URBAN RISK ASSESSMENT ON THE BASIS OF LAND USE AND CHANGE DETECTION MAPPING

Elke Krätzschmar[1] and Christoph Böhm[1]

1. H.G. Geodata Solutions GmbH, Talstrasse 84, 07743 Jena, Germany; Tel.+49(0)3641/ 3518-0, Fax +49(0)3641/3518-25, e-mail: H.G.GDS-boehm@arcor.de

ABSTRACT

Urban Growth is a common challenge and often results in urbanizing naturally unsuitable regions. Apart from that do disastrous events induced by climate such as floods, storms, but also geologic risks such as land slides, volcanic eruptions and earthquakes, …have tremendous influence on natural processes also affecting mankind and can result in life threatening situations especially within urban agglomerations. In order to identify such risks, analysis of up-to-date situation in combination with historical knowledge can help to locate endangered locations and be of tremendous importance for any planning task.

INTRODUCTION

Reliable and up-to-date information on the growth and change of big urban agglomerations are an indispensable input for urban risk assessment and for the risk evaluation of insurance companies (i,ii). In case of disasters in places with high population density and dynamics natural and man made disasters have the maximum impact and result very often in loss of lives, but also causing tremendous costs for individuals as well as companies and national economies.

Even nowadays the insurance and re-insurance market is only partially aware of EO information as reference for ex- and internal statistical data. The paper gives an idea of how the use of geo-spatial information can result in novel derived information.

METHODS

To perform urban risk assessment the basic task is the classification and analysis of spatial distribution and concentration of residential, commercial and industrial areas (land use mapping). Within these classes additional sub-classes are desirable, because e.g. informal settlements, terraced housing estates, villa quarters, represent different damage patterns and distribution of value. Knowledge concerning height of buildings could provide additional information on risk in case of earthquakes or hurricanes, but also regarding concentration of monetary and economic value within the cities. Due to the wide range of factors which influence 'risk' as well as the high impact of the local geographic situation and general characteristics of the urban area of interest pre-define the combinations, the focus on collection, selection and pre-processing of thematic and auxiliary information. Due to this, data necessary for risk mapping (flooding, earthquake, hazard, man-made destruction …) can differ from each other

Overall Technology

The result shows both sources of potential risks (natural and man made) and the elements for the response which typically include risk mitigation infrastructures and risk elements. It can act as a fundamental base for emergency planning and even the design of the Urban Master Plan.

Output scale goes down to 1:10,000 and displays areas with respect to regions or points with a special kind of risk based on the requirements of the user and availability of data. The product is designed for administration, surveillance and planning by local, regional, national, European and International decision makers, legislative organs, city planners and disaster planners or insurance companies. The Risk Mapping Product, when delivered over different cities allows a common harmonized perspective of risk.

Risk mapping technology consists of three main pillars: preparation of the reference data base, upgrading of thematic data available and derivation of GIS-information based on literature as well as extracting and applying expert knowledge for further GIS-modelling.

