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GIS as a Support Tool in Regional Management of Rock Mineral Resources – Experiences from SW Poland

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Abstract

Mining and subsequent transport of rock minerals may cause environmental and social conflicts. Distribution of documented rock mineral deposits, being a derivative of geology, is usually uneven and inconsistent with demand areas. With the aim to facilitate modelling of potential conflicts and analysing the spatial distribution of source and demand areas, procedures have been developed in the geographical information systems (GIS). These tools can be used by public administration authorities, responsible for mineral resource management, to plan optimum development of available rock minerals resources taking into consideration costs and benefits in accordance with sustainable development requirements. A pilot geo-information system for selected two counties (Swidnicki and Wroclawski) in the Lower Silesia region (SW Poland) characterised by large and differentiated rock mineral resources has been developed, based on the proposed methodology and functionality. The system facilitates storage, management and distribution of spatial data related to rock mineral resources, mining and transport and the implemented functions can be used to solve planning, environmental and logistic problems connected with rock mineral management in a given space. The presented studies have been carried out within the frames of the “Strategies and Technological Scenarios of Management and Utilization of Natural Stone Deposits” Project financed from European Regional Development Fund within the Innovative Economy Operational Programme.

Keywords: GIS, rock minerals, management, SW Poland.
1. Introduction

In the first decade of the 21st Century and especially after accession of Poland to the European Union, an intensification of transport infrastructure (especially roadways), as well as building construction industries has been observed. This has resulted in an increasing demand for rock minerals (sands and gravels and dimension and crushed stones). Diversified and large reserves of these mineral resources were beneficial for the economy and allowed to satisfy most of the demand from national sources. On the other hand, increased demand for these products increased the scale of environmental and social conflicts associated with intensification of mining and road transport.

Resources of crushed stones, in particular magmatic and metamorphic rocks are located predominately in SW of Poland, mainly in the Dolnoslaskie government. This region accounts for approximately 50% of total production of crushed stones in the country each year and for nearly 99% of magmatic and metamorphic dimension and crushed stones. Rock minerals, such as clay raw materials are also mostly associated with the Dolnoslaskie region. Among other rock minerals, clay minerals for building ceramics constitute approximately 10% of national production and 6% of reserves. The distribution of sand and gravels resources and their mining in Poland is relatively even. Production of these minerals in the Dolnoslaskie government oscillates around 10% of total output. Location of rock minerals deposits in the Government is shown in Fig. 1.

![Fig. 1. Location of the study areas in the Dolnoslaskie district (SW Poland) against the background of rock mineral deposits (Blachowski, 2014).](image)

It must be noted that development of such a diversified mineral base is often restricted due to environmental and landscape protection constraints, the need to protect underground waters, presence of technical infrastructure and ownership rights to the land where a deposit is documented (Radwanek-Bąk 2008, 2009). The influence of mining on biological diversity is of particular concern, as exploitation of mineral deposits can have many adverse effects such as deterioration, disruption or even destruction of habitats, interference with functioning of species and their relocation. The scope of the interference caused by a mine in each case is individual and depends on numerous factors. These can be the mineral type, the size of a mine, mining technology used, as well as the sensitivity of the environment where the mining takes place. With the aim to protect the scarcest and most endangered species and habitats, the Nature 2000 network has been established in the European Union. These areas do not always prohibit mining of non-energy minerals (within this rock minerals) but must be carried in accordance with UE directives (habitat and bird) (NEEI, 2010). The paper presents the concept and development methodology of a geo-information system designed for optimisation of rock minerals management on the regional scale.
The foundations behind the system include the benefits and constraints of rock mineral development in the context of sustainable development requirements. The system has been developed on the case of three selected district „district” in the Dolnoslaskie Government, i.e. Klodzki, Swidnicki and Wroclawski (Fig. 1) characterised by large and diversified resources of rock minerals and differentiated internal market and distance to external demand areas. The study has been done within the task “Pilot geographical information system for selected regions of stone resources exploitation in the region of Lower Silesia” in the framework of the “Strategies and Technological Scenarios of Management and Utilization of Natural Stone Deposits” project coordinated by the Poltegor-Institute, Institute of Open Cast Mining (http://poltegor.igo.wroc.pl).

