RS-techniques for Land use change detection – Case study of Istanbul

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ABSTRACT: The detection of the Land use change of Istanbul within the last 50 years point out the dramatic change of this city. An area of more than 3000 km² was analysed in the MOLAND-Project, where more than 60 land-use classes have been selected and analysed for 4 years, the reference-year 2000, the year 1988, 1969 and 1945. The material was based on very high resolution satellite imagery like Ikonos and IRS-D, on satellite photographs like KVR and KFA and small scaled military aerial photographs. Some key-actions have been detected, so the built up of the Bosporus-Bridges, which made the rapid grow jump also to the Asiatic side of the city. We describe the technical work in combination with ancillary data, especially with historical ones. Also data like census-data have been integrated into the analyses to enable the development of a differentiated scenario. We aim to point out the possibility of RS-data in combination with other relevant data to reach more detailed understanding of the grow of mega cities. Socio-economical, political, morphological and many other aspects are responsible for this specific development.
To undertake temporal analyses of land-use change in urban and suburban agglomerations in relation to the cities connection (corridors) is the objective of MOLAND (Monitoring Land-Use Dynamics). It follows the MURBANDY (Monitoring Urban Dynamics) initiative but moreover MOLAND is interested in cities on traffic-nod-points which play an important role as corridors. As a gate to the Asian continent and a traditional trade place, Istanbul is a most important city. Istanbul will be compared with 25 European cities, which have been analysed under MURBANDY. The spatial distribution and the quality of the environment in urban and in rural areas surrounding the cities are the main subjects of the investigation conducted within the project, which is based on 3 packages: change detection (CHANGE), understanding (UNDERSTAND) and development of scenarios (FORECAST).

1. Background

Throughout the world processes related to urbanisation, development of transport infrastructures, industrial constructions, and other built-up areas, are severely influencing the environment, and are modifying the landscape. The importance of sustainable urban development at the European and international level is reflected by the various policies and initiatives that address this topic. Within the above context, a project was initiated by the Directorate General Joint Research Centre (DG JRC) of the European Commission. MOLAND was initiated in 1998 (under the name of MURBANDY – Monitoring Urban Dynamics), in support of the preparation of the European Spatial Development Perspective (ESDP). MURBANDY aimed to monitor the development of urban areas and to draw some conclusions on trends at a European scale. This work was extended (under MOLAND) to the computation of indicators (following the requirements of EUROSTAT, European Environment Agency and others), and to the assessment of the impact of anthropogenic stress factors (with a focus on expanding settlements, transport and tourism) in and around urban areas, and along development corridors. The primary role of the MOLAND Project is to provide scientific and technical support to the European Commission's various Directorates-General (DGs), services, and associated bodies, which are responsible for the conception, development, implementation, and monitoring of EU policies related to urban and regional development. At present, the main EU policy areas that are supported by MOLAND include the following: the 6th EC Environment Action Programme's proposed Thematic Strategy on the Urban Environment, for DG ENV (Environment); indicators for Sustainable Urban and Regional Development, for DG ENV, EUROSTAT, and the EEA (European Environment Agency); the ESDP, for DG REGIO (Regional Policy); Impacts of the Structural and Cohesion Funds, for DG ENV; Strategic Environmental Assessment (SEA) of the Trans-European Transport Networks (TEN-T), for DG TREN (Energy and Transport).
From technical point of view, MOLAND has three specific aims:

- to produce quantitative information on the evolution of land use and transport networks, from 1950 onwards, in study areas subject to infrastructural changes (e.g. urbanisation, construction of transport links);
- to develop methods for performing a harmonised analysis of historical trends, including socio-economic aspects, impact of legislation, landscape fragmentation, etc.;
- to develop models for the harmonised simulation of future European-wide scenarios, at local and regional scales.

The implementation of MOLAND is divided into three phases. Central to the methodology is the creation of detailed GIS databases of land use types and transport networks for the study areas, at a mapping scale of 1:25.000. The databases are typically for 4 dates, early 50s, late 60s, 80s, late 90s. For each study area the reference land use database is created from interpretation of satellite imagery. The three historical databases are created from the available data (aerial photographs, military satellite images, etc.) for these dates. MOLAND adopts the CORINE land cover legend, with a fourth, more detailed level of nomenclature needed for the scale used.

