REMOTE SENSING AND PHOTOGRAMMETRY

- MULTISOURCE AND MULTISCALED DATA FOR GIS

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ABSTRACT

This paper aims try to give an overview about the actual strategies in Geographic Information System, Remote Sensing and Photogrammetric development to meet the end users requirements. The last few years nearly every tool to changed Windows environment, the Local Area Network-compatibility grew and animated applications through the Internet are on the way. This fact also influences the science and opens new ways to bring the data to the end users. These ways have to be defined by the scientist; the usability by the end user and the realization has to be done by the developers. This triangle causes problems but as well as the big chance for the commercialisation of our technology.

The data sources are of different quality, resolution and accuracy, the processing of them are various and the results are depended on many facts. The scientific world still is too much concentrated in most accurate data and commonly fixed on one scaled level. We already have the tools to use multiple scaled and resolute data in combination, but to manage them in a proper way is one of the biggest tasks still to do. By the use of data of a Land-use change Detection on Istanbul, produced and analysed under the MOLAND-Initiative, this paper aims to discuss such a data processing in respect to end user requirement and to point out where is scientific work to do in the future.

INTRODUCTION

MOLAND = **Mo**nitoring **Lan**duse **D**ynamics is an initiative founded by the European Commission and guided by the Institute for Environment and Sustainability, Land Management Unit of the JRC. The projects aim was to detect the land use changes of Istanbul, which shows an extreme growth. Four time periods have been selected, 1940ies, 1968, 1987/88 and 2000.

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 infrastructure 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 data sources are from different quality and their processing forces adapted methods in order to keep care of their accuracy and content. Also the interpretation is adapted to this fact.

Ancillary data have been processed as well, which are mostly already generalized. Some data aren't spatial at all, such data are demographic statistics, plans and historical data. Strategies for their integration had to be developed.

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), or for two dates (mid 80s, late 90s) in the case of large areas. For each study area the reference land use database (late 90s) is created from interpretation of satellite imagery, most commonly from the IRS and in a few cases from the IKONOS satellites. SPOT images sometimes complement the available 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 called “cellular automata”, 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

SCALE, RESOLUTION, ACCURACY

The technological development is rapid, in RS science, GIS, Photogranmetry and also in navigation and geodetic instrumentation. We meet scale, resolution, and accuracy in 2D and/or 3d as well as the information linked to the objects with an own definition of their quality. All these things are related to each other, but they are definitely not the same. We meet digital, analogue, spatial and non-spatial, quantitative and qualitative data and all kind of information between.

Digital or digitised data, like used in modern GIS-Environment, are free of scale, they only have got a resolution. We have to be aware, that resolution and accuracy are depended but not the same. Traditional data in form of maps are scaled and have a related accuracy. Nevertheless mapping campaigns in the field, which again use existing data, produced some other data sets. It is important to know or estimate the original scale, the used generalisation to describe the accuracy. Such maps in various scale are very common and needed to built up a database in GIS, especially the topographic maps are important. Other data are produced on their base, i.e. forest maps, geological maps, soil maps and many other suitable for a land-management. In GIS we like such maps as digital as scanned data or finally vectorised layers. Scanning usually is better resolute than the printing quality and the vectorisation itself depended on many other facts. Summarized we can see that maps are a rich source with many question marks concerning their accuracy. The containing data in such maps are already interpreted i.e. land-use data of topographic maps. It is already a kind of classification into groups defined by a legendary.

Other important data-sources are aerial images of former years, which exist either as analogue data, hard copies or scanned images. Their quality and accuracy is depended on technical facts that are usually described in the literature or the camera-description. Accuracy is close related to the quality of the lens, the precision of the film-stage, the calibration and the used film-material. The film and the lens limit the resolution of the photo. Mathematical definitions are in the focus-length related to the film-size, the flight altitude and the overlap.

Finally, to work in digital photogrammetry, these data have to be scanned in a resolution suitable for the final requirements. This in fact even influences the resolution in all 3 dimensions by clear physical equations. For the image-orientation we either need the parameters in certain accuracy or ground control-points in similar or better resolution. So far photogramnmetry is a clear defined method by geodetic means usually the accuracy is around the pixel-size or even a bit better, in heights 2-4 times worse.

