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

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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 livingenvironment 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.

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.

Fig. 1: List of 34 INSPIRE Annex I, Annex II, Annex III themes
(http://inspire.jrc.ec.europa.eu/, 20.11.2011)

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 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.

Fig. 2: Example of a legally binding land use plan of the study area

4.2.2 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"[1] 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

[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

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

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

Ecological Indicators		
Waste	Soil	Energy and resources
Land use	Noise	Settlement development
Air	Nature conservation	Natural scenery and landscape
Water		
Economical Indicators		
Employment	Education	Supply of services
Agriculture and forestry	Accessibility	Regional products
Economic structures	Economic development	Public budget
Social Indicators		
Population development	Civic and democratic engagement;	Individual mobility and public transport
Recreation	Family and child care	Health
Socially responsible business	Inter-municipal cooperation	Distribution of income
Culture, cultural heritage	Participation	Seniors
Safety	Daily Supply	Distribution of work
Living space		Equal rights

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.[2]

The European Commission monitors the sustainable development of the member states by using the following indicators[3]: 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.

[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

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

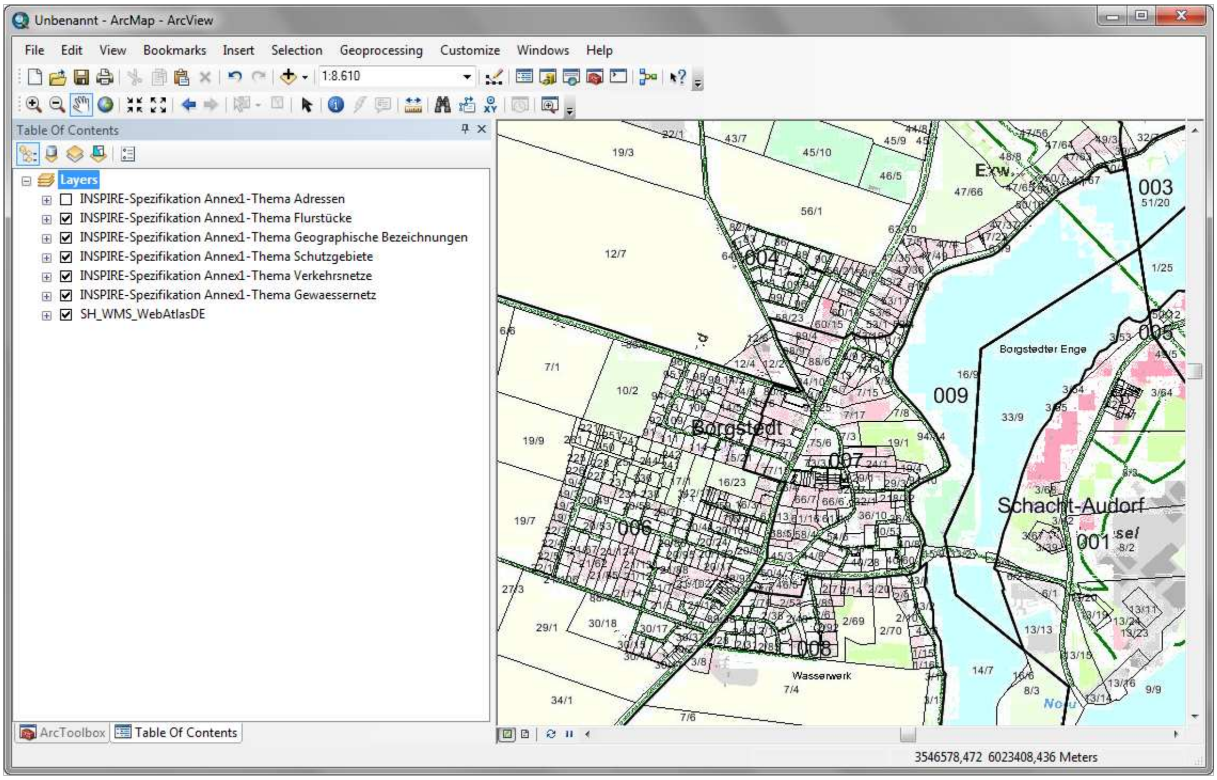


Fig. 4: INSPIRE Annex I data for the planning area, loaded as WMS-services, accessible through the internet, no costs. Data source: Schleswig-Holsteins State Surveying Authority.

