Post-Mining Multi-Hazards evaluation for land-planning

PoMHaz

WP4: GIS development tools

D12 - Deliverable 4.1: System requirements, system design and architecture

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List of Acronyms

DSS	Decision support System
RFCS	Research Fund for Coal and Steel
SDSS	Spatial Decision support System
GIS	Geographic Information System
VR	Virtual Reality
MCDA	Multi-Criteria Decision Analysis
WMS	Web Map Service
KML	Keyhole Markup Language
WFS	Web Feature Service
GUI	Graphical user Interface
RDBMS	Relational Database Management System
CLI	Command-Line Interfaces
CPU	Central Processing Unit CPU
HDD	Hard Disk Drives
NAS	Network-Attached Storage
SAN	Storage Area Network
UPS	Uninterruptible Power Supplies
GPU	Graphics Processing Unit

1 Executive Summary

In response to the intricate challenges of post-mining hazards, the POMHAZ project has articulated a comprehensive system design and requirement framework. This endeavor is propelled by the necessity for a sophisticated GIS-based Decision Support System (DSS) capable of efficiently managing, analyzing, and visualizing diverse spatial information. The proposed summary encapsulates key components and strategies delineated in the report:

Data Formats and Specifications: In navigating the multifaceted landscape of post-mining hazards, the POMHAZ project meticulously opts for GeoTIFF and shapefiles as the cornerstones for raster and vector data representation, respectively. The choice is underpinned by the need for flexibility in accommodating spatial information from geological surveys, satellite imagery, and on-site monitoring stations.

Pre-processing Steps: The dynamic framework of the POMHAZ project necessitates a nuanced approach to data transformation. Meticulous post-processing steps, including data cleaning, quality control, integration, spatial interpolation, and feature extraction, not only ensure data integrity but empower the project with a robust decision-making tool.

General Concept of DSS-Toolbox: The envisaged Decision Support System for post-mining hazard evaluation unfolds as a comprehensive toolbox. The database emerges as a pivotal repository for historical and current data, supporting informed decision-making. The qualitative model base facilitates analytical capabilities, while the knowledge base serves as a repository for specialized expertise. The graphical user interface (GUI) acts as a conduit, ensuring seamless interactions between users and the various components of the DSS.

Front Ends for Interaction with Stakeholders: Recognizing the diverse landscape of stakeholders, the POMHAZ project prioritizes user-friendly front-end interfaces. These include web-based dashboards, and GIS interfaces with interactive data visualization. This diversity ensures effective engagement across a spectrum of technical proficiencies.

Selection of a Suitable Database System: The choice of an apt database system is recognized as pivotal for the success of the post-mining hazard evaluation DSS. Options span Relational Database Management Systems (RDBMS), NoSQL databases, Spatial Databases, Geospatial Data Warehouses, Graph Databases, and Time-Series Databases. Each option is evaluated based on strengths and suitability, considering factors such as data volume, complexity, and scalability. The considered database system of the POMHAZ project will be mainly based on open-source RDBMS such as PostgreSQL.

Required Hardware: The hardware blueprint for the GIS-based DSS takes into account the computational demands of GIS software, dataset sizes, and real-time processing requirements. Components range from workstations or servers equipped with multi-core processors, sufficient RAM, and advanced GPUs to mobile devices for field data collection. Network infrastructure, data storage and backup, power backup, server hardware (if applicable), and cloud computing, hardware are integral components tailored to the specific needs and scale of the POMHAZ project.

In essence, the POMHAZ project's system design and requirements set the stage for a robust, flexible, and user-centric GIS-based DSS. This summary highlights the meticulous considerations and strategic choices aimed at addressing the complex challenges inherent in post-mining hazard assessment.

2 Overview

2.1 Introduction

A decision support system (DSS) is a computer program application used to improve a company's decision-making capabilities. It analyses large amounts of data and presents an organization with the best possible options available. Additionally, the Decision support systems bring together data and knowledge from different areas and sources to provide users with information beyond the usual reports and summaries. This is intended to help people make informed decisions. In our case, these decisions are made to assess and manage multi-hazards at the scale of a coal mining basin, helping individuals make informed choices in the context of POMHAZ project.

After defining and analysing existing methods and determining the appropriate approach for hazard assessment within abandoned coal mines in Work Package 2, our focus shifted to post-mining risk assessment in Work Package 3. This led to the analysis of the Decision Support System (DSS) specification and its development. Consequently, Task 4.1 in Work Package 4 aims to determine the technical requirements for developing a DSS for post-mining Multi-Hazard evaluation for land planning (POMHAZ) architecture. This involves a comprehensive examination of hardware, software, data formats, data management, and security aspects necessary to support the system's functionalities. This integrated system aims to leverage the power of spatial data analysis and decision support functionalities to facilitate informed decision-making and proactive risk management in post-mining environments in the context of POMHAZ project. Figure 1 presents the GIS-based decision support system architecture and the main elements.