A bit different is the content of the aerial data. They aren’t interpreted or generalised but not everything is visible without deeper knowledge. The geometry of objects can be derived by digitisation in 2D or 3D by the accuracy of the orientation, nevertheless we need a context to place the cursor. A border of a road, which is clear defined, can be placed on 2 pixels and become less sharp. In fact we are able to place the cursor in sub-pixel accuracy with help of the PC, but the interpretation is not as precise. For less sharp objects it can be in any case worse.

Satellite images usually come already in digital form; only old satellite photographs from former spy campaigns are analogue ones and have to be processed with photogrammetric methods.

The digital data are mostly pre-processed in order to match the rows, strips or pixels into a complete scene. There are some matching-methods in this pre-processing which are able to influence the accuracy but finally we can expect a correct resolution and accuracy at one-pixel size.

The geocoding of scanned maps or satellite images open a wide field of discussion. It is possible to reach sub-pixel accuracy but in practise we can be satisfied with pixel or 2 pixel absolute accuracy in this process. What we have to keep in mind is the quality of the control points used for the geocoding as well as the transformation algorithm. There exist always the possibility to select best points, which bring the best results. Even complex algorithms like Polynomial of 3rd degree, can give small residuals for the ground control points but finally there is not any guarantee that they are absolute correct in the areas between.

What ever we do, we can expect accuracy of non-generalized digital data in pixel-size, not more and not much worse. If we need other resolution or accuracy, we have to select different sources. But new technologies give a chance for combinations to get high accuracy with more common object information. The mixture of different data and methods can increase the quality where we need it – we use a GIS – so we should use the possibilities.

What ever we do, we need a link to the reality by using the smallest possible vector, the point. Already her we meet an other source, the fieldwork of geodetic measurements. This work is in most cases essential to keep the accuracy under control.

Figure 1. examples of GCPs, left painted on ground (6 cm pixel), right a CD for close range work (1 cm pixels)

RASTER AND VECTOR MODELS

The main sources of a GIS project are rasters, especially in the case of Remote-Sensing and Photogrammetry activities. Modern GIS are able to use both equal well but are not enough installed at the end user. The spatial information world is still spread which makes the data-exchange difficult.

In the past, either raster based or vector based GIS had to be selected. The raster based ones usually had been fine for modelling affairs frequently used for analyses of physical phenomena i.e. terrain modelling, climatologic analyses and others. This type, their origin was usually military ones, found in the scientific world many users, more than practice of the end users. Today such singular systems are used either in the area of terrain-analyses or in raster-data analyses like the most Remote Sensing Tools (Erdas, Ecognition, Idrisi, Surfer…). These tools usually have a link to GIS or support inside the raster information storage of the captured objects. They are used at scientific institutions and sometimes in engineering companies; they are more seldom at the end-user.

Digital Photogrammetric solutions are raster based as well. The distribution is wider and many solutions are spread between scientific institutions, engineering companies and also end users like forestry, open mining and others. Such solutions are usually linked to CAD-systems like AutoCAD, Microstation and others. The analyses from raster to vector data during stereo-editing with manual or semi manual processing is done by an operator either via direct link to other system (Inpho-Microstation) or into an own data system. Only a few systems, i.e. PhoTopoL, support topological data structure and are able to produce both, CAD-data structure as Layers and/or GIS Structure with Databases. Such systems can bridge the different strategies.

The vector based digital data solutions found their origin in the CAD world i.e. cadastre, planning activities and geodetic surveys. This type of spatial digital data-system has been the world of the end users and is it still today. Many cities still use a AutoCAD instead of a complete GIS.

To add information to such vectors, databases had been implemented and the model of topological data had been developed. One of the first such systems was Arc-Info, already topological with an internal database. Many systems have been developed parallel or followed this strategy, nevertheless the raster systems developed independently. To manage huge data volumes, complex relational databases had to be used. I.e. Oracle is able to deal with data-volumes and manages through a GIS the data-collection and the view of the data. More and more analyses are done inside the database; this might be the latest step in the development.