In the second phase of MOLAND, various spatial analysis techniques are applied to the land use and transport databases, and associated socio-economic data, in order to compute different types of indicators of urban and regional development. These indicators are used to assess and compare the study areas in terms of their progress towards sustainable development. Analysis of the fragmentation of the landscapes is also carried out. The land use and transport databases have also been used for a strategic environmental assessment (SEA) of the impact of transport links on the landscape.

In the third phase of MOLAND, an urban growth model is applied. This model, which is based on spatial dynamics systems, takes as input the MOLAND land use and transport databases, as well as maps of land use suitability and zoning status, and simulates future land use development under the input of urban and regional planning and policy parameters.

Here, the aim is both to predict future land use development under existing spatial plans and policies, and to compare alternative possible spatial planning and policy scenarios, in terms of their effects on future land use development.

2 IMAGE-PROCESSING

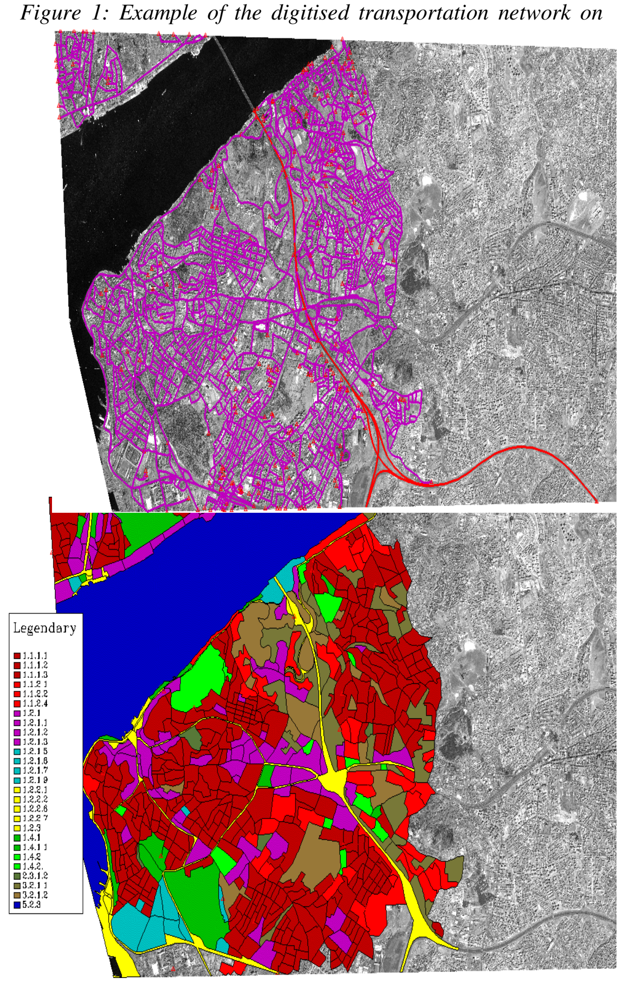
As geodetic basement we chose topographic maps 1:25k and existing digital maps 1:5k and 1:1k. Different types of maps with different accuracy and scaling exist even with different coordinate-system. Transformation of ellipsoids and projections took place. Georeferencation and transformation was done in TopoL-GIS. With partial transformation method we've been able to get most accurate georeferenced maps. With a partial transformation, the maps are not only georeferenced, the errors are reduced, as well as a perfect neighbourhoods and a mistake minimisation of scanning and paper sheets is achieved. A final Affin-transformation moved the image to the new coordinates. The first set of satellite imagery of 2000 was IRS/D with 5m resolution in panchromatic and 25m in multi-spectral mode. Two IRS-D pan imageries pictures have been selected to cover the project area as well as 2 MS-Scenes. The images, delivered in IMG-Format, have been imported into TopoL. Colour-composition and pan-sharping was done. For the Bosporus area, IKONOS imageries have been available as a MS set (blue, green, red and NIR) with 4m resolutions, and as pan with 1m. Also here a colour-composition and pan-sharping was done. Georeferencation of the imageries was done by either globally or by a triangle-network. Always have been picked up ground-control points on the map or on already georeferenced imageries. The year 1988 was prepared on base of Russian satellite photographs from KVR-1000 camera with 2m resolution and KFA-1000 camera with 5m resolution. These data belong to the satellite-based spy-campaign of the 80ies. The pictures have been bought already scanned with high resolution (8 µm). 2 KFA-1000 satellite photographs cover the entire project area. The colours are different to normal film-material; it is describes as pseudo colour. The channels are not separated.