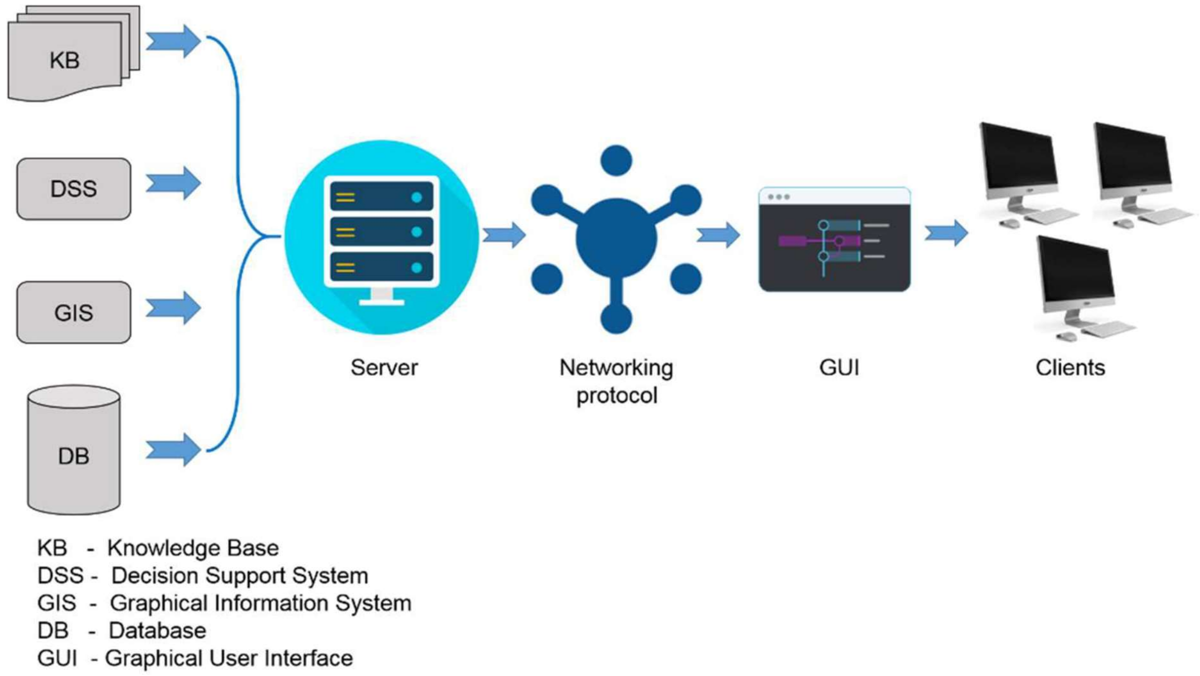

Figure 1- GIS-based decision support system architecture

To address the system requirements and carefully craft the architecture of the GIS-based Decision Support System, we worked collaboratively with our partners to develop a questionnaire. This method ensures comprehensive consideration of all relevant data and IT-input requirements, thereby boosting the accuracy and effectiveness of the DSS. Moreover, this questionnaire will guide us in aligning with the specific needs and preferences of our partners concerning the proposed DSS.

The objective of the POMHAZ project is to tackle the intricate challenges linked to post-mining hazards. Collaborating with seven partners from four EU countries, our goal is to formulate a comprehensive system design and framework for a GIS-based Decision Support System (DSS). This system aims to effectively manage, analyze, and visualize spatial information pertaining to post-mining hazards. To achieve this, careful attention must be paid to the system requirements, system design, and architecture detailed in Figure 1. Ultimately, it will facilitate informed decision-making, risk assessment, and sustainable land planning in impacted areas.

2.2 State-of-the-art

The use of Spatial Decision Support Systems (SDSS) for post-mining Multi-Hazard evaluation in land planning is an area that has received relatively limited attention in the academic and research spheres. Despite the critical importance of ensuring effective and sustainable land management practices following mining activities, the specific application of SDSS for comprehensive multi-hazard assessments in post-mining environments has not been extensively explored.

The state-of-the-art in Decision Support Systems (DSS) based on Geographic Information Systems (GIS) for post-mining hazards assessment was continually evolving. These systems play a crucial role in identifying, analyzing, and mitigating risks associated with post-mining hazards, including subsidence, land degradation, water contamination, and ecosystem disturbance. In the deliverable (2.2 and 2.3) the list of post-mining hazards was established and that corresponds to knowledge base (KB). By integrating GIS with DSS, a comprehensive framework for assessing and managing these hazards is established, aiding in effective decision-making for sustainable land use and environmental management.

Several notable advancements have been made in this domain, such as the integration of advanced remote sensing technologies, machine learning algorithms, and multi-criteria decision-making techniques. These advancements have significantly enhanced the capabilities of DSS-based GIS for post-mining hazards assessment by providing a more comprehensive and accurate understanding of the spatial and temporal dynamics of post-mining hazards.