FROM RASTER TO VECTOR

Different strategies exist to transform raster data to vector structures. In the frame of the named project, to get the possibility to analyse data, vector data have been needed. It is well known that in urban areas a detailed extraction isn't a simple task. How does it worked in this example?

That urban areas give limits in the automated interpretation of satellite data is a commonly known fact. Too much complex are the structures. Only by spectral-radiometric measures such pattern cannot be divided easily. Structure of the urban fabric consists mainly on the neighbourhood of linear elements and areas. Such structured areas define the kind of pattern, but still not the actual use inside. Even during manual visible interpretation, ancillary data have to be used in order to define seriously the corresponding land-use. Only the local knowledge, the context and the association between different areas lead to a reliable interpretation of the land-use pattern. Many scientific researches aimed in the past, to divide even with fuzzy logical based neuronal networks an urban region into at least few classes only, usually with limited success and big efforts.

Figure 2. examples of cluster analyses on MS IKONOS Imagery for a part of Istanbul

The most tools for automated classification create a new set of raster-data. It was decided to create topological vector data as lines and areas combined with a database. This in any case would mean a correction of automated created vectors to suitable topological structure. From the various software tools, which are able to process such clustering and classification, only a few are able to create vector data.

Commonly used algorithms of the unsupervised classification are „K-means“ a „ISODATA“. The modified method of the nearest neighbour, where a distance between the individual cluster centroids is evaluated by different distance measures is used as an adjudicating rule. This method was used in order to test, if such a clustering is able to separate land-use pattern by the multispectral radiometric information of IKONOS data. In figure 2, the classified MOLAND-borders, which have been digitised and interpreted manually, are overlayed as black lines over the 20 different clusters achieved by the automated process. The interpretation of shadow, roof and terrain between leads to a small mixture of single pixels instead of homogeny-structured areas. The colour of the roof differs more than the use, like this, such classification is for a very limited use only. There are still many problems in the aggregation-procedure. It needs a big scientific effort to make this automated process delivering usable results for the end-users. Finally the manual process was faster and more reliable.

We always have to be aware that automated procedures cannot solve all needs, but they can be modified and adapted and, this might be the biggest benefit, they are reproducible independently to the operation while following mathematical rules.

In addition, these benefits are the disadvantages of the manual method. Nevertheless the manual method is a complex one because it combines multi information in order to match the correct information to a land-use pattern. There has to be a legendary as well as a clear rule, which aims to limit subjective interpretation of the uses, however, such data cannot be free of interpretations based on the operators opinion.

The following digitising rules should be adopted for the development of the vector-datasets by the recommendation of the JRC for MOLAND. Selection of relevant information includes the elimination of details for land cover units smaller than 1 hectare for artificial areas and smaller than 3 hectares for non-artificial areas.

Amalgamation and aggregation: When a unit does not respond to the MURBANDY criteria of the minimum mapping unit (1 ha or 3 ha) and minimum width of 25 m:

- If only 1 unit surrounds the small one, this is aggregated to the larger one
- If 2 or more units surround the small one, this is aggregated or subdivided proportionally to the neighbouring units. This aggregation will depend on the type of land cover, which is surrounding the area, because some aggregation is more logical than others.

Simplification. It is related to the amount of detail that is maintained in tracing the border between 2 adjacent land covers units:

- Straight lines, when present, should be maintained as much as possible
- Characteristic land cover features, such as extension of built-up areas along roads, cut-off meanders, should be maintained as much possible at the scale of 1:25 000
- The position of generalized borderline should be fit as good as possible with visible structures on the satellite panchromatic image.

Smoothing. All visible details on the border between two different land-cover classes up to 25 metres detail should be represented and taken into consideration during generalisation. Smaller details should be generalised.

Exaggeration. The linear features should maintain their continuity as much as possible, without causing an interruption in the zone. An exaggeration over 25 meters should be envisaged if useful to maintain a representative structure, especially for roads and railways and for discontinuous build-up area along roads.