The ground resolution is between 4 and 6m but in detail the structure of the films corn can be seen. The quality is fine and can be compared with IRS imageries of the reference year. However the contrast is smaller and the city-structure in detail isn't so clear than in IRS. Then they have been automatically balanced by RGB-colours in the overlapped zone, framed and mosaiced to a new raster. 4 photos of the high-resolution satellite camera KVR-1000 cover the central part of the project area.. The ground-resolution is ranging between 1 and 3m. The processing of the imagery was very difficult. Only special transformation algorithm gave good results. In small areas was the result acceptable. The historical imageries for the years 1968 and 1945 have been created out of aerial photographs. All photos have 18x18 cm size. Flying altitude was calculated from focus length and scale. All slides have been scanned with 600 dpi geometric and 8-bit radiometric resolution. The external orientation was done according to the topographical maps by identical points on the photo and the map with the heights from the maps or taken from the DTM. Relative-, height-, position-, and full-points can be mixed in the bundle-adjustment method in the used PhoTopoL-Software. The strong land-use-change made the identification of control-points especially outside the urban centre difficult. If already 2 points are picked up, the system pans into the expected new position but to find enough suitable points is a kind of detectives work. For the process of orthophoto-calculation, DDE connection between PHOTOPOL and ATLAS-DMT Software was done to use the TIN-based DEM for the calculation and so to get most accurate results. The orthophotos have been resampled to a resolution of 1 m.

3 DIGITALISATION AND INTERPRETATION

All digitisation and interpretation work was done manually on-screen. Automatic processes for feature extraction in urban areas fail if such a detailed legendary is recommended.

Figure 1: Example of the digitised transportation network on



the left (highways in red, other road in pink) and the land-use data set on the right (red = residential, pink = business)

Line-Layer: First the linear elements (lines and polylines), such as transportation (road and rail) and river/sea-canal network, have been mapped according the MOLAND legendary on screen in TopoL. Topological data-structure was recommended. Limit was given by the visibility in the satellite-imageries. More wide linear features have been digitised by a middle line and as far as they have a bigger width than 25 m, they have been mapped in the area-layer as well. These lines are often boundaries for area-objects. So far they have been copied to the file with the area-database of the processed year. The code of the line has been stored in a related database.

Area-Layer: The lines and polylines of the line-layer have been used as basement for the area-layer (polygon with label-point). All other areas with a homogeneous use according to the legendary have been defined by the boundary-line and the labelling-point with the attached database in its middle. The database was filled during defining the label-point inside the boundary. An additional area-layer, a so-called 3d-layer, was added to take area objects into account, which cover other area objects. These are namely big bridges and highway tunnels.

Temporal detections have been undertaken by down-dating the land-use-classes of the 3 layers by going back-wards to 1988, 1965 and 1945. Finally 4 line layers, 4 area layers and 4 3d area-layers have been developed. Using database-analyses and GIS-intersections the changes can be detected and quantified. Fist the entire line layer had to be down-dated by the older images. Additional line-objects have been added and others been erased. The database had to be checked if the object attributes still fit to the legendary. Then the down-dated lines and the lines of the newer area layer have been imported into a new empty layer. To import the database just for information, only the label points with attached area database have been copied. Then also here the lines have been corrected as boundary lines. As far as the area and the use was the same, the area had been created automatically and the attributes taken from the point database.

