Humans and Environment: Cause and Effect Analysis Supported by Spatial Data Infrastructures

Ulrike KLEIN¹ and Hartmut MÜLLER², Germany
¹Centre for Geoinformation, Christian-Albrechts-University Kiel, Germany
²FH Mainz University of Applied Sciences, Mainz, Germany

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SUMMARY

Climatic change, population change and rapid urbanization belong to the main challenges of the present time. For this reason designing a sustainable living environment is one of the important aims of politics and government. Transdisciplinary cause and effect analysis and networked spatial thinking is required to tackle land use concurrencies, environmental degradation, and social problems and to support sustainable decision making for politics, government or even for each citizen. Spatial information can help to analyze the correlation and interaction between humans and environment from a spatio-cybernetic point of view. Ecological, economical and social indicators, based on the underlying data, can be used to simulate and to assess spatially related decisions. Extensive exchange of standardized spatial information between multiple stakeholders is needed to reach this goal. Spatially organized information about human-environment interactions is an indispensable precondition for the realization of such an exchange. At the same time, technical, legal and organizational conditions are to be fulfilled. Spatial Data Infrastructures initiatives like INSPIRE in Europe offer an essential basis for the adequate organization of spatial information. This paper provides a case study for a defined area in the Federal Republic of Germany. Effects of building a new house will be used to apply a holistic spatio-cybernetic model of human-environment connection based on chains of cause and effect, indicators and spatial data infrastructures.
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1. INTRODUCTION

Humans and environment interact in many different ways. New buildings and the associated land use for example cause a complex set of environmental, social, urban and economic interactions (Bock & Preuss 2011, p. 27f., Vester 2007). Current challenges like climatic change, population change and rapid urbanization complicate the design of a sustainable living environment. Trans-disciplinary cause and effect analysis and networked spatial thinking is required to tackle land use concurrences, environmental degradation or social problems, and can even be useful to support sustainable decision making for politics, government and individual citizens.

Spatial information could help to analyze the correlations and interactions between humans and environment in a spatio-cybernetic way. Ecological, economical and social indicators, based on the underlying data, could be used to simulate and to assess spatially related decisions. A spatial organisation of information and data exchange between multiple stakeholders is crucial to achieve the objective of sustainable planning and decision making considering the spatial dimension. Spatial Data Infrastructures initiatives like the European INSPIRE directive are establishing an important basis for technical, legal and organisational conditions (European Union, 2007). But in fact the potential of spatial information and spatial data infrastructure for sustainable planning and decision making is not sufficiently exploited.

This paper provides a case study for a defined area in the Federal Republic of Germany. Effects of building a new house will be used to demonstrate a holistic spatio-cybernetic approach of human-environment connection based on chains of cause and effect, indicators and spatial data infrastructures.

In the following chapter 2 the main interactions between humans and environment in case of “building a house” will be described. Chapter 3 gives a general overview of Spatial Information Management. The German case study for a sustainable planning process is theoretically presented in chapter 4. Chapter 5 provides an initial concept for the support of sustainable planning with the help of Spatial Data Infrastructures and Spatial Information Systems. Chapter 6 shows the study result: a first spatio-cybernetic model for sustainable planning. The conclusions are drawn in chapter 7.
2. INTERACTIONS BETWEEN HUMANS AND ENVIRONMENT