Merging. Gaps between units with identical land cover class should be merged to emphasize the structure of the landscape:

- If the distance between 2 units is less than 25 meters, the units should be merged
- If the units belong to the same land cover class, the border between both units is dissolved
- If the land cover classes are different, the corridor will be deleted and the 2 units will become adjacent

Harmonisation. In the land use database only polygons are present. For harmonisation with other data sets that will be used for intersection with the land cover data, a number of rules should be respected:

- The limit water/land should be respected and maintained during the generalisation process
- The position of shoreline, large river, lakes, canals, etc. should be maintained with precision
- Existing linear structure in the landscape and the land cover features should be maintained. Roads, rivers, limit of parcels, etc. are useful for positioning a limit between two different land cover classes

Within heterogeneous agricultural areas, the aggregated units should maintain the macro morphological structure of the landscape. Aggregation of units that are clearly separated by a natural corridor should be avoided.

It can be clearly seen that already during the definition of the vectors itself; the user has a band of freedom. The definition of the accuracy is difficult. It can be estimated by the accuracy of the source data and the digitisation limits. Analyses, which we made on the MOLAND-data, have shown, that the errors made during the digitisation, controlled by precise cadastral data, related to the geometric accuracy of the source data on a high significant level. This fact is important for the further use of the data and indeed important Meta-Information for a GIS Warehouse at the end user.

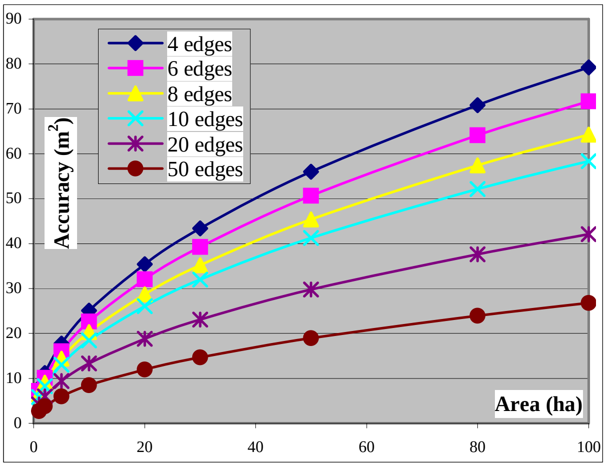

Figure 3. Geometric accuracy variation of areas from different edge numbers and size (Celikoyan 2004)

The definition of the land use classes is another semi quantitative process. As more detailed the legendary is, as easier it is to find a corresponding class. But you will meet always some specific features on study areas, which do not correspond with the pre-defined classification or which limit the correlation with other study areas. To develop such a legendary means to start an iterative process. It's similar to statistic demographic studies. The definition what will be asked and which algorithm will be used, influences the result. As more simple I undertake a study, as stronger I have it predefined, as easier it is to analyse and as easier it is comparable. The opposite, a complex study, delivers more reliable results, the analyses are much more complex and the individual "fingerprint" limit the correlation to other studies. This problem is a circle, which needs to be broken – by a clear definition stored in a metadata set related to the data. All is possible if it is correctly documented and defined.

We have to be aware that the end-user needs data in a clear defined quality within a budget and a limited time. The data have to be integrated to any system and should be open for cross correlations. Here we meet unpopular definitions as scientists.

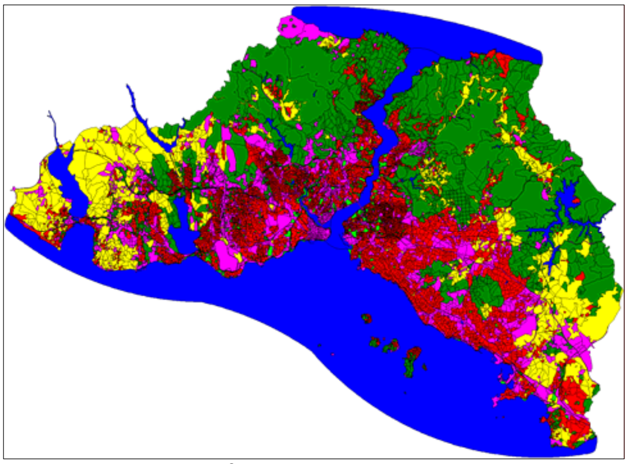

Figure 4. Land-use of Istanbul in the year 2000, analysed on IRS and IKONOS data with a minimum unit of 1 ha, suitable for land-development scenarios.