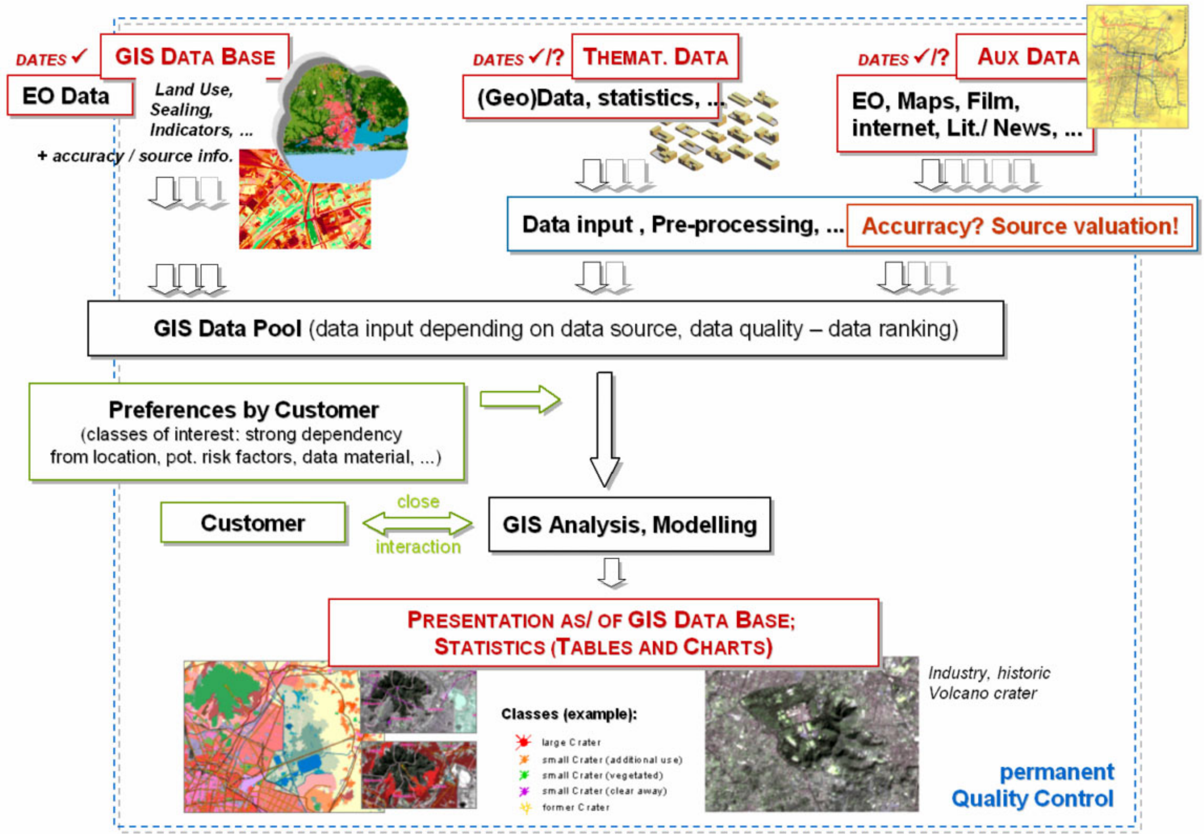

Figure 1: overall technology of Risk Mapping Product

GIS Data Base

Risk mapping is mainly based on land use information stored in a GIS data base. This will always include the land use mapping (with focus on artificial areas). In specific cases general information of the sealing and land use change even for specific single classes can be extremely helpful.

Long term analysis of the behaviour of the main classes provides the input for thematic indicators such as “artificial structures built on former forested area”.

The nomenclature applied is based on MOLAND (EC/IES), a Europe-wide applied nomenclature with focus on urban structures (hierarchic extension of CORINE towards level 4). It provides a suitable base for mapping and modelling a wide range of structures considering local variations and dividing classes mainly by structure type and density. Adaptations in class descriptions are performed to take the use of high resolution remote sensing data, to enable a mainly automatic classification and to be independent of additional information like socio economic data.

EO data acquisition, internal quality control and pre-processing ensure the needed quality of input data for the subsequent information extraction process. For the presented examples various EO data was used as reference data source due to availability reasons (e.g. combination ASTER/ SPOTpan; SPOT or IKONOS), all were acquired within the vegetation season. The maximal view angle (off nadir) of the satellite and the off nadir sun angle are not fixed, however a view angle of the satellite smaller 10° and an off nadir sun angle smaller 30° gets preferred.

Figure 2: land use classes as basis for Risk Mapping Product

In order to achieve an reliable and cost effective product the basic land cover classification is performed with high degree of automation using a hierarchical object-based approach developed in eCognition. Within that process urban structures are combined logically in order to fulfil the class descriptions (e.g. class 'Residential discontinuous sparse urban fabric' is defined via combination of single smaller houses, open soil and other non-vegetation area in combination with a high percentage of heterogeneous vegetation).

Clear definition of automatic and semi-automatic validation ensures the high accuracy of the results of this module, which are the basis for subsequent high level classification. The procedure can be repeated with small interaction by the expert on different sites, shifting class boundaries caused by regional and climate-specific differences. Additional typical land use classes (e.g. hospitals, schools, …) are added to the results of the automatic classification to complete the classification, which cannot be identified using the automatic classification approach and remote sensing imagery.

In most cases risk assessment is focusing on the effect on artificial structures, hence a comparable definition of artificial area (containing urban, industrial, commercial, transport structures combined with extraction, construction and dump sites as well as urban green) is helpful due to the fact that administrative GIS data in general orients on administrative units and not the actual situation of cover.

For risk analysis, such as flood and drainage modelling, it is essential to rely on aerial and up-to date sealing information. For that purpose, an automated object-based approach is applied that sticks to the analysis of NDVI values. The object-based approach also results in vector format and is investigated in more detail in extremely terrain influenced areas (influence due to exposition).

Thematic Geo-Data

Thematic information is used in processing and validation, whenever available, because it adds additional value to the information extracted from remote sensing imagery and increases the usability of the products at customers' site. The range of thematic data and geo-data is wide and as mentioned above the selection of suitable sources refers to availability, reliability and after all the focal investigation. Whereas topographic reference data can in most cases be categorized as most important.