2.1 System Complexity

The human life cycle consists of phases such as birth, education, leaving family, working life, build an own house, start of a family, retirement and death. Each phase has an impact on financial, social, medical and infrastructure capacity as well on natural resources and environment. On the one hand building a new house, for example, has an impact on financial, social, medical and infrastructure capacity planning: new citizens increase the need of infrastructure, medical and social supply. On the other hand purchasing power, working power and tax revenues in the local area rise with each new citizen taking up residence. Social and urban consequences for the designation of new building sites or commercial areas are population decline in the urban centres with a simultaneous growth of the population in the border regions. This leads to the so-called "doughnut effect" and to depopulation of inner cities associated with vacancy and withdrawal of retail. As one result easy access to consumer goods of daily use (like supermarkets, drugstores and medical care) within walking distance usually is not provided. That causes accessibility problems for certain population groups, such as children, elder people or households without a car. For all others, especially caused by the spatial separation between areas of living, working, shopping and leisure, travelling distances increase, raising time and cost for daily mobility. Creating and maintaining new infrastructure for new residential areas is a necessity for the municipalities while on the other hand the old, no longer needed or underutilized infrastructure, such as supply and disposal networks, public transport, schools and kindergartens still have to be maintained. This leads to additional spending on capital equipment for citizens and government. Various effects on the environment may be generated by new buildings and infrastructure. Soil sealing may be caused by construction or the new infrastructure, results in loss of soil and open spaces. The former function of soil sealing, e.g. for groundwater recharge, rain water cleaning and food production is even lost. The micro-climate in cultivated areas is also affected by soil sealing as it leads to increased warming of air masses near the surface and reduced air exchange. New roads divide or destroy the habitat of animals and plants. This causes the loss of species. Settlements near recreation areas are affected because distances to areas of recreation and nature experience are growing. The additional traffic load causes more noise emissions. The increasing noise and air pollution affects the health of the local population and therefore the need for health care increases. Medical practices or hospitals have to be located in the respective areas. This engenders new traffic, new infrastructure, new soil sealing, increased pollution but as well new jobs, new income for the local government, to name a few examples.

2.2 Reducing System Complexity

The Club of Rome has been noting in 1972 in the study "Limits to Growth" that the viability of our planet is running out, "Sustainable development" is required. „Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs“ (United Nations 1987, p. 51).
The main problems of demographic change, rapid urbanisation and climatic change require a holistic, sustainable approach, to reduce the negative influences while maintaining the quality of life.

The interconnected and transdisciplinary view of the interrelationships and interactions between humans and environment is essential to better understand the real forces behind sustainable planning and for giving guidance to decision making. What is needed is "a new vision of reality: the realization that much is related, what we see isolated, that the combining strings behind the invisible things of what's happening in the world are often more important than the things themselves" (Vester, 2007, p. 9).

Such “cybernetic” modelling can be found at Vester (2007) with the “model of sensitivity”. The aim of this model is to reduce the complexity of a system and its subsystems to system-related factors and their interactions in chains of cause and effect in order to carry out forecasts and simulations for different scenarios.

If for example administrative action is divided in natural and human systems one would get a dozen central parts of the system. In the nature system these components are climate, flora and fauna, surface, hydrography, waterbodies and resources. In the human system the components are infrastructure, construction and housing, business, education and culture, social care, health and safety. Each system component contains further subsystems, which are closely related to each other. For each subsystem indicators can be determined. They are used to measure the achievement of economic, ecological or social goals and to plan new activities assuming the possible impacts on other areas. "Overflow values" which require a response can be defined.

A challenge lies in the lack of knowledge about the influences and activities that affect the current situation of humans and environment. Policy and government need new spatio-cybernetic models which are able to deal with the complexity of their decisions and to align their activities on sustainable planning and preservation of the environment. Spatial informatics and Spatial Data Infrastructures can help dealing with this problem.

3. SPATIAL INFORMATION MANAGEMENT

Spatial Data Infrastructures can support the sustainable planning process by providing necessary information to identify potential problems. A Spatial Data Infrastructure (SDI) ‘provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general’ (GSDI, 2004). In that way, the value added of a working SDI is considerably high to support the needs of a sound cause and effect analysis. Some SDI elements shall be described briefly.

**Metadata** - describing data and services - provide documentation of existing geospatial resources, permit structured search of resources while supplying the end-users with adequate information on the resources. International standards for metadata exchange and its encoding exist (ISO 19115/19139). **Web based services** provide standardized access to geospatial information and support their processing. Three classes of web based services shall be named here, the OpenGIS Web Map Service Interface Standard (WMS), the OpenGIS Web Feature Service Interface Standard (WFS), and the OpenGIS Web Processing Service Interface Standard (WPS). The WMS standard provides an interface for processing requests of georeferenced map images in a standard image format like JPEG, PNG, etc. that can be
displayed in a standard web browser (see http://www.opengeospatial.org/standards/wms). The WFS standard defines interfaces for data access (WFS) and manipulation (WFS-Transactional, WFS-T) operations. Via the WFS and WFS-T interface, geographic features and elements can be created, deleted, updated, locked and queried based on various spatial and non-spatial constraints (see http://www.opengeospatial.org/standards/wfs). The third class of services, the WPS, enable additional processing of spatial information. Processing services include capabilities that extend and enhance the range of deliverable output data through processes applied to the input data. In that way high-end geometrical, topological, thematic and temporal analysis of data can be performed.