Land-use data are relatively simple to produce because they are clearly to be defined. It starts to be more complex if we aim to use or to produce data with a special kind of interpretation or lets say a "brain-model" behind. Such data are mapped sources from field campaigns, especially such, which have no clear border. A very special case is a geomphological maps, where behind is a defined structure is model or idea how this form was created. It is a map of ideas and theories, true- they describe and analyse the phenomena excellent, without clear borders. Where is the line, which cuts the valley from the hill? Another case are soil maps, containing complex information for the points, unsharp areas and individual interpretation of the soil-scientist. They have database-information in 3D – that mean relational databases are needed to cover the information in a proper way.

METHODS OF MIXED DATA-PROCESSING

Data, analogue ones or already digital information, geocoded ones or raw data, high or low geometric accuracy, less or dense information, generalizes or “clean” data, there are many possibilities to build a good base for information extraction. Such very different data sources need a multi-scaled GIS, which is able to manage data of different origin, different scale and different quality. Theses data can be raster and/or vector-data. The most GIS already support such mixed data-storage, however they are still not like a data warehouse or a Meta-data GIS. Very fast you can be lost and use data for a not recommended analyse. But such systems have to be able to do more. There is a need to use non-spatial information like statistics, text-files, single photos or others in combination with the classic GIS data. For such a purpose it is necessary to have at least 1 geocode to implement a label-point for this data. In all existing systems is missing an information layer to store information about quality, accuracy, related distribution and others. Such layer about the data, or shortly named Meta-layer, is usually not available.

We tried to combine statistical data via geocoded modelling using parameters out of the land-use data. It might be a kind of non-accurate extraction of new information, but in the lack of other possibilities and in the awareness to be not accurate, such data can be interpreted. In the following example we combined the common demographic statistical data of the of Istanbul with the land-use data in order to compute a residential density of single areas and their temporal change. For this purpose the residential classification, made under MOLAND for 4 years, had to be combined with the re-computed number of inhabitants and an iterated weighting-factor to compute the density.

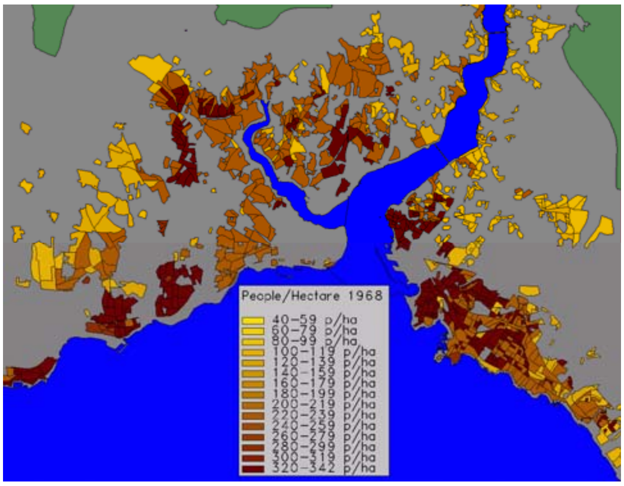

Figure 5. Detailed map of the population density of Istanbul’s centre for the year 1968

Such analyses are based on estimations and their accuracy is not in good quality. But in lack of better information and in awareness that we are not highly precise, such data can point out what normal land-use data or naked statistics never can do. Finally we found an increase in residential areas, an increase in the number of inhabitants, a strong increase in continuous high dense urban fabric and – this might surprise, a decrease in persons per square-meter. This in fact is an additional trigger of urban sprawl that is based on qualitative information that we find more single households, smaller families and a bigger size of the flats even in the bigger blocks.

New improvements to integrate GIS completely in data-base-warehouses (f.e. like Oracle with Spatial options) can show the way to manage it. It’s a big need in modern planning and management to bring all related data together into one system.

This study shows this need already well. Many tricks have been undertaken to reach a interpretable result. Beside such method classical intersections in GIS have been done in order to receive data about the changes. As far as the data have same type (raster or vector), same quality and same content, they easily can be analysed. Even different attributes can be analysed but not non-spatial data with spatial ones.