Ancillary data processing was as far as possible done in GIS or with combination of other database software like. A big number of spatial data have been mapped. These are the topographic maps 1:25k, city-plans, map of the public transport, DTM, administrative borders, geological maps and others. A big number of socio-economic statistics have been pre-processed. For the validation and pre-calculation of statistical data, MS-Excel with dBase III-output enables geo-coding and combination with GIS. But we have to be aware that the combination of spatial data of a specific time, non-spatial, temporal data, non-spatial regional data and GIS-Data are very often difficult to do. Some information is just qualitative and not quantified. Modelling and parameterisation has to be done. The result of this processing solves questions like: how many people live in which kind of residential area. It can help to understand the spreading of the population in Istanbul. Some initialisation of urban grows are indicated by single objects (like the Bosporus-bridge) or by changes in the law (legalisation of some Gecekondu-areas). To point out such facts, is a detective's work where the collected data and the land-use change database helps very much.

4 INTERPRETATION

Key objectives in MOLAND are to quantify the changes in land use patterns, to explain the trends of growth for the selected urban areas, and to help in identifying strategies for sustainable urban and regional development. The extensive data set created within MOLAND allows handling a series of unique land-referenced data. Those data are used to build and, particularly, to test specific spatially referenced indicators. Such indicators serve several purposes:

- Provide a better understanding of complex territorial problems
- Provide a sufficiently complete basis for the approaches to urban and regional spatial planning (particularly regarding sustainable land use management)
- Help city managers and decision-makers in defining local policies

Provide regional/national authorities and international institutions with detailed territorial-referenced information at local and European levels.

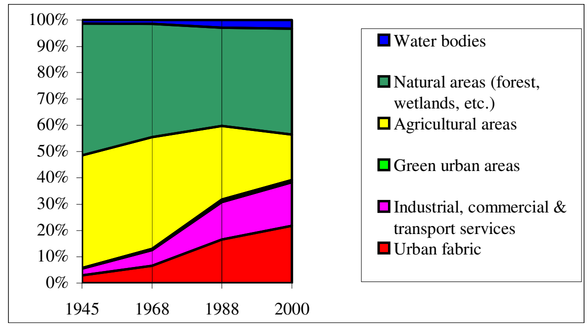


Figure 2:The land-use change by groups of MOLAND Classes

We will give a glance of the statistical operations done on the land-use data of different years. The graph shows the main changes in different groups. Grow of residential area (urban fabric) is strong, mainly between 68 and 88. The same can be detected for business areas. In same time agricultural area lost space.

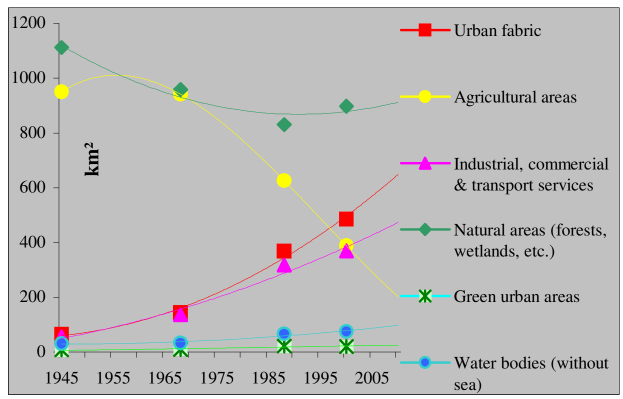


Figure 3: Grow of the different groups by linear time-scale and trend-graphs

Figure 3 shows the change from agricultural to urban land-use. The time-scale was made linear to enable trend-analyses with polynomial function of second degree. The trend might be over-sized but even an effective visualisation of the future. To combine this data with demographic ones, gives other indications.