The Article 3 of the INSPIRE directive defines ‘INSPIRE geo-portal means an Internet site, or equivalent, providing access to the services referred to in Article 11(1)’ [INSPIRE Directive, 2007]. The geo related services named at the article 11(1) are:

- view services
- discovery services
- download services
- transformation services
- invoke spatial data services.

In the nomenclature of the OGC web service specification, Web Map Service (WMS), Web Feature Service (WFS), Catalog Service Web (CSW) and Web Processing Service (WPS) have to be implemented to meet the INSPIRE requirements. Other Standards like HTTP file download or the W3C Standards WSLD and SOAP can be used in this context.

In 2007 the European INSPIRE Directive came into force. Aim of the Directive is the establishment of a European Spatial Data Infrastructure “to support Community environmental policies, and policies or activities which may have an impact on the environment” (http://inspire.jrc.ec.europa.eu/, 20.11.2011). The necessary data content has to be provided by the local and national government of each European Union member state.

Spatial information to be provided through INSPIRE consists of 34 different themes (see Figure 1). As can be seen this list promises a huge amount of information which can be used to support cause and effects chain analysis of environmental, economical and social impacts. These relationships will be detailed further in the next chapter.

<table>
<thead>
<tr>
<th>theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>coordinate reference systems, geographical grid systems, geographical names, administrative units, addresses, cadastral parcels, transport networks, hydrography, protected sites, elevation, land cover, orthoimagery, geology, statistical units, buildings, soil, land use, human health and safety, utility and governmental services, environmental monitoring facilities, production and industrial facilities, agricultural and aquaculture facilities, population distribution and demography, area management/restriction/regulation zones and reporting units, natural risk zones, atmospheric conditions, meteorological geographical features, oceanographic geographical features, sea regions, bio-geographical regions, habitats and biotopes, species distribution, energy resources, mineral resources.</td>
</tr>
</tbody>
</table>

Fig. 1: List of 34 INSPIRE Annex I, Annex II, Annex III themes
4. CASE STUDY: MODELLING SPATIAL RELATIONSHIPS FOR SUSTAINABLE PLANNING

4.1 The Use Case ‘Building a New House’

The first step in modelling spatio-cybernetic relationships for sustainable planning and land use management is the development of chains of cause and effect for the interactions between humans and environment.

A German case study concerning the case “building a new house” in a fictitious planning area is presented in this chapter. Five aspects have been examined to identify the main correlations and interactions: the planning rules, the governmental process, the lifecycle of people, evaluation themes and items for sustainable land management and criteria for sustainable planning. The results and the conclusion will be shown at the end of the chapter. The single steps follow the logical circle of planning, building, living, planning.

4.2 The Framework of Correlations and Interactions

4.2.1 The planning rules

Building a new house in Germany is only allowed in developed areas. The development of new building areas has to consider the regulations of the Federal Building Code (Federal Republic of Germany, 2011). The Building Code prescribes mandatory planning rules and aspects considering

- healthy living and working conditions,
- safety,
- housing needs of the population,
- social and cultural needs,
- maintenance and development of existing districts and central supply areas,
- interests of architectural culture, heritage protection and preservation,
- requirements for worship and pastoral care,
- requirements of environmental protection, especially
  - impact on animals, plants, soil, water, air, climate and the interactions between them and the landscape and biodiversity,
  - conservation objectives and the purpose of protection of Natura 2000 sites,
  - environmental effects on man and his health,
  - environmental impacts to cultural property and other tangible goods,
  - prevention of emissions and the proper handling of wastes and effluents,
  - use of renewable energies as well as the economical and efficient use of energy,
  - representations of landscape plans, and of other plans, particularly the water, waste and pollution control laws,
  - maintenance of best possible air quality in areas,
  - interactions between the various aspects of environmental protection
- concerns of
  - economy, including its medium-sized structure in the interest of a consumer-oriented supply of the population,
  - agriculture and forestry,
- preservation, safeguarding and creating jobs,
- postal services and telecommunications,
- supply, especially energy and water,
- protection of natural resources,
- satisfaction of elementary needs and mobility of the population,
- interests of defence and civil defence,
- results of a community adopted by the urban development concept,
- issues of flood protection.

