically. Since some decades, processes of sub-urbanisation are dominating the development of the built-up area at the urban fringe. In Central Europe all countries have been effected to a greater or lesser extend. In Germany nearly every settlement in suburban areas was able to realise an increase in population and employment. As a result the dispersion of the built-up area on the regional level extends continuously. The structure of the regional settlement systems gets more and more fragmented. The same development occurs in East-German city-regions, where processes of sub-urbanisation have started since the reunification in 1990.

A visible difference, which marks the urban-rural transition, can hardly be found in most Central-Europe city regions. The built-up area of different communities is growing together, as consequence conurbations have been developed (N.U.R.E.C. 1994). In the meantime the same development path emerges in East Germany and other former socialistic states.

Sub-urban areas are those areas that can be found outside the city centre in the periphery of an agglomeration. These fringe areas are closely connected to the city centre by traffic flows. The development of the built-up area differs from sub-urbanisation trends. The process of sub-urbanisation implies mainly the changes of the proportion of inhabitants, workplaces and businesses when comparing rural and urban developments. We talk about sub-urbanisation if in one region the proportion of inhabitants, workplaces or businesses at the urban fringe increases, whereas the city centre loses inhabitants, workplaces and businesses.

Sub-urbanisation processes are the result of relocations. With the further development of sub-urbanisation households and enterprises, which were concentrated in the city centre, now tend to locate in the urban fringe (Cross, 1990). The outward flow of inhabitants is balanced by a sustained immigration from other regions in Germany and from foreign countries. Therefore some regions were even able to compensate the loss of inhabitants in city centres because of migration, the number of inhabitants is constantly increasing. In East-German city regions - except Berlin - the process of sub-urbanisation is accompanied by a depletion of the city centres (Dangschadt & Herfert, 1997). Because of low immigration the decrease of the regional population can not be precluded. Increases in population in suburban regions are accompanied by drastic decreases in population in city centres. Negative growth in population and positive growth of the built-up area implicates that fewer people need more space to live on. (Adam et al. 1998).

Changes in the spatial distribution of households and enterprises are not the only explanation for the development of suburban settlements near large cities. Together with the expansion of the built-up area and the increase of traffic the regional material flows increase as well. The growth of the built-up area results in an increasing demand for open space. On the other hand huge amounts of mineral resources, steel and other materials are needed for the construction and the maintenance of buildings and technical infrastructures. Additionally, it is necessary to think about those material flows which are a result of city-regional growth patterns, e.g. the energetic consequences of increasing efforts to overcome distances because of disperse settlement (Hall, 1994).

The material aspects of sub-urbanisation are of minor importance in scientific research so far. If material and energetic flows of suburbanised settlements are analysed, which is a tradition in urban ecology and environmental science, these investigations still concentrate on the administrative areas of large cities. Because of advanced sub-urbanisation urban regions should be the objects of investigation (Baccini & Brunner, 1991).

The periphery around the city centres has a spotty character and can be described as a "middle landscape" (Rowe, 1991). Inhabitants activities are not only concentrated on their residence. Commuting to workplaces and to recreational facilities becomes more and more important (Mogridge, 1985). As a consequence the formerly perceptible transition between urban and rural areas is resolving. As a substitution we can now find archipels of settlement islands that are connected through interactions between inhabitants and businesses via traffic networks. Because of these regional development processes it seems to be necessary to consider the structure of settlements in urban regions more intensively (Newman & Kenworthy, 1989).

Despite the considerable attention in science and politics for the continuing trend of sub-urbanisation you will find only a few investigations which compare urbanisation trends in different city regions. Comparative studies of urbanisation at an international scale are difficult, because the data sources tend to be limited and inconsistent.

Direct comparisons of the urbanisation are handicapped by different reporting practices of national statistical agencies and the absence of comparative data sources at the international level. Despite these difficulties, it is important that we attempt to document the immense diversity in the extent of urbanisation with the best and most recent data sources. But it is still an open question how to measure the degree of urbanisation in a city region.

As case studies, the city regions of Hamburg, Dresden, Munich, Frankfurt/Main, Turku, Copenhagen and Aalborg were chosen, and the following indices and measures were used:

- Proportion of space used for residential areas.
- Urban-country-gradient.
- Lorenz function for the built-up area and forests.
- Lorenz-Münzner coefficient for the built-up area and forests.
- Loewenstein concentration index for the built-up area.
- Proportion of residential areas near open space.
- Accessibility of forests.

4.1.1 The urban-country-gradient

The main problem in comparing the degree of urbanisation in different regions is concerned with the geographical distribution of the built-up areas. Usually land cover data only refer to the administrative boundaries. Therefore official statistics do not allow predications about the distribution patterns of residential areas, whereas CORINE Land cover data allows the comparative study of geographical distribution.

Based on a consistent regional demarcation, a comparative analysis of the urban-country-gradient for the regions of Hamburg, Munich, Dresden, Frankfurt and Copenhagen have been carried out. Using ArcView a comparative analysis of the transition from the urbanised areas to the rural surroundings have been implemented. The main objective of the study is to analyse the spatial regression of urbanisation. We have used the „ring-zones-model“ as analytic approach (Simon, 1990, Einig et al, 1997).

Comparing the curves of the urban-country gradient clarifies the different urbanisation levels in the five regions. Hamburg, the second biggest city in Germany, has an extensive built-up area. The proportion of the built-up area is decreasing below 40% in the 13-km ring-zone. In Munich, the third biggest city in Germany, the proportion of the built-up area is decreasing below 40 % in a 9-km ring-zone. Hamburg and Munich are mono-centric regions, dominated by one central city. The Frankfurt/Main region is composed of various bigger cities. The proportion of the built-up area decreases in this region below 10 % when the 39-km ring-zone is reached. In Frankfurt we find this high degree of urbanisation at the urban fringe, because this region has a polycentric settlement structure. Compared to the German regions the urban-country gradient of Copenhagen shows a higher proportion of built-up areas. It has to be considered that for Copenhagen we have only calculated one sector of the whole circle-sector model. On this account the region of Copenhagen reaches the highest degree of urbanisation.

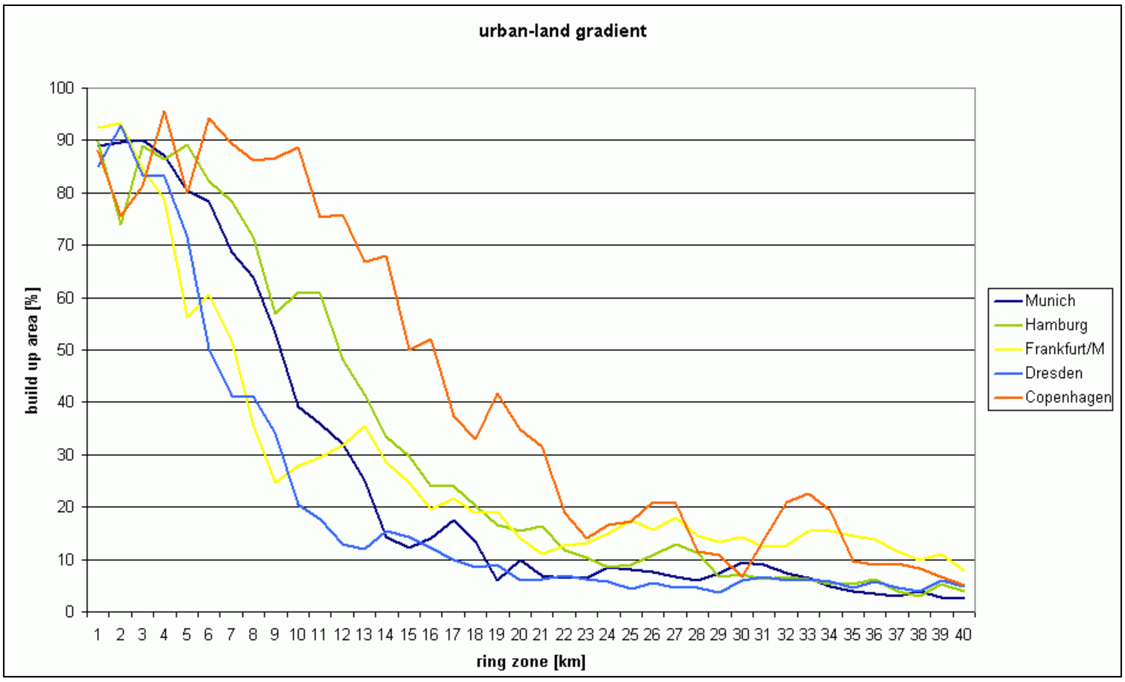


Figure 4.1. Urban-country gradients

4.1.2 Concentration of the built-up area

When calculating the urban-country-gradient with the ring-zone model it is not specified into how many patches the total built-up area is divided. Therefore it is hypothetically possible that two different regions have the same curve of the urban-country-gradient, although in one region the total built-up area is concentrated in one single patch and in another region the total built-up area is distributed over several single patches. To record the distribution of the total built-up area among single patches we calculate the range of concentration of the total built-up area. This answers the question if the total built-up area is evenly distributed on single patches or it is concentrated in a few patches. With a Lorenz-function we can visualise the degree of concentration. By calculating the Lorenz-Münzner coefficient or the Gini coefficient, the degree of concentration can be expressed by a single value.

For the regional area of Hamburg the highest Lorenz-Münzner coefficient was obtained, i.e. the main proportion of built-up area can be found within a few large patches. For the Munich region we have calculated the second highest Lorenz-Münzner coefficient, followed by the Dresden, Frankfurt and Aalborg regions. Hamburg and Munich have a mono-centric structure, and therefore it is not surprising that these regions have the highest Lorenz-Münzner coefficients. In contrast to this, Frankfurt has a markedly polycentric structure with four large cities. In the Frankfurt region the urban fringe is extremely urbanised, so that the proportion of sub-urban areas of the total built-up area is more extensive than in other regions. For Aalborg the smallest Lorenz-Münzner coefficient was obtained, indicating a concentration of the built-up area on larger patches.

	Lorentz-Münzner coefficient	Gini-coefficient
Hamburg	0.79020608	0.78771332
Munich	0.75298196	0.75040326
Dresden	0.69509047	0.69291831
Frankfurt/Main	0.67621935	0.67463940
Aalborg	0.61592825	0.61083793

Table 4.1. Concentration indices by Lorenz-Münzer and Gini

4.1.3 Accessibility of open space near settlements

Easy access to open space is very important for the quality of life in a city region. Availability of large open spaces becomes a more and more relevant location factor for companies, which are looking for a new location. Highly qualified managers and specialists can only be motivated to move into another city region, if it has open space for sports and recreation and enough facilities for children to play. Especially open space, easily accessible within a short walking distance - so that it can be used every day - is very important. Using CORINE land cover data it is possible to roughly estimate the availability of residential areas with nearness to open space. In the current context, "Not far away" means open spaces, where the distance from the residential area is less than 500 metres, which guarantees a good accessibility of open space within walking distance. The percentage of the residential area that is less than 500 metres away from open space was calculated for the study areas (table 4.2 and figure 4.2).

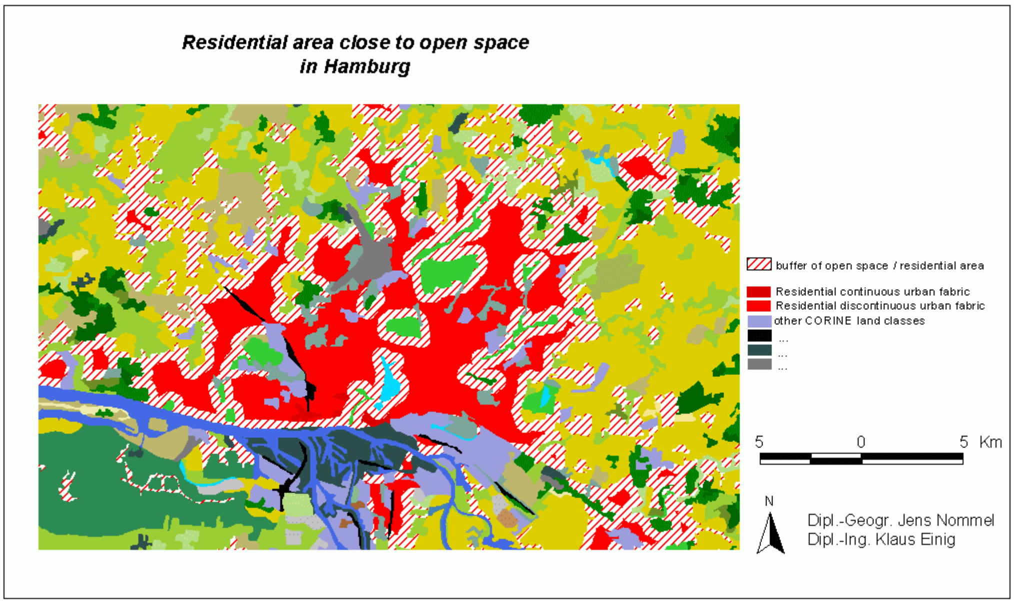


Figure 4.2. Residential areas close to open space

	Residential urban fabric	Resid. urban fabric close to open space (<= 500 m)		Resid. urban fabric faraway from open space (> 500 m)	
	km²	km²	%	km²	%
Hamburg	618	479	76,5	139	22,5
Munich	455	380	83,6	74	16,4
Frankfurt	639	568	89,0	70	11,0
Dresden	393	339	86,2	54	13,8
Copenhagen	452	321	70,9	131	29,1
Aalborg	161	145	90,5	15	9,5
Turku	90	84	93,2	6	6,8

Table 4.2. Proportion of residential areas close to open space

An interesting result of this comparison is that every region has more residential areas that are near to open space than far away. The Hamburg and Copenhagen regions have lowest percentage of residential areas near open space, followed by Munich, Dresden, Frankfurt, Aalborg and Turku. These results lead to the conclusion that polycentric structured regions dispose of a higher proportion of residential areas near open space than mono-centric regions. Furthermore, the regions with a small city as a regional centre (Aalborg, Turku) show more favourable values in accessibility of open space than large city regions. In these cases the total surface of residential areas has a lower expansion and as a result the distance from residential areas to open space is lower.

4.1.4 Accessibility of forests

Forests have a special importance for the recreation of human beings as well as many habitats for a lot of species. Additionally they have a climatic function. Therefore accessibility and nearness to residential areas are important indicators for the recreational value of open space in a city region. A region with a proportion of forests between 15 % and 20 % is evaluated as a region with a low developed recreational quality. An active exchange between open space and forests is ideal for recreation. Therefore the proportion of forest should not exceed 60 %. (Schmidt & Rembierz, 1987). Specifying the proportion of forests gives no information about the quality of the recreational quality because the geographical distribution is not considered. To consider the spatial distribution of forests the distances from forests to residential areas have to be measured.

For the Turku region the relative distribution of grid cells per distance class shows the best distance values. 72 % of all grid cells are in the distance class 0-500 metres. Then the distance curve drops down, in the 1500 metres class we find no grid cells. Contrary to that, the distance classes in the Aalborg region are evenly distributed over all distance classes. In all distance classes (except the 1501-2000 metre class) we get the worst values for the Aalborg region. The Hamburg region shows the second worst distribution. Calculations for the regions of Dresden, Munich and Frankfurt show more favourable results. For Frankfurt and Dresden we have a high proportion in the distance classes of forest areas in walking distance (less than 2000 metres). The proportion of those grid cells, which are far away from residential areas (more than 2500 metres) is less than 5 %.

In the future, we want to analyse the temporal change of the land-use pattern. This will be a method to identify the regional status quo and the development paths systematically.

Another set of examples of indicators and maps are demonstrated for the region of Eastern Denmark / Southern Sweden. The accessibility of a location is defined as the number of potential users - given a mode of transportation. Mobility - on the other hand - is the ability of the users situated at a location to reach and make use of a facility.

This way accessibility becomes an attribute to the facilities and mobility an attribute to the users. Measurements of the accessibility must be in terms of the number of users given the restriction provided by the mode of transport - example given the number of people that can reach a certain forest within 15 minutes drive by car. Accordingly measurements of mobility must be made in terms of the amount of resource available - example given the number of hectares of forest available with in 15 minutes drive by car.

The analysis was carried out using ARC/INFO's Network module. Forest facilities as well as population were connected to the nodes of the road network. Speed limits were estimated generally for urban areas to be 90, 70 and 50 Km/h for respectively motorways, semi-motorway and normal, paved road. For non-urban areas the same limits was set to 110, 90 and 80. Travel time for each segment of road was calculated by multiplying length and allowed speed. Road network, forests, urban areas and shore-lines originated from the Øresund-2000 digital map – a topographic map in scale 1:200.000 produced by the Danish National Survey and Cadastre in cooperation with the Swedish National Land Survey. Danish population data at parish level was obtained from Statistics Denmark. Population data for Sweden was not obtained.

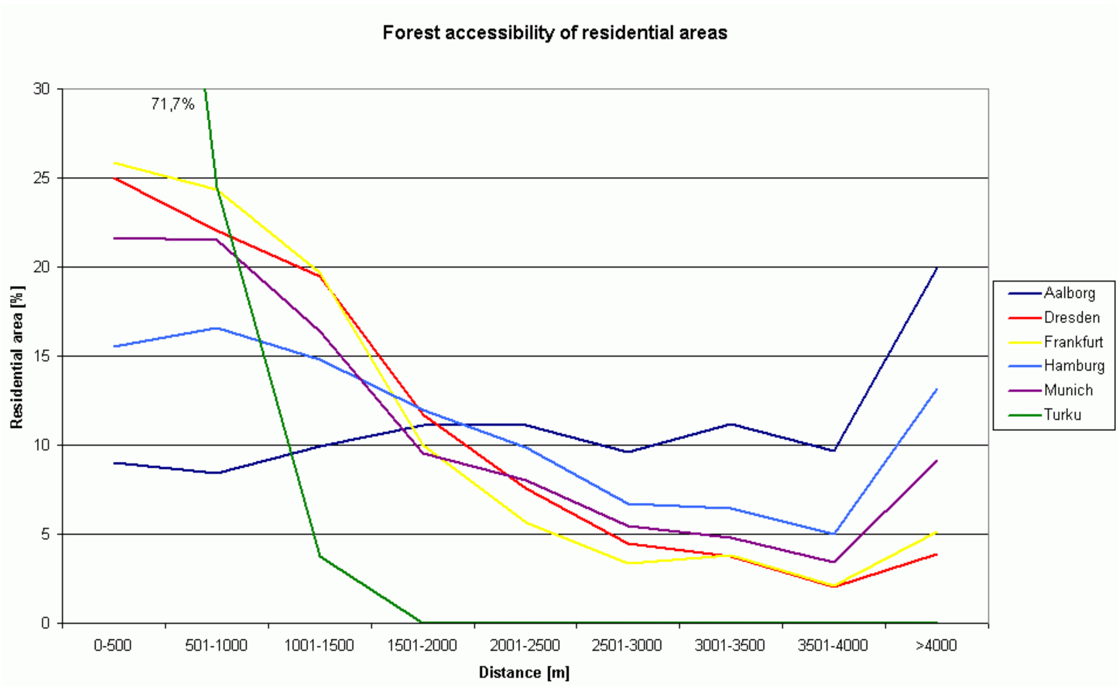


Figure 4.3. Forest accessibility

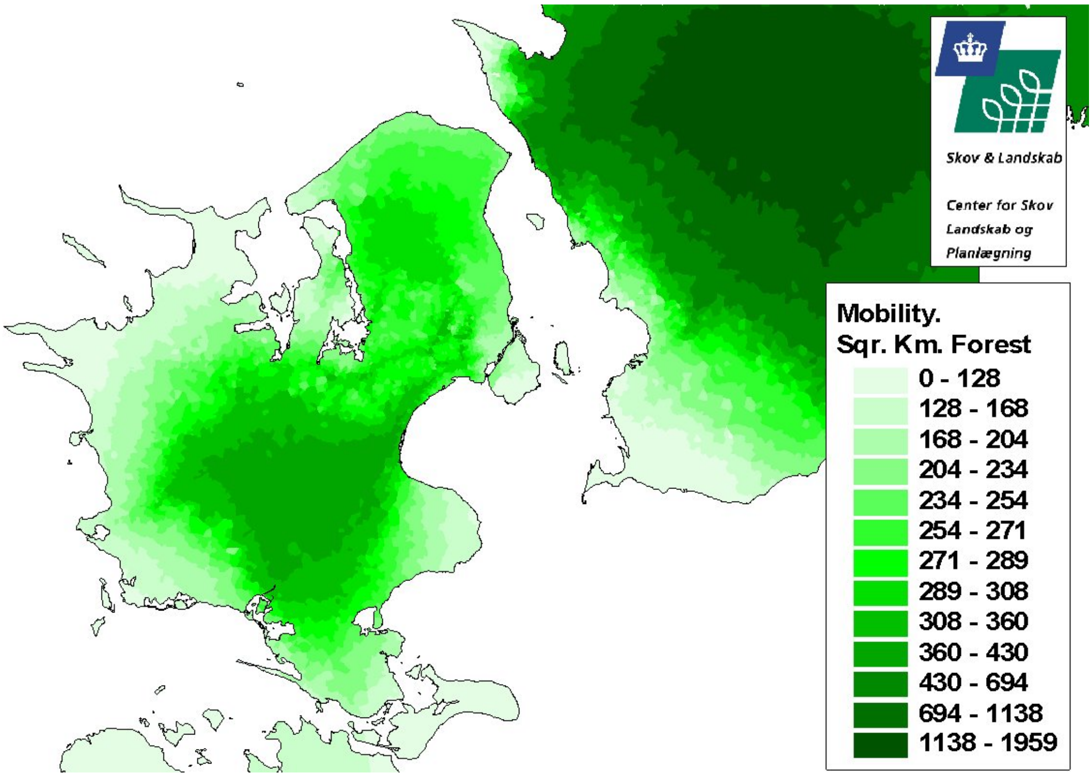


Figure 4.4. Mobility in terms of forest resources (Km^2) within 30 minutes drive by car

