Usage of a Multidisciplinary GIS Platform for the Design of Building Structures

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Abstract

Topic of this paper is the usage of the multidisciplinary GIS platform for Design of Building Structures and GIS platform for education at the Brno University of Technology (BUT). The GIS technology has been made use of at BUT Brno in a limited extent since as early as the 90's, but as it was out of acceptable price range the utilization in greater extent was not possible. With the support of research projects the GIS platform became part and parcel of accredited study programmes at BUT Brno three years ago. Current informatics infrastructure was completed with necessary systems Geomedia 6.0 (Intergraph) and Arc/Info (ESRI), which are commonly widespread platforms. On initiation of Institute of Geodesy, Faculty of Civil Engineering GIS data warehouse has been established for the needs of tuition at BUT Brno, it contains all types of basic maps of CR and other types of data (ZABAGED, Orthophoto, BM – CR of various scales, cadastral maps, purpose-built maps, historical maps, special data – laser scanning, DMT, satellite data and others) in the localities of interest. The data warehouse is continuously supplemented. A part of GIS platform is a catalogue of maps containing fragments of cadastral, civilian and military map works since 1825 till now.

Hardware for the platform is the server HP Proliant DL380 G5 rack with 2x Quad-Core Intel Xeon Processor E5440 (2,83 GHz, 80 Watts, 1333 FSB), 32 GB RAM memory PC2-5300 Fully Buffered DIMMs (DDR2-667) with Advanced ECC, disc space 8x 146 GB HDD SAS 10000 rps, Hot-plug and net interface 2x Gbit LAN. ArcGIS requires database connectivity. As the university information system and additional university applications are in the long term based on Microsoft technology, in this case the platform MS SQL 2008 in 64 bits version was also used.

On the basis of standard multidisciplinary GIS platform the interests of several individual branches and worksites has been succeeded to be integrated e.g.: branch of Geodesy and Cartography (application in range of real estate cadastre, geology and geodynamics, GIS of small municipalities and others), branch of Water Management and Water Structures (solution in the field of hydrology), branch of Construction and Traffic Structures (GIS in traffic) and others. Informatics infrastructure is guaranteed at Faculty of Civil Engineering by Institute of Computer Aided Engineering and Computer Science, within the BUT by Faculty of Information Technology. The software solution of tasks in Open-GIS systems (Grass) ranks among contemporary trends. This article will be completed with demo results of hitherto solved tasks in the GIS sphere at the Institute of Geodesy, Faculty of Civil Engineering, BUT. Current civil constructions and structures are designed as optimized from a lot of aspects. Information integrated within the information system enable when proportioned to take into account even the influence of the outer conditions resulting from the geographical position and there out arising parameters e.g. the amount of rainfall, the speed and the direction of the wind, length of sunshine intensity, geology etc. The platform provides database enabling to simulate different variability of practical conditions of project assignment in the region. Data structure provides localized and geospatial data from global or regional character up to the detailed information of a particular cadastral allotment.

Modern decision making in flood risk management is based on theoretical means which make possible objective forecasting of flood consequences, both qualitative and quantitative. Necessary tools for the practical implementation of the risk analysis methods in floodplains are the contemporary mathematical models of water flow in the inundation area linked to a powerful GIS. The main task of GIS is to administer the input data, to analyse them and to present the results.

Keywords: GIS, data warehouse, application of GIS

1. Introduction

Geographic Information Systems (GIS) belong among the youngest but at the same time the most developing sphere of information technology. At Brno University of Technology (BUT) this technology has been introduced into practical tuition in a limited extend since as early as 90th and gradually it has found multidisciplinary usage.

Information concentrated in GIS and being made use of in a lot of technical civil engineering branches prove to be very suitable and important. For example a landscape planning often made in a principle nonreversible way has a great impact on the life of the whole society. If the basic goals and tasks dealing with the landscape planning are to be attained, the influences on sustainable development of landscape to be evaluated, the influences of the intentions dealing with our environment to be judged objectively, then for reaching these decisions we should have right and reliable information at our disposal. Quality of processed spatial analytic source material as well as landscape planning documentation play an important role in these cases [3], [10].