The result of the planning process is a land-use-plan which is legally binding for all buildings. Facilities of infrastructure, demarcation of parcels, places for recreation, disposal etc. are defined in this plan. An example can be seen in Figure 2.

The planning and building permits process

After the planning is finished the parcel can be sold and the new house can be designed within the previously defined planning framework. Before the building of the new house can start, the local governance has to agree to the planning. For the standardization of this process a form called "Statement of a local authority for a building permit" exists. This form contains multiple questions concerning the new house, the existing land-use planning, the availability of infrastructure and the local situation. Assuming that the distance or proximity to an object

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1 http://www.kreis-oh.de/media/custom/335_4115_1.PDF?
is relevant in this form there must be an already identified cause-effect-chain. The knowledge about this can be adapted to the spatial analysis of causes and effects between humans and environment. Important aspects in the form from the perspective of a local authority are listed in the table below.

Table 1: Spatial relations between humans, environment and the new building

<table>
<thead>
<tr>
<th>Access to</th>
<th>Distance to</th>
<th>Position in/on</th>
<th>Proximity to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road infrastructure</td>
<td>Railway</td>
<td>Protected sites</td>
<td>Natural monument</td>
</tr>
<tr>
<td>Waste water disposal</td>
<td>Forest and heath</td>
<td>Flood endangered area</td>
<td>Cultural monument</td>
</tr>
<tr>
<td>Rain water disposal</td>
<td>Water body</td>
<td>Land protection dyke</td>
<td>Open wire transmission line</td>
</tr>
<tr>
<td>Energy</td>
<td>Industrial mass production of livestock</td>
<td>Noise protection area of an airport</td>
<td>Dumpsite</td>
</tr>
<tr>
<td>Drinking water</td>
<td>Other emitting livestock</td>
<td>Areas of influence of contaminated sites</td>
<td></td>
</tr>
<tr>
<td>Water for fire</td>
<td>Emitting industry</td>
<td>Areas contaminated with weapons</td>
<td></td>
</tr>
<tr>
<td>Fighting purposes</td>
<td></td>
<td>Areas where the soil tends to settlements</td>
<td></td>
</tr>
</tbody>
</table>

4.2.3 The needs and lifecycles of citizens

In case the agreement of the local governance has come to effect the building is started and is then finished, new citizen move into the house. Roughly, these citizens have needs like (Maslow 1943)
- physiological needs: breathing, sleeping, food, warmth, health, housing, clothing, exercise
- the need for safety: Law and order, protection from hazards, fixed income, insurance, accommodation
- social needs: family, friends, partnership, love, intimacy, communication
- individual needs: greater appreciation of status, respect, recognition (awards, praise), wealth, influence, personal and professional success, mental and physical strength
- the need for self-realization: individuality, talent development, perfection, enlightenment, self-improvement

On the other hand, the new citizens are part of the local society and in that way have to be administrated by local municipalities. Each life situation causes different usage of the available resources, supplies and infrastructures. Especially demographic change and rapid urbanization will cause effects in
the utilization of social and technical infrastructure. This leads to questions concerning sustainability.

4.3 Aspects of Sustainability

As it was shown in chapter 2 each new house has effects and engenders new land use in the human-environment-system. Following the aim of sustainability the planning process is very complex and attention has to be paid to many different aspects. To measure the impacts on the system components and the sustainability of the decision a set of evaluation items is helpful.

4.3.1 Indicators for sustainable land management

Heiland et al. (2003) identified ecological, economical and social indicators for the evaluation of sustainable area development (see Table 2). Indicators can be used to measure the achievement of objectives. In most cases criteria are defined to meet aims and targets. These criteria reflect political aims as well as criteria for sustainable planning.