A time consuming and very important point is the quality analysis of thematic geo-data. Apart from geometric accuracy that can be checked for maps with topographic character via standard techniques it is often difficult to value geo-data received from the local authorities or from any other source (e.g. from the private sector or any organisation) especially when working on sites in developing countries. In many cases it is not possible to find out any product source information, not to mention acquisition date, basic reference, homogeneity according to the mapped coverage. Selecting and valuing suitable map, GIS and GIS-like material has essential influence on the quality of the resulting modelling process.

The maximal timeframe between collection of thematic information and recording of the image data should not be longer than 5 years if the data is used for extraction of information not visible in the satellite imagery (input for land use classes). In other cases constraint between data collection and recording of the image data has to be considered in the classification and balanced by combination and extended knowledge selected from other sources. For linear structures implemented in the GIS data analysis the timeframe should not be longer than 15 years and be updated by the expert. Due to the direct correlation between geometric accuracy, information density and scale, any use of thematic information in the rectification process, information extraction and validation requires a careful assessment of the spatial accuracy and thematic correctness of the data.

Within the past it became clear that even the internal validation process of the created classes is best to be done by using thematic reference data recently collected by the local partner. This may be ground truth information, local mappings from organisations or reliable local statistics (plausibility checks) from the customer.

Auxiliary Data

Auxiliary data contains again a wide number of sources. Most important for any relief intensive area is an elevation model. If data are not ortho-rectified, a precise registration has to be performed. Therefore, elevation data, e.g. from SRTM mission are required and are in many cases the only reliable source available. It is used as source for modelling exposition and slope layers which act as essential input for flood, landslide modelling as well as mapping of areas threatened by volcanic activities.

When investigating in cities, mapping risk factors is first of all combined with the question of potential risk towards people and secondly towards man-made objects (housing, industry). Here, valuing potentially affected people and potential damage is done by combining general statistical analyses from literature with the actual land use classification. Using this principle it was e.g. possible to estimate the actual population number of the Mega-cities of Lagos and Mexico City with an extreme degree of population growth (migration).

Including external non-topographic data always requires considerable manual internship for all data has to be checked and marked geometrically and thematically – in single cases thematic data can even contradict, in other cases data coverage is not optimal. Hence data assessment and selection can fundamentally influence the final output.

In many cases it is even a desired effect of thematic information not to be cartographically correct (e.g. the overall line structure of the underground railway system whose location is of importance for earthquake hazards).

Highly interesting in most cases in the analysis of historic, if possible spatial, data due to the fact that historic geo-data (CORONA or aerial photographs) provides the interpreter directly with an aerial idea of how the area looked like decades ago. In many areas with high risk potential the reasons are man-made. A representative example is again Mexico City where numerous small volcano crater were just removed over the years and covered by housing and industry. When looking at actual data there is no evidence on the former situation, available mappings do not exist.

Suitable auxiliary data can vary extremely according to the potential hazard or hazard-combination (mapping of geologically formations; sketches and statistics not having precise local borders but helping to characterize the site; information from internet describing/ documenting historic geo-events; actual news (including documentation) – interesting for both: natural and man-made disasters; …). Again, via manual internship all auxiliary data has to be checked and marked geometrically and thematically mainly on visual basis.

Therefore, a proper data search and preparation requires a large amount of time. For the presented cities, Mexico City (Mexico), Accra(Ghana) and Lagos(Nigeria) only approximately one third of the data collected was reliable enough to be included in analysis. For the final user, documentation of this process is very important so that potential thematic or geometric restrictions and limitations in coverage become clear. As a matter of fact this may cause differing GIS processing over the sites of interest.

RESULTS AND CONCLUSIONS

The poster represents the whole process of data collection information extraction from different types of space based data and development of risk maps and risk-related GIS processing for the example of Mexico City (Mexico), a mega city affected by earthquakes and volcanic history (iii,iv). The specific problems of extremely fast city growth is presented on Lagos (Nigeria) and Accra (Ghana), as typical fast growing African mega cities (v).

Based on the complex GISdata source, it is then possible to extract and name. Preliminary risk factors (such as industrial areas with especially high risk such as oil and gas stores and pipelines, industry located directly on geologically endangered areas, housing on steep hills below new wood clearing, sky scrapers on top of tunnels and underground …).

As secondary risk factors areas endangered by natural flooding (due to rain and Tsunami) or affected by breaking dams, areas influenced by planned industrial sites, deduction of ancient river beds … can be named.

Also extracted information on big, long-term construction sites, for infrastructure facilities (airports, harbours and railway installations) or finally the course of major power transmission lines (high fire risk) would be of great use. In case of catastrophes occurring as well as for the validation of security facilities the location of hospitals, fire brigades and technical support organisations is useful.