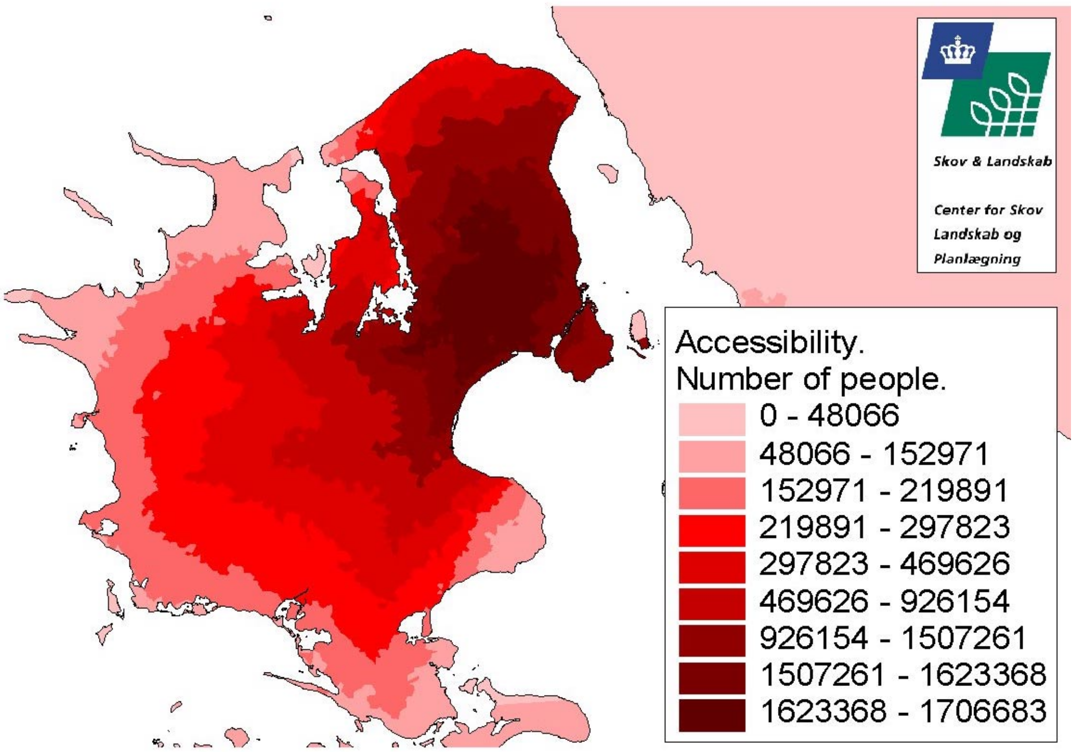


Figure 4.5. Accessibility in terms of the number of people that can reach the location within 30 minutes of drive by car

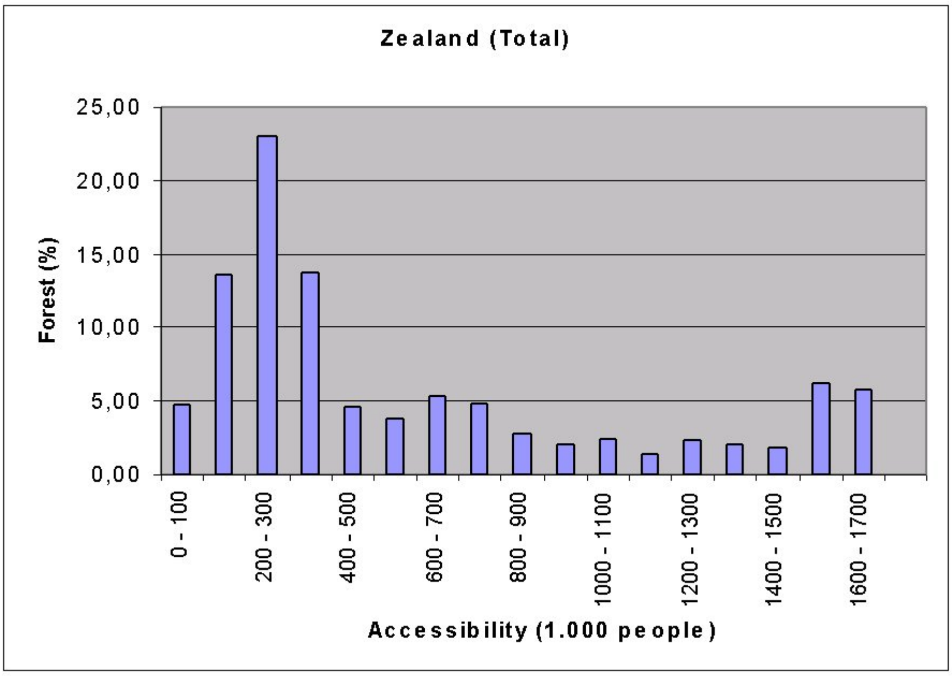


Figure 4.6. The distribution of Zealand forests over accessibility classes

A number of different assessments were carried out including:

- Mobility in terms of forest resources within 5, 15 and 30 minutes drive.
- Gain in mobility within 30 minutes due to the Øresund Bridge.
- Accessibility in terms of population Zealand within 30 drive.

To assess the effect of the mobility on the population, a diagram showing the populations distribution over classes of mobility was calculated. Diagrams of this kind are well suited as indicators when comparing mobility between different regions or parts of towns. This kind of comparison was carried out for the 8 counties of Zealand, and one example of a mobility/population diagram for the entire island of Zealand is shown below.

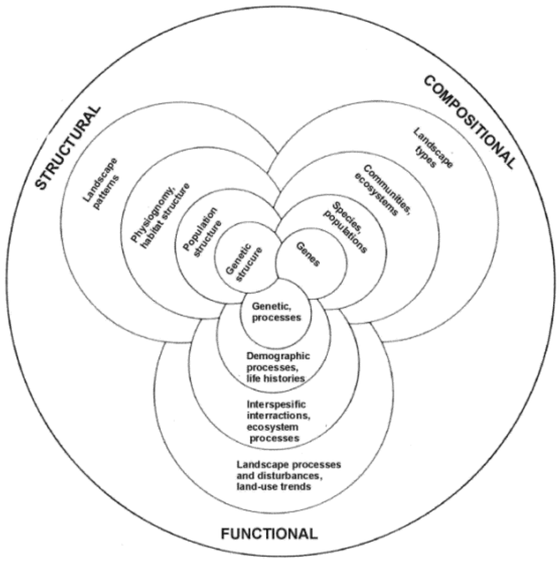
Like in the case of mobility, indicators of accessibility can be used to demonstrate how the forests are affected. Below is diagram showing the distribution of the forests of Zealand over the classes of population that can reach them within 30 minutes of drive.

4.2 Methods for environmental indicator creation - biodiversity example

The loss of biodiversity is one of the most important environmental problems. The extinction rates of species have been estimated to be 1,000 –10,000 folds higher than natural background extinction rates. The level of biodiversity loss varies in different parts of the Earth, but the decreasing trend seems to be typical on every continent. Thus, the agricultural intensification, land abandonment, mono-specific forestry, urban and transport infrastructure development, climate change and the introduction of alien species threaten biodiversity also in Europe.

Maintaining biodiversity is important for ecological, economic, social, recreational, educational and aesthetic reasons. Maintaining biodiversity is an essential part of sustainable development. Preservation of biodiversity is advocated in many international agreements, programmes and policies. The most important of those is the Convention of Biological Diversity, which has been ratified by most countries of the world.

The term biodiversity is widely used but there is no common definition of the term. Clearly the meaning of biodiversity varies depending on the context. Thus, the scientific and social / political use of the term could be very different. The simplest definition is "variety of life". The commonly accepted and used definition tries to distinguish the major parts of biodiversity: e.g. "biodiversity is the total variety of life on earth including all genes, species and ecosystems and the ecological processes of which they are part." Following Noss (1990) biodiversity can also be divided to compositional structural and functional components, shown as interconnected spheres, each encompassing multiple levels of organization (fig. 3.7). This conceptual framework may facilitate selection of indicators that represent the many aspects of biodiversity that warrant attention in environmental monitoring and assessment programs.



Compositional, structural and functional biodiversity. Rewritten from Noss 1990.

Figure 4.7. Compositional, structural, and functional biodiversity

4.2.1 Operationalisation of biodiversity

The broad and vague content of biodiversity is clearly a problem, when biodiversity is applied to real world problems. One has to choose what elements of biodiversity are picked up to represent whole biodiversity. This step is the most crucial, when biodiversity indicators are developed. But because of limited resources, the number of indicators cannot be very high. Species and biotopes are surely one of the most basic elements of biodiversity and those are commonly used as biodiversity indicators. But in practice all species and biotopes cannot be used, so one has to focus on a few species and habitats. Many criteria - e.g. rarity, uniqueness, representativeness, typicalness, irreplaceability, complementarity and vulnerability - could be used as kind of biological criteria.

If species are used as biodiversity indicators, it has to be chosen, which species group would be the most suitable one. There has been used many different taxonomic groups as indicating biodiversity. Vascular plants, birds, mammals and beetles are often claimed to indicate biodiversity values. Unfortunately, often one species group doesn't indicate very well biodiversity in other species groups.

The suitability of biodiversity indicators strongly depends on, what purposes they are meant to serve. Different indicators could be appropriate for e.g. monitoring, site valuation and assessment or indicating sustainable development.

- Biological theories

  Biological theories can give planners some useful hints concerning the kind of matters, which should be taken into consideration in planning processes, in order to maintain biodiversity in an area. However, it is difficult to apply those theories in practical use. Often models need data, which are not available. Planning problems are often very concrete, whereas the theories very seldom can give answers to that kind of questions, because the ecological circumstances varies from one area to another.

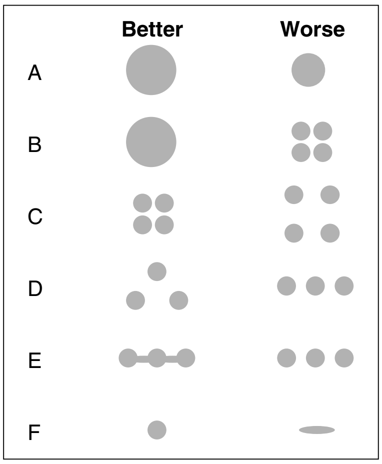


Figure 4.8. Recommendation for protected areas planning (Diamond, 1975)

- Habitat loss and fragmentation

  Habitat loss is one of the most important problems concerning biodiversity. Usually the loss of original habitat causes decreases in patch sizes and an increasing isolation between habitat patches. Also the size of the core areas decreases, whereas the size of edge areas increases. Species, which are specialised to the decreasing habitats, and species, whose dispersal ability is weak, suffer from fragmentation more than generalist species with good dispersal ability. When the proportion of suitable habitat decreases under the critical threshold, the species preferring this habitat begin to decrease very fast.

- Scale

  Biodiversity indicators are dependent of the area, which is examined. Rare species in a city can be common in a province and rare species in a province can be common in a state. Thus, it is reasonable to maintain biodiversity at global, national and regional scales. But if the area is too small, it could be unwise from a biological point of view to put too much effort maintaining biodiversity in that area, because the biodiversity of a small area is insignificant on a larger scale. Time scale is very important, when the target is to maintain biodiversity in an area. Occurrence of some biodiversity doesn't necessarily mean, that valuable biodiversity features would stay in an area in the long term.

- Available data

  The lack of adequate biodiversity data is a constant problem. Data sets do not usually cover very large areas. E.g. there are quite a few biologically relevant data sets, which would cover the whole Europe. Data covering regional and local areas are more abundant, but the spatial and temporal accuracy needed in land use planning processes is often not too good. Data from various sources is very heterogeneous and therefore not so easy comparable. Additionally, data in different publications, reports and registers are often only in printed and not in a digital form. But even if the available data could be inaccurate, incomplete, incompatible and sometimes misleading, it is better to use that kind of data in planning in stead of using no data at all, if one of the goals is maintain biodiversity. By collecting and converting data from different sources to a digital form one could get remarkable help for finding and valuing biologically valuable areas at a regional scale.

4.2.2 Collecting existing bio-diversity data

Without bio-diversity data it is clearly impossible to take care of biodiversity in the planning process. Even incomplete biological data could be helpful in planning, if the data are in a useful form. Biodiversity data exists in many various sources - publications, reports and registers contain information about biological features. However, the amount and quality of data concerning different regions vary very heavily. Often the data only cover some species groups and some habitats.

4.2.3 Indicator species

Because it is impossible to measure and monitor biodiversity, indicator species has been used as surrogates of biodiversity. But there is no consensus, which indicator species would be the most appropriate. If saving one species automatically save many other species, it could be a good choice for an indicator species. But finding these umbrella species is difficult, because it is difficult to know how many other species really fall under the umbrella.

Generally, a flagship species is used as an indicator. Flagship species - often large vertebrates - are species that arouse public interest and sympathy. Unfortunately, from a biological point of view, these species are often rather poor indicators of biodiversity. The most accurate way to evaluate the biological value of a site is to use known locations of species and habitats. The more valuable features, e.g. species, occurring a site, the more valuable the site could be. These places are called hotspots. Unfortunately, a chosen indicator taxon does not necessarily coincide with species richness in other taxa. Additionally, the species composition in hotspots could be rather similar.

4.2.4 Site selection algorithms

During the last decades, site selection algorithms have been developed. These algorithms try to identify the smallest set of sites needed to represent a targeted group of natural features in a region. These algorithms have used most in choosing reserve areas, but they can be useful in other land-use planning processes. Site selection algorithms offer a useful tool for planning. However, it must keep in mind some limitations of algorithms:

- Input data is crucial
- A change in one selected site will alter the set of remaining sites that best complement them
- Many selected sites are not inherently more valuable than unselected
- Usually only absence/presence data are available.

4.2.5 Protected areas

If biodiversity has to be maintained, it must be areas, where land-use pressures are not so high. Strictly or less strictly protected areas are therefore fundamental to biodiversity. The data is usually available and the indicator can indicate rather well both the willingness to take care of biodiversity and the probability of which biodiversity is preserved for posterity.

4.2.6 Fragmentation

Habitat loss, caused by fragmentation and isolation, is a remarkable problem from bio-diversity point of view. As a result of fragmentation, fluxes of radiation, wind, water and nutrients across the landscape are altered significantly, which in turn have important influences especially near the edge between the remnant and the surrounding matrix. Larger remnants and remnants, which are close to other remnants, are less affected by the fragmentation process.

Figure 4.9 illustrates rare species in disturbed an undisturbed areas in Lohja. The undisturbed areas are defined as areas whose distances to the nearest buildings and arable lands exceed 50 m. Furthermore, the distances to the nearest roads should be more than 10 m, 25 m, 50 m or 75 m depending on the size of the road. This indicator describes rather well the extent of human disturbances in the region. But many biologically valuable species and habitats are located in disturbed areas.

On the other hand there might be very few valuable habitats and species in undisturbed areas - e.g. the forest patches, which have been managed for forestry, can be poor from a biodiversity point of view, even if they seem to be located in undisturbed areas.

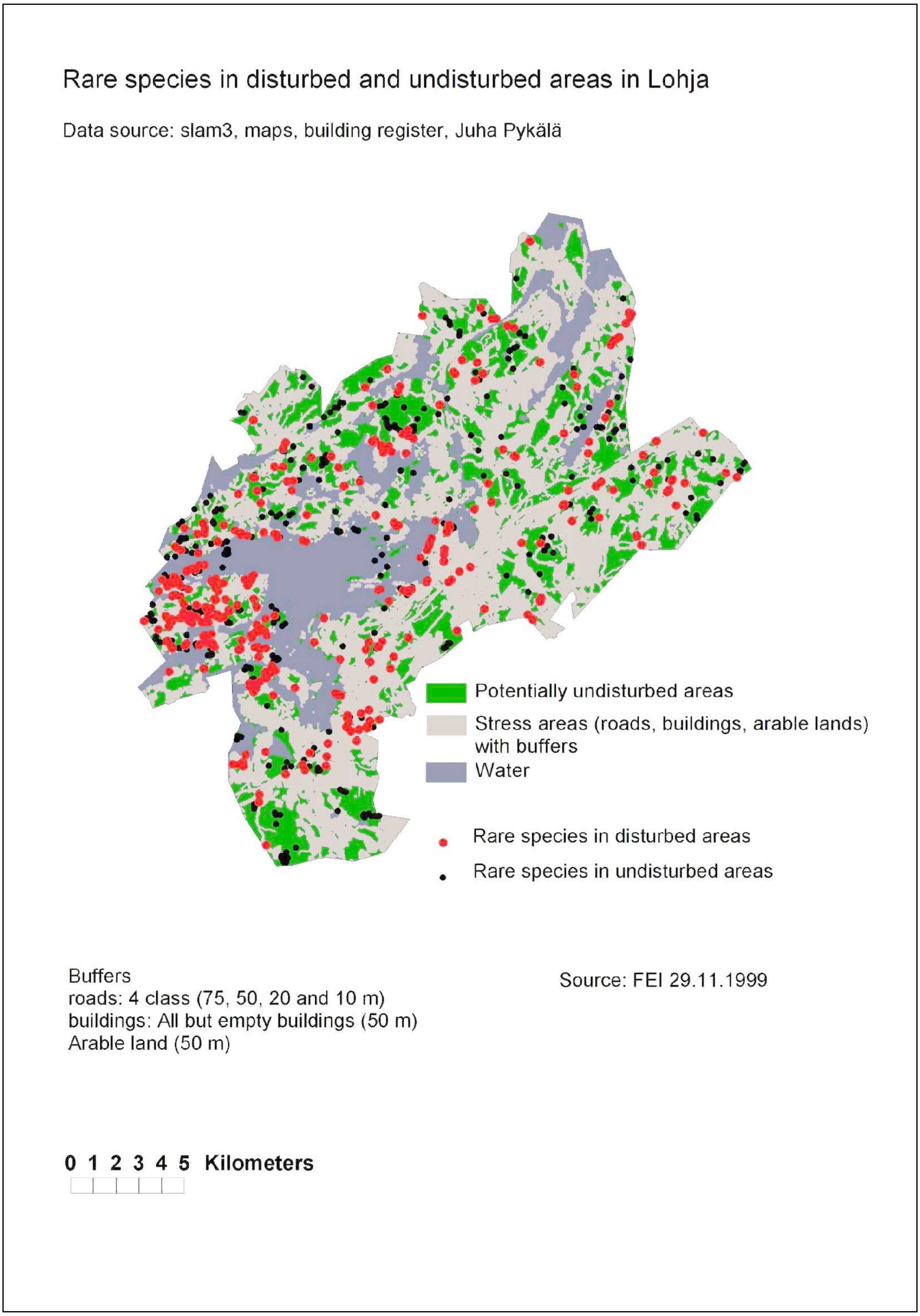


Figure 4.9. Rare species in disturbed and undisturbed areas

4.3 Methods for environmental indicator creation - geology example

Land use planning seeks to resolve the conflict between man's need to utilise land for housing, industry and infrastructure, extraction of minerals, waste disposal, and his need to protect environment. Over time the perceived balance between the advantages and disadvantages of particular forms of development alters, and planners frequently have to reassess the cost and benefits of such activities. To do this they require appropriate information from many specialists, including geologists (Northmore, K. et al. 1999).

4.3.1 Aquifer sensitivity

The geologic materials supply drinking water, but also construction materials (sand, gravel, clay, hard rock aggregate and dimension stones) for buildings and roads. Potential sites for safe disposal of various wastes can be chosen utilising geological information. The aquifer sensitivity map, an interpretation of geologic framework, makes it apparent to planners where groundwater is most at risk. Information is needed for both aquifer protection and site selection of potential risk activities, for example waste disposal, that increase the contamination risk to the aquifer (Kauniskangas et al. 1996; Curry et al. 1997).

GTK has made investigations considering the permeability of the upper part of superficial deposits in Asikkala municipality situated in Regional Council of Päijät-Häme. In the test area the deposits have been classified according to their permeability properties. This is done by utilising and reclassifying the 1:20 000 Quaternary geological mapping data. Field measurements of permeability and dielectric coefficient of the soil are used in the quality control of the reclassification. The dielectric coefficient is related to the permeability of soil. In addition, data from airborne geophysical surveys has been used, especially high frequency electromagnetic imaginary component and total radiation. The reclassified and quality controlled aquifer sensitivity map can be supplemented with data of fracture zones in bedrock.

In the figure 4.10 there is an example map of the permeability of the upper part of soil. The map is from Vesivehmaankangas area in Asikkala municipality. Vesivehmaankangas glaciofluvial delta is a part of the II Salpausselkä end moraine zone and is one of the most important aquifers in Päijät-Häme. The reclassified Quaternary mapping data has been combined with digital elevation model (DEM) to demonstrate the morphology of the research area. A preliminary evaluation of the location of fracture zones may also be interpreted from the hill-shaded DEM.