TEMPORAL ANALUSES

In order to detect the change, temporal analyses can take place like in MOLAND. Such analyses are usually done by backdating the information of the reference, the newest year. In such cases the most accurate data are the actual ones and the older years can be less precise. We are able to adapt the more accurate vector-data to the less precise older data. In our case we used satellite photographs from 1988, aerial photographs from 1968 and the 1940ies. The resolution however was partly better than of the reference data (IRS and IKONOS) but the geometric accuracy had still some distortion based on non-availability of camera-information.

The operator has to decide what line should be edited and which one is still ok. It is again a subjective decision but based on actual and older information, in sole cases with ancillary data as well. So far such a procedure is reliable in information and might be a bit less precise in geometry.

Such results give the opportunity to undertake many analyses to understand what infected the urban sprawl or specific changes. It is a important information for the decision makers to see and hopefully understand the dynamic of big cities. It can help to set up suitable development programs.

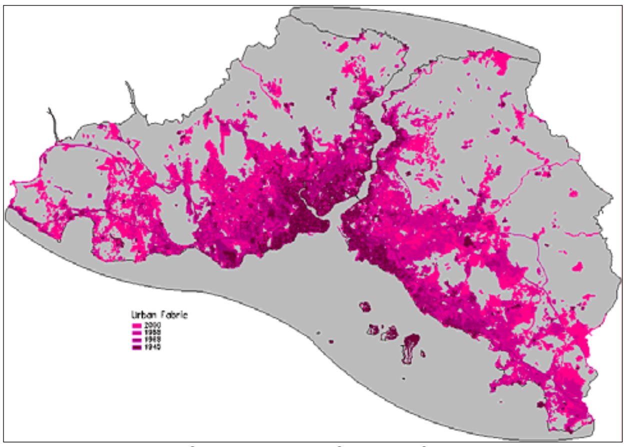

Figure 6. Growth of Istanbul’s artificial surface (residential and business) from 1945 to 2000.

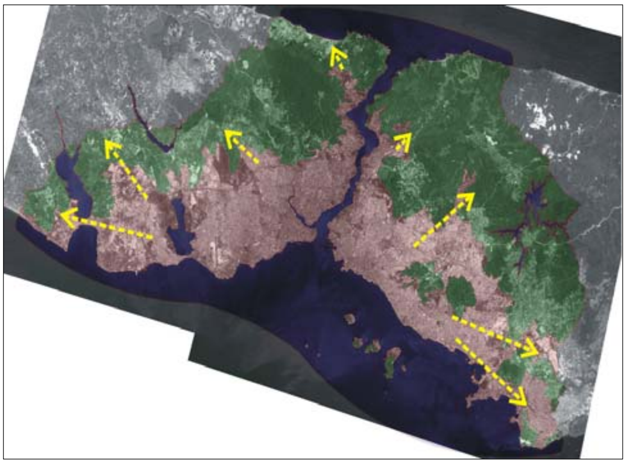

Figure 7. Estimated growth-axes of Istanbul within the next 25 years

Spatial statistics are able to highlight the problems and trends. Some trends are already done in the municipality to plan the need of fresh water and others. But by the use of statistical methods also trends can be computed by different mathematical methods, which finally help to estimate the future.

DATA-INTEGRATION IN A GIS-WAREHOUSE

Metadata and GIS-Warehouse is the frame making the achieved data available not only for the GIS-Operator. As already described, several datasets will be produced in the GIS to describe the line-features and areas of the land-use. They are done based on remotely sensed data and aerial images – so called raster-data. These raster-data, pre-processed and geocoded, build the first information in the warehouse. For the reference year, different imageries have been processed and geocoded. Even they have different resolution and information, they are free of scale in the digital environment and can be placed besides each other.

Vector-datasets will be achieved for the reference year, one for lines, one for areas and one for 3D-Objects. Each datasets stores the vectors and the related database.

If we take into account, that 3 other historical years (vectors and rasters) have to be stored in the system and ancillary data are added as well, such amounts of datasets have to be managed. This can be done by a hierarchical file and folder system on the PC or by a Meta-data, which are more than data about data. Such a metadata-file contains information about the data and links to the single data-sources in order to keep the overview and enable immediate access to the needed information.