Table 2: Indicators for sustainable land development, adapted from Heiland et al. 2003, p. 203

<table>
<thead>
<tr>
<th>Ecological Indicators</th>
<th>Economical Indicators</th>
<th>Social Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste</td>
<td>Energy and resources</td>
<td>Population development</td>
</tr>
<tr>
<td>Land use</td>
<td>Soil</td>
<td>Civic and democratic engagement,</td>
</tr>
<tr>
<td>Air</td>
<td>Noise</td>
<td>Individual mobility and public transport</td>
</tr>
<tr>
<td>Water</td>
<td>Nature conservation</td>
<td>Recreation</td>
</tr>
<tr>
<td></td>
<td>Natural scenery and landscape</td>
<td>Socially responsible business</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culture, cultural heritage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Living space</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3.2 Criteria for sustainable planning

Sustainability can be measured on different scales and is influenced by political decisions and aims. The United Nations, for example, created a set of indicators to allow a comparison of sustainable development between the nations worldwide. Income inequality, corruption, mortality, education level, vulnerability to natural hazards, desertification and many other
Factors are measured by indicators like proportion of population living below national poverty line, adult literacy rate, land affected by desertification (United Nations, 2007). The focus of sustainability is on living conditions and the ability to take part in the global economy.

The European Commission monitors the sustainable development of the member states by using the following indicators: socio-economic development, sustainable consumption and production, social inclusion, demographic changes, public health, climate change and energy, sustainable transport, natural resources, global partnership, good governance (Eurostat 2009). Focus is set on the EU Sustainable Development Strategy.

Sustainability in Germany means generational fairness, quality of life, social cohesion and international responsibility (Federal Statistical Office of Germany, 2010). These political aims originally were published in 2002 forming a national strategy for sustainable development. Sustainability in area development, if not politically influenced, concerns ecological, economical and social aspects.

A set of criteria for sustainable planning can be found in Behrendt 2010, p. 114. These criteria are divided into ecological, social and economic factors. Ecological criteria are

- reduction of primary energy consumption and increasing use of renewable energy
- improvement of water quality
- promotion of biodiversity, enhancement and maintenance of protected areas
- improvement of soil quality and conservation of sensitive soils
- improvement of air quality
- avoidance of urban sprawl

Socially sustainable planning criteria are:

- creating good housing and living conditions and strengthening less-favoured areas
- evaluate and manage the cultural heritage
- improve mobility

An economically sustainable design ensures

- improving the business environment and promoting jobs
- strengthening the financial capacity of the municipality.

Indicators from chapter 4.2.1 can be used for measuring and monitoring values of these criteria.

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2 An electronic atlas is available under http://data.worldbank.org/atlas-global
3 Indicators and maps available under: http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators

TS01D - Spatial Data Infrastructure, 5585
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FIG Working Week 2012
Territory, environment and cultural heritage
Rome, Italy, 6-10 May 2012
Causes:
New house: new citizens, new cars, new tax revenues, new purchase power, new working power

Affecting an increasing need of:
Ecologically: soil, energy, water, resources, land use, solid waste disposal, waste water disposal, rain water disposal
Economically: employment, education, supply of services, agriculture and forestry, foods and goods, government, industry, transport network, regional products
Socially: recreation, entertainment, child care, health care

Causing impact on:
Ecologically: air quality, water quality, soil quality, use of resources, use of land, occurrence of species, biodiversity, protection of natural resources, landscape, nature conservation, settlement development, volume of waste
Economically: accessibility, use of supply, public budget, settlement development, economic structure, economic development
Socially: population development, distribution of income, participation, distribution of work, healthy living and working conditions, safety, culture protection, individual mobility

Affecting:
Ecologically: soil sealing, air pollution, water pollution, emissions, resource consumption, energy consumption, contamination, number of species, noise
Economically: financial capacity of the municipality, attractiveness for business and industry
Socially: physiological needs, safety, social needs, individual needs, self-realisation