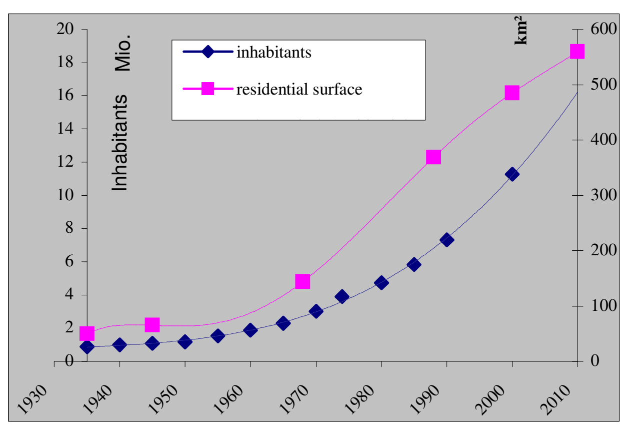


Figure 4: Growth of population and residential surface

In Figure 4 the populations grow and the in-crease of residential area have been compared. Interesting is the extreme grow between 68 and 88 of the residential surface. In detailed studies can be seen, that a big amount was in less dense residential areas, might be legalised Gecekondu. After 1988 the situation changes. Both lines still have a strong increase, but the residential surface slows down meanwhile the population rate increases. This affects a higher population density. More big buildings with bigger density have been built. These types of residences grow strong, similar to the population. By interpretation of the CHANGE Data, key-areas of specific change can be detected and analysed. Such areas have a role for the development of the entire city and they are result of some specific human impact. A number of environmental indicators will be used to measure the sustainability of areas. They will be related to political keys, such as law-restrictions. Especially in Istanbul some events (road-construction) initiated the increase of "Gecekondu" areas.

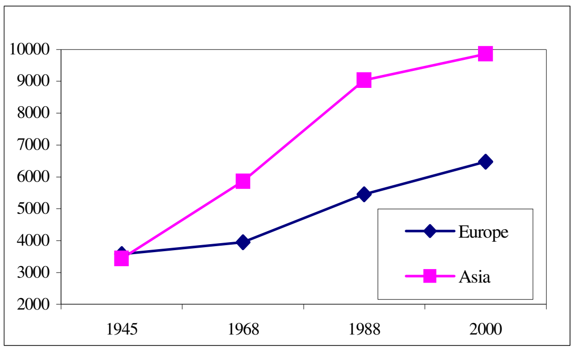


Figure 5: Change of transportation network on the Asian and European side

The difference in the increase of the transportation network shows the stronger development of the Asiatic side. The main initiation was the bride-construction in the year 1972 and 1987. Also when the bridge was not ready, the development already had started.

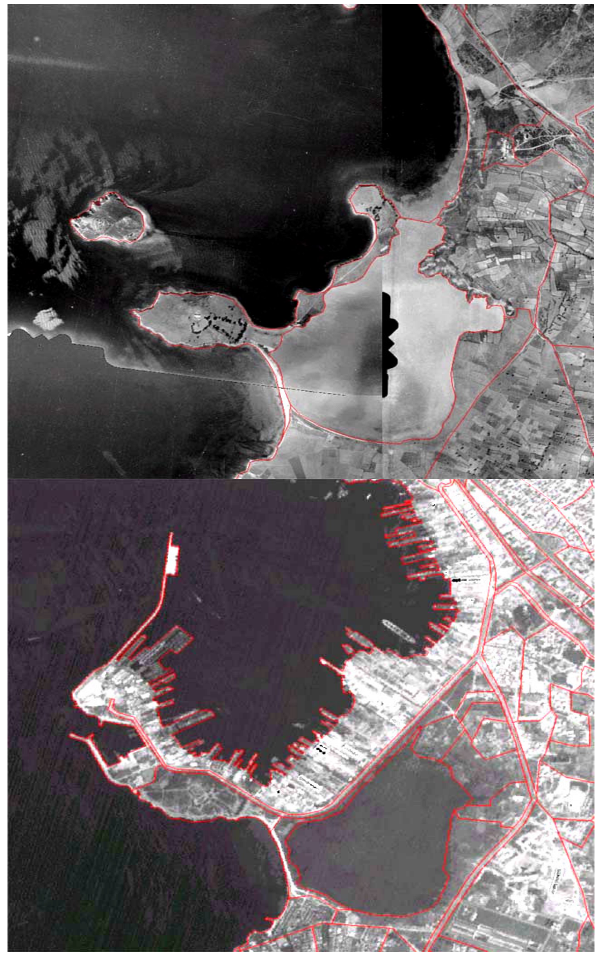
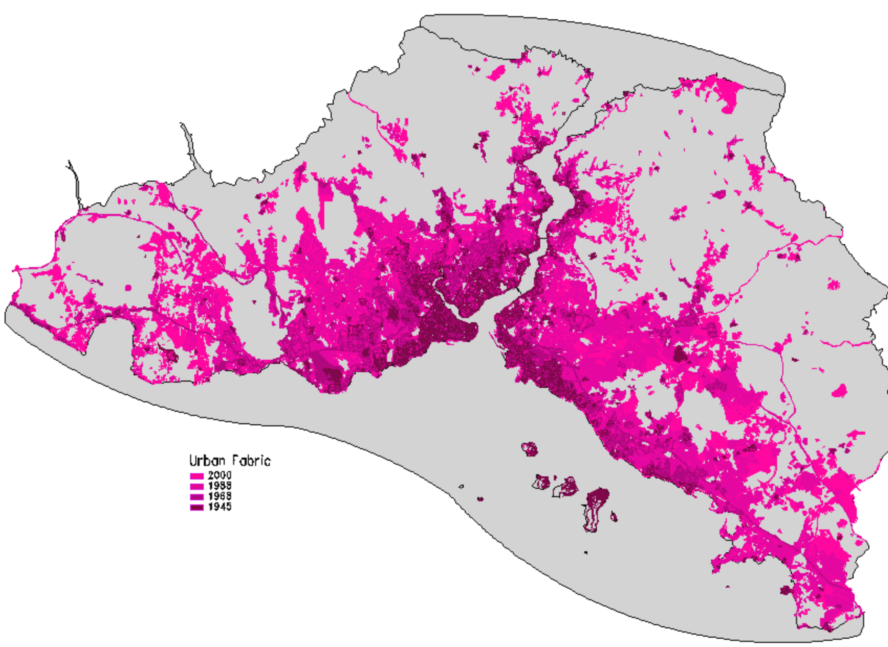