If we accept the access of different users, doing analyses and link this data to own applications, we have to implement a GIS-warehouse. Haderle [1994] describes five elements that are essential in the design of a data warehouse:

The first component of the complete data warehouse system is that of the operations data stores that may be in any of several operating environments. It means that the managing system of the data-warehouse can be separate to the data-server.

The second element is the access to a distribution network. The suitable network will support the delivery of data from the operations systems to the data warehouse, and, consequently, the information from the data warehouse to potential users across net or a complex system of local area networks and wide area networks. The concept of enterprise data requires that any user needing information and having adequate security access be able to retrieve the information easily and quickly.

The third element of the warehouse is data delivery, the ability to move data from the operational sources to the data warehouse. This requires not only the network system described above, but a process and system for extracting and summarizing data from operations systems at the correct intervals.

A graphical user interface (GUI) front-end with the ability to locate available data is the fourth element. Here is an essential component for using the data warehouse as enterprise data. The warehouse must be accessible to all who need to use its data. This is a weakness of the stand-alone GIS in that the only people who can access it are the users of the application. With the warehouse, the user can retrieve the information directly.

The fifth and final component, is that of end-user knowledge tools that provide decision support functionality. I would argue that the data warehouse is valuable as a repository of information even without additional knowledge tools. So long as the warehouse is designed and indexed adequately with a supportive GUI, users will be able to find and compile the information they need.

MODELLING FOR URBAN NEED

Are this data usable for the end-user? Is there something behind such statistic and scientific work?

Clearly yes – but something has to be done. The situation in the local authorities is sometimes difficult. The different divisions use different software-solutions with different capabilities. A common GIS is seldom available. Often the data cannot be exchanged between the divisions ore haven't got same structure or coordinate system.

The big efforts put in the idea of an Open GIS Structure is still on the way and haven't reached the end user. We are faced with this problem to deliver data. This makes an early contact necessary to prepare the data in a way, that they can be used. Sometimes the decision makers are not able or willing to understand the results – in that case we have to extract the most important facts into scenarios.

For Istanbul the prepared dataset is the only continuously dataset which covers the entire city with its suburbs. There exists a good chance to use them as a base for the integration of other, partial data. It is our task to deign such core data models, which can be the carrier of other Metadata. We should not be too much stressed by the arguments of low accuracy – for regional planning and the design of strategies I'm not interested in a sub-meter polygon.

Such a collection of data can be rapidly used for crises preparedness. We built on the prepared data a Tsunami-risk map for Istanbul to detect the most endangered areas.

It can be done always better, but up to the date we have a more accurate model, we already have something for the planning. Anyway we have to accept a produced data set as a temporary information which has to be updated or increased in geometric and/ or the related information.

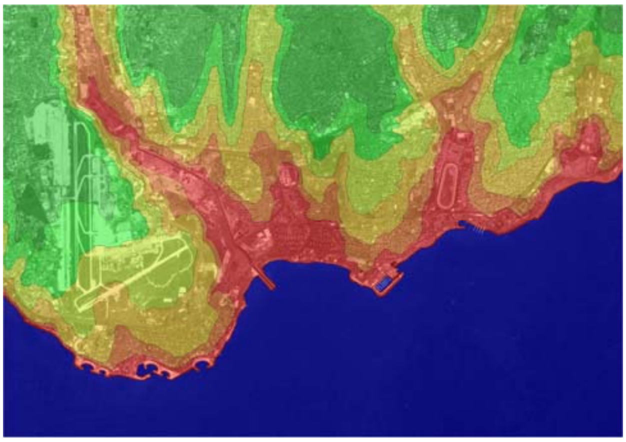

Figure 8. Tsumani risk mape of the Istanbul Airport region, based on the ancillary data of the MOLAND project

MODELLING AND FORECASTING SCENARIOS OF URBAN AND REGIONAL DEVELOPMENT

Previous works addressing sustainability through the development of indicators did not adequately take into account spatial parameters, the importance of which is basic to any study on urban and regional development. For instance, nowadays any work focusing on urban sustainability must address carrying capacity. Assuming that the appropriate carrying capacity or the ecological footprint of a certain area is determined also on the basis of territorial parameters, a spatial approach has to be satisfactorily considered.