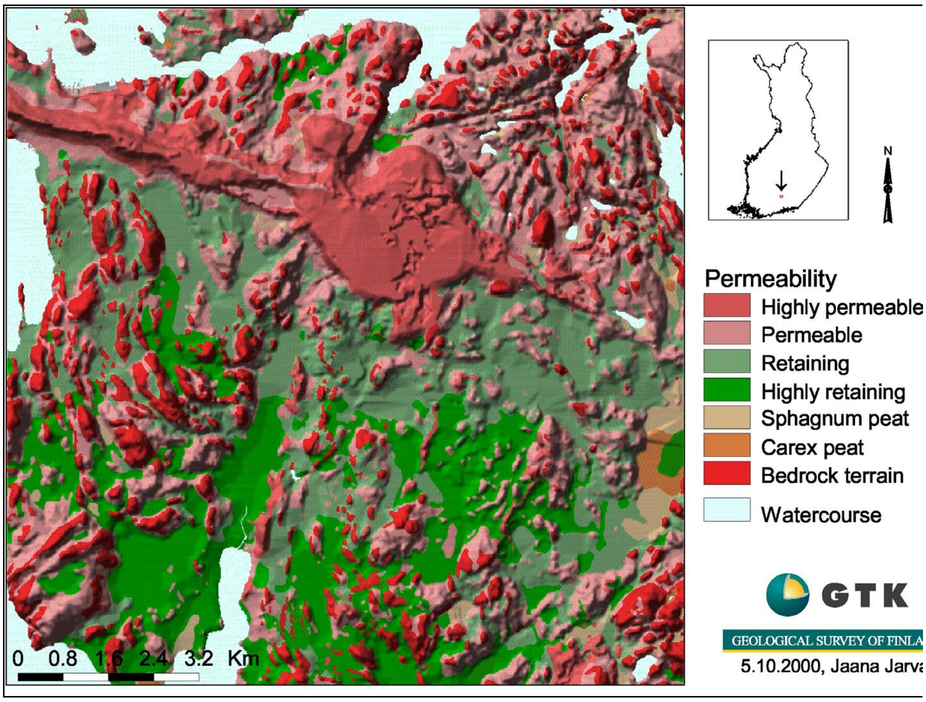


Figure 4.10. Thematic map illustrates the permeability of the upper part of superficial deposits in Vesivehmaankangas, part of Asikkala municipality. The hill-shaded DEM may be used in the preliminary study of the fracture zone locations. Digital Elevation Model

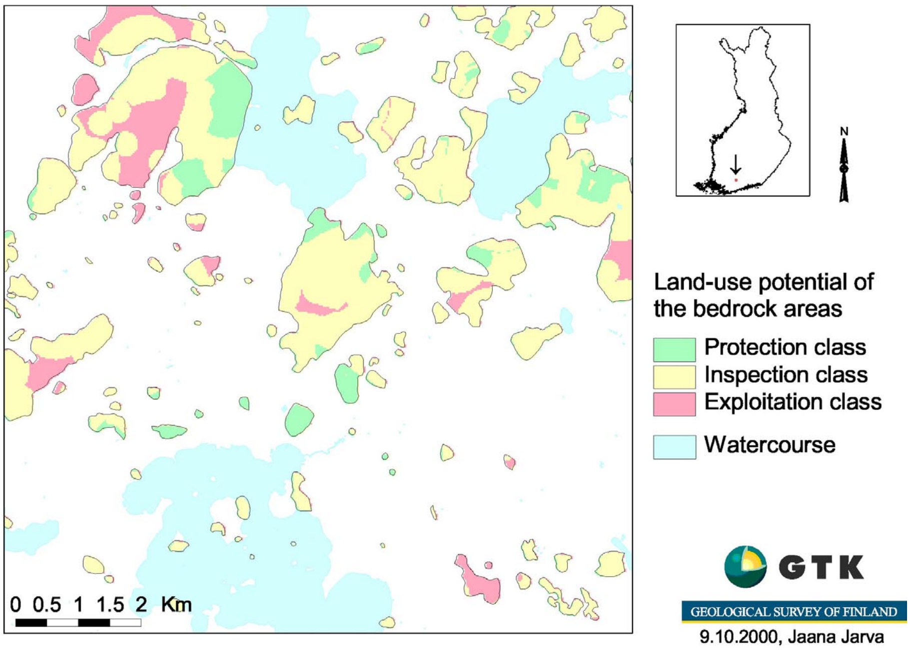


Figure 4.11 The example thematic map of the evaluated land-use potentiality for bedrock areas in a part of Loppi municipality.

4.3.2 Land-use of bedrock areas

There is growing pressure to exploit bedrock material for construction purposes in Finland. Simultaneously the need for protection of the bedrock areas for scientific, scenic and other purposes has been identified. For the sustainable land use planning aims a comprehensive geographical information processing method has been developed for the bedrock areas.

The aim of this co-project is to investigate the distribution of bedrock areas with protection needs and exploitative bedrock areas by considering the various limitations of the rock material utilisation and rock material suitability within Hämeenlinna-Riihimäki region. The GIS analysis frame in Plate 4.1 is based on the method, which is presented by R. Laurini and D. Thompson (Laurini & Thompson 1992). It shows the GIS-processing flowchart of the classification of bedrock areas. Vector data sets have been used in the analysis process at the first stage. They have been clipped, buffered and finally converted to raster format for classification and evaluation.

The first objective of the study was to find out the appropriate way to delineate morphologically distinct bedrock hill areas i.e. areas with overburden thickness on average less than 2 to 4 metres. The topographic database of the National Land Survey of Finland (NLS) has information on bedrock outcrops and cliffs. This data has been completed with Quaternary geological mapping data of GTK. This database has information on bedrock areas where overburden is less than one metre and on small outcrops and striae. These databases need to be enhanced with the supplementary information gained from the analysis of the Digital Elevation Model (DEM) of the NLS.

There exists a requirement to obtain a rough estimation of the land use potential in the bedrock areas by considering their protection needs and exploitation suitability. For the practical reasons in the end result map the bedrock areas have been classified into three classes: protection, inspection and exploitation. Protection class includes areas that have strong protection needs. The bedrock areas that do not have strong protection limitations compose the exploitation class. Areas that need more close inspection when considering their potential land use either for protection and exploitation are included in the inspection class. The processing of bedrock protection is done by using a 2-level approach. The limitations are divided into main and secondary levels. The bedrock material suitability and utilisation factors are managed as one level.

All the information has been converted to raster format. The grid cellsize is 25x25 metres. The evaluation of grids has been done within each level. The stronger the protection status is the higher the value of the grid cell. Bedrock areas have been evaluated with negative numeric values depending on their rock material suitability. The good-quality bedrock areas have the most negative numeric values.

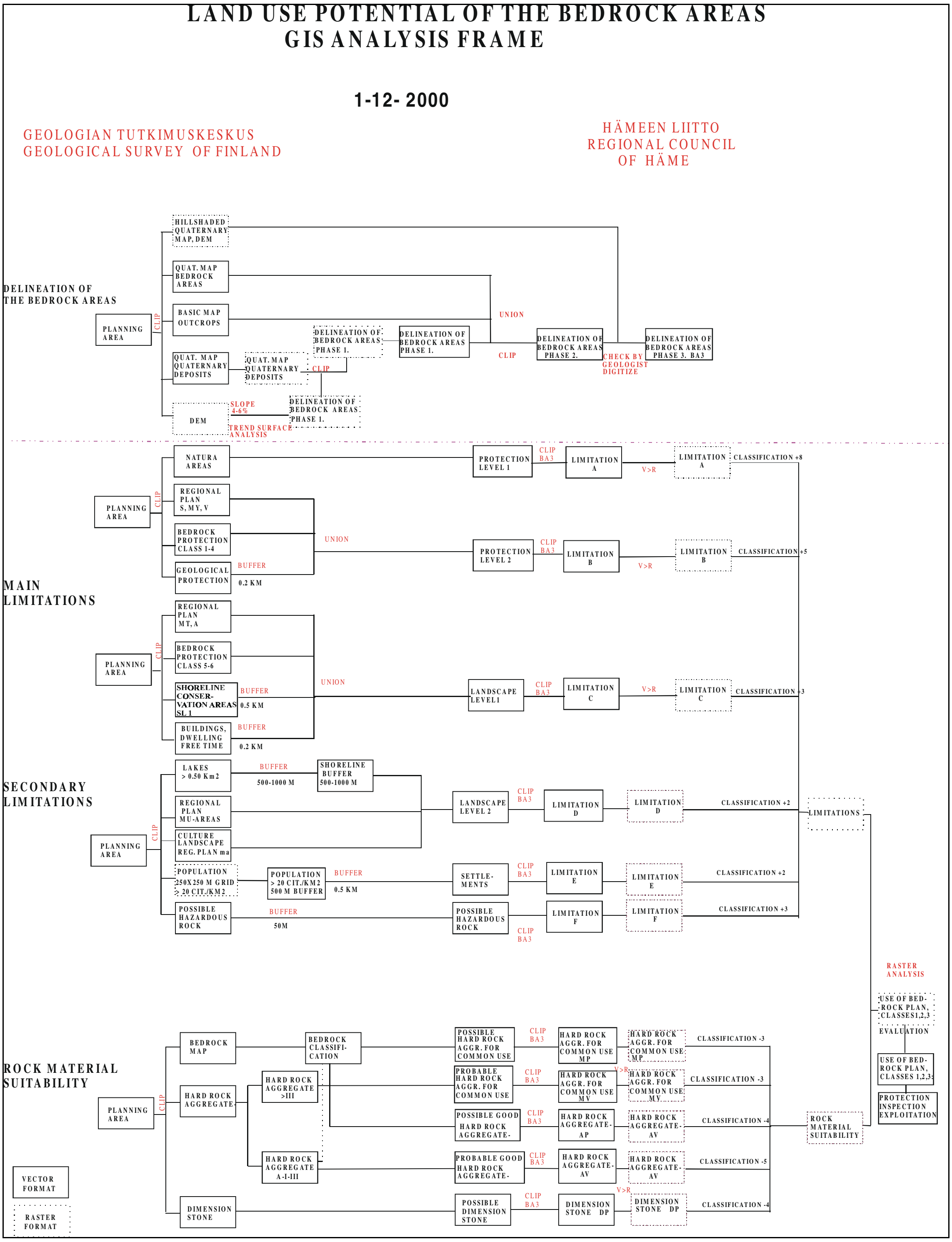


Plate 4.1 GIS-processing flowchart of the classification of bedrock areas

Converting the data into raster format makes it easier to compare different kinds of data sets. In this study the end-result was obtained by summing up the grids. In protection and inspection classes each subclass composes of an individual grid data set. On the other hand the exploitation class is one grid data set. Therefore in the calculations the protection values are cumulative. The more there are protection factors in one area the more improbable is its exploitation. The resulting synthesis is shown in figure 4.11. The thematic map covers a part of Loppi municipality.

4.3.3 Construction suitability

Sustainable land use planning includes also economical aspects. Several indicators related to soil or/and bedrock properties can be taken into consideration when estimating the costs of foundation. Construction conditions are affected by geologic factors such as thickness of clay, bearing capacity, ease of excavation, slope steepness and frost susceptibility. Suitable and good construction conditions diminish waste of construction resources and reduce building costs. (Strachan, A.D & Dearman, W.R. 1983)

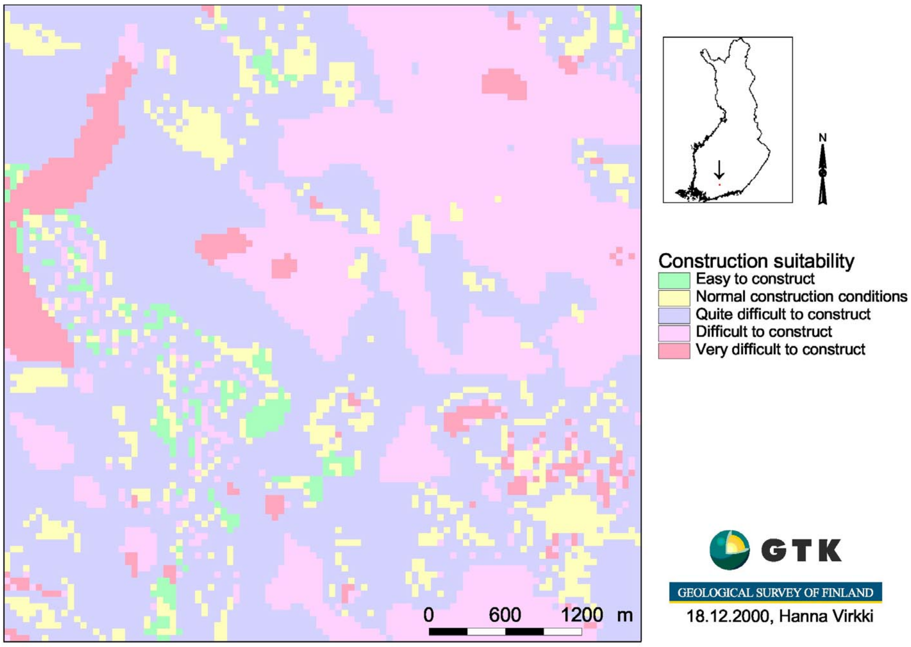


Figure 4.12 The map of construction suitability.

The estimated construction suitability of the superficial deposits, the thickness of clay areas and slope steepness are among the most important geological factors when estimating the costs of foundation. The construction suitability of superficial deposits can be roughly estimated from the 1:20 000 Quaternary geological mapping data. The data can be reclassified by using the known bearing capacity and frost susceptibility properties of different soil types. Slope steepness can be calculated from the Digital Elevation Model (DEM). In this study the slope steepness classification is based on geotechnical construction suitability classification used by the geotechnical department of the city of Espoo. On the aero-electromagnetic (AEM) maps the most significant anomalies are related to clay areas. In the research area geophysicists have estimated the thickness of clay areas. The clay thickness is calculated according to the resistivity of clay controlled with drilling data. The developed grid has been divided into five classes according to the geotechnical construction suitability classification used by the geotechnical department of the city of Espoo. The higher the value the thicker is the clay areas.

In the figure 4.12 there is an example of a construction suitability map, which has been made by utilising three grid data sets, mentioned above. This map is a combination of construction suitability of Quaternary deposits, thickness of clay areas and slope steepness. The resulting map is based on an average value of the grids. The higher is the value of calculated average value the more difficult is to construct to that area.

In figure 4.13 there is an example of one type of construction suitability map. This map is based on the Quaternary geological mapping data. A geologist reclassifies the mapping data with a comprehensive background in the geological mapping process. Construction suitability depends on frost susceptibility, bearing capacity and structure of soil. In addition, differences in elevation are taken into consideration in this classification.

4.3.4 Geology and nature diversity

Comprehensive understanding of environmental changes requires knowledge on baseline conditions and trends. Geo-indicators designed for Lohja municipality constitute an attempt to do this for geological systems. Geological data has been interpreted by taking into consideration geological factors affecting biodiversity. The results are shown as thematic map planners may use for estimation of the potential biodiversity.

The subject contains a group of indicators. The nutrient effect of bedrock indicates the possible influence of the bedrock chemical composition on the vegetation. Figure 4.14 illustrates the nutrient effect of the bedrock. The biological significance of bedrock appears as special species of plants in carbonate rich bedrock areas or a wide range of plants outside their typical habitat. The influence of the bedrock depends not only on the chemical composition of the various lithological units, but in order to classify the nutrition effect of each rock type also the bedrock sequence must be taken into consideration. The thematic map is based on the interpretation of a geologist specialised in carbonate rocks and reclassification of the 1:100 000 bedrock map.

The soil fertility is based on the capability of superficial deposits to retain nutrients and water. Soil types were divided into five classes. In the peatlands also the acidity of the peat was taken into account. The division was based on the reclassification of 1:20 000 and 1:100 000 Quaternary geological mapping data. With the help of this map it is possible to predict the potential lushness of vegetation. The estimation of soil moisture complements this indicator. The estimated soil moisture map is based on the high frequency electromagnetic imaginary component of airborne geophysical surveys. Solar radiation index indicates the amount of potential radiation by considering the steepness and aspect of slopes that are calculated from DEM. It shows the location of steepest and sunniest (or shaded) slopes.

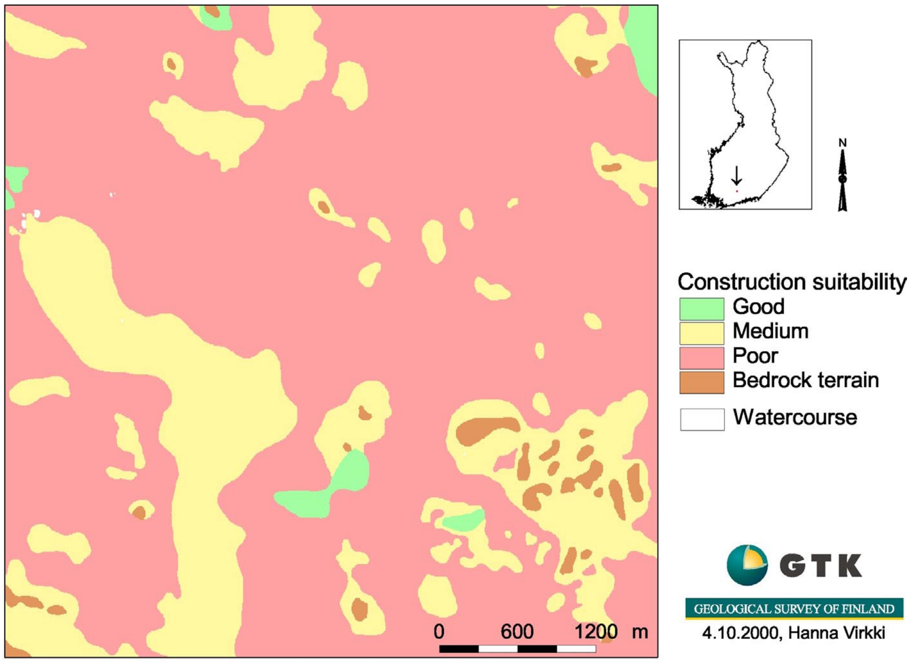


Figure 4.13. The map of construction suitability based on the interpretation of the geologist.

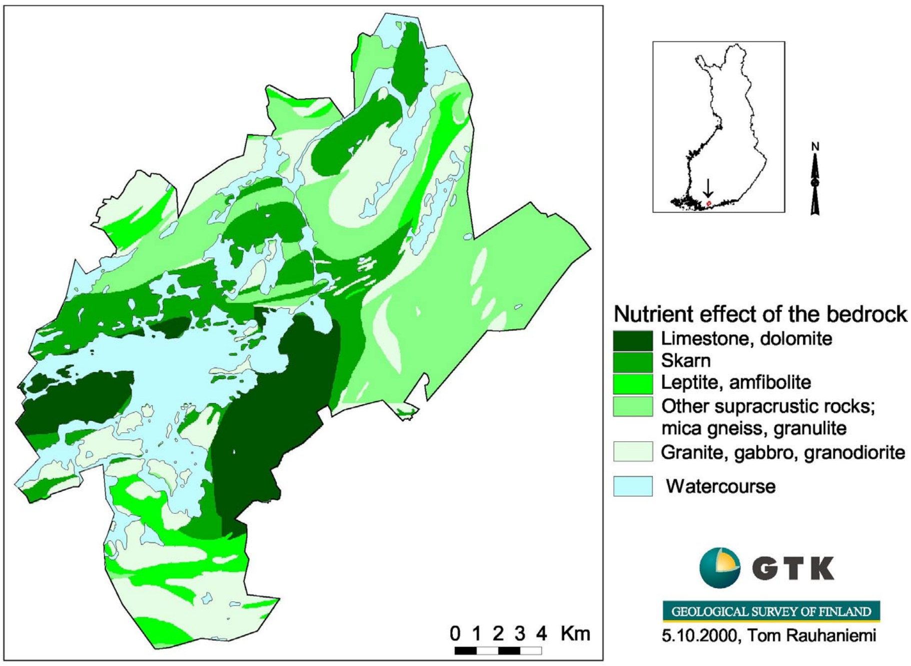


Figure 4.14. The nutrient effect of the bedrock in Lohja municipality.

4.4 Change analyses method with satellite data

Remote sensing data is a useful source of information in urban planning. Updated data, also covering wide areas, is possible to require with reasonably low costs. Detection of urban sprawl and other land use changes is valuable information. Remote sensing data can be used as a map or it can be used for updating the existing maps.

Usefulness of the remote sensing data for urban planning depends on the planning function and temporal, spatial and spectral resolution of the data. The MURBANDY project is one example that uses different kind of satellite data sets for monitoring urban dynamics.

Remote sensing imagery requires radiometric calibration (sensor calibration, atmospheric correction, solar and topographic correction) and geometric correction. The tested automatic change algorithm has been developed for forest monitoring, but it can be used also for detection of other changes where vegetation has been declined or improved. It depends on objects and the used channels how well the images describe the changes. New roads and gravel areas (e.g. pits) are distinctly detectable in the change image but detection of expansion of population centre might be difficult. The expansion of the factory area is quite difficult to separate from the change caused by phenology. The change can be observed from the difference between biomass indices or deciduous tree indices.

Remote sensing data is valuable data source for urban planning. The data can be used as background material or it can be used in producing derived products like change data. The automatic change algorithm is a feasible tool for change detection. The tested algorithm has been developed for forest monitoring so it is most suitable for that purpose. The algorithm can be used also for detect other changes where vegetation has been declined or improved. It is important that biomass and deciduous tree indices describe the change. It depends a lot on objects how well the change magnitude, calculated using the channel values, describes the change.

4.5 Methods for Integrated indicator creation - ground water example

Ground water areas are generally good terrains for construction and that is why many densely built-up areas are situated on important ground water areas. Yet the different functions of the densely built-up areas cause considerable risks to the ground water. It has been noted that the settlement on ground water areas has lead to increased chloride- and nitrate contents in the water. Also other factors of the communities, for example, the industry, the sewage systems, oil reservoirs, dump sites and other contaminated areas as well as the traffic system may deteriorate the quality of the ground waters. The aim of this tool is to find out how the densely built-up areas in general have expanded in relation to the ground water areas and which pressures they may cause.

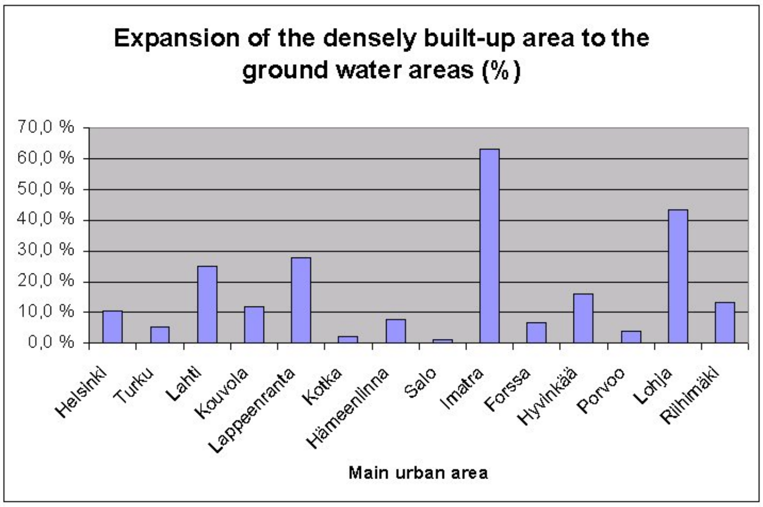


Figure 4.15. The expansion of the densely built-up area's into ground water areas.