Referring to the protection of basic rights and freedoms of an individual the process of landscape planning has to be interconnected with the land record in the frames of information system of the real estates which is one of the most significant items of a democratic society in a state respecting the rule of law. The building act emphasises a continuous updating of spatial analytic data on the basis of Base Map of CR. This map and its digital equivalent – primary base of geographic data (ZABAGED) is updated in the form of a periodic aerial surveying of one third of the state territory, which at present enables a real 3 – 5 year period of updating of the Base Map of CR and taking into account the landscape development and a changes rate. In the future there will be a tendency to update some geodetic elements in shorter periods out of external databases – for example the road database. Topography of the state map is created by a cadastral layer updated on the basis of cadastral map topography. If the project of Czech Office for Surveying, Mapping and Cadastre to digitize cadastral maps until 2015 is carried out we can think about a digital state map at a scale of 1:5000 covering the whole state territory after 2016 [2], [3], [7], [8].

In present time we are seeking for constitution of a common platform and GIS standards on the basis of experience and data flow of the individual platforms working by higher area administration unit e.g. county or municipalities or facility managements e.g. ČEZ, E.ON, RWE, O2 etc. [1], [4], [5], [6].

Technical specializations lectured at BUT realize the necessity and advantages of making use of GIS sources for development of their study programs as well as special subjects. Guarantee of the platform is Faculty of Civil Engineering (FCE) with contribution of Institute of Geodesy, Institute of Water Structures and Institute of Computer Aided Engineering and Computer Science. The FCE applies GIS databases in the accredited study programs Civil Engineering and Geodesy and Cartography. GIS platform within BUT is participated by other faculties too: Faculty of Architecture, Faculty of Business and Management and Faculty of Mechanical Engineering.

2. Information infrastructure of GIS

The development of information infrastructure at BUT is guaranteed by the Centre of Computer and Information Services. Each faculty is connected with the system by its own network. A basic qualification to take advantage of GIS progress at FCE is the faculty network serviced by Institute of Computer Aided Engineering and Computer Science.

In 2006 with the support of the development projects together with the Ministry of Education at FCE projects ESRI – ArcGIS products and Leica Extensions products for ArcGIS have been installed. As a whole, it concerns 300 licenses of 10 different modules working through web user interface. The multidisciplinary usage is ensured by the GIS BUT data warehouse.

From the point of view of guarantee the complexity of GIS at BUT, the Institute of Geodesy FCE stands guarantor also for GeoMedia. The platform Intergraph GeoMedia came into being by joining the international project RRL (Registered Research Laboratory). By virtue of the observed publishing activities, Intergraph provides the RRL members with the free license so that they can test GeoMedia products, and also offers a possibility of free consultations 15 hours a year through E-mail (Intergraph Synergy email Support Services), one position for being trained in basic functions of the system, one position in the course for handling any functional overlay GeoMedia module for one year and one free participation in yearly World conference Intergraph for one person. Within this program each year about 30 students are provided with license (for one year).

At present an innovation of the above mentioned GIS platform is under discussion:

- it is pondered above the extension of the platform by ArcGIS server with multi-user's access. This server enables the access to spatial data through software ArcGIS mobile clients included, AutoCAD and web browsers. It gives you scope for the publication of GIS projects on the geoweb,
- innovation of mobile technology data capture in field with making use of standard PDA+ArcPAD,

- upgrade of program module MGEO (MicroStation V8) for geodetic and graphical data processing,
- sustainable development of platform is ensured in the form of maintenance for existing GIS products.

Information infrastructure described above is in preference built with the aim of maximum usage in all branches not only within the FCE but also BUT both in full time mode and combined mode study. It can be used even in the processes of the lifelong learning programs for the practice in civil engineering and public administration, for supplementary activities of faculties and for research development and expert activities. By implementation of GIS platform the tuition has been extended and the quality has increased not only with the subjects that have a lot in common with GIS but also with the subjects using spatial data. In view of general trend of digitalization even in the intermediate horizon we can expect graduates to became involved in work more easily which is one of most important criterion to judge the quality of education. Another contribution is a possibility to offer specialized subjects covering the needs of the practice mainly in the programs of lifelong learning for practice in civil engineering as well as in public administration.

