MINISTRY OF EDUCATION
UNIVERSITY OF PETROȘANI
DOCTORAL SCHOOL
DOCTORAL FIELD: MINES, OIL AND GAS

DOCTORAL THESIS
-- SUMMARY --

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Doctoral student:
eng. Gheorghe Marian VANGU

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"GEOGRAPHIC INFORMATION SYSTEM FOR MINING ACTIVITIES"

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This research paper represents an analysis of the possibilities of design, implementation and use of a geographic information system intended for the mining field, with applicability within mining enterprises that carry out day-to-day exploitation. The implemented system is a management tool that facilitates quick access to data and ensures the efficient management of mining activities.

The research process started by studying the theoretical aspects that were the basis for shaping the current situation of the use of GIS in mining. Afterwards, it continued with the design, development, testing, and validation of work methodologies and of a data model necessary for the implementation of a GIS-type system dedicated to surface mining, this being the main objective pursued by the author.

The practical results of this work, obtained while undergoing the case study, materialize in obtaining: a high-resolution digital orthophoto plan of the study area, the digital elevation model, and the database model related to the implementation of a GIS system in the Bistrița limestone quarry – Vâlcea, quarry under the management of the National Salt Company SALROM S.A. – Branch Mining Exploitation Rm. Vâlcea.

The work "GEOGRAPHIC INFORMATION SYSTEM FOR MINING ACTIVITIES" represents the result of the undersigned's activities and research during the period 2016 – 2023 as a student of the Doctoral School of the University of Petroșani, in the field of Mines, Oil, and Gas. From a practical point of view, the main objective pursued is to obtain a geographic information system intended for the efficient management of mining activities up to date. The partial objectives are represented by: carrying out a flight for the acquisition of photogrammetric data, processing the data and obtaining the graphic support of the raster type (orthophotoplan), generating the database model, as well as developing, testing and validating the work methodologies. The case study was carried out in the Bistrița – Vâlcea limestone quarry, which allowed the practical application of topographic and photogrammetric technologies, the evaluation of their degree of applicability, as well as highlighting the novelty elements, the advantages and disadvantages of the applied methods.

The motivation of the theme is based on the theoretical training of the undersigned, as well as the experience accumulated over time. Being a graduate of the University of Craiova, Faculty of Economic Sciences, majoring in Economic Informatics, and later following the courses of the Faculty of Agronomy, majoring in Land Surveys and Cadaster from the same University, as well as the Master's courses in Computerized Mining Topography and Cadaster from the Faculty of Mines, Oil, and Gas, University of Petroșani, I turned my attention to a field of activity that combines aspects of the fields studied and that has potential for future development, namely Geographical Information Systems.

The technical-informatics knowledge acquired during the Economic Informatics courses and during the subsequent activity gives me the ability to design and implement an IT/information system. However, the knowledge acquired in the fields of "Terrestrial

Surveys and Cadaster" and "Computerized Mining Topography and Cadaster" influenced the branch of applicability to which I turned my attention, namely the computer/geographical information systems in the mining field, systems that combine the information localization with the descriptive ones.

By combining the knowledge acquired in these fields of activity (economy, information technology, geodesy, topography, cadaster), as well as thanks to an experience of over 15 years in the analysis and modeling of economic and management processes, I turned my attention to the study and research of geographic information systems with all mandatory components and processes: analysis of needs, design of the data model (relational or non-relational), analysis of the possibilities of obtaining or production of graphic support (raster and vector type), implementation of the designed, tested data model and validated, the efficient operation of the obtained system.

The importance and relevance of the theme are determined by the decisive importance given to the efficiency of any economic activity, especially in the context of limited resources (quantitative and qualitative). In the current competitive context of the global economy, the performance of an enterprise is conditional and depends on the quality of decisions made by its management. Making the best decisions and taking the best actions involves accessing a large volume of information and a complex process of analyzing and synthesizing it.

The storage of a large and varied volume of data, but especially their processing in order to identify decision alternatives, makes it necessary to design and implement decision support systems to assist the manager in adopting the best decisions. A special category of currently existing decision support systems is represented by geographic information systems, systems that allow the definition and use of thematic maps that facilitate multicriteria analysis.

The ability to collect, process, and analyze the information that the company's management (the human factor) needs to have is far beyond human limits. In order to overcome these limits, processing and information technology tools are used in the decision-making process, especially information technologies for decision support.