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

Spatial Aspect (cf. Table1, Table 2)	**INSPIRE theme (cf. Figure 1)**
Soil	Soil
Energy	Energy Resources
Water	Hydrography
Resources	Land cover, Soil, Mineral resources
Land Use	Land use
Waste disposal	Utility and governmental services
Waste Water Disposal	Utility and governmental services
Rain Water Disposal	Utility and governmental services
Employment	Production and industrial facilities
Education	Utility and governmental services
Supply of services	Utility and governmental services
Agriculture and Forestry	Agricultural and aquaculture facilities
Foods and Goods	Agricultural and aquaculture facilities
Transport Network	Transport networks
Government	Utility and governmental services
Industry	Production and industrial facilities
Regional Products	Agricultural and aquaculture facilities
Recreation	Land use
Entertainment	Land use
Child Care	Utility and governmental services
Health Care	Human health and safety
Air quality	Atmospheric conditions
Occurrence of species	Species distribution
Protection of natural resources	Protected sites
Population development	Population distribution and demography
Culture protection	Protected sites

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.

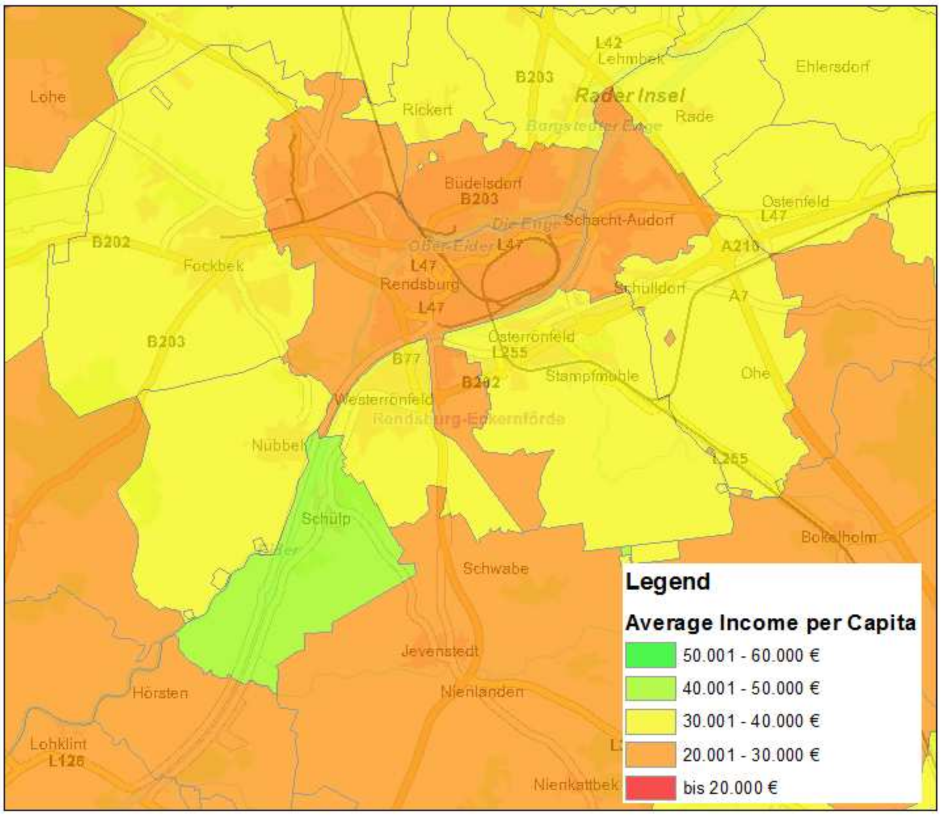


Fig. 5: Average income per capita projected on municipal boundaries.
Data source: Department of Statistic North, Schleswig-Holsteins State Surveying Authority.