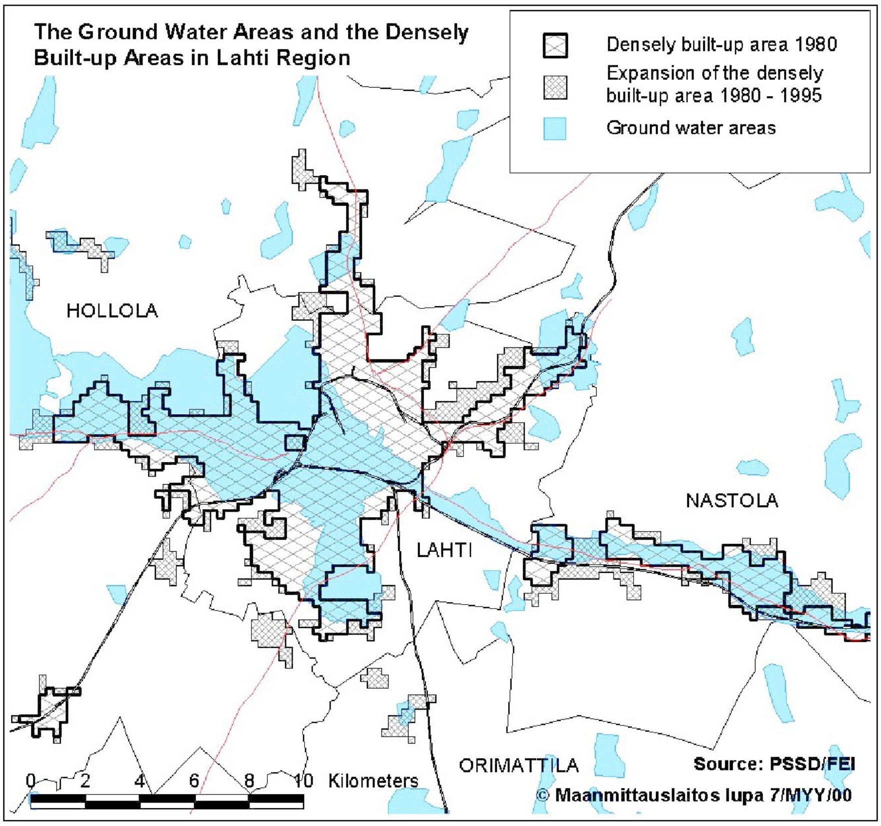


Figure 4.16. Expansion of the densely built-up area into the ground water areas in the Lahti Region

Examining the expansion of the densely built-up areas into the ground water areas requires several kinds of GIS data. First, we need the definitions of the ground water areas. Ground water area data is classified into three classes depending on the importance of the ground water area as a water supply. In this study all the three classes have been combined in order to get a general overview of the situation. Most of the ground water areas in Southern Finland are classified as “important” or “suitable” as water supplies. Also the definitions of the densely built-up areas are needed.

Subtracting the area of the year 1980 from the area of the year 1995 creates the expansion of the densely built-up area. The expansion areas are intersected with the ground water areas. Thus it is possible to calculate, how large share of the densely built-up area’s expansion is covering the ground water areas (fig. 4.15). The share of ground water areas inside the densely built-up areas of the main urban regions are determined as proportion between *the ground water area inside the densely built-up area* and *the densely built-up area in total*.

4.6 Classification of urban and rural areas

Whenever analysing urban areas one has to be able to define these areas geographically. There has to be a demarcation line between urban and non-urban (rural) area. Furthermore, the current land-use distribution is important.

The community structure consists of a physical entity whose main parts are dwellings, jobs and services. The Ministry of Environment defines that the built environment is one of the focuses in their monitoring. In the new Planning and Building Act in Finland the importance of monitoring data concerning the built environment will be further stressed as a tool of control and guidance activities. The aim of the monitoring system of spatial structure (MSSS) is to create a database in which a great deal of the monitoring of the built environment can take place. With the help of MSSS information the following measures can be produced: land-use and its efficiency, accessibility to different functions, differentiation of communities and their sub-areas, self-sufficiency of communities, urban sprawl and the relations between the locations with built and natural environment. Monitoring the spatial structure requires the spatial as well as the temporal dimensions. One part of the monitoring system are concerned with land-use classifications of urban and rural areas based on the following categories:

Urban area:

- Centre of urban area
- Inner city
- Sub centre
- District centre
- Area with mainly block of flats
- Area with detached house
- Mixed suburban area
- Unbuilt suburban area

Rural area:

- Built-up mixed rural urban zone
- Unbuilt mixed rural urban zone
- Rural village
- Dispersed settlement
- Unsettlement area

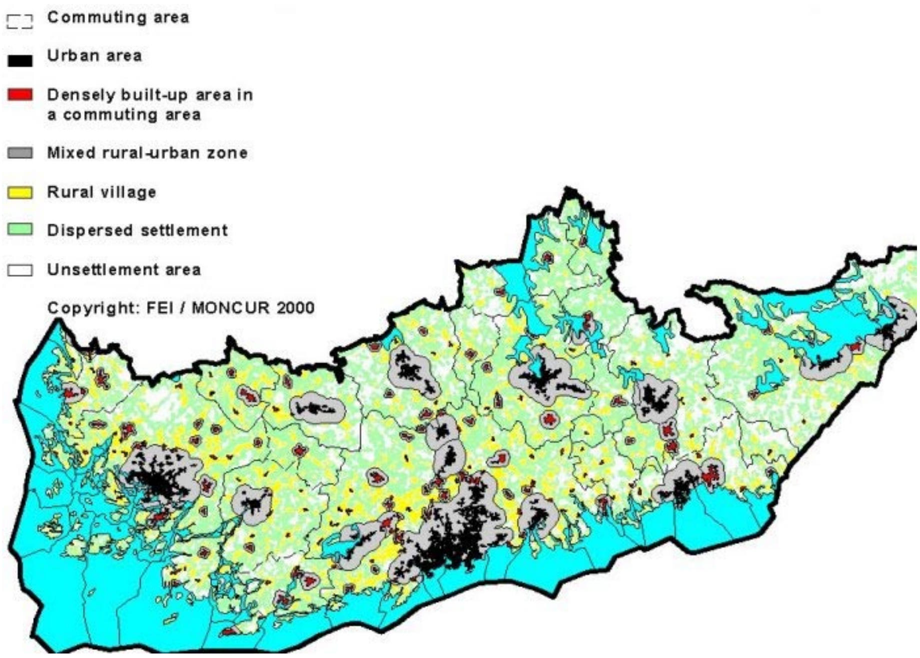


Figure 4.17. Land-use classification in Southern Finland, 1995

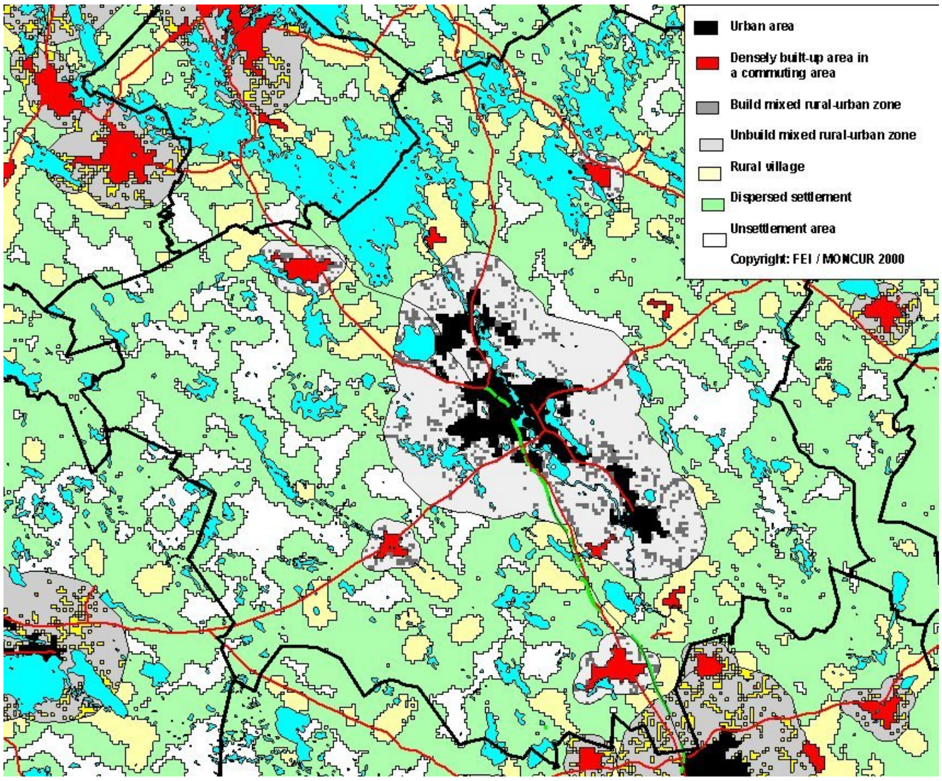


Figure 4.18. Land-use classification in Hämeenlinna

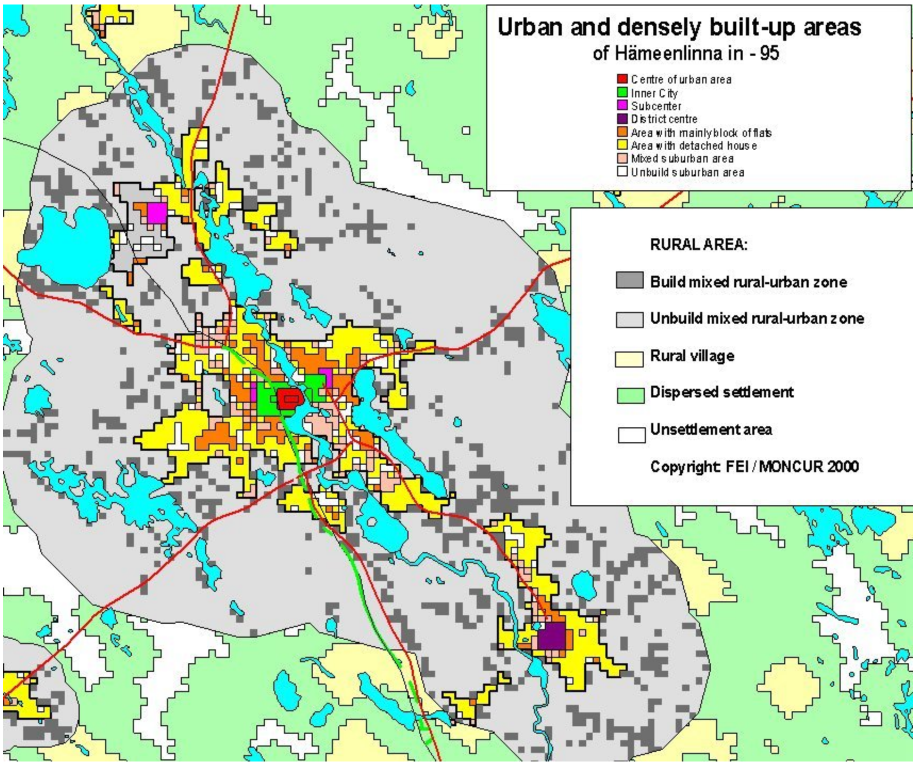


Figure 4.19. Land-use classification in Hämeenlinna - urban centre

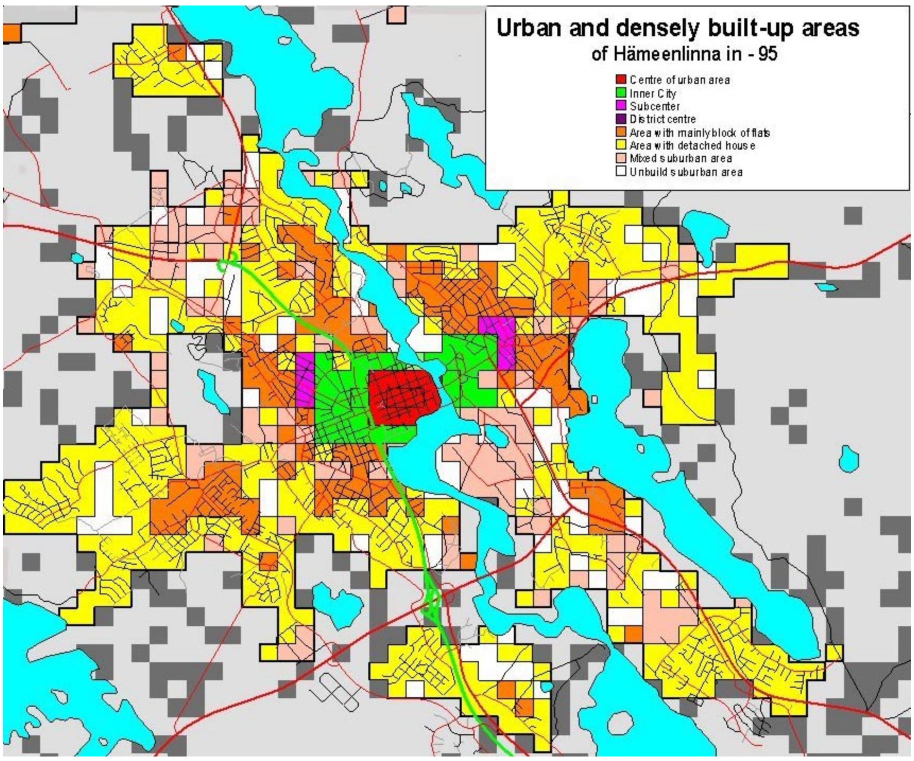


Figure 4.20 Land-use classification in Hämeenlinna – zoomed view

DFLRI and NERI have defined a more detailed urban land-use classification system. The system has two hierarchical levels - a coarse one and a finer. Which to use, depends on the quality of the input data and the geographical scale of the output product. With sparse input data or when producing maps of large areas the coarser class system (1, 2, 3…6) may be preferable. Whereas, having adequate input data and the need to produce detailed land-use maps the more detailed class system (1-1, 1-2, 1-3…6-0) might be a better choice. The finer classes can, of course, always be collapsed into the coarser since they are true subdivisions of those.

To ensure that the sum of a number of finer classes always adds up exactly to one coarser class it is necessary to include a misc. class in some of the coarser class. Those misc. classes have all been given a "-0" (dash-zero) name to secure homogeneity throughout the classes. It is important to stress the difference between, e.g. class "2" (Business) and class "2-0" (misc. Business). The first is the coarser class containing all "2-*" subclasses, while the latter is the misc. class containing items that classify as "2" but not fits any of the ordinary "2-*" subclasses. The mixed classes are described further below in connection with the actual classification process. They are mainly defined using a number of pureness criteria.

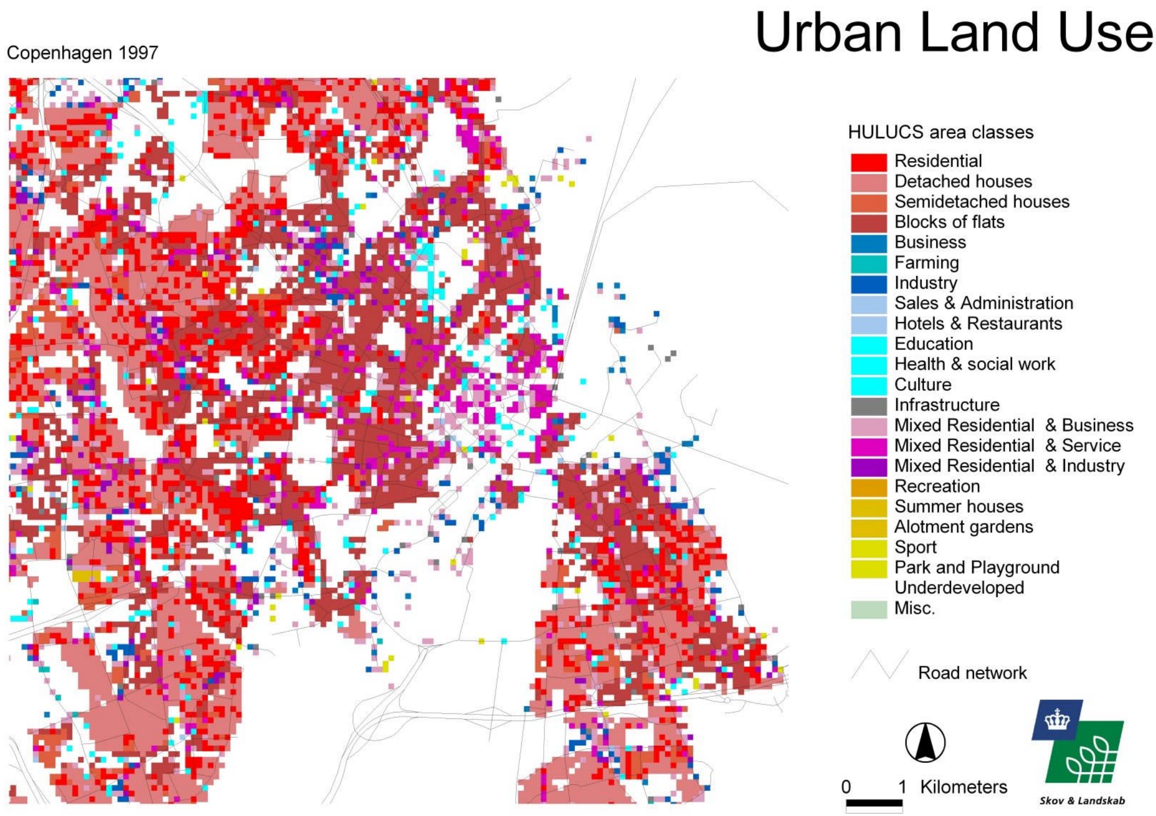


Figure 4.21 Urban land-use map

4.6.1 Demarcating the built-up area

The idea of the task is first to demarcate the built-up areas and then pick the built-up area, which is possible to consider as urban area.

The idea is to demarcate built-up areas using spatial data of each building point. The data is based on the Finnish building register, where each building has location information as point. The spatial accuracy of a building in the database is about 5-10 metres.

The definition of the demarcation line between the built-up and rural areas is based on Delaunay triangulation. The maximum distance between individual buildings (i.e. length of a side of a triangle) is 200 metres as agreed among the Nordic countries. All groups of buildings having three or more buildings are in principle and by definition built-up areas. One or more triangles together form a single unified built-up area. The surface area of a built-up area can be measured after determining the buffer zone around the frontier lines of the combined set of triangles. The width of the buffer zone can be for instance 30 or 50 metres.

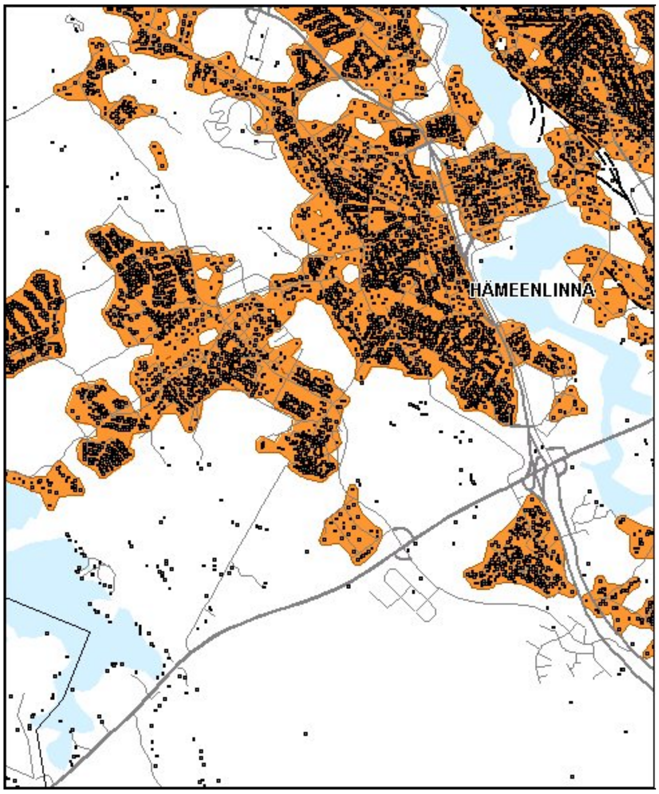


Figure 4.22. Urban area in the Häme region

4.6.2 Defining the urban area

Following our definition, urban areas are collections of built-up areas, which fulfil a condition based on the amount of floor space within the built-up area. The built-up areas are considered as urban areas, if the amount of floor space is at least 5000 floor square metres. The current classification of urban and rural areas is applied in the Häme Region (fig. 4.22). The method is used to identify the built-up areas in region plans. One objective of the work was to clarify how much there is in the Regional Plans building capacity and the first step is to find the unbuilt areas of the built-up areas in Regional Plans. The demarcation of the built-up areas was performed by VTT, and Häme Regional

Council performed the identification of built-up areas within the regional plan.

4.6.3 Identifying the densely built-up area

The definitions of densely built-up areas are a part of the Monitoring System of Spatial Structure (MSSS). First of all, the areas with high population and building density are located. The most important criteria in defining the densely built-up area are:

- The number of buildings
- Gross floor area
- Amount of population

In addition, the following criteria are taken into account:

- Large, individual buildings are considered to be a part of densely built-up area if they are located at the edge of the densely built-up area and are connected to it functionally, even though the distance would not be short enough (large industrial buildings, storehouses etc.).
- String like settlements comparable to dispersed settlement are not included in the densely built-up areas.
- Large unbuilt areas such as fields, forests and water areas located inside the densely built-up area also separated out.

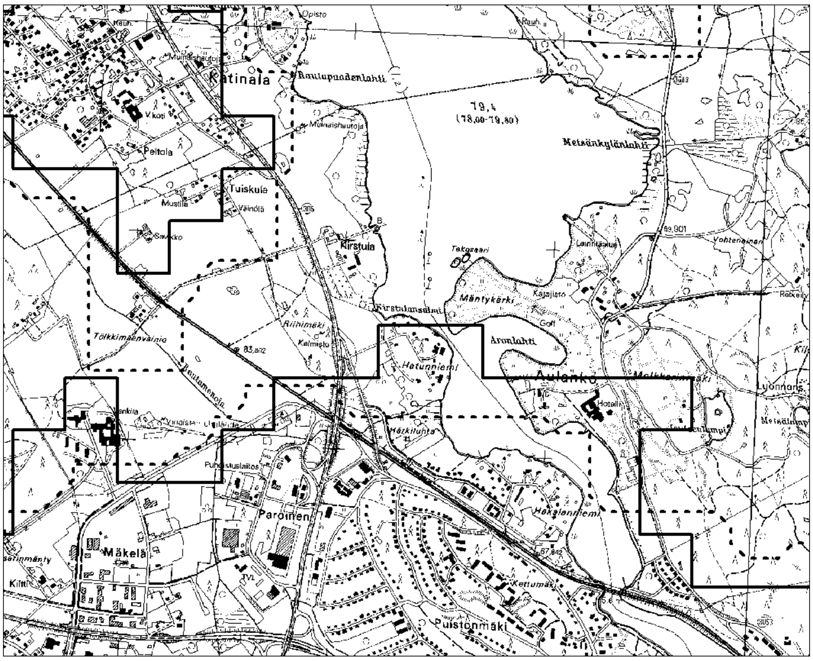


Figure 4.23. Densely built-up areas - an example. Topographical map in background

4.7 Methods for creating socio-economic indicators

An ecologically sustainable area can be described as an area, which requires the supply of as little energy and raw materials as possible, (especially non-renewable materials), and produces the minimum of harmful emission and wastes, from all the building and operating processes. A sustainable area should also offer people a good living environment and be economically affordable (Lahti & Harmaajärvi 1992, Harmaajärvi & Lyytikkä 1999). The aim of the project is to develop methods and tools for describing and assessing impacts of urban growth from the point of view of sustainability and economic and environmental competitiveness, as well.