3. Multidisciplinary data warehouse GIS

In the frame the project integrated and multidisciplinary tutorial information system for GIS contents of multidisciplinary data warehouse BUT in corporation with FCE, Faculty of Architecture, Faculty of Business and Management and Faculty of Mechanical Engineering have been formulated. The main aim of the project was to build information system, which would technically integrate the tuition of various technical branches and disciplines. The project paid particular attention to the development of modern technologies applied in bachelor's, master's and doctoral study programs in full time mode and combined mode including the support of medically handicapped students and applicants recruited of disadvantaged social groups. The platform of data servers has been built on ESRI ArcGIS technology.

Data contents of multidisciplinary data warehouse – see Fig. 1.

a) digital state cartography works

b) ortophotos

c) digital purpose maps of large-scale

d) digital terrain models

e) laser scanning

f) satellite surveying data

g) historical data and maps

Multidisciplinary data warehouse should be used by authorized access through BUT intranet up to the level of source data.

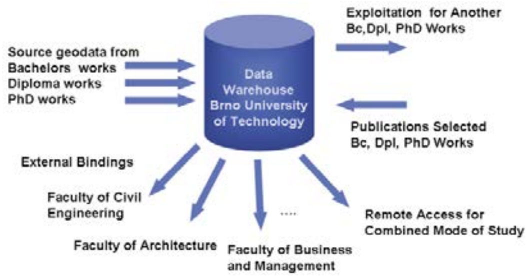

Fig. 1: Structure of the Multidisciplinary data warehouse GIS BUT.

Multidisciplinary data warehouse covers needs of Faculty of Civil Engineering (FCE) in bachelors, masters and doctoral study programs Geodesy and Cartography, Civil Engineering and Architecture of Building Structures. At the Faculty of Architecture BUT ensures study programs Architecture and Urbanism. At the Faculty of Business and Management BUT supports the study program "Software Engineering and Informatí" specialization "Management Informatí", subjects: Data and Functional analyse, Database systems, further study program "Economy and Management" specialization "Economy and Management of Enterprise" subjects: Strategic Management, Information Support of Processes, Applied Mathematic. At the Faculty of Mechanical Engineering BUT the facultative subject Land Information Systems was initialized, taught in the frame of study program Geodesy and Cartography at FCE as offer of extension subjects among faculties of BUT.

4. Hardware guarantee of GIS platform

Hardware parameters of the platform were estimated in part of applications needs, which are necessary for these processes, further by average values representing volume of student's projects (space of GIS project in Bachelor's or Master's thesis is approximately from 600 MB till 4,5 GB, in average 1 GB). The main element of hardware platform is the server dedicated to ensuring access to the spatial data by software

ArcGIS (including of mobile clients), AutoCAD and web browsers. From multiyear experience the HP Proliant DL380 G5 rack server in following configuration was selected:

- processor – 2x Quad-Core Intel Xeon Processor E5440 (2.83 GHz, 80 Watts, 1333 FSB)
- memory – 32GB RAM PC2-5300 Fully Buffered DIMMs (DDR2-667) with Advanced ECC
- disc space – 8x 146GB HDD SAS 10000 rps. Hot-plug
- net interface – 2x Gbit LAN
- redundant supplies and fans

For maximum performance 64 bit platform was chosen. System is based on Windows 2003 Server R2 – 64 bit version. Disc subsystem was initialized in RAID-5 mode with one disc in hot-swap mode.

ArcGIS server demands database connectivity. Because the university information system and others university applications are in the long term based on Microsoft technologies the tested platform MS SQL 2008 in 64 bit version was chosen. With regard of the server singularity within faculty and whole university the processor's licensing was chosen.

Server is located in central node of FCE network and connected to 1 Gb port of central switch HP Procurve 5412zl – see Fig. 2. To speed up the connection rate the port duplexing will be made. In the next stage the 10 G bit connection is proposed.

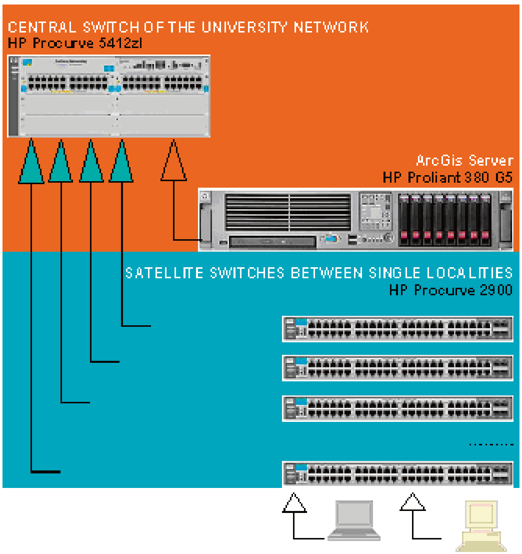

Fig. 2: Configuration of server for GIS platform.