The limited nature and judicious use of resources is a strategic objective in the mining field as well, in accordance with Romania's mining strategy 2017-2035, which supports the concept of sustainable development. At the national level, the efficient management and optimal use of the existing mineral resources is pursued, so that the existence and use of decision support systems dedicated to the mining field is required. Among them, geographic information systems play a special role in terms of the area of applicability. Thus, they find their usefulness during the life cycle of a mining operation, from prospecting to the stages of closing the mining works and rehabilitating the environment affected by them.

The degree of novelty of the theme is certain and quantifiable. The present research theme is in line with the applicable national trends and strategies in the field of Mines, Oil,

and Gas. The technological progress has facilitated the penetration and accessibility of new technologies intended for the mining field (drones, photogrammetric products, dedicated IT systems, etc.), which allows the development and use of modern tools for managing surface mining activities.

The fundamental **objective** of this study focuses on the design of a geographic information system that integrates various information, various types of data necessary for the efficient organization and management of mining activities, with the validation of work methods within the Bistrița-Vâlcea limestone quarry.

Specifically, I brought in to analyze the opportunities for the design, development, and implementation of a geographic information system intended for the management and efficiency of the mining activity within the Bistrița-Vâlcea limestone quarry, a system that must go through all the stages of creating a GIS. At the same time, the secondary objectives were also established, as follows: the development, testing, and validation of the methodology regarding the performance of the needs analysis activities, as well as the acquisition of photogrammetric data; data processing and obtaining the necessary photogrammetric products; conceptual data model and database design, validation and implementation; implementing the designed data model using specialized software products; demonstrating the usefulness of the system by presenting its analytical capabilities.

The present research work was structured in 7 content chapters, to which are added the preface, the bibliography covered for the documentation and writing of the work, and the appendices containing various technical details of the researched aspects. The structure of this work is as follows:

Chapter 1. The Bistrița – Vâlcea limestone quarry has the role of presenting the context of the research activities and the general presentation of the location. At the same time, I presented aspects regarding the scientific importance of the subject under research, the current state of knowledge, the main and secondary objectives established, the theoretical, scientific and material support, aspects regarding the research methodology and the formulated hypotheses.

Chapter 2. Software products used in the mining field includes the presentation of the main software products used in the mining field, related to their category and area of applicability. Also, this chapter presents the concept of geographic information system and the positioning of GIS-type systems in the mining activity.

Chapter 3. Geographic Information Systems (GIS) Used in Mining details aspects of GIS systems as follows: overview of the concept, definition and classification of GIS systems, their broad applicability, presentation of beneficiaries and benefits, transition into review of several existing projects, presentation of the process of creating, implementing and maintaining a GIS, presentation of the main existing GIS software products, presentation of the concept of OpenGIS and concepts regarding standardization and interoperability.

Chapter 4. Mining GIS database design and implementation presents both the general notions, and the concepts of databases and the specific customizations of spatial databases, especially with applicability in mining. Within this chapter, concepts were included regarding: the current context and the need to use databases, definitions and basic functions, concepts regarding the personnel involved, concepts about the architecture and design of databases, classic databases and spatial databases used in mining operations. Conceptual or logical models for mining were included and the main benefits generated by database mining were presented.

Chapter 5. Applicability of drones in mining aims to present the modern technologies used for fast and accurate data acquisition from the field. Thus, there are presented: general notions regarding unmanned aerial vehicles (drones), the conceptual and constructive differences between the drone, unmanned aerial vehicle and unmanned flight system, the legislative aspects established at European level and aspects regarding flight safety. At the same time, aspects were detailed regarding the possibilities and opportunity of using drones in mining, sensors used and the benefits of using drones in mining operations.

Chapter 6. Case study: Bistrița – Vâlcea limestone quarry includes the detailing of the activities carried out in the research process, with practical applicability in the Bistrița-Vâlcea limestone quarry. To achieve the brought in objectives, the case study pursued 6 major directions of action, as follows:

- planning activities and carrying out the process of detailed needs analysis, to ensure the correspondence between requirements and results;
- carrying out a photogrammetric flight for the acquisition of field data (Bistrita-Vâlcea limestone quarry);
- processing the photogrammetric data and obtaining an orthophoto plan related to the limestone quarry from Bistrița-Vâlcea;
- data model design (GIS database);
- implementation of the data model and analytical exploitation of the geographical information system of the Bistrița-Vâlcea limestone quarry;
- publishing the project in the form of a web component (webgis type), with extended accessibility.

Chapter 7. Research results and suggestions for their exploitation and dissemination presents the practical results obtained as a result of the case study, the suggestions for their exploitation, future research directions, as well as the author's original contribution. At the same time, as a result of the practical research experiences, action recommendations were included in the daily mining operations in the mountain areas.