One of the primary focuses has been on the development of predictive models that leverage historical data, spatial analysis, and machine learning algorithms to forecast potential post-mining hazards. These models enable the identification of high-risk areas and the implementation of proactive measures to minimize the environmental impact of mining activities after mine closure.

Furthermore, there has been an emphasis on the development of user-friendly interfaces and visualization tools that facilitate the interpretation of complex spatial data, thereby enabling stakeholders (the clients of the system) to make informed decisions in a timely manner. These interfaces often incorporate interactive maps, 3D visualizations, and customizable dashboards, allowing users to explore, analyze, and communicate the findings of post-mining hazards assessments effectively.

Prominent research studies and academic papers have contributed significantly to the advancement of DSS-based GIS for post-mining hazards assessment. Some relevant references that were prominent up until 2022 include:

Table 1 - Key studies focusing on DSS since 2008

Authors	SDSS Study focus
Yilmaz, I. (2015).	GIS and multicriteria decision analysis for land-use suitability analysis: a case study of Samsun, Turkey. Environmental Earth Sciences, 73(11), 6611-6625.
Agostini P., Critto A., Semenzin E., Marcomini A. (2009).	Decision Support Systems for Contaminated Land Management: A Review. In: Marcomini A., Suter II G., Critto A. (eds) Decision Support Systems for Risk-Based Management of Contaminated Sites. Springer, Boston, MA.
Newman, J.P., et al., (2017).	Review of literature on decision support systems for natural hazard risk reduction: Current status and future research directions. Environmental modelling & software, 96, pp.378-409.
Pavloudakis, F., Galetakis, M. and Roumpos, C., (2009).	A spatial decision support system for the optimal environmental reclamation of open-pit coal mines in Greece. International Journal of Mining, Reclamation and Environment, 23(4), pp.291-303.
Malczewski, J. G (1999)	GIS and Multicriteria Decision Analysis, John Wiley & Sons, New York.
Hao, M., Li, B., & Wu, J. (2019).	Assessment of ecological restoration effects on post-mining area using a combined method of GIS-based landscape metrics and remote sensing. Ecological Indicators, 106, 105490.
Singh, A., & Ghosh, S. K. (2016).	Spatial multi-criteria decision analysis for landfill site selection: a case study in the Assam State, India. Journal of Geographic Information System, 8(01), 70.

F. Ai, Y. Dong, T. Znati (2015)	A dynamic decision support system based on geographical information and mobile social networks: a model for tsunami risk mitigation in Padang, Indonesia, SafetyScience90; 62–74.
Horita F., de Albuquerque J.P., Degrossi L.C., Mendiondo E.M., Ueyama J. (2015)	Development of a spatial decision support system for flood risk management in Brazil that combines volunteered geographic information with wireless sensor networks

These references offer valuable insights into the application of GIS-based DSS in the context of post-mining hazards assessment and highlight the methodologies and techniques that have been employed to improve the accuracy and efficiency of these systems.

Some notable progresses in the development and use of DSS for Post-mining hazards assessment include:

Advanced Spatial Analysis Techniques: The integration of advanced spatial analysis techniques, such as machine learning algorithms, remote sensing data, and high-resolution satellite imagery, has significantly improved the accuracy and precision of post-mining hazards assessment. These techniques enable the identification of potential hazards, such as land subsidence, water contamination, and soil erosion, with greater efficiency and detail.

Real-Time Monitoring and Early Warning Systems: State-of-the-art DSS-GIS systems now incorporate real-time monitoring capabilities, utilizing IoT (Internet of Things) sensors, drones, and geospatial data to provide early warnings and timely alerts for potential post-mining hazards. This integration enables proactive risk management and the implementation of preventive measures to minimize the impact of hazardous events.

3D Visualization and Virtual Reality (VR) Integration: The integration of 3D visualization and VR technologies has revolutionized the way post-mining hazards are visualized and communicated. These technologies provide stakeholders with immersive and interactive experiences, enabling them to explore and understand complex spatial data in a more intuitive and engaging manner. This enhances decision-making processes and facilitates effective communication among multidisciplinary teams.

Multi-Criteria Decision Analysis (MCDA): State-of-the-art DSS-GIS systems now employ sophisticated multi-criteria decision analysis methodologies to assess and prioritize post-mining hazards based on various environmental, economic, and social criteria, which is the case of the POMHAZ project. These systems enable stakeholders to make informed decisions by considering multiple factors simultaneously, thereby facilitating a comprehensive and holistic approach to post-mining risk management.

Cloud-Based GIS Solutions: The adoption of cloud-based GIS solutions has facilitated greater data accessibility, collaboration, and scalability in post-mining hazards assessment. These solutions allow for the seamless integration of data from various sources, enabling stakeholders to access and analyze spatial data in real-time from any location, thereby improving the overall efficiency and effectiveness of the decision-making process.