5. Tuition of GIS at BUT

GIS according to one of many definitions is an information system with special determination consisting in the integration of various branches on the homogenous information platform. From this point of view it belongs to interdisciplinary branches and according to [9] it has a close relationship to information technology above all to geodesy (data capture) and cartography (presentation). It is clear that the Institute of Geodesy has primary integrated GIS tuition into its program of Geodesy and Cartography. Nowadays it contains basic information about GIS foundation of information systems, database systems, methods of data mining, basic graphs theory, topology (DIGEST norm) data models (vector, raster, matrix), digital terrain model, data capture, metadata, data quality, data sources, map algebra, spatial analyses, perspectives of further development of GIS. GIS appears in the syllabus of Faculty of Civil Engineering BUT. Further it is taught in the Institute of Water Structures in the subject called "Hydroinformatics", the aim of which is to get acquainted with the principals and functions of hydroinformation in water supply to give necessary information about data capture and simulation models in water economy and get practical skills making use of hydroinformation in semester projects. The subject involves: theoretical and practical bases of utilization of modern information and communication technologies for modelling, management and decision making in field of water management, collecting and processing of input data. Application of simulation models in water management (rainfall-runoff models, simulation of water flow in pipe systems and open channels, ground water flow modelling, simulation of sediment load motion, solute transport), processing and evaluation of modelling results (application of GIS etc.).

Institute of Landscape Water Management teaches GIS in the subject "Geographic information systems" in the first year of master study program in the specialization Water Management and Water Structures. Tuition of Geographic information systems has to provide students with basic information about the principles of data of digital technologies. The conception of tuition is devoted to history and basic of GIS focusing on spatial analyses, digital models of relief and tools for solving the problem of watershed and nature protection.

GIS teaching has a good tradition in the specialization "Construction of Traffic Structures" at the Institute of Railway Structures and Constructions. Students are introduced to the problems of database systems and geographical information systems and to practice acquiring knowledge and skills. GIS teaching consists of: introduction into GIS problems, definitions and divisions of GIS, data GIS models, phases of formation, typology of GIS, GIS managing data structures, definition, collection and organization of graphical data, procedure within formation of a GIS project, planning of geographical technologies, geographical analyses, spatial questions, questions on mapping objects and attribute tables, characteristics of programming products of firms Intergraph, Autodesk, Bentley, ESRI, introduction into problems of modelling over GIS platform, basic tasks – transport optimization, goods delivery, optimal routes, region attendance, crisis management, application of GPS systems in transport etc, new trends of GIS development, connection of GIS and the Internet, usage of GIS within public authorities, usage of GIS for certification of line constructions, expert systems and its usage within railway transport. The same structure has also the doctoral study program.

Current civil constructions and structures are designed as optimized from a lot of aspects. Information integrated within the information system enable when proportioned to take into account even the influence of the outer conditions resulting from the geographical position and there out arising parameters e.g. the amount of rainfall, the speed and the direction of the wind, length of sunshine intensity, geology etc. (Fig. 3). The platform provides database enabling to simulate different variability of practical conditions of project assignment in the region. Data structure provides localized and geospatial data from global or regional character up to the detailed information of a particular cadastral allotment.