Figure 7: A port-area on the IRS-D Image 2000 (down) and on the Orthophoto 1945 (up)

Figure 6 visualises the grow of artificial fabric. While the grow on the European side is concentrated around the central part of Istanbul, the increase on the Asiatic side is fixed along the coast of the Marmara Sea.

Figure 6: Grow of the urban fabric



Based on the undertaken studies and the natural limits, axes of further grow of urban fabric can be estimated. This is shown in figure 8. The forest gives a limitation to the north. The length of the arrows indicates the intensity of increase.

Scenarios out of trend-analyses can be undertaken and a virtual grow of the city can be animated. Such scenario visualise the problems of the city, where increase is dramatically big. The project-data could be a suitable base for emergency planning. The output can be used in a large variety of applications, not only by

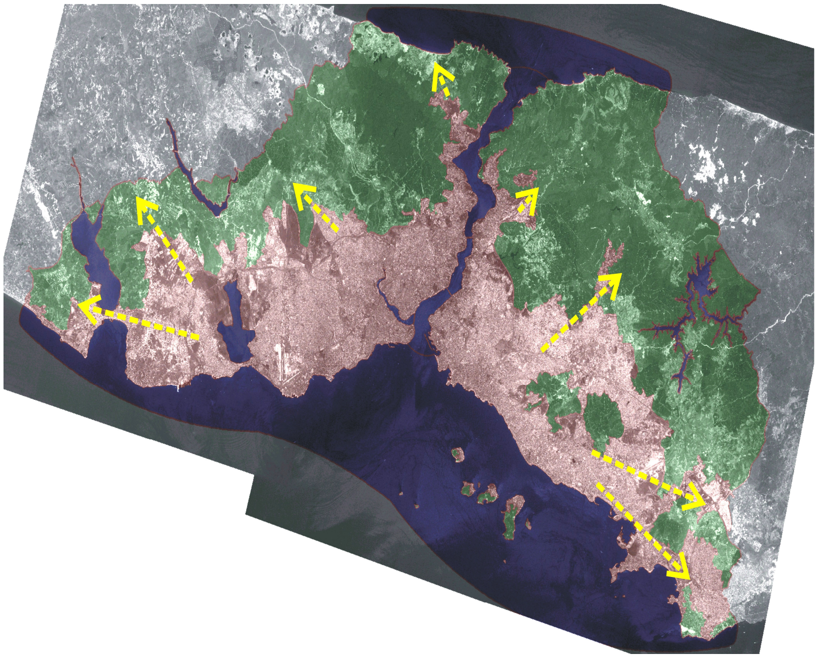


Figure 8: Expected main-axes of the further grow

the city of Istanbul, but also by the ministry for regional development and environment. The project also contains valuable information for the development of tourism and for potential investors. It also could be part in the national earthquake program, together with ancillary data sets like geologic maps.

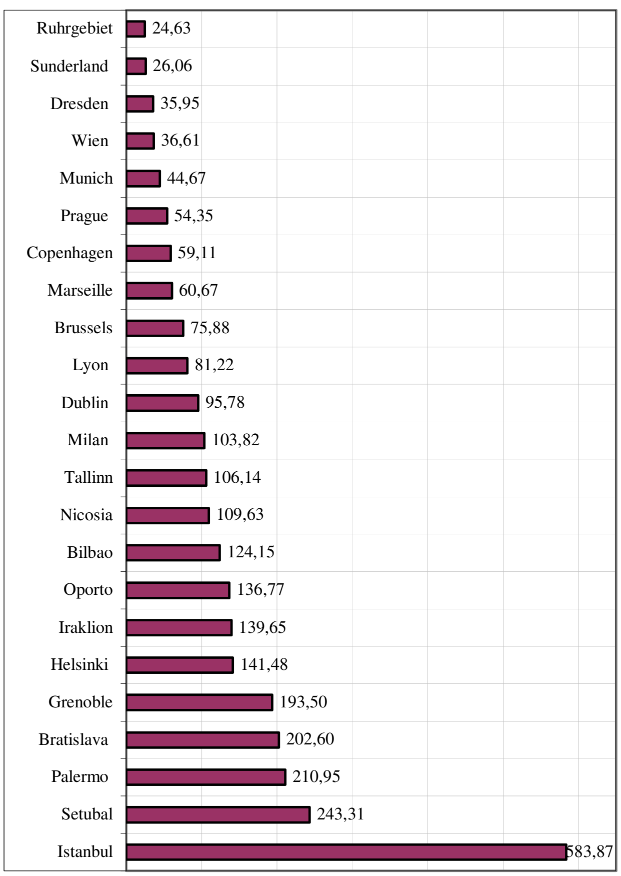


Figure 9: Urban grow within the last 40 years in percent, analysed under Moland or Murbandy

5 MODELLING AND FORECASTING SCENARIOS OF URBAN AND REGIONAL DEVELOPMENT

The urban and regional growth model that is used in MOLAND is based on spatial dynamics systems called "cellular automata". The model takes as input five types of digital maps, for the geographical area of interest:

- actual land use types present in the area;
- inherent suitability of the area for different land uses;
- zoning status (i.e. legal constraints) of the area for different land uses;