The tools is divided into the following categories:

- Capacity for urban growth
- Building potential - compared with plans
- Services - social infrastructure
- Technical infrastructure
- Competitiveness capacity (affordability)
- Urban costs
- Urban ecology
- Environmental quality
- Built environment
- Natural environment.

The methods and tools are developed for three different spatial planning levels: regional planning (test area: Hämeenlinna-Riihimäki-Hyvinkää zone), sub-regional planning (test area Sipoo municipality) and interregional planning (the Southern Finland).

4.7.1 Efficiency of built-up areas – density

The idea is to classify built-up areas by density, where the density descriptor may be population or the efficiency of the buildings. The method is based on the location and size of the building points. So called natural neighbourhoods are built around the array of building points using Delaunay triangulation. A network of Thiessen polygons is generated from the point locations creating what is called a Voronoi diagram. Any location within a region will always be closer to the enclosed point in that region than to the enclosed point of any other region. Building efficiency is determined to each building using the above mentioned natural neighbourhoods and the gross floor area of each building point. The idea of the sliding density method is not to represent single point values but give average value in greater area. The average of the building density is calculated using focal method. Data points lying within a prescribed radius of a grid node are calculated to the grid cell value. As a result of the method continuous building efficiency grid from single building points is generated.

4.7.2 Building potential (capacity)

The aim of assessing the building potential of an area is to find out where and in which degree it is possible and desirable to locate new areas for dwelling or other functions. In the international context there is a common understanding that infilling and complementary building possibilities are desirable to utilise for sustainable development. New areas should be located in connection with existing urban structure and in the vicinity of good transportation connections.

The plans show the planned total capacity of the area and using the area density method it is possible to define the existing building stock. The remaining capacity (reserve) is the planned capacity. The designed capacity in master plans and especially in regional plans has often been defined very generally. There are often no capacity figures in separate area units of the master or regional plans. The total capacity is often estimated at municipal level. In this kind of situation it is necessary to assess the capacity using the realised e.g. residential areas.

4.7.3 Evaluation of the potential of services

Assessing the location and accessibility of existing services can be utilised, when planning new areas and assessing the need of new services. The results concerning distances to services also form a part of the basis for assessing economic and ecologically impacts of transportation. Based on this method it is possible to consider the distance to daily and special services. The method creates a surface grid, which describes the supply of services in various areas. The values of the grid represent distances to groceries or other daily services and converted distances to centres, which offer special goods or services supply, as well. Besides, there is a value, which describes the service level of the area. Distances to daily services and the special services have been determined from the classified centre network (fig. 4.24). In relation to special services distances have been counted to three centres with at least 20 functions.

4.7.4 Evaluation of urban costs

Assessing urban costs includes determining the distances to connection (road) networks, developing urban growth alternatives as well as evaluating the costs of different urban structures and transportation. Costs incurred by new urban structures of an area are evaluated in following groups:

- Construction costs (buildings, networks, parks, green areas).
- Operation costs (heating, lighting, maintenance, e.g. life cycle of 50 years).
- Transportation costs (commuting, school trips, personal business trips, e.g. life cycle of 50 years).

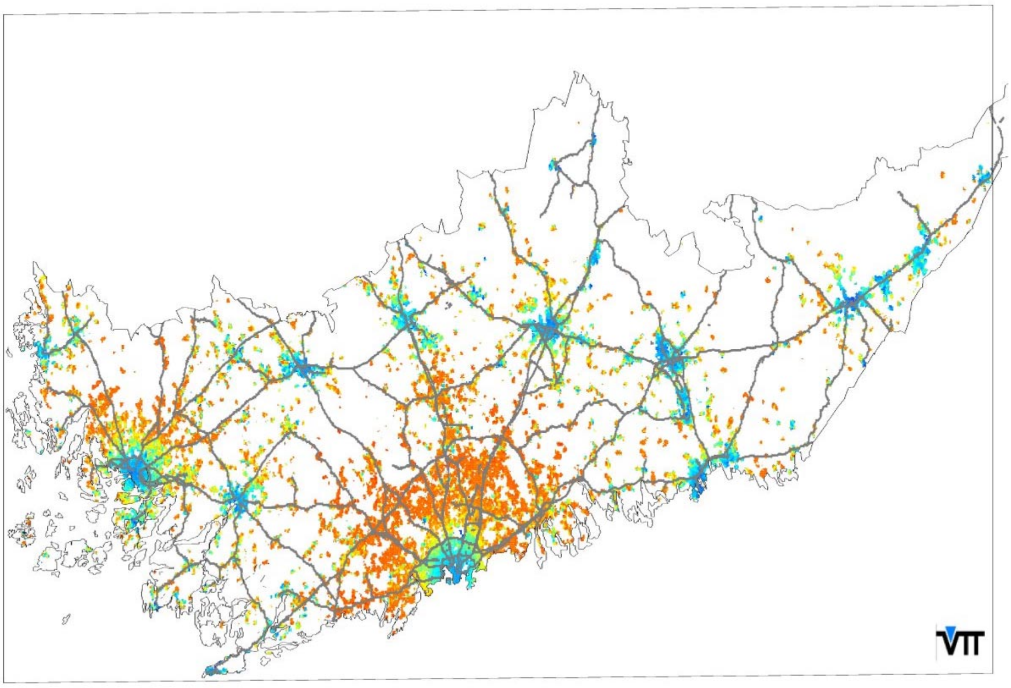


Figure 4.24. A Distance model to daily and special services in the South Finland Area (grids of 125 m x 125 m)

- FIM/floor-m^2, FIM/inhabitant, FIM Total, •/floor-m^2, •/inhabitant, • total.

Additionally, costs are evaluated for the following structures of an area:

<u>Buildings</u>

- Residential (detached houses, row houses, blocks of flats)
- Other buildings (services etc.)

<u>Networks inside an area</u>

- Transportation networks
- Water supply and sewerage network
- District heating network

<u>Other structures inside an area</u>

- Parks, grounds etc.

<u>Transportation</u>

- Commuting
- School trips
- Personal business trips.

Costs are evaluated using the unit cost method. Continual costs of operation and transportation are summed with investments by using present value calculation with a time period of 50 years and interest rate of 5 %. The method for cost evaluation is developed on the basis of VTT's cost analysing methods.

The costs of connecting technical infrastructure are evaluated by assessing need for new networks. The first step of the determination of the costs of urban infrastructure is to depict the existing infrastructure network. The method creates buffer grids that measures continuous distance from individual lines (road networks). The procedure is implemented by forcing the algorithm to measure the distance to the nearest node of the network. The new grid represents a continuous surface of distance from a single (line network), where distance values increase as they move away from the point (line network). Therefore, it is possible to generate a continuous buffered surface from a series of points (network) representing e.g. road networks. The resulting grid is an effective and very accurate representation of a buffer that measures the distance to the nearest road point from every location in the map area. Figure 4.25 illustrates distances from road network in a part of the Häme region.

Table 4.3 shows the economic impacts of urban structure and transportation. The costs are based on VTT's case studies concerning urban development in different regions. Costs are assessed using a life cycle of 50 years and interest rate of 5 %.

VTT Communities and Infrastructure 2000
ECONOMIC IMPACTS OF URBAN STRUCTURE
LIFE CYCLE 0F 50 YEARS, CONSTRUCTION, OPERATION AND
TRANSPORTATION COSTS (costs per floor square metre or metre)

CONSTRUCTION AND OPERATION	**Costs**
	FIM/floor sqm
DWELLINGS	
Flats	6841
Terraced houses	7274
Detached houses	7191
NETWORKS	
Types of areas:	
Flats	660
Terraced houses	867
Detached houses	1330
TOTAL	
Types of areas:	
Flats	7501
Terraced houses	8141
Detached houses	8521
CONNECTION NETWORKS:	
	Costs
	FIM/m
Transportation	1703
(Width 10 m)	

TRANSPORTATION COSTS , COSTS PER COMMUTING AND CENTRE DISTANCE				
	FIM /vehicle-km			
	Commuting		Others	Others constant
Cars	3 054		7 371	82 924
Buses	80		187	4 385
Total	3 134		7 558	87 309
COSTS PER VEHICLE KILOMETRE (50 a)				
Cars	27.7			
Buses	72.8			
PERFORMANCE (Vehicle kilometres per inhabitant, commuting and centre distance-km)				
	Commuting		Others	Others constant
Cars	110.4		266.5	2997.6
Buses	1.1		2.6	60.2
modal split				
Commuting		Others		
0.69		0.73		
0.15		0.11		

Table 4.3. Costs of urban structure and transportation

The needed costs caused by construction and operation of connection (road) network if new urban growth is located in different parts of the Häme region are shown on the figure below.

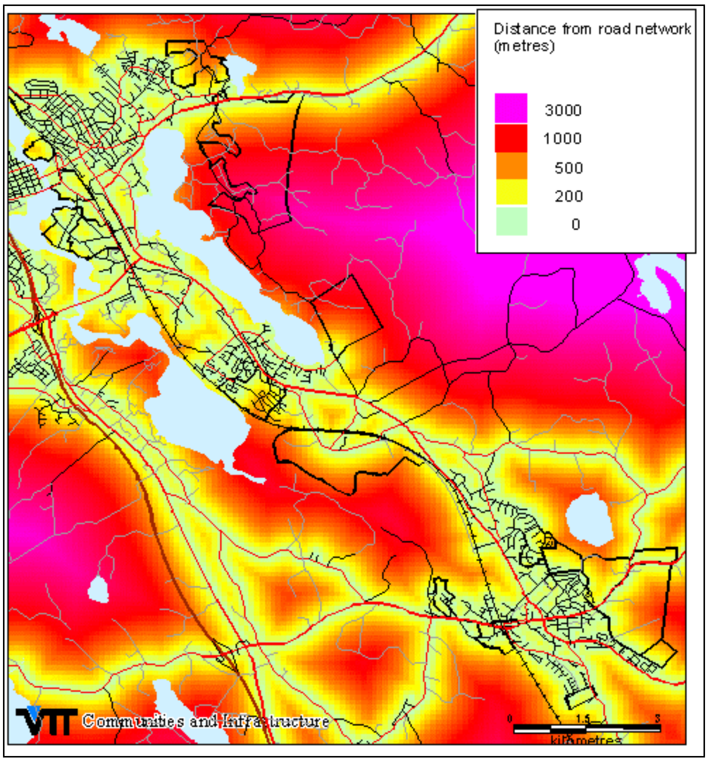


Figure 4.25. Distances to road network in a part of the Häme region

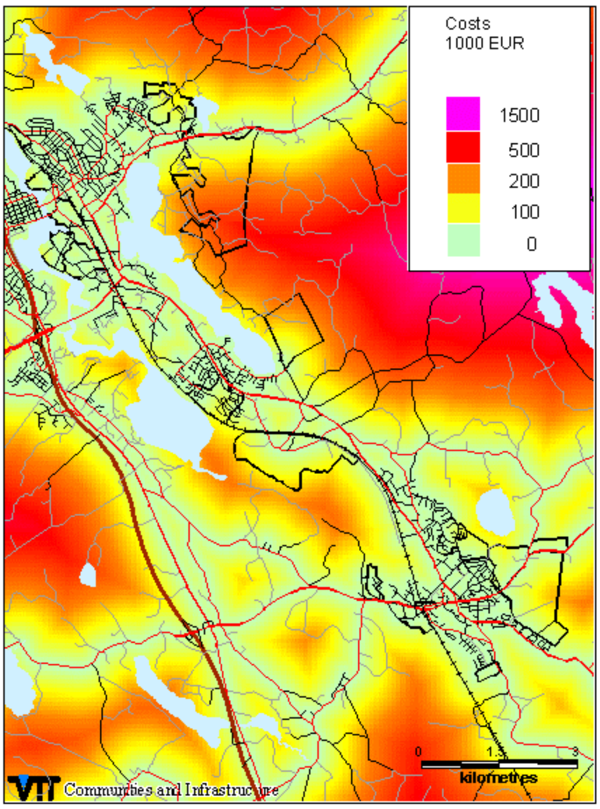


Figure 4.26. Construction and operation costs of new connection roads in a part of the Häme region. Life cycle is 50 years and interest rate is 5 %.

4.7.4 Methods for environmental impact assessment

Below we describe a combination of GIS-based and urban ecological methods for defining environmental impacts of construction, transportation, energy consumption and emissions (CO_2, CO, SO_2, NO_x, CH_4, particles etc.) The impacts are expressed as total impacts as well as relative impacts (e.g. per floor-m^2 and per inhabitant). The evaluation method is developed on the basis of VTT's ecological assessment models EcoBalance and Emicus.

The methods are generally based on grids. The input GIS data can be grids, points, lines or polygons. The methods represent the data as a continuous surface, where any location can be queried and a meaningful value obtained.

Environmental impacts of construction and maintenance of urban structures as well as transportation are assessed including quantitative evaluation, calculation of emissions and qualitative assessment, by assessing the quality of environment. The ecological impacts of transportation using a 50-year life cycle are presented in table 4.4. The results using these methods are presented as "ecological impact surfaces", and the figures 4.27 and 4.28 describe environmental impacts of new road networks, needed if new urban growth is located in different parts of the Häme region. Impacts are based on distances from the existing network (figure 4.25). The environmental impacts described are energy consumption, raw material consumption and CO_2 emissions. All impacts are assessed using a life cycle of 50 years.

PSSD VTT 2000	ECOLOGICAL AND ECONOMIC IMPACTS OF URBAN STRUCTURE LIFE CYCLE 0F 50 YEARS (impacts per floor square metre or metre)				
	Energy consumption kWh/floor sqm	Raw material consumption Building materials kg/floor sqm	Fuels kg/floor sqm	CO2 emissions kg/floor sqm	Other emissions kg/floor sqm
DWELLINGS					
Flats	13674	1135	2150	5100	49
Terraced houses	13537	1382	2150	5100	49
Detached houses	13537	1382	2150	5100	49
NETWORKS					
Types of areas:					
Flats	574	771	38	131	0.6
Terraced houses	665	1045	43	150	0.8
Detached houses	741	1471	44	278	0.8
TOTAL					
Types of areas:					
Flats	14248	1906	2188	5231	49
Terraced houses	14202	2427	2193	5250	49
Detached houses	14278	2853	2194	5378	49
CONNECTION NETWORKS:					
	Energy consumption kWh/m	Raw material consumption Building materials kg/m	Fuels kg/m	CO2 emissions kg/m	Other emissions kg/m
Transportation	590	12 600	0	168	0
(Width 10 m)					

Table 4.4. Ecological impacts of urban structure

4.7.5 Economic and ecological impacts of transportation

Commuting forms about 25-30 % of all passenger traffic in Finland. Commuting is estimated using a commuter database, containing the location of home and workplace for all Finns. The database is in grid format (125 metres * 125 metres) and produced by Statistics Finland.

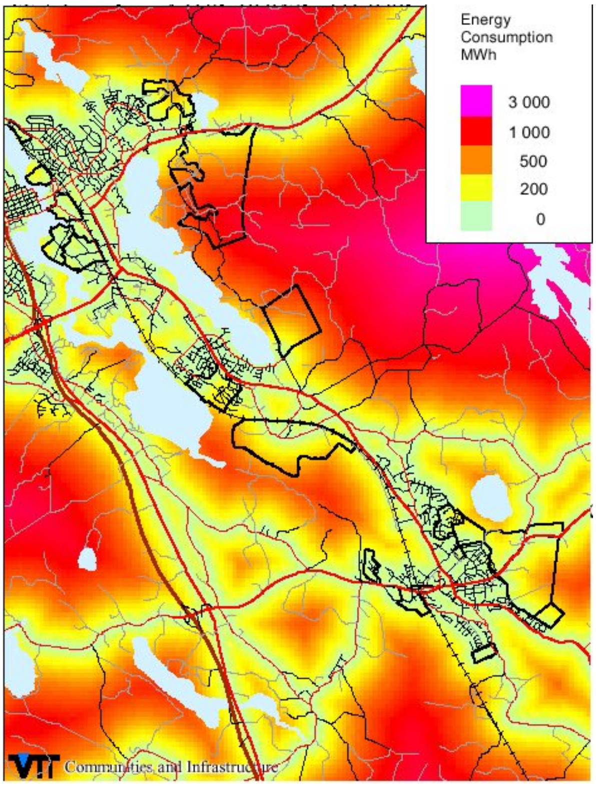


Figure 4.27 Energy consumption (MWh) of new road network

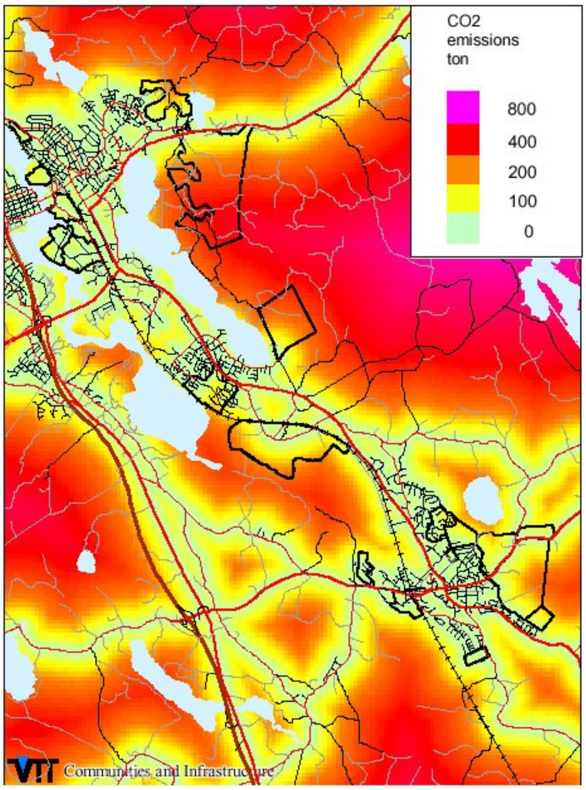


Figure 4.28. CO_2 emissions of new road network

During the fifteen years period (1980 -1995) the average commuting distance in Finland has generally increased by 2 km. The biggest changes of commuting have happened at the edge zones of urban districts, where to new inhabitants have migrated. Those new inhabitants commute often to the main centre area of the district where most of the workplaces are, instead of nearest areas. This phenomenon extends the commuting area. However, in some areas near centre or downtown area commuting distances have shortened.

To estimate commuting and its economical as well as ecological impacts, it is possible to estimate quite exactly commuting mileage in the future by the commuter database. The commuting mileage is assessed by the following method. So-called "commuting distance surface" is created calculating the average commuting distance from dwellings to workplaces.

There must be enough arguments to calculate the average commuting distance in order to avoid random variation. The minimum amount of commuters is for example ten. There are several extrapolation techniques. One technique is Inverse Distance Weighting, which is used in MapInfo. This method creates a grid covering to whole area. The size of the grid is freely chosen and the value of the grid cell is a result of calculation. Original data points (commuter) lying within a prescribed radius of a grid cell are weighted according to their distance from the cell and then averaged to calculate the cell value. Figure 4.29 describes commuting distances at different planning levels.

4.7.6 Economic and ecological impacts of transportation / commuting

Again the commuter database of Statistics Finland is used. Modal split is divided into

- Light traffic (pedestrians and bicyclists),
- Public transportation (buses and trains),
- Private cars.

The costs and energy consumption as well as emissions of commuting are assessed using the methods developed at VTT. The economic and ecological impacts are assessed on a life cycle basis, using a life cycle of 50 years. Present value of costs is determined using interest rate of 5 %. Using the coefficients in table 4.4 and 4.6 the energy consumption of commuting is calculated (fig. 4.30).