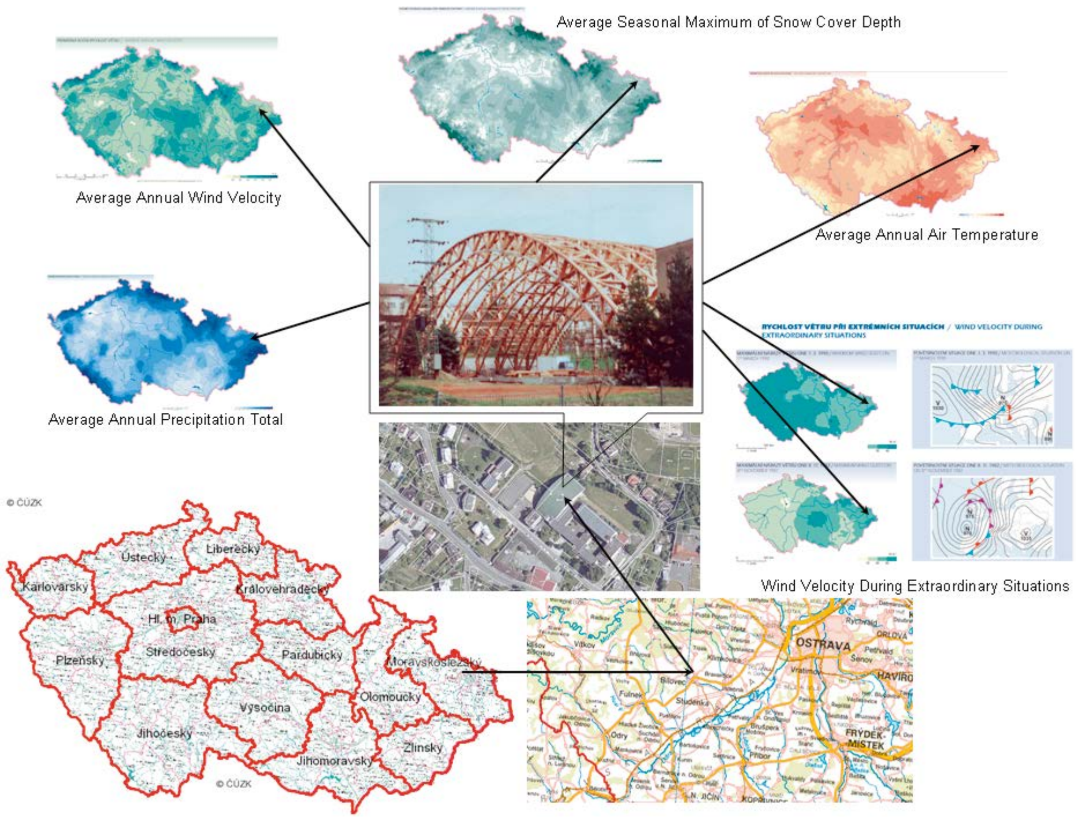

Fig. 3: GIS Usage for designing of civil engineering structures.