The MOLAND methodology adopts a spatial approach, defining the urban system as that portion of land covered with continuous artificial surfaces, including a surrounding buffer area. The various sets of indicators for urban and regional sustainability are, therefore, differentiated according to the spatial dimension. If a standard geographic unit for different urban systems can be fixed, deriving spatial referenced indicators allowing comparisons amongst systems become feasible. For this reason the geographic unit of analysis must be clearly specified, because shifting units can affect the results. By necessity, the data on which the indicators are based must be territorially differentiated.

A core set of urban and regional indicators, which includes land use and socio-economic information, has not yet been precisely defined and agreed at international level, and within the project the definition of specific indicators for the sustainability in urban areas, as a systems connected to regional backgrounds, is one of the most investigated topics. The technical framework for providing such a quality of information has never been previously developed at large scale. As stated by Bittermann and Haber, 1998: "good concepts and theoretical foundations for spatially relevant pressure indicators are lacking throughout the bulk of the international indicator literature". MOLAND addresses these deficiencies and offers a new point of view by linking "classical" socio-economic indicators to territorial parameters.

Particular effort is devoted to the development of easily handled indicators, since potential users of these results include city managers, local administrators and planners, up to international bodies. Such users may also be willing to have a comprehensive framework of the situation. Due to the complexity of the urban systems and the quantity of data managed, the number of indicators has to be reduced to the minimum. Furthermore, in order to attain all the sectors that need to be considered MOLAND targets a set of cross-sectoral indicators, with a focus on pressure indicators. The user, in this way, should be able to handle more information with a manageable effort. The indicators developed under MOLAND can be divided into two main categories:

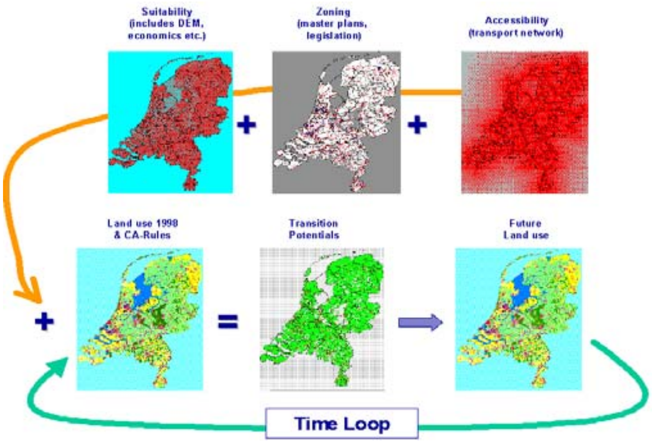

Figure 9. Time-loop analyses – production of scenarios

- Spatially referenced indicators providing information on different land use types and changes;
- Cross sectoral spatially referenced indicators to target and evaluate more complex processes for landscape changes (e.g. fragmentation). Socio-economic data, prepared in a spatially disaggregated format, are included in this category to cover topics of relevance for different policies (environment, transport, social cohesion, etc.). The aim here is to address carrying capacity and general urban and regional sustainability issues.

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).

CONCLUSION

Many different spatial data, in analogue or digital form, are available, but they still did not find the way to a central data warehouse at the end users. So many spatial data are available and only a part of them have reached the end user in a suitable digital form. Several Tools exist beside each other but the Meta-data management isn't really on the market.

There is still a lack of tools to solve such a multi scaled and multi format spatial data system in an easy way that it becomes attractive for the user. Indeed, many administrations have got a solution for their specific need. But they cover only a part of the possibilities.

Software Developers have a task to develop such data-warehouses, based on a GIS with advanced Database access including an intelligent Meta-data management.

The Scientists have to define, how such a structure of metadata can look like. Especially the accuracy and resolution, the origin and the method of pre-processing have to be integrated in such information about the information. This information can help to control the interaction between the data to protect the user against risky operations.

The science is still too much focused on methods to receive better geometric accuracy. The final need of information isn't enough in focus. There is a big market in the combination of non-spatial data with spatial ones in order to receive new information. We should take more courage to try new ways in this direction. If we are aware, where is the risk, where we have loose of accuracy, we aren't running too much in danger. There is a lot to do.

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