2. Materials and methods

The methodology of a GIS based information system for rock minerals resources management has been developed and tested on the example of three representative district (middle level administrative units in Poland) in the Dolnoslaskie Government. The general principle of geo-information system functioning is the internal environment of an administrative unit and presentation of selected information through web services on the Internet. The main stages of geo-information system development methodology include: project of a the system’s functional structure including access authoring and update procedure, analysis and selection of appropriate programming environment, collection, verification and processing of source data related to rock mineral deposits, development of the system’s database, development and testing of spatial analysis tools, preparation of thematic map templates for visualisation purposes, development of the system web map application. In the following section the methodology behind data sources and database development, as well as the general concept of the geoinformation system development and functionality taking into account the conditions associated with implementation of national spatial information infrastructure have been described and discussed.

2.1 Description of data sources

The input materials for construction of the databases of rock mineral deposits geoinformation system come from many sources and they are characterized by diversity in terms of content, detail, timeliness and forms of their storage.

The source materials, which were used for preparation of graphical part of rock mineral deposits’ database, came from: Geology Department of the Lower Silesia Marshal Office (mining areas and terrains licensed by the Marshal of Government in accordance with provisions of the act Geological and mining law (Journal of Laws 2011.163.981), Environmental Protection Department of individual district (mining areas and terrains licensed by District Offices (Journal of Laws 2011.163.981) and MIDAS database run by Polish Geological Institute. The source materials, which were used for preparation of description part of rock mineral deposits’ database, came from geological documentations stored in: archives of Geology Department of the Lower Silesia Marshal Office, Government Geological Archives in Wroclaw and resources of Environmental Protection Department in individual district. Procedure of acquiring data from geological documentations has been described in the thesis (Górniak-Zimroz et al., 2010).

Description and graphical data has been also acquired from databases run by Polish Geological Institute. These were described in the thesis (Blachowski et al., 2010a). From the above-mentioned sources, the complementary data was obtained for rock mineral deposits regarding e.g.: technical parameters of the deposit, state of land use, information on owner of the deposit and concession, start and end dates of exploitation, mining supervision body, state of the deposit, description of documentation and photos of selected deposits of construction stones and quarries. Reference data in the form of vector and raster layers has been also obtained from District Cadastral Facility in Wroclaw, from Regional Board of Water Management in Wroclaw, from Marshal Office in Wroclaw (Government Urban Development Bureau, currently the Institute of Territorial Development) and from General Directorate of Environmental Protection.
2.2 Database of geoinformation system (Geodatabase)

The preparation of a database for spatial data is the key and most laborious stage of a geo-information system’s construction. It includes the following basic actions: database design, database preparation, database management. The design stage includes determining the structure of databases with spatial data, including: determination of description and spatial data needed for analyses (including required attributes of objects), determination of boundaries of the analysed area, determination of sources and formats of data and selection of target coordinate system. According to the adopted design of the geo-information system’s database, it contains data of the following characteristics: basic, reference and supplementary. The first characteristics concern deposits and resources of rock minerals, the second include reference data, such as e.g. boundaries of administrative units, land use, system of protected natural areas. The third are results of analyses conducted in the system or results of works conducted within other task of the Project: Strategies and technological scenarios ....

It was assumed that developed database for the Świdnicki and Wrocławski district may be in future updated and expanded. After analysing the input materials coming from sources listed in part 2.1, the actions have been undertaken related to development of data structure needed for construction of Pilot system for Wrocławski district. Individual sets of data and classes of objects are stored in file database of geographical data (geobase) for the Wrocławski WroSGSS.gdb and Świdnicki district SGSS_Swidnica.gdb. The National Geodetic Coordinate System 1992 has been adopted as coordinate. Basic data of the system includes the following classes of objects, which detailed characteristic has been presented in the thesis (Górniak-Zimroz et al., 2011): boundaries of documented rock mineral deposits, boundaries of mining areas, boundaries of mining terrains, locations of mining and processing facilities, companies from the mining industry, and aggregate posting stations in railway transport.

The second type of spatial data stored in the system includes a set of reference data. It includes: boundaries of district, boundaries of municipalities, villages/cities, road infrastructure, railway infrastructure (including aggregate reloading points), surface and underground waters, protected areas and object, such as landscape parks, nature reserves, natural monuments, nature and landscape complexes, Natura 2000 areas, areas of flood hazard, geological structure, soils, land use.

![Fig. 2. Location of rock mineral deposits in Wrocławski district.](image)
This data is stored in geobase of geo-information system as classes of vector objects. Selected thematic layers are obtained from online systems of spatial information that publish WMS (Web Map Service).

Based on the above-mentioned data, graphical and description database GIS has been prepared for the Wroclawski district including 46 rock mineral deposits and for the Swidnicki district including 92 rock mineral-deposits. Also, the data concerning mining terrains and areas was gathered in the system. Figure 2 shows location of rock minerals deposits in the Wroclawski district on the background of river network, built-up areas, protected areas and forests, and in the Swidnicki district on the background of Kondracki’s physical-geographical division Fig. 3.