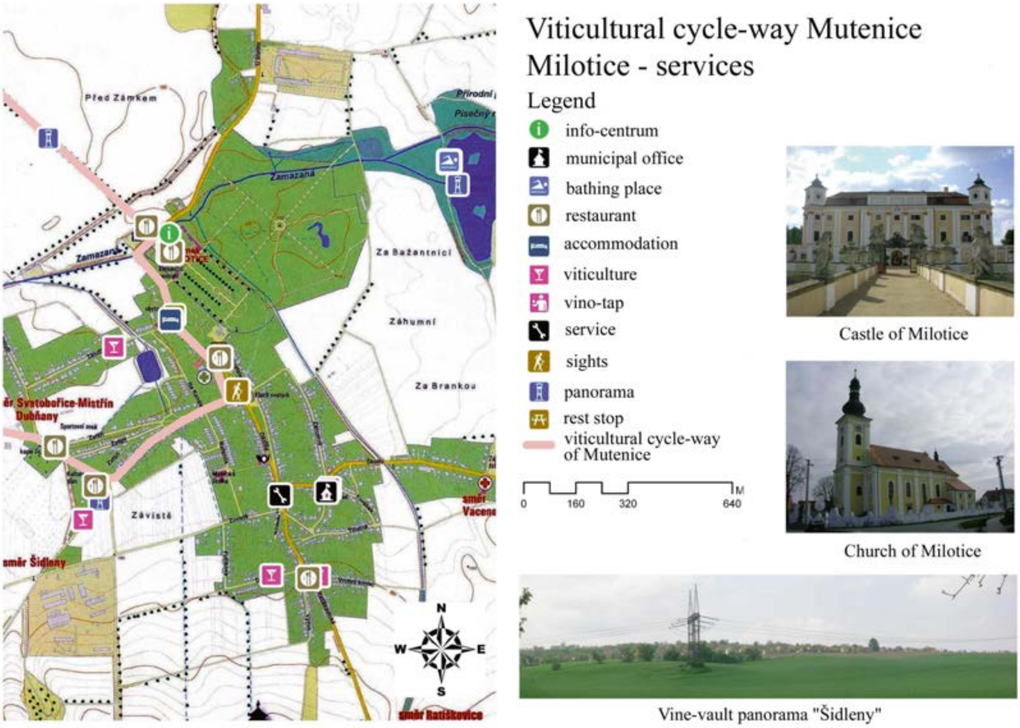

Fig. 4: Output of the diploma project "GIS of Moravian Viticultural cycle-ways".

6. The selected applications

Applications in the GIS sphere at the FCE date back to early 90th that time, the staff of Institute of Geodesy worked on the project of AM/FM (Automated Mapping/Facility Management) applications. It concerned the system for maintenance of gas pipeline LINDA, program for data management of anticorrosive protection of CR gas pipelines – GASACOR and GASSERV and a program PEARSON for evaluation of pipeline defects. The applications go back to the beginning when GIS started to be used for the first time. Nowadays LINDA product was integrated into more sophisticated graphical system VKM (geodetic software for the creation of map of medium and large scales, geometric plans etc.) and a GVIEW system (interactive map browser with possibility of conversion of a number of various data formats and some GIS functions implemented). The taking advantage of GIS, marked a great boom when it was used for solving particular tasks which was connected with the introduction of ESRI products e.g. the system Arc/Info implemented with the platform modules Leica and Intergraph GeoMedia. The branch of Geodesy and Cartography of the FCE in the fields of research and applications concentrated on 4 main directions: geological applications, GIS of small municipalities, GIS of maintenance of field points and GIS for tourism and sport. Fig. 4 shows GIS layout from the diploma project "GIS of Moravian Viticultural cycle-ways".

One of the most important tools of data management in GIS is their updating by data capturing. With the development of new electronic integrated mobile communication technologies it is possible to make use of computer PDA (Personal Digital Assistant), which are equipped with GPS (Global Positioning System), camera, high quality display, memory and GSM (Global System for Mobile Communications) technology – see Fig 5 and Fig. 6. The technology of data capturing is controlled by software e.g. ArcPad (ESRI) or Terra Sync (Trimble) etc. This process is under way either by the system of surveying the object in field or by its locating and demarking in field on the basis of coordinate GIS data. Ordinary accuracy of position destination is within the range

Fig. 5: *Data capture and updating of objects in flood area*

Fig. 6: *Survey extent of flooding line*

of 2 – 10 m. Mobile GIS is suitable for territorial arrangement in the sense of the pegging of basic directions in the field determined for a precise detailed geodetic surveying etc. Through the GSM communication technology there is an easier access through authorized internet client to data of basic servers and thus the update can be made directly in the source data.

7. GIS – based flood risk management

The modern decision making in flood risk management is based on theoretical means which make possible objective, forecasting of flood consequences, both qualitative and quantitative. Necessary tools for the practical implementation of the risk analysis methods in floodplains are the contemporary mathematical models of water flow in the inundation area linked to powerful GIS. The main task of GIS is to administer input data, analyse them and present results. Next describes basic ways and means of application of GIS in flood risk analysis.

System definition and qualitative analysis

- Preliminary phase of the risk analysis process which is based on putting together enough input data dealing with the floodplain properties, hydrologic and hydraulics conditions etc.

Quantitative analysis – flood hazard quantification

- Preparation of input data for hydrodynamics models. (pre-processing) and computing results evaluation (post-processing).
- Data evaluation from historical flood events.
- Flood hazard map creation (see Fig. 7, 8).

Quantitative analysis -Estimate of floodplain vulnerability

- Floodplain classification (see Fig. 9) resulting from vulnerability definition of individual sub-areas (categories). The content of category depends on floodplain occupancy (population, buildings and civil engineering works, public services, utilities and infrastructure etc.)
- Determining of vulnerability through the post-disaster survey of damages in floodplains.

Quantitative analysis – Evaluation of risk

- Evaluation of risk and flood risk map creation (see Fig. 9).