- accessibility of the area to the transport network;
- socio-economic characteristics (e.g. population, income, production, employment) of the area.

The information on land use types and transport networks is derived from the detailed GIS databases that were produced for each of the study areas, as part of MOLAND. The output from the urban growth model is maps of predicted land use development over twenty years.

The underlying spatial dynamics of the MOLAND urban and regional growth model are determined by so-called "transition rules", which specify the interaction between neighbouring land use types.

By modifying the input data (e.g. zoning, suitability, transport links), the MOLAND urban and regional growth model can be used to explore, in a realistic way, alternative future scenarios of land use development. The following types of spatial planning and policy "interventions" – with sample "real" applications – can be easily simulated with the model:

- Addition / removal of transport links: This can be used, for example, for a Strategic Environment Assessment (SEA) of the Trans-European Transport Network (TEN-T).
- Modification of land use zoning: This can be used, for example, to assess the effects on land use development of prohibiting the development of artificial surfaces in natural areas.
- Modification of land use suitability: This can be used, for example, to assess the effects on land use development of decreasing the flooding risk, due to infrastructural improvements.
- Modification of socio-economic data: This can be used, for example, to assess the effects on land use development of a changing economic climate (e.g. decreased industrial production).
- Modification of model's transition rules: This can be used, for example, to capture the particular cultural characteristics of an area (e.g. in certain areas, nearness to water might be considered attractive for residential areas).