Open Data Initiatives and Interoperability: Efforts to promote open data initiatives and interoperability standards have enhanced data sharing and integration among different DSS-GIS platforms. This has facilitated the seamless exchange of geospatial data and information between different stakeholders, promoting collaboration and knowledge sharing in the field of post-mining hazards assessment.

By leveraging these state-of-the-art advancements, decision-makers, environmental agencies, and mining companies can effectively assess, manage, and mitigate post-mining hazards, contributing to the sustainable and responsible management of mining activities and their environmental impacts.

3 Data formats and specifications

In the context of the POMHAZ project, the development of a sophisticated GIS-based Decision Support System (DSS) demands meticulous attention to data formats and specifications to establish a robust foundation for efficient data management, comprehensive analysis, and intuitive visualization. Given the multifaceted nature of post-mining hazards, encompassing challenges such as land subsidence, water contamination, and ecological destabilization, the selection of appropriate data formats becomes paramount. By strategically opting for geospatial data formats such as GeoTIFF for raster data representation and shapefiles for vector data, the DSS can seamlessly accommodate various types of spatial information sourced from diverse geological surveys, satellite imagery, and on-site monitoring stations. The adherence to specific data specifications, including standardized metadata documentation and quality control protocols, not only ensures the integrity and reliability of the data but also facilitates the seamless integration of multi-source data for comprehensive hazard assessment and management within the POMHAZ project.

Here are technical details regarding required data formats and specifications for the POMHAZ project:

Geospatial Data Formats:

Geospatial data typically combines location information (usually coordinates on Earth) and attribute information (the characteristics of the object, event, or phenomenon of interest) with temporal information (duration of coexistence of the location and attributes).

- Shapefiles (.shp): Shapefiles are a common vector data format for representing geographic features. They store geometry (points, lines, and polygons) and attribute data.
- GeoTIFF (.tif): GeoTIFF is a format for georeferenced raster images. It allows embedding spatial information, such as coordinates and projection details, within the image file.
- Geodatabases: Consider using geodatabases, like Esri File Geodatabases (.gdb) or Spatialite databases (.sqlite), to efficiently manage and store complex geospatial datasets.

Attribute Data Formats:

- Comma-Separated Values (CSV): CSV is a simple, widely supported format for tabular data. It's suitable for attributes related to geographic features.
- GeoJSON (.json): GeoJSON is a format for encoding geospatial data in JSON (JavaScript Object Notation), making it ideal for web-based applications.
- Relational Databases: For large and structured attribute datasets, consider using relational databases like PostgreSQL with PostGIS extension or MySQL with spatial extensions.

Metadata Standards:

- Implement metadata standards like ISO 19115 or FGDC to provide comprehensive documentation about your geospatial data. This metadata should describe data sources, accuracy, update frequency, and other essential details.

Data Quality Standards:

- Establish data quality standards and specifications, such as data accuracy, precision, and resolution, to ensure that the data used for hazard assessment is reliable and fits for its intended purpose.

Data Interoperability Formats:

- Utilize standard data exchange formats for interoperability, such as Web Map Service (WMS), Web Feature Service (WFS), or Keyhole Markup Language (KML) for sharing data with other systems or stakeholders.

Data Compression:

- Depending on the volume of geospatial data, consider data compression techniques like ZIP, GZIP, or LZW to reduce storage and transfer requirements without sacrificing data integrity.

Time-Series Data Formats:

- If your hazard assessment involves time-series data (e.g., monitoring data), consider formats like NetCDF or HDF5 that are designed to store and manage multi-dimensional data, including time.

File Naming Conventions:

- Develop a consistent file naming convention for your datasets and layers, making it easier to organize and locate specific data within the system.

Data Security and Access Control:

- Implement security measures and access control mechanisms to protect sensitive hazard assessment data, particularly if the DSS is accessible via the internet.

Adhering to these technical data formats and specifications ensures that your GIS-based DSS for Decision Support System (DSS) for post-mining Multi-Hazards evaluation for land-planning can efficiently manage, analyze, and visualize geospatial data while maintaining data quality, interoperability, and security.

4 Pre-processing steps to transform raw data

In the dynamic framework of the POMHAZ project, the implementation of a GIS-based Decision Support System (DSS) mandates a meticulous execution of multifaceted post-processing steps to uphold the reliability and efficiency of the raw data transformation process. Within this context, the initial phase of data processing involves meticulous data cleaning and quality assurance protocols, guaranteeing the removal of inconsistencies and inaccuracies that may skew the accuracy of the assessment.

This comprehensive post-processing approach, coupled with robust visualization and reporting mechanisms, empowers the POMHAZ project with a sophisticated decision-making tool that facilitates proactive risk management and fosters sustainable post-mining practices.