8. Conclusions

GIS at Faculty of Civil Engineering BUT has its long-term tradition both in teaching and in the implemented application. Because of the initial individual attitude and a lack of unity concerning particular solution in relevant branches it has not been subject to a great publicity up to national or international standard. The third dimension of GIS emerged by synthesis of a varied kind of spatial information and its interpretations. Thus we can obtain new information, which is not directly measurable but geometrically simulated and represented graphically in geographic contexts. By synthesis of geographic information we can access for example the influences of construction towards our environment and vice versa the influences of the environment upon construction of buildings mainly on their durability. Ecological interventions change the picture of the climate in the vicinity of the construction. Geographic arrangement has an influence of the existence of warm and cold areas interconnecting with the sunshine of a landscape wind stream, transmission of noise and others. With respect to the

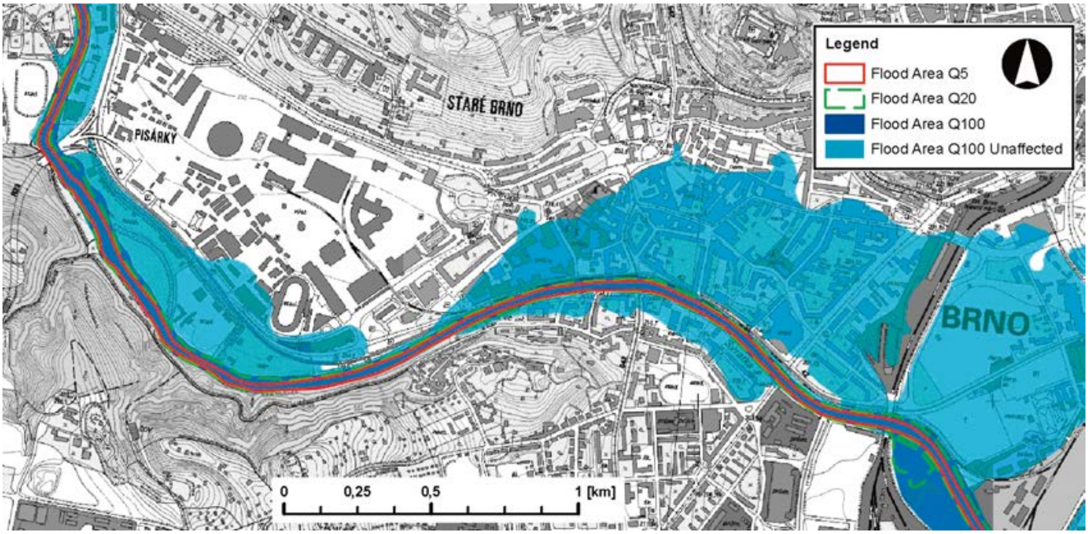

Fig. 7: *Sample of Flood Map – Locality Brno*

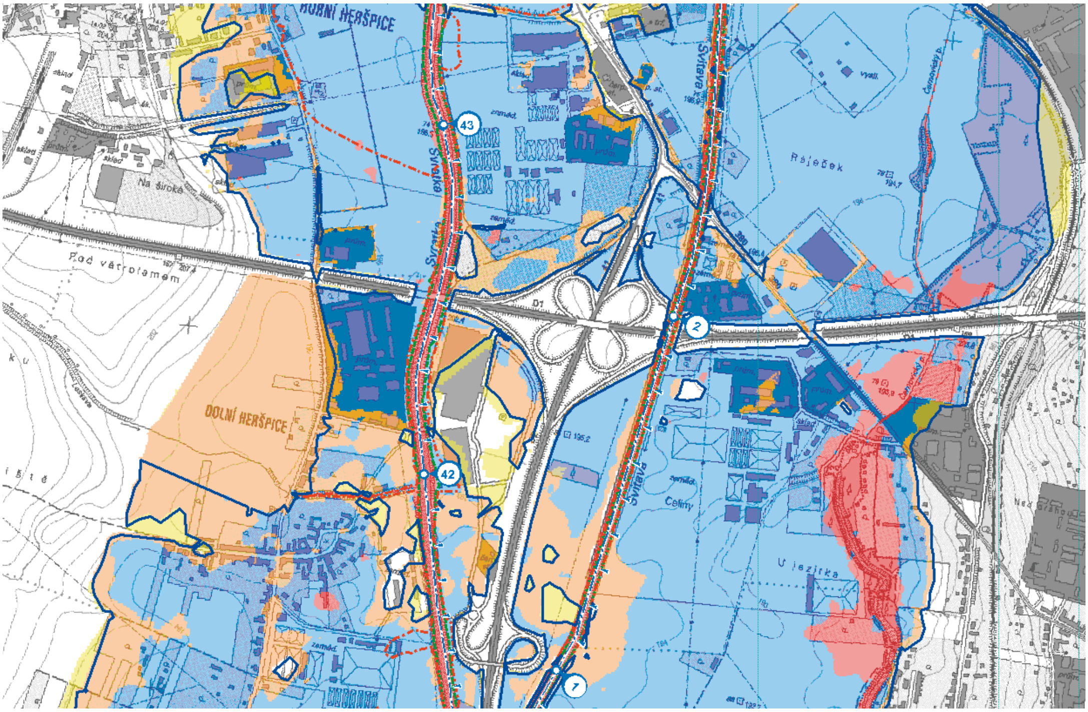

Fig. 8: *Sample of Flood Hazard Map – Locality Brno*

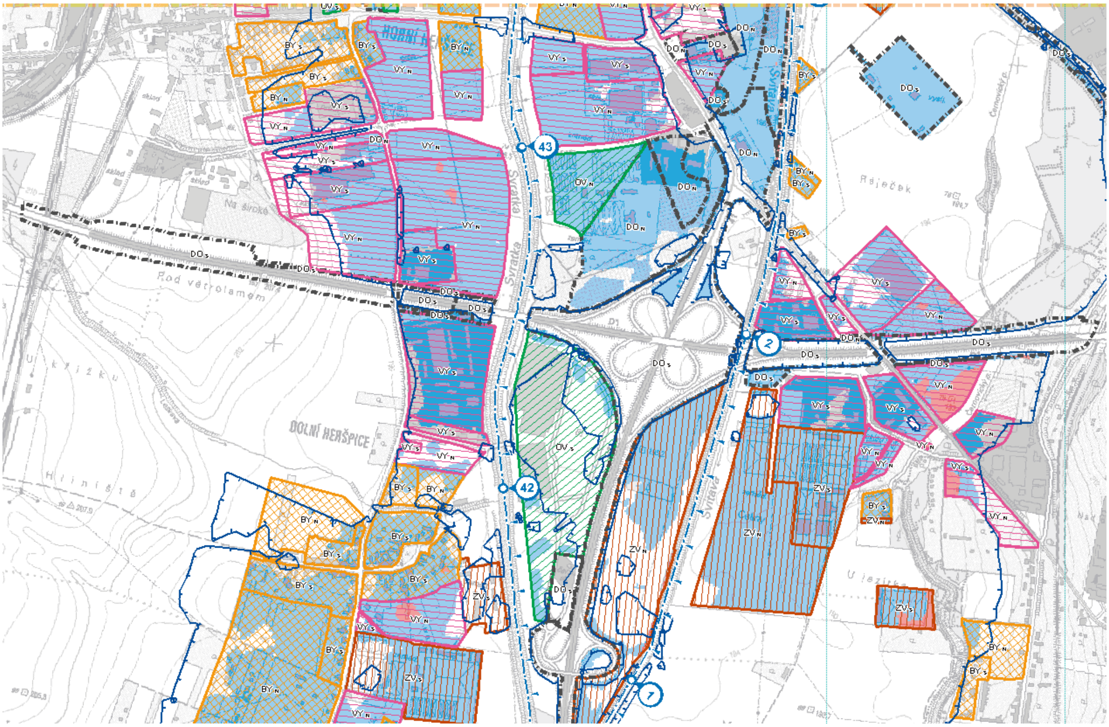

Fig. 9: Sample of Flood Risk Map – Locality Brno

protection of our environment the complexity of linking the information is necessary for safe run of the construction especially with large road structures (highway, railway corridors, biocorridors etc.). In the sphere of building industry GIS is important at the synthesis of information for the project of new construction location of the construction geography, weather, rainfalls, level of bottom waters, snowfall areas, flood areas geology etc. It aims to make periphery marginal conditions of construction designs more precise and of higher quality.

This paper was created with support of research task of Ministry of Education No 00216630519.

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