	Energy consumption	CO2	other emissions
	kWh/ vehicle kilometre	kg/vehicle kilometre	g/vehicle kilometre
private car	0.754	0.19	9.329
public transportation	3.098	0.8	17.12

Table 4.6. Energy and emissions coefficients

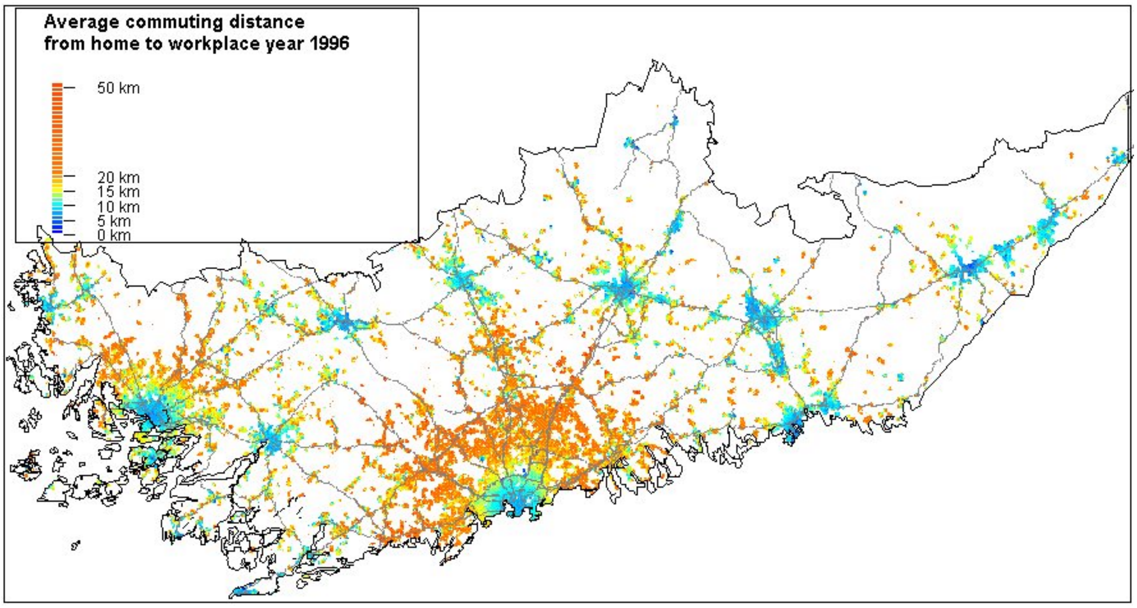


Figure 4.29. Average commuting distances from dwellings to workplaces in South Finland

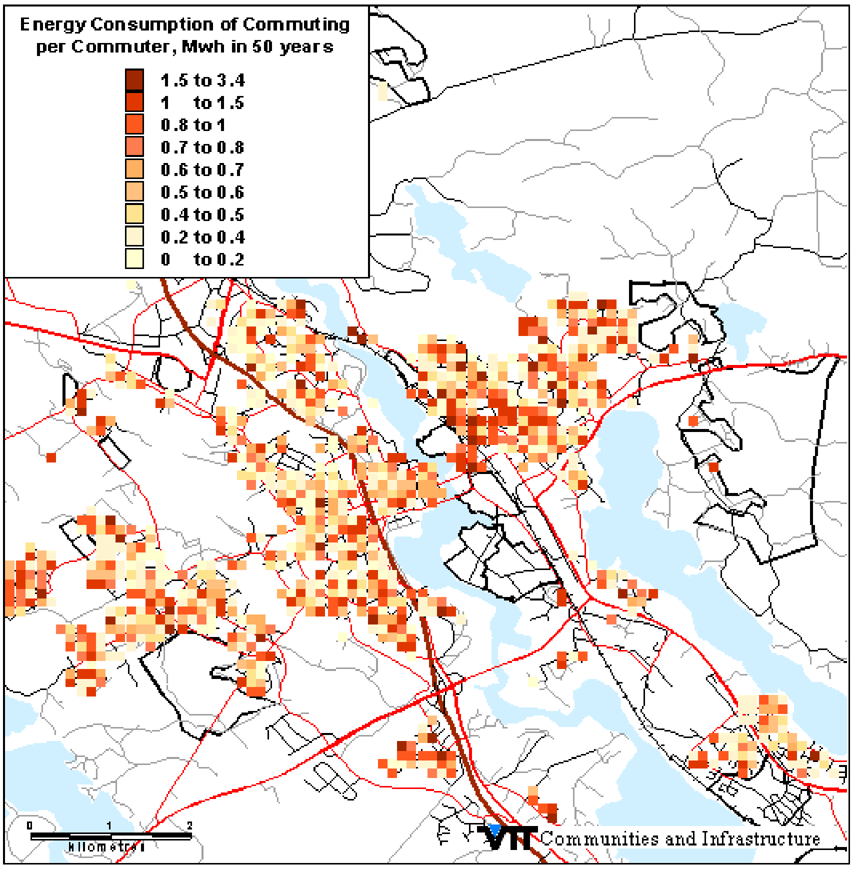


Figure 4.30. Energy consumption of commuting

4.7.7 Commuting distances and workplace self-sufficiency

Analysing the spatial distribution of workplace self-sufficiency in 1995 and its changes during the 1985-1995 period is based on data from Statistics Finland. First, we make the following essential definitions:

- Workplace self-sufficiency
  The workplace self-sufficiency of an area has traditionally been expressed as the proportion between the number of workplaces and the employed labour force in the area. This number is usually expressed as a percentage. The area unit is normally a municipality or a part of it. The workplace self-sufficiency is even nowadays represented this way. However, the traditional workplace self-sufficiency can be over 100% (e.g. in the central areas). The workplace self-sufficiency of an area is influenced by the area boundaries used, so the traditional workplace self-sufficiency does not tell how large a proportion of workforce living in an area actually go to work within the same area. In principle the workplace self-sufficiency of an area can be 100% even if nobody of the inhabitants are working inside the same area. A real workplace self-sufficiency should be expressed as the proportion between the number of people working in an area and the employed labour force of the same area.

- Commuting distance
  The commuting distance means here the one-way beeline home-to-work distance. The data used here consists of one-way journeys from home to work below 100 km. When the distances are longer, secondary apartments become common. The data also contains the work journeys that are directed outside the commuting region. The impacts of the part-time tele working have not been taken into account. A short commuting distance means here a one-way work journey that is under 2 kilometres long. The actual distance between home and workplace is on an average 10 – 15 % longer than the beeline distance. At this distance the light traffic (e.g. walking or cycling) is a possible choice.

- Commuting region
  A municipality is a part of a wider commuting region if over 20% of its workforce commute outside the borders of their own municipality and over 7% commutes to the central municipality. The borders of the commuting regions have changed during the past years because of the incorporation of the municipalities, among other reasons. The definitions used here are from year 1993.

The common trend is that the workplace self-sufficiency has declined. For traditional self-sufficiency in workplaces the decline has been moderate. The real workplace self-sufficiency has decreased in 4/5 of all the municipalities and in the rest the rate stayed almost the same. The share of municipalities with a real workplace self-sufficiency above 80 % was half of all the municipalities in 1985, whereas the share was only one-third in 1995. There are many reasons behind the changes of self-sufficiency in workplaces. Changes in economical structure, housing and labour market have been remarkable. The specialisation of labour market has caused the enlargement of the commuting areas. The employees have to search work from a wider area and also the employers have to search workers from a wider area. There is also a lot of labour force released from the agriculture.

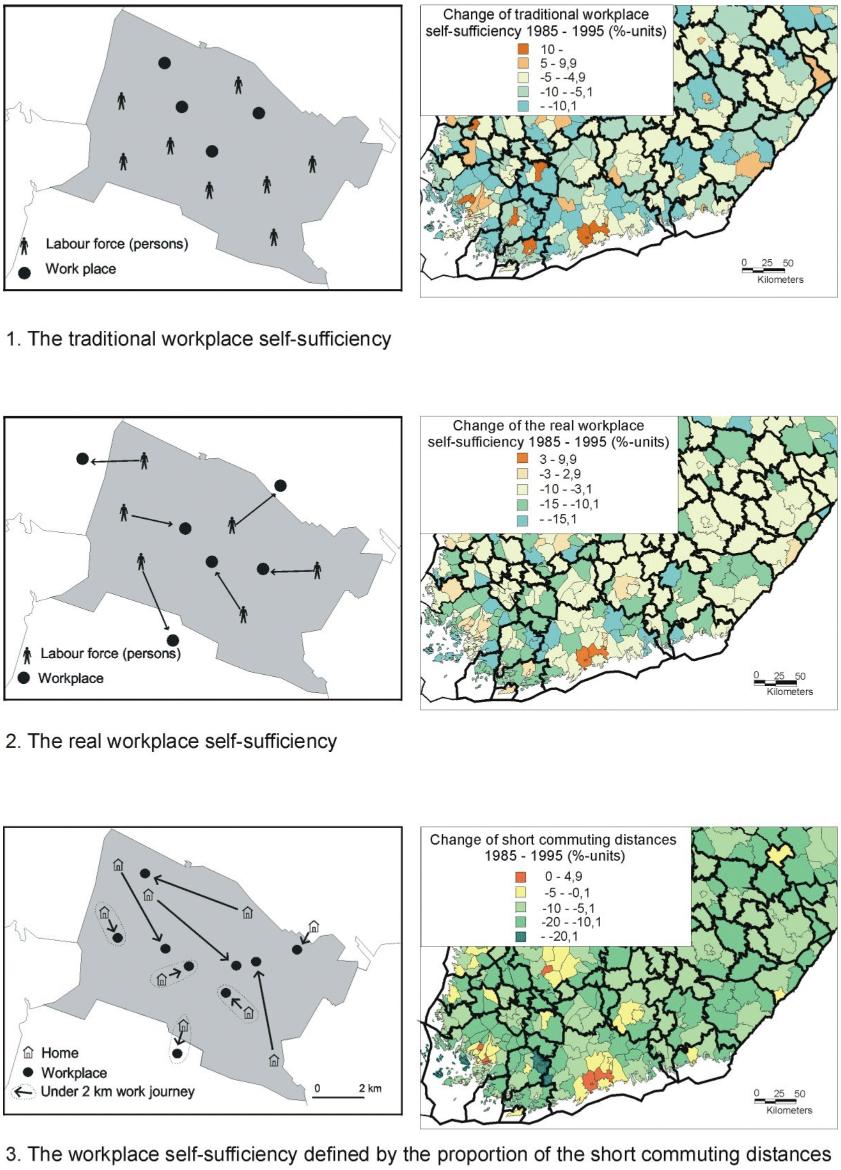


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Figure 4.31. The workplace self-sufficiency – definitions

This labour force has to commute to urban areas if the distance is not too long.

4.7.8 Road Traffic Noise in Turku urban area

Since noise has notable effects on individual's health, it is important to take into consideration the road traffic - one of the main external sources of noise in residential areas. Results of the modelling can be used to optimise mobility structures in future community to avoid unnecessary cumulative noise problems.

Two main points are considered in the study. First, the regional planning process is taken into account (Regional Council of Southwest Finland). Second, the environmental health issues are considered (Baltic Region Healthy City Office). The noise level in residential areas (estimating the number of people living above a certain noise level) and in recreational / protected areas is calculated. Also the possible silence of an area (as an attraction factor) is examined.

Two different kind of traffic data where used in the noise model. For the city centre area and for smaller roads, traffic model data from Turku city were used. For the main roads we acquired data from the Finnish National Road Administration.

The noise calculations were based on the Nordic Road Traffic Noise Prediction Method where the main steps are:

- Calculation of the basic noise level for road blocks
  The roadblocks are deviated to equal interval emission points.

- Distance correction
  The distance correction is -3 dB per doubling of distance.

- Elevation correction
  This is done in two steps - by using visibility and elevation change analysis

- Screen correction of buildings
  The correction is entirely empirical. It is useful for space-average noise levels only.

Using the noise model described above we produced noise maps for the Turku urban area. From the maps it is possible to find areas of different noise levels areas as well as silent areas (see figure 4.32).

4.7.9 Injuries Caused by Traffic Accidents in City of Turku

Traffic accidents causes far too much human suffer (e.g. injuries and even loss of human lives). For this reason, it is important to map possible high-risk areas of serious traffic accidents and evaluate the consequences of traffic accidents. The main point of this study is to locate traffic accidents and clarify the consequences of these accidents.

In this study we used police and hospital statistics from Turku city and examined the years 1996 and 1997. Every accident was assigned a location and the police and hospital statistics were combined using social insurance number. Combined statistics were presented on maps, thus illustrating the spatial distribution of different traffic accidents and in some case the consequences of the accidents - e.g. the number of sick pay days and bed days in hospital (see figure 4.33).

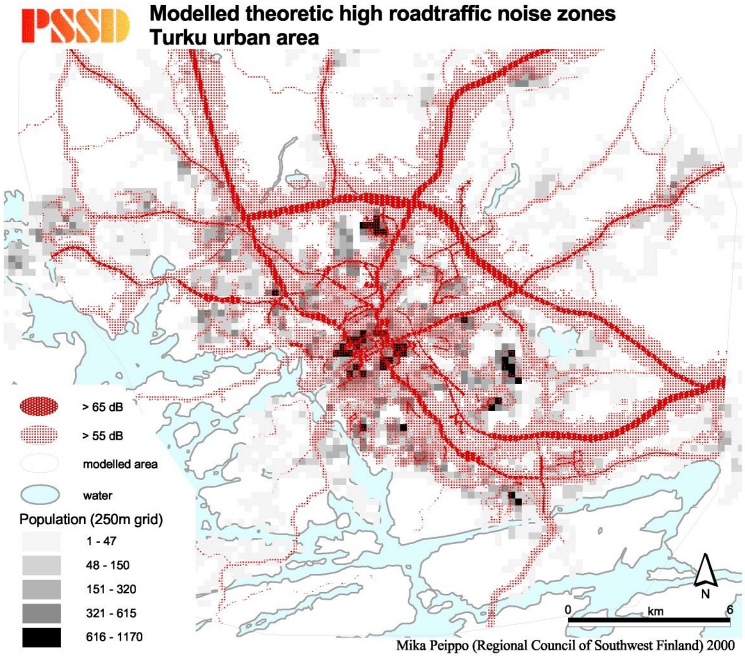


Figure 4.32. Road traffic noise zones in Turku

Figure 4.33. Serious injuries caused by traffic accidents in Turku

5 Technology and interfaces

Information technology plays a key role in the PSSD project. First, the whole project is concerned with GIS based planning - primarily using the grid data model. Second, the methods and tools developed during this project was put into a Web-based so-called Planners Toolbox, thus utilising the dynamics of the Internet. Finally, the Internet provides new opportunities to publish and visualise data on environmental and planning topics. There, a lot of technical tolls have been developed as a part of the Planning System for Sustainable Development.

5.1 Aggregation and disaggregation of spatial data

A planning system for sustainable development involves a wide range of different spatial data, but integrating different kind of spatial data may often cause problems. Many data in the social and environmental sciences are collected for polygon units, but the systems of units often differ between the different data sets. Environmental defined regions such as vegetation zones or watersheds will seldom match the boundaries for official defined zones like counties and municipalities. For example, air quality and traffic count data are collected and usually reported as point data, whereas land-use is reported as polygons. Population data is collected by points (households) but reported by region (parish or municipality) due to confidentiality requirements. Consequently, we need tools to aggregate and disaggregate spatial data into new spatial units - e.g. grid cells.

5.1.1 Spatial aggregation – points to grid cells

Aggregating point-based information into grid cells is one of the more simple operations in spatial analysis. Basically, this task consists of two steps, where the first step is common to all kinds of data, whereas the second step depends on the type of data.

First, a *polygon-on-point* overlay between the point theme and the grid cell theme is carried out. Thus, the attribute data of the grid cell theme will be assigned to the point theme. When this processing is finished, each observation point is assigned a unique grid cell number.

For numeric data, the next step will be to create a new table, with one record for each unique value of the cell-id, and two columns - the first one containing the cell identification and the second one the sum of point values within the cell (fig. 5.1).

For categorical data, the next step is more complicated. Often a cell contains points representing different categories, and therefore no single value can be assigned to the cell. Of-course this problem can be solved in many ways, but a rather simple approach would be to create a cross-table containing the grid cell number as the primary key,

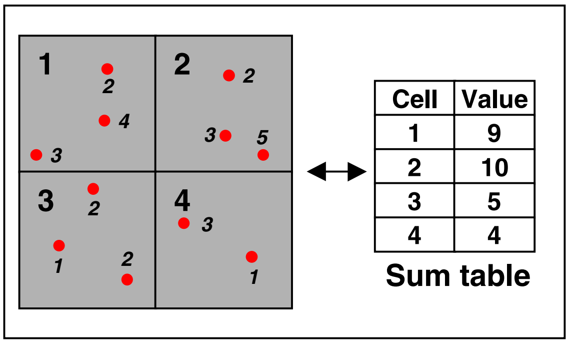


Figure 5.1. Aggregating numeric point values into grid cells

whereas the additional columns represents unique values of the case item (fig. 5.2). In practice, the cross-table can easily be made using the Report Writer extension of ArcView 3.1 – or Seagate Crystal Reports. The Avenue script *Pnt2Cells.ave* performs all steps of the point-to-grid cell aggregation. Finally, the output tables - a sum table for numeric data or a cross-table for categorical data - can be joined to the theme table of the grid cell theme.

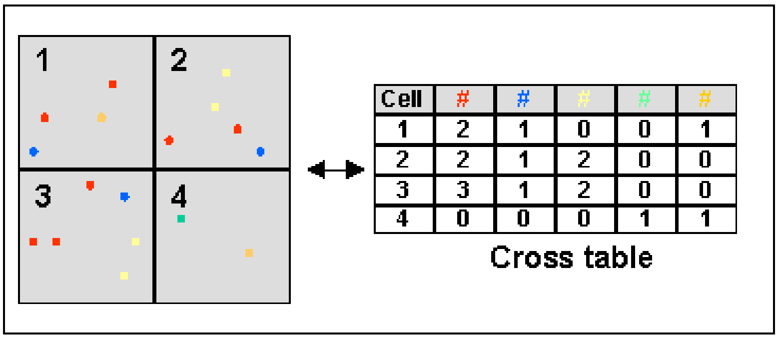


Figure 5.2. Aggregating categorical point values into grid cells

The example below demonstrates the result of aggregating address-based population data from the island of Als into a grid cell theme. Address geocoding in ArcView is a process that creates a theme based on address data. During geocoding, ArcView reads these addresses and locates them on a theme representing the street network, for example the Danish Address and Road database. This involves the process of address matching, comparing two addresses to determine whether they are the same. To match addresses, ArcView looks at the components of addresses in both the population data file and the street network theme. As a result, ArcView creates a geocoded point theme storing the attributes of all records in the address event table and the XY co-ordinates of the successfully matched records. Using this point theme and a grid cell theme covering the same area as input data to the *Point-to-GridCell* routine, a map showing the population distribution was created (fig. 5.3).

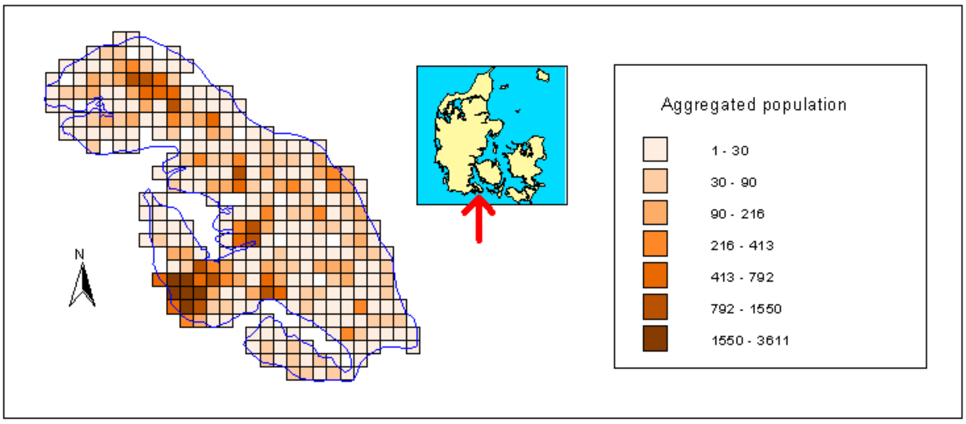
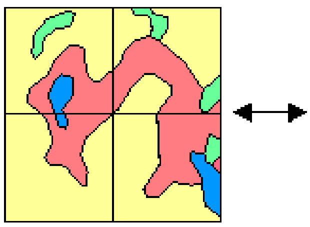


Figure 5.3. Population data aggregated to 1 km grid cells

5.1.2 Spatial disaggregation – polygons to grid cells

In this case it is important to distinguish between *intensive* and *extensive* variables (Goodchild & Lam, 1980). A spatial intensive variable is expected to have the same value in each part of a polygon, as in the whole polygon. Ratios like average income and categorical data like land use are examples of intensive variables. A variable is said to be spatially extensive, if the value of a larger region is expected to be the sum of the values for its component parts. Population is an example of an extensive variable.

Intensive data is more easy to handle, because the original polygons are derived from the spatial variation itself, and therefore internal homogeneous. Often a cell contains sub-polygons representing different categories, and therefore no single category can be assigned to the cell. A cross-table containing the grid cell number as the primary key, whereas the additional columns represents unique values of the case item will solve this problem (fig. 5.4). Again, the cross-table can be made using the Report Writer in ArcView 3.1 – or Seagate Crystal Reports.



Cell	Area	Area	Area	Area
1	28.0	5.8	60.3	5.8
2	35.1	0.0	55.6	9.3
3	19.9	1.2	79.2	0.0
4	32.0	9.0	55.9	2.9

Cross table

Figure 5.4. Converting intensive polygon data to grid cells

Extensive data is much more complicated to convert. The classical method is based on combining source zone values weighted according to the area of the target zone they make up - therefore it is often referred to as the area weighted method (Goodchild & Lam, 1980). This area weighted overlay method assumes that the variable of interest is evenly distributed within the source zones and this seems unlikely in most cases. However, if no information is available about the distribution of values within the source zones, this procedure might give the best results.

Basically, the disaggregation method for numeric values described here, is an enhancement of the traditional area weighting method, permitting additional information to be taken into account (Hansen, 1997).

An additional map theme, indicating the spatial distribution of the variable of interest is involved. The disaggregation is done through a combination of all three, map layers. Obviously, this technique is dependent on the correlation between the auxiliary map theme and the variable in question. For example, the land-use pattern seems to be a reasonable indicator of the spatial distribution of population.

- First, an intersection between the source zone theme and the weight theme is made.
- Second, the cumulated values of area multiplied with weight are calculated for each source zone polygon.
- Third, a second intersection between the new theme resulting from the first step and the grid cell target theme is computed.
- Finally, the new interpolated value is computed by summing up for each cell, the original source zone value multiplied with the ratio of the sub-polygon area weight to complete polygon area weight (calculated in step two).

The steps in the disaggregation algorithm are illustrated in fig. 5.5.

The quality of the results using this method is primarily dependent on choosing a reasonable weight theme. Furthermore, the individual weights will influence the result.

The next example illustrates how to disaggregate parish-based population data into a grid cell theme. Again the study area is the island of Als. As auxiliary weight theme, CORINE land-use was chosen. Each land-use class is assigned a weight, indicating the relative population density of that class compared with other classes. Thus, land-use classes representing urban areas are assigned high weight values, whereas classes representing forests, bogs, lakes etc. are assigned low values or zero. The original population data at parish level and the CORINE theme are shown on fig. 5.6. Based on these themes and a 1-km grid cell theme, a new disaggregated population map was produced (fig. 5.6).