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 descision-makers need information for spatial effects concerning their planning.
Solution: One possibilty is to support planning by data viewing tools. Another possibility it 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.

Fig. 6: Spatial analysis for analyzing the spatial relationship. Example: potential emissions. Data Source: Schleswig-Holsteins State Surveying Authority (aerial photography), Ministry of the Environment Schleswig-Holstein (noise), fictitious data for biogas plants and planned sites.

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.

Fig. 7: Automatically generated environmental impact of house building. Data Source: Schleswig-Holsteins State Surveying Authority (aerial photography), fictitious data for the impact.

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.

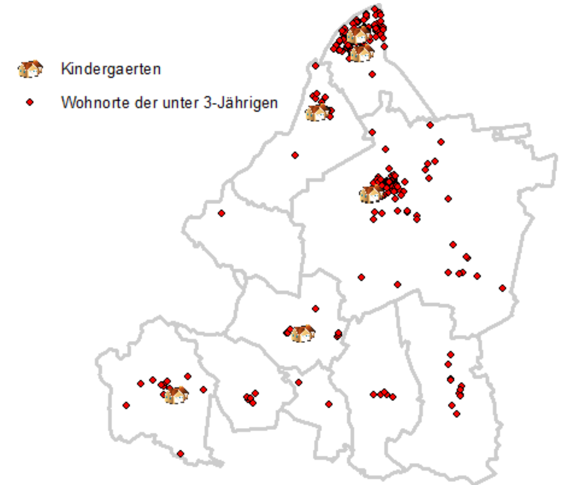
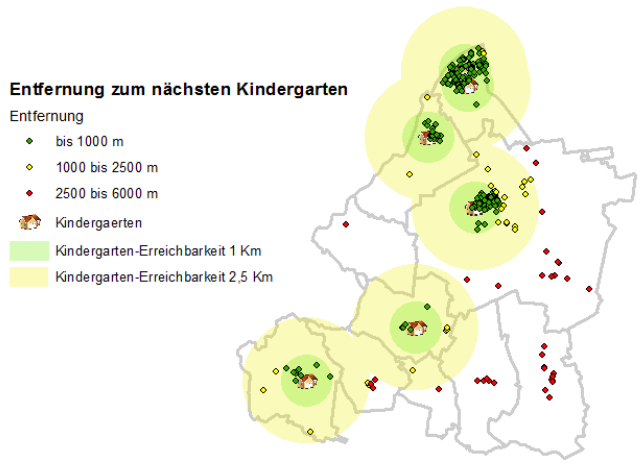
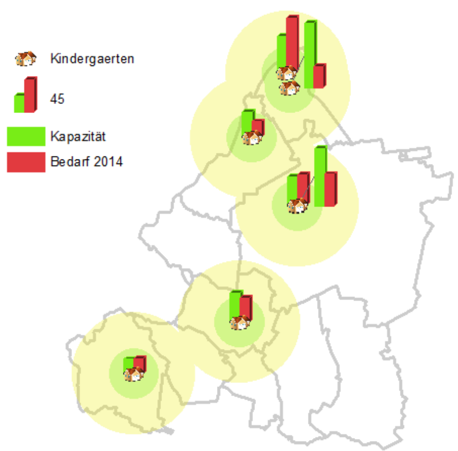
<table>
<tr><td>
</td><td>First all residences of children younger than three years old and the addresses of the kindergartens in the community are collected and geo-referenced in a Spatial Information System.</td></tr>
<tr><td>
</td><td>Subsequently the spatial distance between the residences of the 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.</td></tr>
<tr><td>
</td><td>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.</td></tr>
</table>

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.