Sustainability Responses:
Ecologically: reduction of primary energy consumption, increasing renewable energies, improve water quality, promotion of biodiversity, enhancement of protected areas, improve soil quality, improve air quality, avoidance of urban sprawl
Economically: improving the business environment and promotion of jobs, strengthen the financial capacity of the municipality
Socially: creating good housing and living conditions, strengthening less-favoured areas, evaluate and manage the cultural heritage, improve mobility

Fig. 3: Cause and effect chain for building a new house
4.4 Effect Chain for Building a new House

After analyzing, organizing and combining the above mentioned aspects a first cause and effect chain for building a new house can be created. In the flowchart of Figure 3 the different causes and effects are shown. It starts with the effects of the building of a new house (new house, new citizens, new car etc.). They lead to increasing needs of infrastructure, supply, resources and so on. This increase causes ecological, economical and social impacts on air quality, living conditions, emissions etc. These impacts lead to a change of evaluation criteria like soil sealing, air pollution, energy consumption, for instance. Sustainability responses reflect the aims defined for example by policy.

In the following chapter 5 the identified chains of cause and effect were approximately translated into spatial information to show possible support processes applying spatial informatics.

5. SUPPORT FOR CAUSE AND EFFECT ANALYSIS BY SPATIAL DATA INFRASTRUCTURES

Spatial data infrastructures have a high potential to support cause and effect analysis for sustainable planning. Some examples are shown in this chapter.

5.1 Getting an Overview of the Planning Area

*Task:* Planners and decision-makers need an overview of the situation before starting the planning process.

*Solution:* The available INSPIRE-Data services (see list of Figure 1) concerning geographical names, administrative units, addresses, cadastral parcels, transport networks, hydrography and protected sites can be combined in a Geoportal or a Spatial Information System to allow an overview of the situation in the planning area. Figure 4 shows WMS Services which are currently available for the themes of INSPIRE Annex I concerning the case study test area.

In the first phase INSPIRE services are provided only as WebMappingServices (WMS). The capabilities of the WMS-Services are:
+ Availability of the data
+ Free access through the internet
+ Data from different sources combined to one layer
  - no analysis supported
  - no cartographic methods supported
  - no changes or updates allowed
5.2 Examination of planning aspects

Task: As analyzed in chapter 4 ecological, economical and social aspects have to be considered while planning a new house in a sustainable way.

Solution: Most parts of the necessary spatial information will be available after full implementation of a spatial data infrastructure like the one defined by the European INSPIRE-directive. Table 3 shows a subset of the information required for the sustainable planning process (cf. Table 1, Table 2) in conjunction with the associated INSPIRE theme (cf. Figure 1).
Table 3: Spatial aspects in sustainable planning and available information from INSPIRE SDI

<table>
<thead>
<tr>
<th>Spatial Aspect (cf. Table 1, Table 2)</th>
<th>INSPIRE theme (cf. Figure 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Soil</td>
</tr>
<tr>
<td>Energy</td>
<td>Energy Resources</td>
</tr>
<tr>
<td>Water</td>
<td>Hydrography</td>
</tr>
<tr>
<td>Resources</td>
<td>Land cover, Soil, Mineral resources</td>
</tr>
<tr>
<td>Land Use</td>
<td>Land use</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Waste Water Disposal</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Rain Water Disposal</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Employment</td>
<td>Production and industrial facilities</td>
</tr>
<tr>
<td>Education</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Supply of services</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Agriculture and Forestry</td>
<td>Agricultural and aquaculture facilities</td>
</tr>
<tr>
<td>Foods and Goods</td>
<td>Agricultural and aquaculture facilities</td>
</tr>
<tr>
<td>Transport Network</td>
<td>Transport networks</td>
</tr>
<tr>
<td>Government</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Industry</td>
<td>Production and industrial facilities</td>
</tr>
<tr>
<td>Regional Products</td>
<td>Agricultural and aquaculture facilities</td>
</tr>
<tr>
<td>Recreation</td>
<td>Land use</td>
</tr>
<tr>
<td>Entertainment</td>
<td>Land use</td>
</tr>
<tr>
<td>Child Care</td>
<td>Utility and governmental services</td>
</tr>
<tr>
<td>Health Care</td>
<td>Human health and safety</td>
</tr>
<tr>
<td>Air quality</td>
<td>Atmospheric conditions</td>
</tr>
<tr>
<td>Occurrence of species</td>
<td>Species distribution</td>
</tr>
<tr>
<td>Protection of natural resources</td>
<td>Protected sites</td>
</tr>
<tr>
<td>Population development</td>
<td>Population distribution and demography</td>
</tr>
<tr>
<td>Culture protection</td>
<td>Protected sites</td>
</tr>
</tbody>
</table>