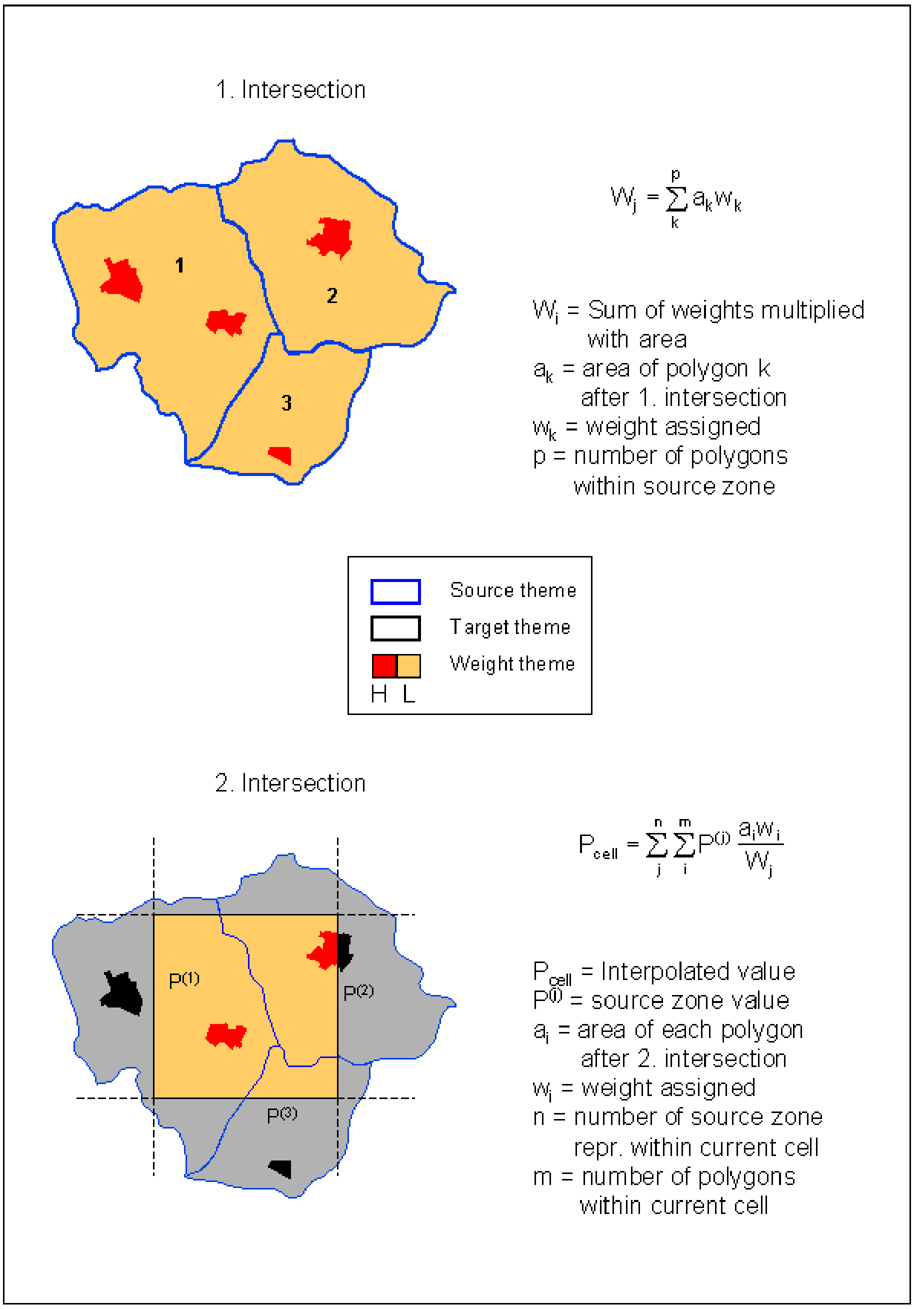


Figure 5.5. Converting extensive polygon data to grid cells

Comparing the interpolated population distribution (fig. 5.6) with the "real" population distribution (fig. 5.5) shows the same general pattern of population density. However, if you go into detail and compare population values for individual cells, the differences are more evident. Particularly, in the urban areas the differences are significant. Perhaps, land-use isn't a satisfactory indicator for population density. Furthermore, CORINE land-use is too coarse regarding the thematic classification as well as the spatial resolution. Nevertheless, the developed disaggregation technique seems to give a useful distribution compared with the original population data at parish level.

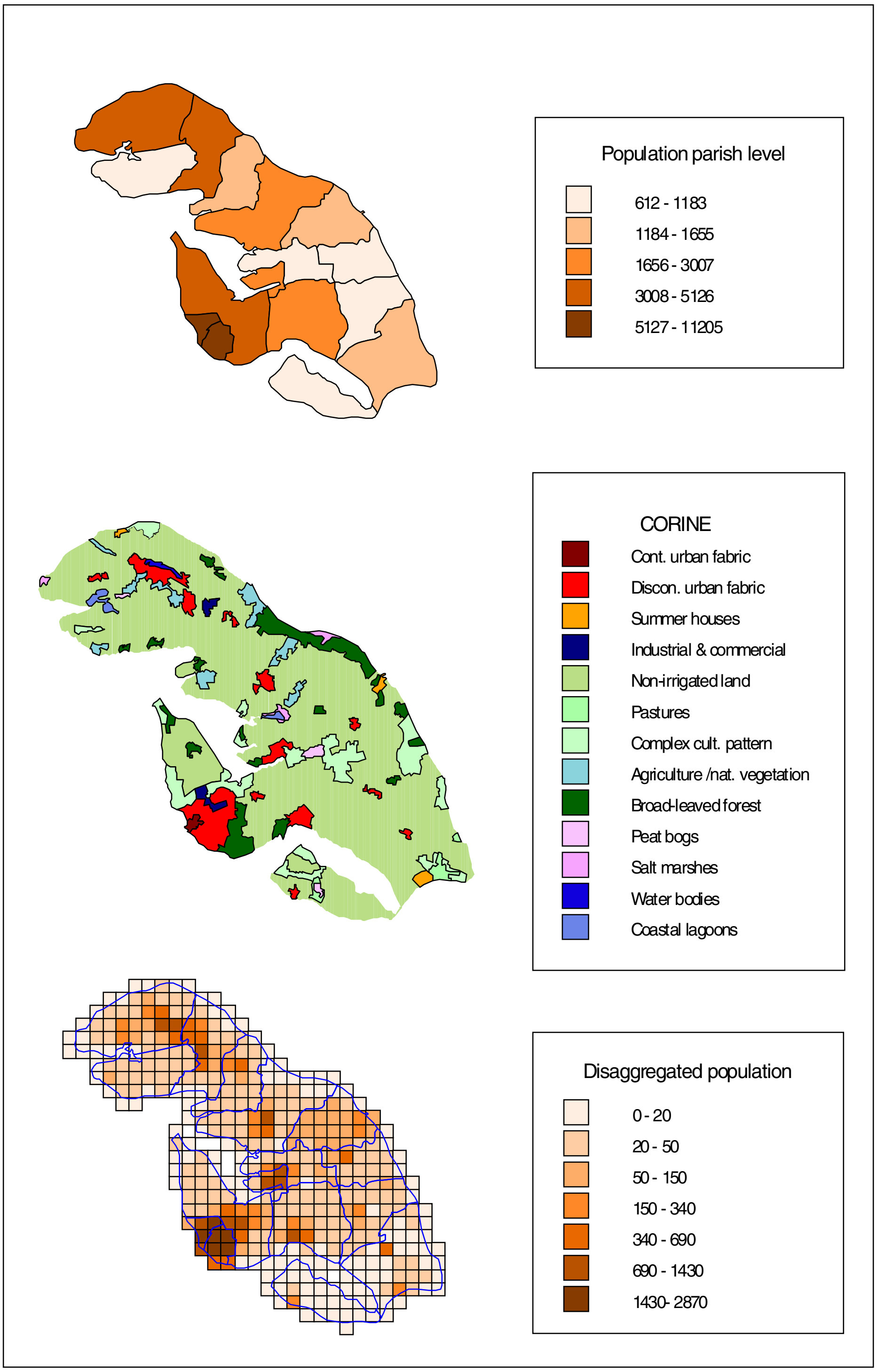


Figure 5.6. Population data disaggregated to 1 km grid cells

5.2 Spatio-temporal visualisation

5.2.1 Mapping spatio-temporal changes of densely built-up areas

The spatial changes of the densely built-up area are divided into distinct parts in order to examine the spatial change of the densely built-up area and it's impact on variable's (e.g. population) temporal development.

The changes (growth / degradation) of the densely built-up area (see the paragraph "Definition of the densely built-up area") can be divided into two main categories:

The internal change of the densely built-up area
<u>+ The spatial change of the densely built-up area</u>
The change of the densely built-up area

The internal change (e.g. population change) is calculated so that the borders of the area are "standardised" as they were at starting point of the analysis period. The spatio-temporal changes of the densely built-up area can be divided into following parts:

- The spatial expansion of the existing densely built-up area
- Integration of a densely built-up area with another densely built-up area
- Separation of a densely built-up area into two separate areas
- The birth of a new densely built-up areas
- The death of the densely built-up area. When the population of the densely built-up area decreases under the minimum level (200 inhabitants in the Nordic Countries), the population structure of densely built-up area becomes more like a village.

The spatial changes of the densely built-up areas can be analysed with this division. In this way it is possible to find out how big share of the change of the variable (e.g. population) is due to expansion / reduction of the densely built-up area in previous mentioned ways.

When analysing the spatial changes of the densely built-up areas between 1980 and 1995, the densely built-up areas' borders from these two years will be compared to each other. By overlaying these two polygons, it is possible to see where new densely built-up areas have been born, where the densely built-up areas have disappeared and where they have been joined or separated. The expansion area can be separated, if the polygon according to the densely built-up area in 1980 is erased from the polygon of densely built-up area in 1995. By comparing the changes of the variable in different parts of the densely built-up area, it is possible - for example - to calculate how big share of the change of the densely built-up area is due to expansion.

Figure 5.7 illustrates the typology of spatio-temporal changes. It describes the different types of spatial changes during the time (year 1980-95) of a densely built-up area as an example. Figure 5.8 shows a real example of the phenomenon in the urban regions, Imatra and Lappeenranta (Finnish towns from the southeast part of the Finnish - Russian border).

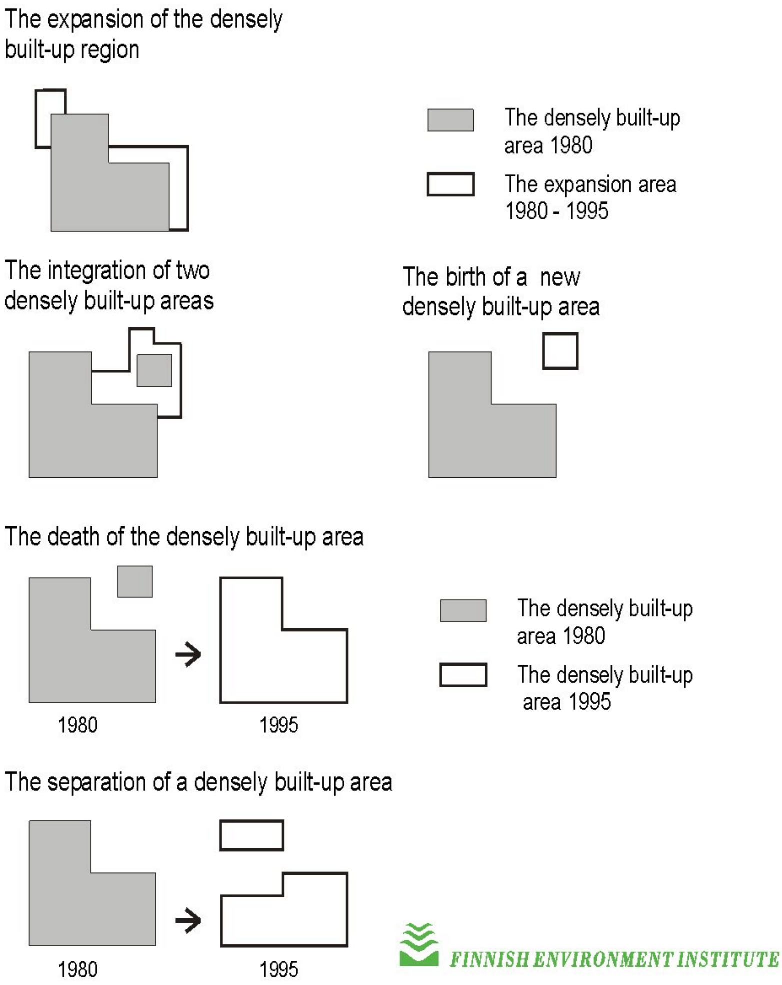


Figure 5.7. Expansion of densely built-up area

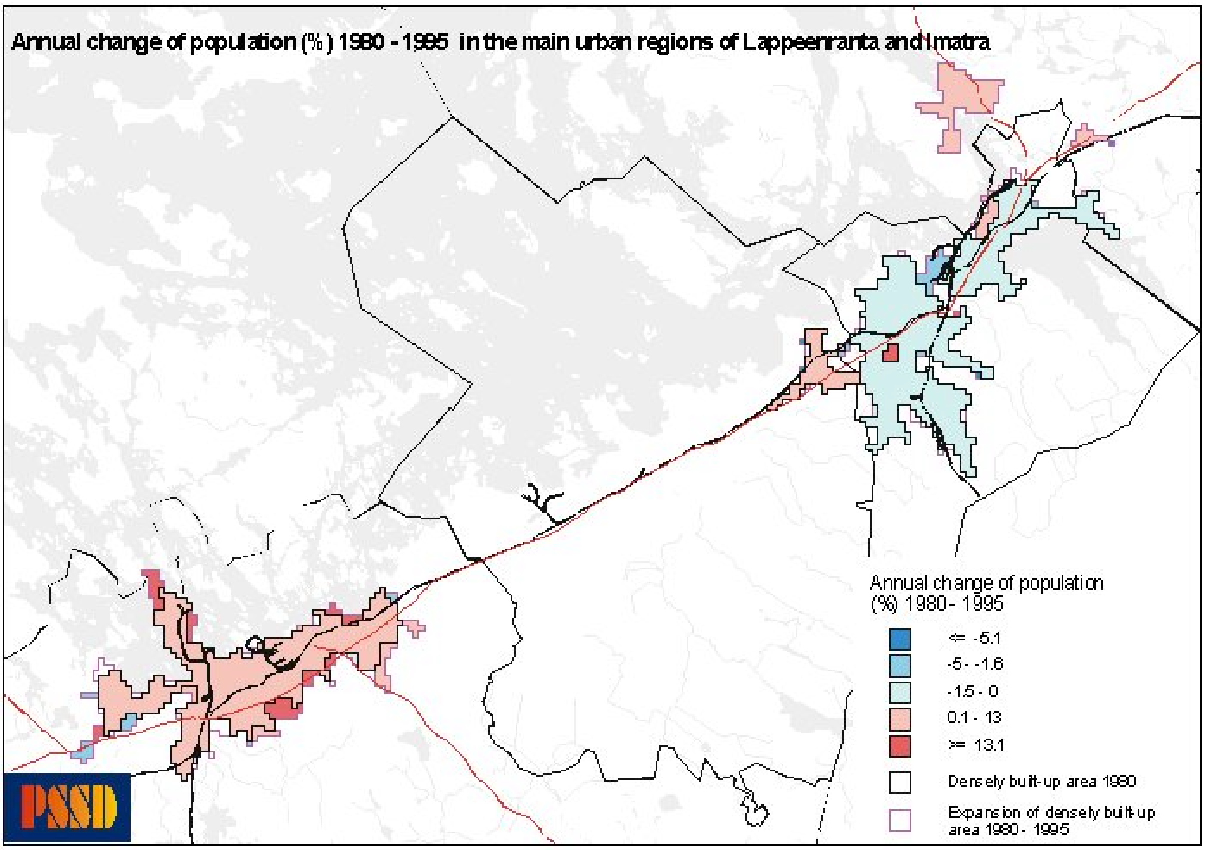


Figure 5.8. Annual change of population in the Lapeenranta/Imatra area

5.2.2 Time-series animation of urban growth

The study of geography is basically spatial but in order to understand geographical phenomena it is necessary to study how these patterns change over time. Geographers, planners and cartographers have long attempted to visualise changes by integrating spatial and temporal information on a map. Usually the result is a series of maps showing certain themes at different times.

Among the methods that can be used to visualise temporal characteristics of geographic data, animated maps seem particularly suitable. The viewer will experience an impression of continuity if the difference between successive frames is not too large, and an appropriate display speed is chosen.

The Internet offers a number of tools for implementing cartographic animation. The advantage of the Internet is that it makes the display of the animation possible on virtually any computer and anywhere using only a standard Internet browser like Microsoft Internet Explorer or Netscape Communicator. A common form of animation is the animated GIF89a file – an extension of the widely sued GIF format for distribution of pictures on the Internet. The playback of GIF89a files is done automatically by the Internet browser but is not accompanied by any controls that could adjust the display.

Behind time-series animation the following spatio-temporal models are available, dependent on your data:

- The space-time cube
  A three-dimensional cube that represents one time and two space dimensions. T. Hägerstrand originally developed the space-time cube. The trajectory of a two-dimensional object through time creates a worm-like pattern (fig. 5.9).

- Time slices
  Time-slice snapshots are an intuitively appealing space-time model with roots in traditional cartography, imitating the progressive nature of a slow-motion video (Langran, 1992). The individual time slices represented by maps describe the situation at the times of map creation (fig. 5.9). Thus the snapshots represent states rather than changes, providing no information on how to go from one state to the next. The various map series are usually many years apart causing a very low temporary resolution. Traditionally, time-slice snapshots have been used extensively in time-series animation (Acevedo & Masuoka, 1997).

- Spatio-temporal database
  Simple cartographic snapshots are not sufficient for highly dynamic phenomena. Time must be incorporated as a fundamental component of a geographic information system. Whenever new data becomes available, the database is updated reflecting the real world situation (fig. 5.9). Every object has both geometric and temporal attributes. Thus a historical record is built up within the geographic information system, providing very good opportunities for theory building and dynamic visualisation.

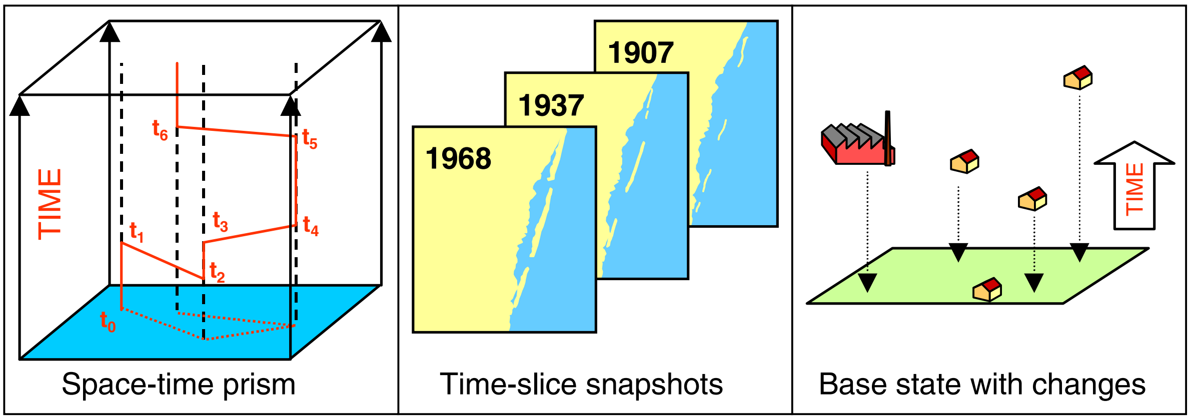


Figure 5.9. Concepts of space and time

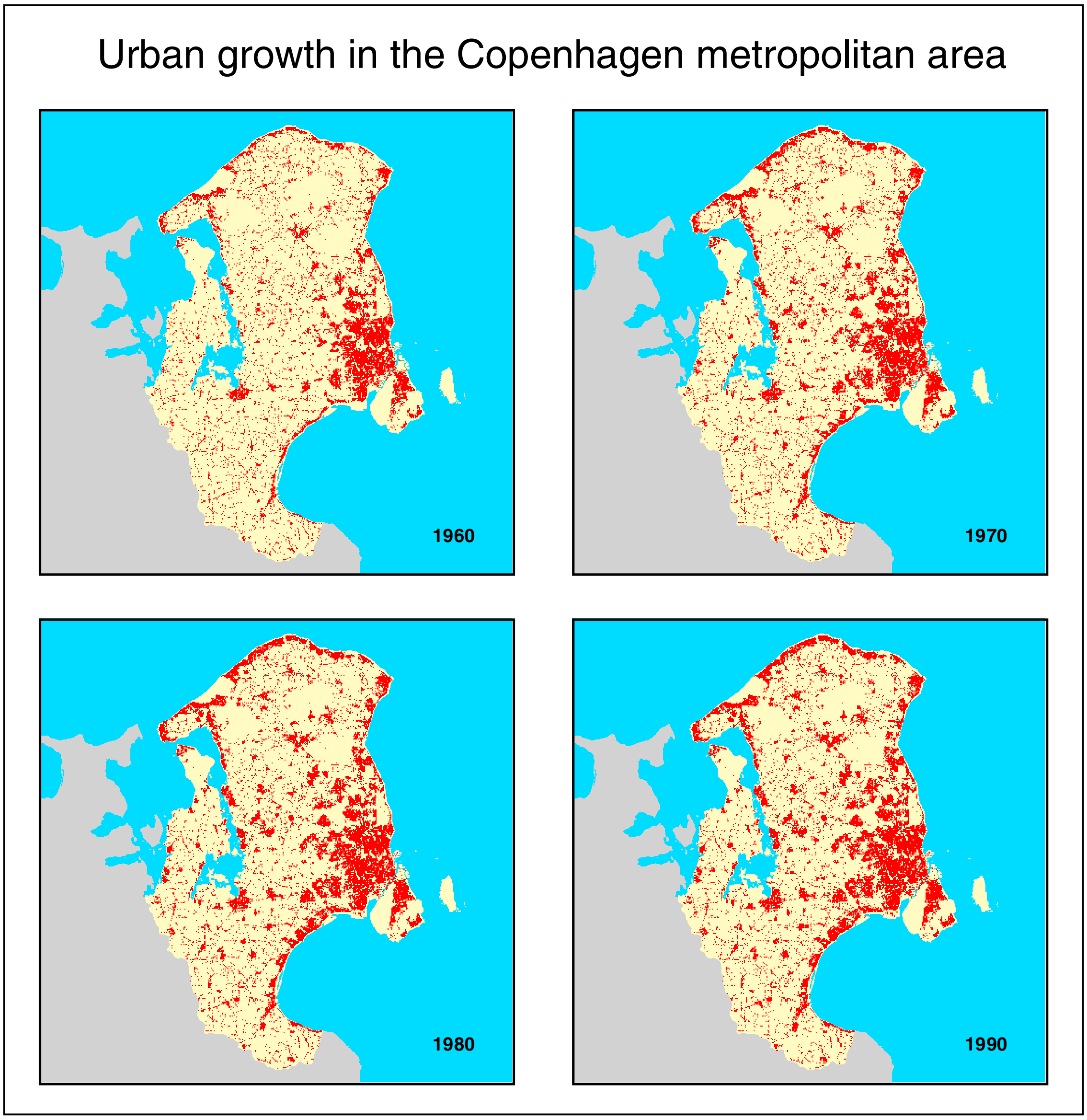


Figure 5.10. Snapshots from a time-series animation

Currently, we are using the last approach (Hansen, 2001). The Danish Building & Dwelling database can be considered as a kind of spatio-temporal database, because all building entities are assigned a year of construction as well as point-based addresses. Furthermore 100 m square cells covering the Copenhagen Metropolitan area were generated. Using overlay techniques all cells can be assigned a year of construction - in this case the minimum year of construction within each cell is assigned the cell.