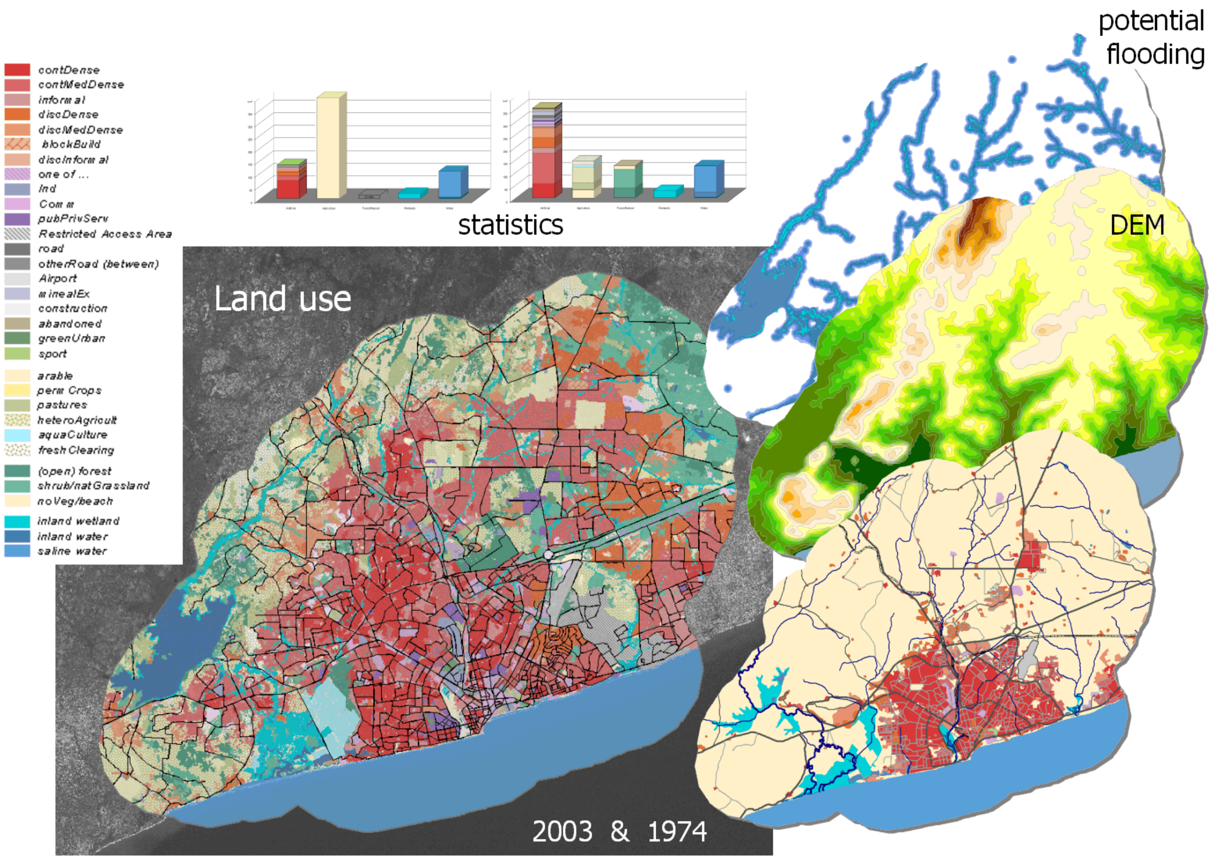

Figure 3: example of output data for Risk Mapping of Accra

The value adding process as final and most important step is a combination of various primary and secondary information to risk factors via GIS processing and modelling as well as the appropriate presentation of the complex relations.

REFERENCES

i Eyre C, A Shaw (contact person). 2004. Earth Observation Responds to Geo-information Market Drivers. Interim summary report of 'Earth Observation Responses to Geo-information Market Drivers – Insurance Segment' (ESRIN/Contract No. 17814/03/I-LG). Aon Limited • 8 Devonshire Square • London EC2M 4PL United Kingdom

ii Mathieu P-P, 2005. Space for insurance. Environmental Finance, June 2005, 26 p.

iii Ezcurra E, Mazari-Hiriart M, Pisanty I and Aguilar A G, 1999: The Basin of Mexico: Critical environment issues and sustainability. UNU Studies on Critical Environmental Regions. United Nation University Press. 61 pp.

iv Ribbeck E, 2002. Die informelle Moderne: spontanes Bauen in Mexico-Stadt. architektur-und-wissenschaftsfänderungs-verlag, Heidelberg, 2002.

v Grava S et al, 2003. International Studio: Disaster resilient Accra, Ghana. Columbia University Earth Institute, Centre for Hazards and Risk Research at Lamont-Doherty Earth Observatory, University of Ghana. [http://www.arch.columbia.edu/Studio/Spring2003/UP/Accra/index.html]