Even if not all indicators for sustainable planning (see chapter 4.2.1) contain concrete spatial information they can be projected on spatial statistical units like municipal boundaries with the help of statistical data. Figure 5 shows an example for the average income per capita projected on municipal boundaries. This spatial information is necessary to get an overview of the available purchasing power in the capita where the new building is planned and its neighbourhood. Planners for example need this information for location analysis for the establishment and development of companies.
Fig. 5: Average income per capita projected on municipal boundaries. Data source: Department of Statistic North, Schleswig-Holsteins State Surveying Authority.

The reasoning as given in the current chapter of spatial planning needs for spatial information on the one hand and the future deliverables of the Spatial Data Infrastructure as defined by INSPIRE on the other hand should be seen as a preliminary attempt of mutual assignment of both areas. More work will have to be done in future to detail this approach in more concrete and specific terms.

5.3 Analysis of Spatial Connections

*Task:* Planners and decision-makers need information for spatial effects concerning their planning.

*Solution:* One possibility is to support planning by data viewing tools. Another possibility is the use of spatial tools like buffer generation or Point-in-Polygon-analysis for supporting sustainable planning. These tools can be used for analyzing spatial relationships between causes and effects. In Figure 6 the risk of impacts for new citizens caused by emissions of biogas plants and highways is shown in correlation with potential sites for new buildings.
Spatial analysis in the described way can only be performed if the data of the Spatial Data Infrastructure are accessible through Web Feature Services (WFS). As outlined in the previous section the INSPIRE implementation will provide this functionality in future.

5.4 Measuring the Impact

Task: All effects on the environment or on the humanity should be spatially summarized in the planning process to get the overall view of the impacts on a specific area.

Solution: The next level for supporting cause-effect-analysis with Spatial Data Infrastructures includes the use of Web Processing Services (WPS). WPS allows combining different Web Feature Services with spatial tools and, in that way, creating complex applications. The end user is not required to go through a complex dialogue with the system but rather gets the final result of the spatial calculation which is performed fully automatically responding his request. Indicators can be automatically generated depending on spatial existence or spatial relationships, for instance. An evaluation of the impact of building a new house on defined indicators can be generated automatically. Figure 7 shows an example where environmental impact is automatically measured spatially and displayed on the screen.
5.5 Creating Scenarios

Task: Simulation of scenarios is becoming increasingly important assuming population change or climate change.

Solution: Depending on defined spatial relationships multiple scenarios can be created. The case which is shown in Figure 8 illustrates the planning process of kindergarten places for the next years depending on the number of children living in the local community. After the implementation of INSPIRE the necessary information will be available in the following INSPIRE-datasets: addresses, transport networks, statistical units, buildings, land use, utility and governmental services, population distribution and demography (cf. Figure 1). Spatial analysis is needed to obtain the presented results. For this kind of analysis real vector data is needed. Web Mapping Services (WMS) generate pictures, but for data access Web Feature Services (WFS) are indispensable.
First all residences of children younger than three years old and the addresses of the kindergartens in the community are collected and geo-referenced in a Spatial Information System.

Subsequently the spatial distance between the residences of the children and the kindergartens were analyzed. An acceptable distance was defined at 2500m. As can be shown many children live outside of this distance radius.

Based on these results a capacity utilization scenario was created by allocating all children the nearest kindergarten. The capacity for children is shown by the green bar, the red bar indicates the demand in year 2014 depending on the number of children living in this area today. It is obvious that in some kindergartens the capacity will not fully be used while in other places the need exceeds the available resources available. Cross border capacity planning could be helpful for sustainable planning.