Based on the cell map theme, successive maps for the years 1945 - 1995 were produced and exported into Windows Metafile format. Animation Shop 2 from Jasc Software is a powerful yet easy-to-use program that creates animations from one or more graphic images and offers a wide variety of effects and transitions for enhancing animations (Jasc Software, 1999). Therefore, the individual map frames were loaded into Animation Shop and animated GIF's and AVI files were produced. In order to achieve a reasonable visual impression of the urban dynamics, the display time of the individual map frame was set to 0.5 second. Figure 5.10 illustrates a few frames from the animation.

5.3 Maps on the Internet

The easiest way to publish maps on the Internet is as images. These images might be static (GIF, JPEG etc.) or dynamic using animated GIF89a files (see the above paragraph). However, nowadays the user wants to interact with the map - to change the contents and symbols, retrieve information about certain features or just zoom or pan. GIS software of the present time offers some possibilities for presenting maps on the Internet. ESRI and MapInfo have developed off the shelf Map-server software (ArcIMS and MapExtreme) to be used directly for publishing purpose. However, this software is rather expensive and requires some minimum server administration. On the opposite side, universities and minor software developers provide more simple solutions. Concerning the PSSD project these solutions seems most promising.

The Java-based approach uses applets to access geographic data and attributes directly. When a client is addressing the Map Server, HTML code containing the Java-applet is returned. The Java applet is capable of reading geographic data directly and transforming them into graphic elements to be shown on the client's screen.

Jshape (www.Jshape.com) is an example of an applet based web GIS. Jshape is able to publish ArcView shape files through the WWW. No back-end Mapping server is required. Jshape is freeware and can run on most hardware / software platforms (Windows, UNIX, MAC). Furthermore, JShape works with most WWW browsers that support Java.

JShape is a so-called "thick" client approach. The concept of a *thick client* describes an environment in which most of the application processing is done on the client computer. Each time JShape starts, it will download all the shape files from the Web server to the client.

This approach results in slow loading time, if the shape files are huge, but the gain is very fast pan/zoom/query etc. operations. An exam-

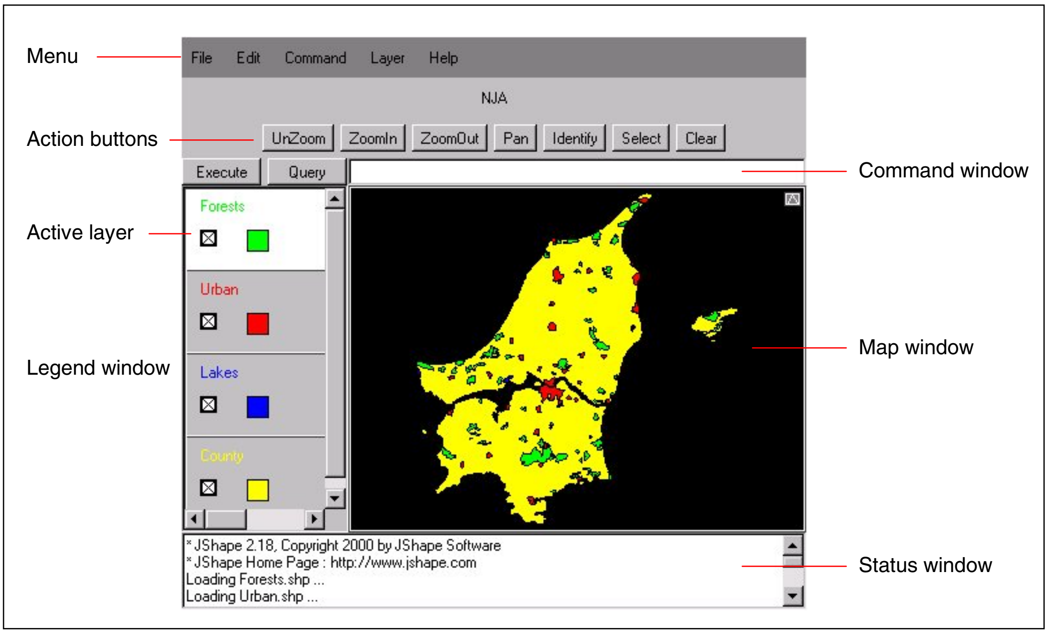


Figure 5.11. Example of the standard user interface created with the JShape applet

ple of a Jshape user interface is shown in fig 5.11.

The above figure is made using shape file data from Northern Jutland county and the following HTML code:

```
<html><center>

<applet code="jshape.class" width=480 height=440 archive="jshape.zip">
<param name="project" value=" NJA">
<param name="mbcolor" value="black">
<param name="list" value="1,2,3,4">
<param name="scale" value="10">

<param name="layer1" value="Forests.shp">
<param name="info1" value="Forests.dbf">
<param name="title1" value="Forests">
<param name="bcolor1" value="green">
<param name="lcolor1" value="green">
<param name="size1" value="1">
.........
```

The block above is repeated for all shape filesto be presented

```
</applet>

</center></html>.
```

*Geo*Tools is a free Java based mapping toolkit developed by the Centre for Computational Geography at Leeds University. It allows maps to be viewed interactively on web browsers without the need for dedicated server side support. The project is open source and is covered by the GPL. GeoTools is composed of the following elements:

- Viewer - The viewer is probably the single most important class in the entire *Geo*Tools system. The Viewer is the component that actually displays the final map onto the screen, each viewer contains one or more map themes to display. Viewers also handle most of the mouse interaction needed to deal with panning, zooming, highlighting and selecting.
- Theme - Themes are one of the most complex classes in the *Geo*Tools package. The role of a theme is to govern how a given set of features should *appear* on the screen, by combining information on the features, shading scheme, associated data and shared highlights.
- Layer - Layers contain the actual geographic features that make up part of a map. There are a number of different layer types, the key ones contain polygon, line or point data. Each feature in a layer should have an ID associated with it.
- Shader - The roll of a shader is to add colours to maps. A number of shaders are available, ranging from the simple *MonoShader* (that colours everything the same) through to the more complex *RampShaders*.
- Geodata - The roll of a GeoData object is to map an ID value to a data value.
- Highlight manager - The roll of a highlight manager is to allow for easy interactivity to be added to a map. As each feature on a map has an associated ID then, if a theme has an attached Highlight manager any feature picked on the map by the user can have its ID broadcast by the Highlight manager to any other listening components.
- ShadeStyle - The shadestyle provides *hints* regarding how features for this theme should be displayed. It can control for example, whether each feature is outlined or filled and if the colour for these should be fixed or took from the themes shader.
- Scaler - A scaler is held by the viewer and passed to each of its themes. The scaler contains all the routines necessary for a set of features to be scaled, paned and cropped to appear in the viewers display area.

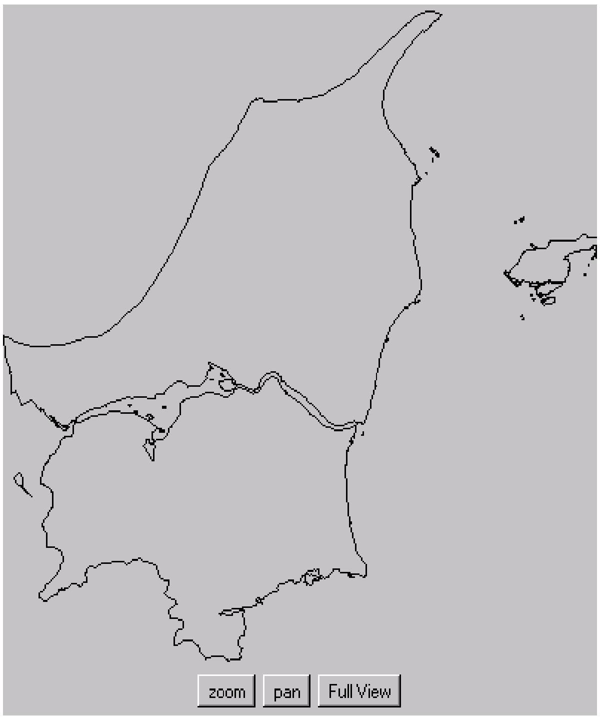
Figure 5.12 shows a very simple example using GeoTools.

Open GIS Consortium (OGC) has just adopted a new web map server interface specification, which has extraordinary implications for e-commerce and e-government. It enables automatic overlay - in ordinary web browsers - of map images obtained from multiple dissimilar map servers (Open GIS Consortium, 2000). Based on the abstract model of geography defined by OGC, a Geography Mark-up Language is developed (GML). The Geography Mark-up Language is an XML based encoding standard for geographic information.

GML or Geography Mark-up Language is an XML based encoding standard for geographic information developed by the OpenGIS Consortium (OGC).

GML is intended to enable the transport and storage of geographic information in XML. The initial GML specification is restricted to 2D geometry, but later on 3D and topological relationships between features will be added. When GML data is exchanged across the Internet, they are transmitted as feature collections.

The encoding is not concerned with the visualisation of geographic features. GML contains no information about how the features might appear. To draw a map with GML it is necessary to transform the GML into XML encoded graphic elements, for example *Scalable Vector Graphics* (SVG), *Vector Mark-up Language* (VML) or *Virtual Reality Mark-up Language* (VRML). However, in some applications there will be no graphical display of the geographic data. Instead, these data might be input into some numerical models.




```
<HTML> <CENTER>
.....

<APPLET
CODE="SimpleShapefileViewer"
WIDTH="400"
HEIGHT="450"
archive="geotools076.jar">
<PARAM NAME="shapefile" VALUE="County">
</APPLET>
......

</CENTER></HTML>
```

Figure 5.12. Simple example using GeoTools

A lot of standards for encoding geographic information are already here, but GML is based on the OGC specification, which has been developed and adopted by the main GIS vendors. Furthermore, GML is based on XML, providing methods to verify data integrity. Thus, the DTD specifies the structure of an XML document in a way that a parser can verify that a given document complies with the DTD. In addition, any XML document can be edited using a simple editor like NotePad. Based on the draft proposal by the Open GIS Consortium, James Macgill (2000) - Department of Geography, University of Leeds - has made a preliminary GML reader. All in all, the Geography Mark-up Language seems to be an important element in Internet maps.

5.4 Planner's Toolbox – concepts and ideas

An important result of the PSSD project is an Internet-based database application, the so-called Planner's Toolbox, which should gather all the results of the project in a way that can be used and expanded also beyond the project period. Here we present some basic ideas about the thoughts lying behind the Planner's Toolbox.

5.4.1 Defining the functionality

The screen is split into three parts: main area, frame on left and static buttons area above the main part (fig. 2.10). The portal page welcomes the user. The portal page main area has elements like PSSD title, PSSD logo, actualities (few current topics) and latest additions (list of newest entities). The static buttons area has choices *Home* - takes to the portal page, *Search* - search capabilities, *Site map* - diagrams illustrating the structure and *Help*.

The Search button of the static button area is for free text search in the whole database, but it can also make filtered searches based on some attributes. The left frame areas remain static. Although the interface encourages surfing through Planner's Toolbox, the user can always navigate using frame choices. The frame choices offer different points of view to information. The Toolbox application also handles the connection to the TUHH indicator creation platform and indicator test site and other www-pages related to the PSSD project.

First suggestion for the left frame choices is Planning items, Tools, Methods, Theory, Indicators, Data, Updating and Links. When the user selects some of these, the main area shows a selection-specific introduction page to Toolbox from that particular point of view. In the introduction pages there're three possible filtering capabilities:

- The user selects from an entity list or hot word list directly and then presses the buttons to get the results. As a result comes a list of titles, which fulfil the criteria.
- The user selects one and gets the results in window. The result window has active elements. The text in the fields may include hyper links.

- There is a list of entities, which refer to the chosen entity and also a list of linked entities to which the chosen entity refers.

5.4.2 Defining the data contents and concepts

The fundamental item in the Toolbox is a logical information entity. Every task, every tool is an entity. Thus, every entity description - or content - must have a defined structure. The entity consists of name, abstract (few sentences), description (the whole logical text) and hot words.

Besides, there are select lists for items like DPSIR category, geographical scale, planning item, creator and so. Also files containing maps or scripts may be part of the entity.

5.4.3 Defining the interaction

The Toolbox is totally dependent on the users. The users upload data and tools to the toolbox and by doing so share the information with others. This is the critical point - the strength and the weakness of the usefulness of Toolbox. Therefore a great weight should be put to the user-Toolbox interaction: the input tools, their usability and clarity and the logic of functions.

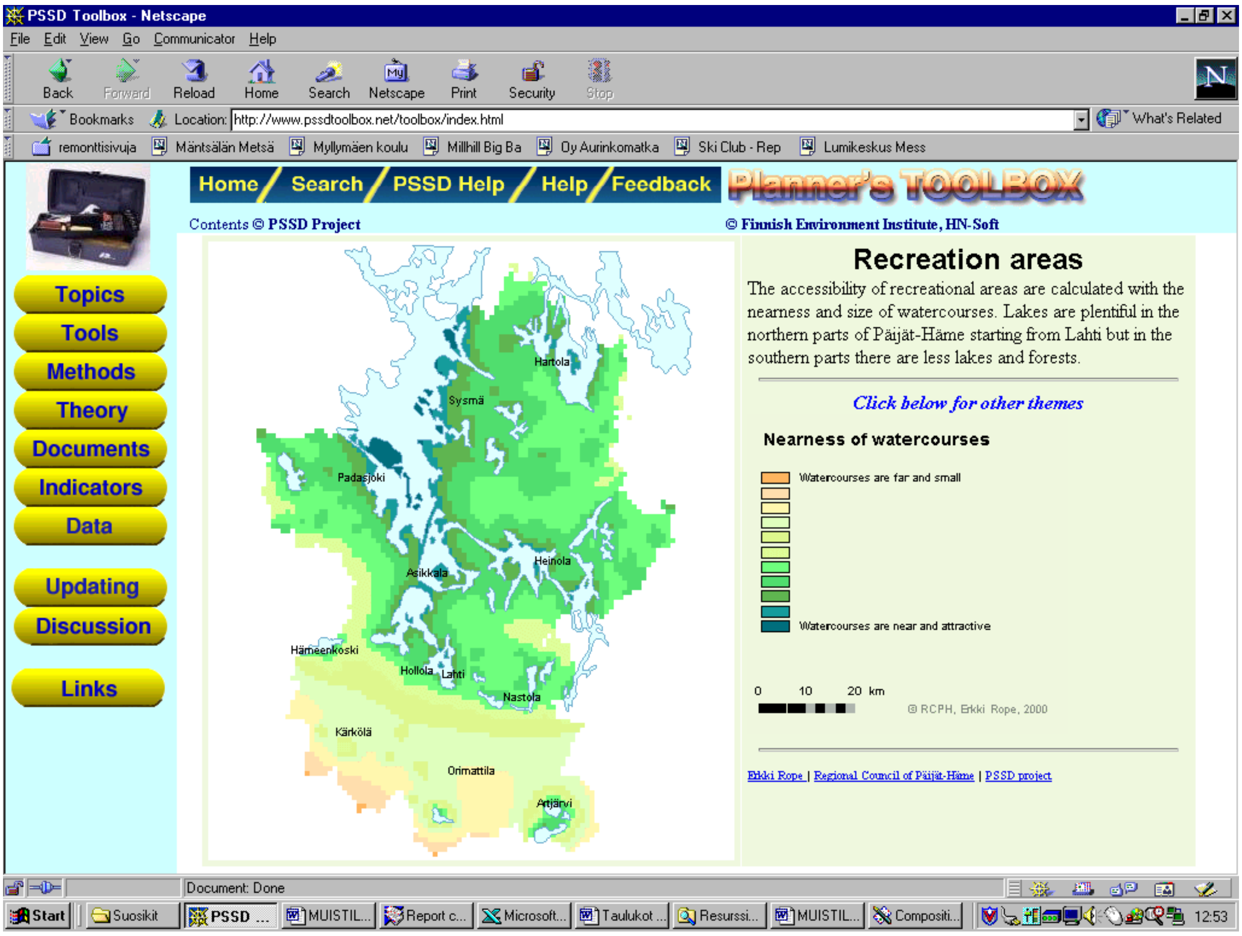


Figure 5.13. The Planner's Toolbox interface

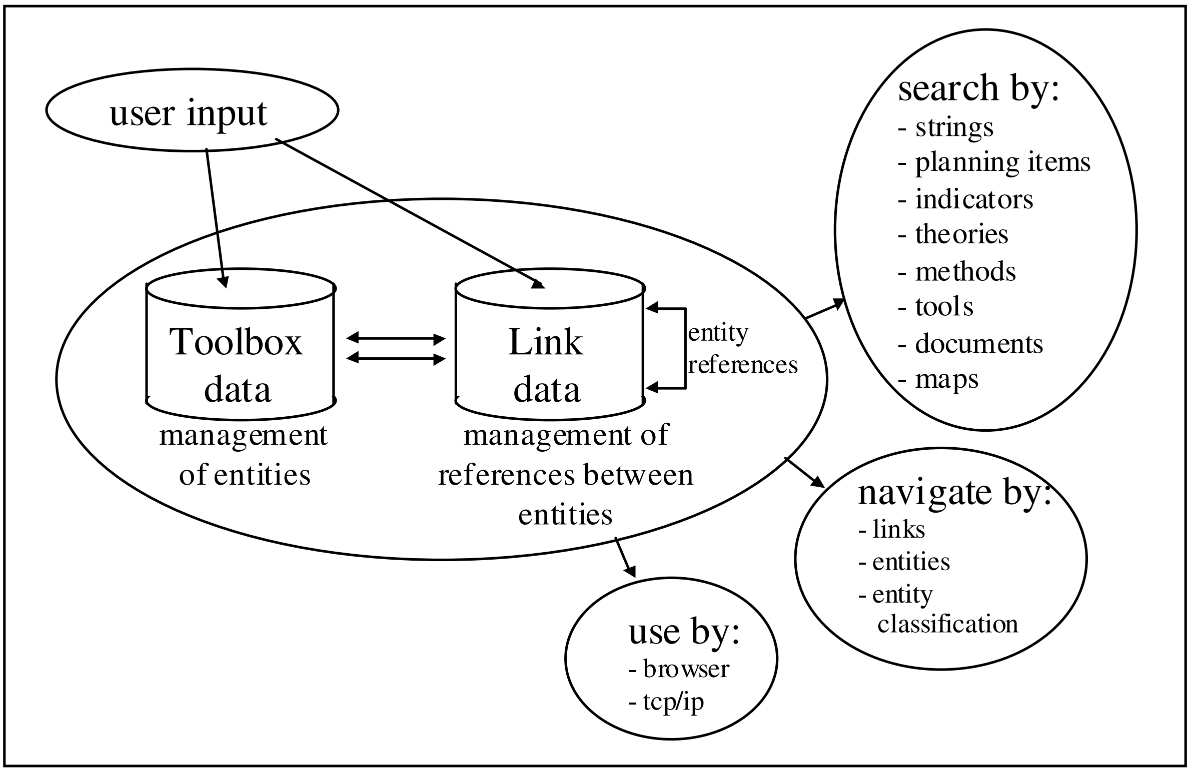


Figure 5.14. Planners ToolBox - basic concepts

6 Conclusions

This methodical PSSD report indicates pretty well how difficult matter we are dealing with, trying to combine the principles of sustainable development, numerous spatial research methods, still numerous indicators, GIS techniques and multilevel customs of spatial planning. The reader's impression may be more or less mosaic but justified.

The PSSD project produced and presented a versatile selection of map aided methods for the use of spatial planning professionals but the integration of methods proved to be too laborious within the project schedule. The small number of real-life applications expresses also that the contribution of spatial planners in the project may have remained too small compared to researchers. The fruitful discussions and integrated views were not managed to give enough substance to integrated methods.

However, the report indicates also that grid techniques fit fairly well to the very different types of map analyses that are needed within spatial planning. Thus the grid hypothesis that was set at the start of the project proved to be right. It is now quite safe to say that grid techniques also lend itself to a foundation of much wider international co-operation between spatial planners in the field of GIS analyses and spatial planning maps. It is important to state though in this context that also in the PSSD project the most significant technical obstacle to international co-operation was associated with the copyrights and price of GIS data. Accessibility in general and the urban dynamics in connection to nature environment were popular targets for GIS methods in this project. In a way this emphasis shows also areas where grid technique may be at its best – or at least popular in general – within spatial planning.

One important aim of the PSSD project has been to stimulate the international discussion in the as yet quite narrow field of GIS methods applicable in regional planning. This report has been a serious effort to support that aim. It is to be hoped that the reader feels same after reading it.

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PSSD - Planning System for Sustainable Development – is a part of the Baltic Sea Region's INTERREG II C program. The current report describes some theories, methods and tools developed under the PSSD project. First, the theoretical foundation of the project is described. Secondly, the role of indicators in sustainable development is discussed and a Web-based indicator generator is described. Thirdly, we describe a number of methods and tools, which support planning for sustainable development. Finally, some technical interface tools – especially a Web-based interface to the methods and tools, the so-called Planner's TOOLBOX, are described.

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