Here are some detailed post-processing steps to consider:

Data Cleaning and Quality Control:

- Remove inconsistencies, errors, and outliers from the raw data to ensure data integrity and accuracy.
- Conduct quality control checks to validate the data against predefined criteria and standards.

Data Integration and Fusion:

- Integrate data from multiple sources, such as geological surveys, environmental monitoring stations, and satellite imagery, to create a comprehensive dataset.
- Fuse different data types, including spatial and non-spatial data, to generate a unified view of the post-mining environment and potential hazards.

Spatial Interpolation and Extrapolation:

- Use spatial interpolation techniques, such as kriging, inverse distance weighting, or spline interpolation, to estimate values at unmeasured locations based on nearby sample points.
- Employ extrapolation methods to predict values beyond the extent of existing data, enabling the projection of potential hazard zones in the post-mining landscape.

Feature Extraction and Identification:

- Extract relevant features from the raw data, such as landforms, water bodies, vegetation cover, and infrastructure, using image processing and feature detection algorithms.
- Identify specific hazard-related features, including unstable terrain, contaminated water sources, or land subsidence areas, through pattern recognition and object detection techniques.

By implementing these post-processing steps, the GIS-based DSS can effectively transform raw data into valuable insights and information, enabling stakeholders to make informed decisions and implement proactive measures for post-mining multi-hazard assessment and management.

5 General Concept of DSS -toolbox

Fundamentally, a Decision Support System (DSS) for post-mining Multi-Hazard evaluation for land-planning comprises several essential components, illustrated in Figure 2: (1) the database, (2) the Qualitative model, (3) knowledge base, (4) the graphical user interface (GUI), and (5) the user.

However, the composition of DSS components may vary, depending on the specific focus on aiding decision-making tasks and the utilization of associated technologies. The database assumes a critical role, housing all the necessary data and information essential for designing and constructing a model tailored to address the Multicriteria post-mining hazards structure, thereby enabling the generation of pertinent analyses for informed decision-making.

The qualitative model base serves as the repository for various models intended for the processing of raw data, facilitating analyses that contribute to the decision-making process. Consequently, the model management system supports the development, updating, and retrieval of models.

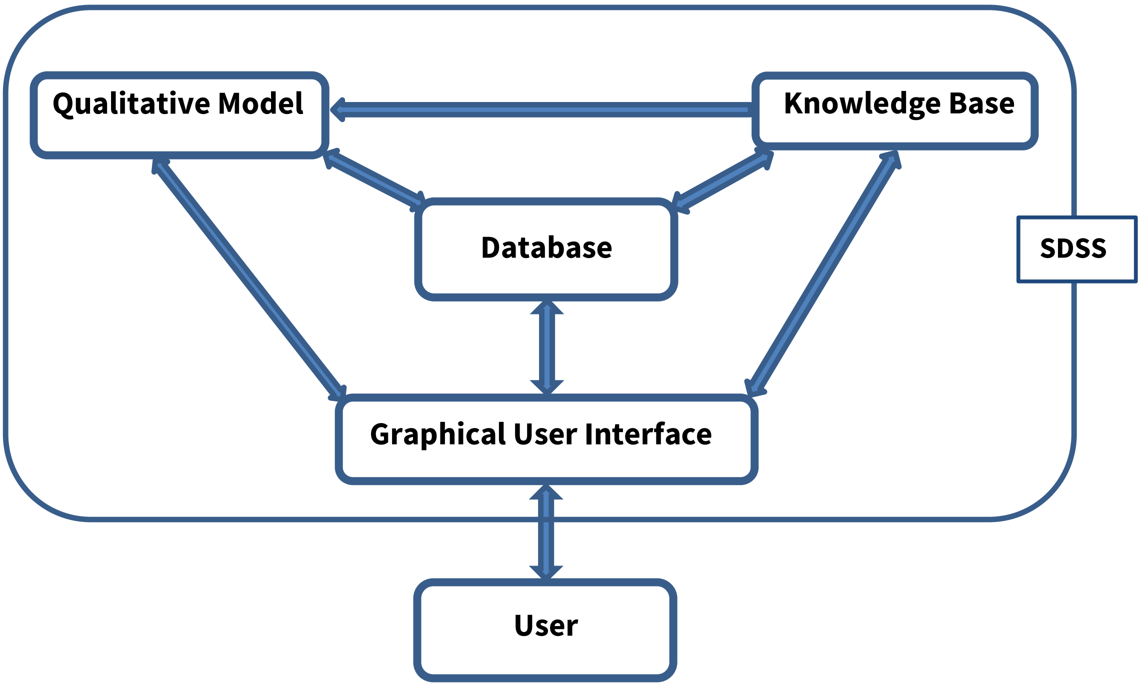

Figure 2 - A schematic view of a decision support system for the POMHAZ project

The knowledge base contains historical data for background reference. In addition, the GUI serves as a communication conduit between the user and the DSS, facilitating interactions with the model base, knowledge base, and database. Below, we provide detailed insights into each component:

Database: A database functions as a repository for both historical and current data, instrumental for informed decision-making. It stores data, often residing in databases or data warehouses, dedicated to aiding significant decisions. POMHAZ users are granted access to this data, allowing them to manipulate and query it.