2.3 Development of the Geoinformation System for Regional Rock Minerals Management

The initial target in the project work plan aimed at developing a geoportal within the project consortium for selected administrative units (district) characterised by large and diversified resources and reserves of rock minerals in the Dolnoslaskie government. With this in mind, functionalities available for the project partners commercial and free and open source software have been analysed. These included ESRI ArcGIS Desktop and Server environment, as well Quantum GIS and geo server software distributed under the GNU General Public License.

Pilot web map applications have been developed and used for tests during the course of this study. However, this initial goal has been modified to accommodate for the development and growth of spatial data infrastructure in Poland during the duration of the project. In cooperation with the selected two district: Swidnicki and Wroclawski, rock mineral database according to the adopted structure, analytical tools and visualisation layouts for display purposes have been prepared with the aim of integrating them with the already existing district spatial information systems. In addition, such data, tools and functionalities have been created for the third, Klodzki district. However, in this case no cooperation agreement has been signed.

In the first phase of this part of the project, pilot web map applications have been developed for the purpose of testing functionalities for supporting rock mineral management, such as: query and identification tools based on attributes and relative locations, spatial analysis tools and web browser enabled editing of graphical and descriptive data. Graphical interfaces and example tools for the Wroclawski district and for the Klodzki district have been shown in Fig. 4 (in Polish), respectively. The figure presents the deposit and resource query and identification capabilities. The structure of information returned to the user from the System’s database depends on the authorisation level (public or restricted to member of organisation).
In the second phase of this work task, attention has been directed to refine databases related to resources of rock minerals and their mining for the pilot district and to enhance of spatial analyses for the purposes of providing information on the character of rock minerals management. In the result, a set of maps representing results of analyses concerning rock minerals resources and rock mineral mining in these unit have been developed. These included, for example: resource categories, status, mining methods used, geological and economic reserves, production, accessibility of undeveloped deposits with respect to spatial and environmental constrains, transport accessibility (road, rail) and other. Each feature class representing results of analyses has been described with basic elements of metadata in accordance with the INSPIRE metadata profile. Databases including symbologies defined for particular thematic layers have been incorporated into spatial information systems of the cooperating district with the option to publish as web maps.

The experience gained in this work package has been used as recommendations for the project’s task concerning the design of a complex geoinformation system for rock mineral mines (Blachowski, et al, 2013).

3. Discussion

The concept of building a geoportal of rock mineral deposits initially designed for two selected district, which has been adopted by the authors, has been aimed at three objectives: creating a flexible module structure of a geoinformation system, aimed at collection, processing and presentation of spatial data, testing various analytical functions of the gathered geo-data and providing a complete subject information about the rock mineral deposits. The adopted objectives have been achieved, which has been shown in section 2. In particular, initially assumed territorial limitation has allowed for practical completion of the data for documented deposits, and thanks to that, the tested analytical function has provided verifiable results (fig. 2, 3). Diversified needs of both district (based on signed agreements) served for widening the range of geoportal’s functionality. It must be noted that implementation of the geoportal in subsequent district will result in enriching it with more functions. Modular structure allows for such on-going expansion.

4. Conclusions

Within task 5 entitled Pilot geographical information system for selected regions of rock minerals deposits within the project Strategies and Technological Scenarios of Management and Utilization of Rock Mineral Deposits, the geo-information system has been developed for the Wroclawski and Swidnicki district as two selected regions of occurrence and exploitation of these raw materials in Dolnoslaskie Government. The geo-information system fulfils a complementary function to existing public registers and run portals from, among others, the Polish Geological Institute and selected district offices. As a result of the works on the system, the project of an online map portal has been proposed, which provides functionality including, among others, tools for composing your own thematic maps and their printing, searching of data according to set description or location
criteria, identification of objects on the map, downloading documents, visualizations of spatial models for selected deposits, as well as remote edition of spatial and description data, and procedures for geo-processing of data. This way, it can support conducting statutory tasks of district office units and municipalities that comprise it. It may also constitute a source of information for entrepreneurs from mining industry and other industries.

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References

9. Radwanek-Bąk B., 2008, Availability of deposits areas as a basic condition for rational management of mineral deposits part I Surowce i Maszyny Budowlane, nr 6 (in Polish)
10. Radwanek-Bąk B., 2009, Availability of deposits areas as a basic condition for rational management of mineral deposits part II, Surowce i Maszyny Budowlane, nr 1 (in Polish)
11. http://geoserver.org