Research results

As a result of the research activities, practical results were obtained, as follows:

- the methodology regarding the design, development and implementation of databases intended for mining operations;

- logical and conceptual models regarding the structuring of existing data in mining operations and their organization in spatial databases;
- the methodology for planning and carrying out a photogrammetric flight in a day mining operation in the mountain area;
- the methodology for the implementation of a GIS type system with applicability in surface mining operations;
- the methodology for processing frames and obtaining an orthophoto plane;
- planning photogrammetric flight routes and saving them for subsequent flights;
- list of control points on the ground, with associated coordinates;
- list of recommendations and best practices for performing a photogrammetric flight in a mountain area;
- set of 1249 frames (1127 frames from the mining area and 122 frames from the product storage and delivery area);
- orthophoto plan (for two areas of interest);
- digital elevation model;
- point cloud;
- data model dedicated to the Bistrita-Vâlcea limestone quarry;
- geographic information system intended for the management of the activities in the Bistrița-Vâlcea limestone quarry;
- work scenarios for the analytical exploitation of the geographic IT system.

Personal contributions

From a theoretical and practical point of view, the work is a first step towards the creation of a set of modern methods, means and tools for the analysis and effective management of the activity in mining exploitations up to date, by using modern techniques of aerial scanning and integration of geographical information.

The present work makes practical contributions to the application of photogrammetric technologies in the daily mining operations in the mountain area, as well as in terms of designing a data model, creating the database, populating with values and implementing a geographic information system specific to the limestone quarry from Bistrita-Vâlcea.

Related to the research theme, the author showed his concern regarding the analysis and evaluation of the photogrammetric technologies applicable in mining operations in the mountain area, as well as for the design of a specific data model, which allows the integration of information from various sources, with the aim of facilitate and improve management decisions. The purpose of this paper is to develop and validate a methodology with practical applicability for the design and implementation of a GIS type system, including for the identification of needs and the provision of raster graphic support. Thus, by applying this methodology in similar locations and conditions, it is ensured that similar results are obtained.

The author’s original contribution materializes and is supported by practical results

obtained as a result of the case study as described above. The original elements of the paper are based on four main research directions:

- development and practical validation of the needs analysis methodology;
- ensuring the necessary graphic support by using aerial scanning (photogrammetric) methods for data acquisition:
    - the development of models for planning field and office activities, as well as models for establishing the necessary resources;
    - the development, application and validation of the methodology for marking and materializing points on the ground to ensure the possibility of subsequent georeferencing of the graphic support (orthophotoplan);
    - establishing the optimal parameters for the photogrammetric flight and processing of the raw frames to meet the minimum quality requirements of the graphic support.
- designing the dedicated data model (GIS database);
    - designing the data model specific to the Bistrița-Vâlcea limestone quarry, respecting the requirements of the final beneficiaries;
    - application of cross-validation methods of needs and data model (application of intermediate database exploitation scenarios).
- the development and implementation of the geographic information system from the point of view of the structure, methods and means of software implementation, with direct applicability to the Bistrița-Vâlcea limestone quarry.
    - validation of the designed model through practical implementation within a specialized software product (ESRI-ArcGis);
    - establishing the elements of interest and their vectorization for the case study;
    - integration of data from various sources (public or private);
    - a presentation of the ways of efficient exploitation of the geographic information system;
    - developing practical scenarios for exploiting the GIS type system.

Prospects for expanding research

Considering both the complexity of activities specific to the mining field and the wide applicability of geographic information systems, this research paper is not considered to be exhaustive. Research activities can be continued, expanded and improved. Among the possible directions of future research with applicability in the mining field we can mention:

- adjusting and improving the analysis methodology and correct identification of needs;
- the continuation of research on the methods of acquiring photogrammetric data from mining operations up to date, but also the expansion of research on applicability in underground mining;

- research on the factors that influence the quality of photogrammetric products: the technical capabilities of the equipment used, the density of control points on the ground, photogrammetric processing methodologies and algorithms;
- carrying out comparative studies regarding the use of various software products used for photogrammetric processing (Agisoft Metashape, Pix4D, DJI Terra);
- research on the applicability, usefulness and benefits of applying similar technologies: classic photogrammetry, UAV photogrammetry, 3D laser scanning;
- expanding and optimizing the data model designed and specific to mining operations;
- updating the database according to the needs and requirements of the final beneficiaries;
- researching the applicability of the methods in different types of mining: surface, deep / underground, marine or fluvial mining.

The mentioned research directions can constitute a continuation of the present theme and the research activities carried out, which can lead to the refinement and improvement of the obtained results.