Model Base: The model base houses an array of quantitative, statistical, optimization, or simulation models, providing essential analytical capabilities for the DSS. These encompass models like linear programming, integer programming, and nonlinear programming. The proposed-DSS is endowed with the ability to invoke, run, and modify a qualitative model, and also combine multiple models.

Knowledge Base: Many managerial decision-making challenges are intricate, demanding specialized expertise for resolution. The DSS's knowledge base is the repository for this expertise, accessible to support the functioning of other DSS components. Their knowledge informs the system's algorithms, risk assessment methodologies, and decision-making frameworks, ensuring the DSS is finely tuned to the complexities of post-mining environments. Expertise is pivotal in translating raw data into meaningful insights, supporting accurate hazard assessments, and ultimately facilitating informed and sustainable land planning decisions within the POMHAZ project.

Graphical User Interface: The GUI encompasses all aspects of user-DSS application interaction. This user interface enables users to: (a) Interact with the database, model base, and knowledge base. (b) Enter or update data. (c) Execute the chosen model, view model results, or even rerun the application with different data and/or model combinations. The user interface significantly influences the DSS's power, flexibility, and ease of use.

User: The individual facing the problem or decision that the DSS is designed to support is referred to as the user, manager, or decision-maker. There are two primary user categories: managers and system specialists or analysts. Therefore, understanding user needs is imperative. In general, managers anticipate a more user-friendly DSS compared to staff specialists.

Additionally for underground mines:

The specification of the DSS, the database and the decision-making process for underground mines should not differ significantly from open pit mines. On the contrary, the system should ultimately be able to work independently of the respective location only based on the parameters and data uploaded to the system. It therefore makes sense to specify and configure the SDSS directly with the maximum (3D) requirements instead of having to upscale them again afterwards.

While there are no changes for the "User" part, slight changes make sense for the “Database”, "Qualitative Model", "Knowledge Base" and "Graphical User Interface" parts:

Database: It should be able to store large scale 3D-data with high performance and handle complex spatial analysis according to the needs of the DSS.

Model Base: The model base must be expanded accordingly for underground mines. Depending on the depth, local geology, type of mining, use of backfill, etc., there are different manifestations on the surface, which have a decisive influence on risk management and the DSS. Depending on the application, simple mathematical formulas or highly complex numerical methods are used.

Knowledge Base: Since, in contrast to the open pit, it is not possible to see the mines directly, the processing of historical data, maps and mining documentation is essential here. Particularly in the case of very old mines or mines that are very close to the surface, great care must be taken here. Therefore, the knowledge base has to be adjusted accordingly.

Graphical User Interface: While a simple 2D or 2.5D view is sufficient for displaying the results for open pit mines, a full 3D underground view should also be provided for underground mines, depending on the user group. This enables a more intuitive understanding of the process and facilitates the interpretation and any necessary correction of results. Due to the significant increase in hardware requirements for visualization, computationally intensive processes such as rendering, caching, etc. should run on the server infrastructure.

In the context of the POMHAZ project, the interface users can include various stakeholders and entities involved in or affected by the project in the different European countries. These users interact with the system, contributing and extracting information based on their roles and responsibilities. The potential interface users for the POMHAZ project can include:

- Researchers and Scientists
- Land Planners and Urban Developers
- Environmental Agencies
- Policy Makers and Government Officials
- Local Communities
- GIS Specialists and Technicians
- General Public
- Consultants and Advisors
- Educational Institutions

6 Selection of a suitable database system

Selecting a suitable database system for post-mining Multi-Hazard evaluation for land-planning to build a Decision Support System (DSS) is crucial, as it impacts data management, retrieval, and analysis. The choice of database system depends on factors such as data volume, complexity, scalability, and specific project requirements. Here are several suitable options:

- **Relational Database Management System (RDBMS):**

PostgreSQL with PostGIS Extension: PostgreSQL is a powerful open-source RDBMS known for its robust spatial data capabilities through the PostGIS extension. It's suitable for managing and analyzing complex geospatial data. For all decision makers with standard Criterion

MySQL with Spatial Extensions: MySQL, another open-source RDBMS, offers spatial extensions for handling geospatial data efficiently. It's a good choice for smaller to mid-sized projects.

Microsoft SQL Server: For organizations already using the Microsoft technology stack, SQL Server provides excellent spatial data support, making it convenient for integration.