The alternative spatial planning and policy scenarios are presented to the MOLAND urban and regional growth model in the form of digital data-sets of the transport networks, socio-

economic data, land use zoning status, and land use suitability. Based on these scenarios, and on the actual land use types at the start of the forecasting period, the model then predicts the likely future development of land use development, for each year over the next twenty years. In order to compare the alternative predicted land use maps produced by the model, in terms of the long-term sustainability of the input land use planning and management parameters, various indicators – including those describing landscape fragmentation – are computed and analysed.
Currently, the MOLAND urban and regional growth model is being calibrated for MOLAND's extensive Europe-wide network of cities and regions, using the MOLAND land use and transport databases, as well as the ancillary data-sets acquired from local authorities. The latest version of the model also incorporates data describing the socio-economic properties of the area, and will be used to simulate the interactions between the cities and their surrounding regions. This so-called "macro-model" is being tested on the four new "extended" MOLAND study areas, where extensive regional changes in land use are likely to occur as a result of major economic and infrastructural developments (e.g. the Dresden-Prague transport corridor).

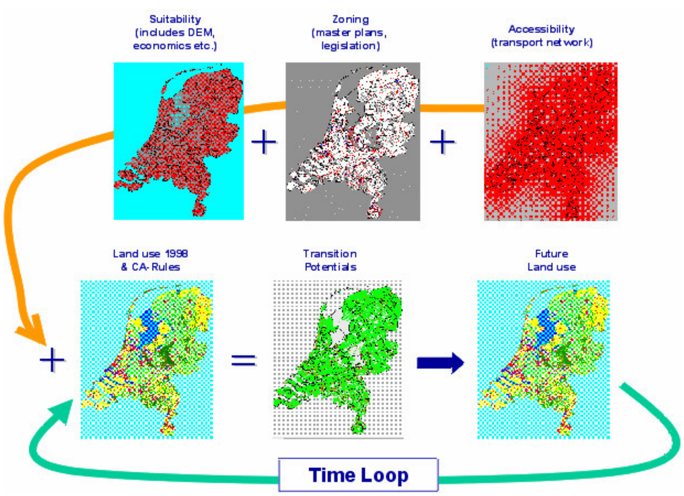


Figure 10: Example of an iterative procedure by interactive analyses with Moland data

6 CONCLUSIONS

The issues dealt with by MOLAND require a concrete and active involvement of regional and local authorities. This is for two main reasons.

- In the field of Regional policy the subsidiarity principle reaches its full dimension: local/regional bodies implement with almost full autonomy directives and measures for regional developments decided by the EC. This is particularly true for structural funds related to urban and local infrastructure (ports, airport etc.) and for the application of SEA at local/regional level. The debate has also been at the centre of the ESDP, and will have to be solved in the establishment of ESPON.
- From a purely technical point of view, only at the adequate local level is there a need for information to fully assess and analyse the impact of measures taken or planned.

In the frame of the activities of the project, particular efforts have been dedicated to establish links and contacts with national, regional and local authorities. These contacts have resulted in formal collaborations either following already established mechanisms in the EC (such the Working Groups in DG ENV, projects funded in the INTERREG Programme, the 5th RTD Frame-work Programme, etc.) or establishing bi-lateral agreements.
An active collaboration has been initiated with EUROCITIES (originated in the frame of the working groups set by DG ENV) to network cities and local administration. This will result in a series of proposals for thematic network to the EC, in which the partner-cities will aim to adopt as much as possible of the MOLAND methodology.
The 'instrument' to formally set up a large thematic network on the issue of urban (and regional) sustainable development is provided by the European Research Area which will drive the research activities of the European Commission. It s essential to extend the scope of such network to 'institutional users' (e.g. local administration, EC services etc.) and to institutes and organisations with a specialisation and tradition in the various fields related to the "urban affaire".

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