REFERENCES

Behrendt, D., Kleinhügelkotten, S., Kloten, M. & Neitzke, H.-P. (2010): Kriterien für die Nachhaltigkeit der Nutzung und die Vermarktbarkeit städtischer Brachflächen. In: Stefan Frerichs, Manfred Lieber & Thomas Preuß (Hrsg.): Flächen und Standortbewertung für ein nachhaltiges Flächenmanagement. Methoden und Konzepte, Beiträge aus der REFINA-Forschung, Reihe REFINA Band V, Berlin. (In German)

Bock, S. & Preuß, T. (2011): Flächenverbrauch: Fakten, Trends und Ursachen. In: Stephanie Bock, Ajo Hinzen & Jens Libbe (Hrsg.): Nachhaltiges Flächenmanagement - Ein Handbuch für die Praxis. Ergebnisse aus der REFINA-Forschung. Berlin. (In German)

Doytsher, Y., Kelly, P., Khouri, R., McLaren, R., Müller, H., Potsiou, C.: Rapid Urbanization and Mega Cites: The Need for Spatial Information Management. FIG Congress 2010 – Facing the Challenges – Building the Capacity, Sydney, Australia, 11-16 April 2010, http://www.fig.net/pub/fig2010/papers/ts01b\ts01b_potsiou_doytsher_et_al_4709.pdf

European Union (2007): Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Official Journal of the European Union L108 Volume 50, 2007. http://inspire.jrc.it/directive/l_10820070425en00010014.pdf

Eurostat (2009): Sustainable development in the European Union. 2009 monitoring report of the EU sustainable development strategy. Luxembourg. http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-78-09-865/EN/KS-78-09-865-EN.PDF

Federal Republic of Germany (2011): Federal Building Code (1994, BGBl. I S. 2414) and (2011, BGBl. I S. 1509). Berlin. For an English translation of the 1997 version see http://www.iuscomp.org/gla/statutes/BauGB.htm

Federal Statistical Office of Germany (2010): Sustainable Development in Germany, Indicator Report 2010. Statistisches Bundesamt (Federal Statistical Office), Wiesbaden

GSDI (2004): Developing Spatial Data Infrastructures: The SDI Cookbook, Version 2.0, 25 January 2004. www.gsdi.org/docs2004/Cookbook/cookbookV2.0.pdf

Heiland, S., Tischer, M., Döring, T., Pahl, T. & Jessel, B. (2003): Kommunale Nachhaltigkeitsindikatorensysteme - Anspruch, Eignung, Wirksamkeit - Indikatoren zur Zielkonkretisierung und Erfolgskontrolle im Rahmen der Lokalen Agenda 21. UVP-Report 17, S. 202-206. (In German)

Kristensen, Peter (2004): The DPSIR Framework. Nairobi. http://enviro.lclark.edu:8002/rid=1145949501662_742777852_522/DPSIR%20Overview.pdf

Maslow, Abraham H. (1943). A theory of human motivation. Psychological Review, 50, p. 370-396.

Müller, H., Siebold, M., 2008, Good-Practice Example of a German Regional SDI as a Component of the Future INSPIRE Framework. Surveying and Land Information Science, The National Society of Professional Surveyors, The American Association for Geodetic Surveying, and The Geographic and Land Information Society, Volume 68, Number 2, June 2008 , pp. 93-99.

Regionale Planungsgemeinschaft Anhalt-Bitterfeld-Wittenberg (2009): Dorfumbau - Zukunftsfähige Infrastruktur im ländlichen Raum. Projekt im Rahmen des Modellvorhabens "Demografischer Wandel - Zukunftsgestaltung der Daseinsvorsorge in ländlichen Regionen des BMVBS. Köthen. (In German)

Schmidt, S., Buehler, R. (2007): The Planning Process in the US and Germany: A Comparative Analysis. International Planning Studies, Vol. 12, No. 1, 55-75. Routledge, Taylor&Francis Group. http://www.spia.vt.edu/SPIA/docs/ralphbu/papers/lu_d_usa.pdf

United Nations (1987): From one Earth to One World. Report of the World Commission on Environment and Development, Brundtland Report.

United Nations (2005): World Population Prospects: The 2005 Revision. DESA, Population Division, New York. http://www.un.org/esa/population/publications/WUP2005/~ 2005WUPHighlights_Final_Report.pdf

United Nations (2007): Indicators of Sustainable Development: Guidelines and Methodologies. Third Edition. New York. http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf

Vester, F. (2007): The Art of interconnected thinking: Tools and concepts for a new approach to tackling complexity, MCB Verlag GmbH (Management, Cybernetics, Bionics), Munich.

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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.

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