- **NoSQL Databases:**

MongoDB: MongoDB is a popular NoSQL database that can handle unstructured or semi-structured geospatial data efficiently. It's suitable for projects with dynamic data needs.

Cassandra: Cassandra is a distributed NoSQL database suitable for handling large volumes of time-series and spatial data commonly used in environmental monitoring for post-mining assessments.

- **Spatial Databases:**

SpatiaLite: SpatiaLite is an open-source spatial database that is well-suited for projects with moderate spatial data requirements, offering GIS functionality and SQL support.

Oracle Spatial: Oracle Spatial is a commercial option for large-scale projects with extensive spatial data needs, offering advanced geospatial data management capabilities.

- **Geospatial Data Warehouses**

Data warehousing solutions: For extensive data analytics and reporting, consider building a geospatial data warehouse using tools like Amazon Redshift, Google BigQuery, or Snowflake. These data warehousing platforms can handle large datasets and complex queries.

- **Graph Databases:**

Neo4j: If the project involves analyzing complex relationships between geospatial entities (e.g., ecological networks or geological strata), a graph database like Neo4j may be suitable for representing and querying such data.

- **Time-Series Databases:**

InfluxDB: When dealing with time-series data in post-mining assessments, InfluxDB is a specialized database for storing and querying temporal data.

The following table provides an overview of each database system's strengths and suitability for different project requirements:

This comparative table 2 outlines the key strengths and suitability of each database system based on the specific requirements and characteristics of the post-mining multi-hazards evaluation for land-planning. The information provided can assist in selecting the most appropriate database system that aligns with the project's data management, analysis, and reporting needs.

Table 2 - comparative table of database systems for post-mining multi-hazards evaluation for land-planning

Database System	**Strengths and Suitability**
Relational Database Management System (RDBMS)	- PostgreSQL with PostGIS Extension: Robust spatial data capabilities, suitable for managing complex geospatial data. Suitable for large-scale projects requiring advanced spatial analysis and management capabilities.
	- MySQL with Spatial Extensions: Efficient handling of smaller to mid-sized projects. Suitable for projects with moderate geospatial data requirements.
	- Microsoft SQL Server: Seamless integration with the Microsoft technology stack. Excellent spatial data support for medium to large-scale projects.
NoSQL Databases	- MongoDB: Efficient handling of unstructured or semi-structured geospatial data. Suitable for dynamic data needs and projects with flexible data structures.
	- Cassandra: Distributed database suitable for managing large volumes of time-series and spatial data. Ideal for handling complex environmental monitoring data.
Spatial Databases	- SpatiaLite: Open-source option with GIS functionality and SQL support. Suitable for projects with moderate spatial data requirements and a need for basic geospatial analysis.
	- Oracle Spatial: Commercial option with advanced geospatial data management capabilities. Suitable for large-scale projects with extensive spatial data requirements and complex analysis needs.
Geospatial Data Warehouses	- Data warehousing solutions (e.g., Amazon Redshift, Google BigQuery, Snowflake): Suitable for extensive data analytics and reporting. Ideal for handling large datasets and complex queries in the context of post-mining multi-hazards evaluation.
Graph Databases	- Neo4j: Suitable for analyzing complex relationships between geospatial entities, such as ecological networks or geological strata. Ideal for representing and querying intricate spatial data networks.
Time-Series Databases	- InfluxDB: Specialized database for storing and querying time-series data. Suitable for managing temporal data in post-mining assessments and facilitating time-based analysis.

Considerations for choosing the right database system include data volume, data complexity, the need for spatial indexing and analysis (which is the POMHAZ case), and the compatibility with existing infrastructure and tools. Ultimately, the choice should align with the specific requirements of the Post-Mining Hazard Assessment project and the capabilities required by the Decision Support System.

7 Front ends for interaction with stakeholders

In a Decision Support System (DSS) for post-mining Multi-Hazard evaluation for land-planning, it's essential to provide a variety of user-friendly front-end interfaces to accommodate a broad range of stakeholders. Here are some common front-end interaction options:

a. Web-Based Dashboards:

Web-based dashboards are accessible via web browsers, making them highly versatile for stakeholders who need to access the DSS from different locations. They often include interactive visualizations, charts, and maps to present data and insights effectively.

b. Mobile Applications:

Mobile apps provide flexibility, allowing stakeholders to access the DSS on their smartphones and tablets. This is particularly useful for field personnel, inspectors, and decision-makers who need real-time information while on-site.

c. Desktop Applications:

Desktop applications offer more extensive functionality and data processing capabilities. They are suitable for technical experts and analysts who require in-depth data manipulation and modeling features.

d. Geographic Information Systems (GIS):

Leveraging GIS interfaces allows users to work with geospatial data directly. Stakeholders involved in spatial analysis and land management can benefit from GIS front-ends that offer advanced mapping, geoprocessing, and spatial query tools.

e. Command-Line Interfaces (CLI):