Fig. 8: Kindergarten capacity planning depending on spatial distance to children residence. Fictitious data.
6. DESIGNING A DIGITAL WORLD FOR SUSTAINABLE PLANNING

As can be seen in chapter 5 spatial data infrastructures can support cause and effect analysis for sustainable planning in many different ways. It was shown that all aspects in the process of sustainable planning can be analyzed and simulated depending on the data available, for example employing the European INSPIRE Directive.

Fig. 9: First level of a spatio-cybernetic cause-effect-chain for building a new house.

As a prospect on further work, only a high end support would allow a holistic, spatial cybernetic thinking. All system components and their multiple spatial relationships can be...
modelled in a spatio-cybernetic model of the planning area depending on data available in spatial data infrastructures. A first attempt of a spatio-cybernetic model definition is shown in Figure 9.

7. CONCLUSIONS

Humans and environment interact in many different ways. Building a new house for example engenders a complex set of interactions. The change of land use has environmental, social, urban and economic impacts which have to be modelled. Cybernetic control instruments like the “model of sensitivity” (Vester 2007) are available. With the help of such instruments the complexity of systems can be downsized to a manageable level. Indicators can be transferred to the spatial context with the help of spatial informatics.

The framework of correlations and interactions within spatial planning consists of planning rules, of governmental processes, and of the needs of citizens. Aspects of sustainability have to be taken into account and, more than that, they have to guide the whole planning process. Environmental, economical and social indicators can be used to operationalize sustainability factors. Spatial Data Infrastructures with a clear definition of standards for data and services can provide the necessary information.

The presented case study of building a new house in Germany shows at a general level how the European Spatial Data Infrastructure which was initiated by the INSPIRE directive and which is under construction can support sustainable planning by providing data and services in an appropriate way.

As can be seen in chapter 5 spatial data infrastructures can support cause and effect analysis for sustainable planning in many different ways. It was shown that all aspects in the process of sustainable planning can be analyzed and simulated depending on the data available, for example employing the European INSPIRE Directive.

As a prospect on further work, only a high end support would allow a holistic, spatial cybernetic thinking. All system components and their multiple spatial relationships can be modelled in a spatio-cybernetic model of the planning area depending on data available in spatial data infrastructures. A first attempt of a spatio-cybernetic model definition is shown in Figure 9. The presented concept of using cybernetic control instruments will have to be assessed and to be detailed further. The European Spatial Data Infrastructure will have to reach its operational status. As soon as that status is reached high end support is going to be available to foster holistic, spatial cybernetic thinking in spatial planning.

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BIOGRAPHICAL NOTES

Ulrike Klein got her diploma in geomatics at the university of applied sciences in Hamburg, Germany. After two years in a spatial consulting company she turned 2003 to Kiel University where she got her doctoral degree in Geography. Since 2009 she is on one hand director of the Centre for Geoinformation at the Kiel University and on the other hand director of an engineering company. She is part of the DVW - German Association of Geodesy, Geoinformation and Land Management working group 2 – Spatial Information and Spatial Data Management.

Hartmut Müller got his diploma and doctoral degree at Karlsruhe University, Germany. After 8 years of research he turned into the marketing and software development departments of international enterprises for 6 years. Since 1991 he is a professor at Mainz University of Applied sciences. Since 1998 he is a member of the board of i3mainz, Institute for Spatial Information and Surveying Technology. In the DVW – German Association of Geodesy, Geoinformation and Land Management he was the chair of working group 2 – Spatial...
Information and Spatial Data Management until 2010. In FIG he is the Chair of Working Group 3.1 Spatial Information Management.

CONTACTS

Dr. Ulrike Klein
Centre for Geoinformation, Christian-Albrechts-Universität Kiel
Boschstr. 1
D-24118 Kiel
GERMANY
Tel. +49 431 239521 11
E-Mail: uklein@gis.uni-kiel.de
Website: www.gis.uni-kiel.de

Prof. Dr.-Ing. Hartmut Müller
Mainz University of Applied Sciences
Lucy-Hillebrand-Str. 2
D-55128 Mainz
GERMANY
Tel. +49 6131 628 1438
E-Mail: mueller@geoinform.fh-mainz.de
Website: www.i3mainz.fh-mainz.de