For technically oriented users, a CLI can provide direct access to advanced functionalities and data manipulation. CLI interfaces are often used by data scientists and analysts who prefer working with scripts.

f. Chatbots and Conversational Interfaces:

Chatbots provide a conversational way to interact with the DSS. They can answer queries, provide data summaries, and guide stakeholders in finding relevant information. This is particularly useful for stakeholders who prefer a more natural language interaction.

g. Customized Reporting Tools:

Reporting tools enable stakeholders to generate customized reports and summaries based on their specific needs. These tools can offer various report templates and export options.

h. Interactive Data Visualization Platforms:

These platforms allow stakeholders to explore data through interactive visualizations, graphs, and charts. They can be helpful for non-technical stakeholders to gain insights quickly.

The choice of front-end interfaces should consider the diverse needs and technical proficiencies of the stakeholders involved in post-mining assessment, from technical experts and analysts to policymakers, environmentalists, and community members. Providing a variety of options ensures that the DSS can be effectively used by a wide range of users.

The following comparative table (Table 3) provides an overview of the key features and suitability of different front-end interaction options for stakeholders involved in post-mining Multi-Hazards evaluation for land-planning.

Table 3 - comparative table for front-end interaction options for post-mining Multi-Hazards evaluation for land-planning

Front-End	Key Features and Suitability
Web-Based Dashboards	- Accessibility from different locations. - Interactive visualizations, charts, and maps for effective data presentation. -Suitable for stakeholders who require easy access to summarized data and insights from various locations.
Mobile Applications	- Flexibility and real-time access for field personnel and decision-makers. - Useful for stakeholders who require on-site access to real-time data and insights on their smartphones and tablets.
Desktop Applications	- Extensive functionality and data processing capabilities. - Ideal for technical experts and analysts who require in-depth data manipulation, modeling features, and advanced analytical tools.
Geographic Information Systems (GIS)	- Advanced mapping, geoprocessing, and spatial query tools. - Beneficial for stakeholders involved in spatial analysis and land management, requiring direct interaction with geospatial data for comprehensive assessments and decision-making.
Command-Line Interfaces (CLI)	- Direct access to advanced functionalities and data manipulation. - Suitable for technically oriented users, data scientists, and analysts familiar with command-line operations and scripting.
Chatbots and Conversational Interfaces	- Natural language interaction for answering queries and providing data summaries. - Helpful for stakeholders preferring conversational interactions and quick access to specific information through a user-friendly interface.
Customized Reporting Tools	- Generation of customized reports and summaries. - Offers various report templates and export options for stakeholders requiring tailored reports and comprehensive summaries to support decision-making processes.
Interactive Data Visualization Platforms	- Exploration of data through interactive visualizations, graphs, and charts. - Useful for non-technical stakeholders to gain quick insights and understand complex data through user-friendly visual representations.

8 Required hardware

Creating and developing a Decision Support System (DSS) based on Geographic Information System (GIS) for post-mining hazards assessment involves selecting appropriate hardware to support the system's computational and data processing needs. The choice of hardware should be aligned with the POMHAZ-project's scale, complexity, and data requirements. Here's a detailed overview of the hardware components commonly used for this purpose:

1. **Workstation or Server**:
   - Central Processing Unit (CPU): Depending on the computational demands of your GIS and DSS, consider multi-core processors with sufficient clock speed to handle data processing and analysis efficiently.

- Memory (RAM): GIS applications are memory-intensive. Adequate RAM, typically ranging from 16GB to 64GB or more, is essential for smooth operation, especially when working with large datasets.
- Storage: Opt for fast and capacious storage, including solid-state drives (SSD) for faster data retrieval and hard disk drives (HDD) for long-term data storage. Utilize RAID configurations for data redundancy and security.
- Graphics Processing Unit (GPU): High-end GPUs may be necessary for 3D visualization, spatial analysis, and rendering, especially in large-scale GIS projects.

2. **Multiple Monitors:**
   - Multiple displays enhance productivity by providing more screen real estate for data visualization, map viewing, and concurrent data analysis.
3. **Network Infrastructure:**
   - High-speed, reliable networking infrastructure is crucial for seamless data transfer, especially when collaborating on GIS projects with remote teams. Gigabit Ethernet or faster connections are common.
4. **Mobile Devices:**
   - For field data collection and real-time updates, consider mobile devices (tablets, smartphones, rugged field laptops) that can integrate with the central GIS-DSS system.
5. **Data Storage and Backup:**
   - Implement network-attached storage (NAS) or storage area network (SAN) solutions for centralized data storage and backup. Use redundant storage systems for data resilience.
6. **Power Backup:**
   - Uninterruptible Power Supplies (UPS) or power generators are essential to prevent data loss due to unexpected power outages.
7. **Server Hardware (if applicable):**
   - For large-scale enterprise projects, dedicated servers with multiple CPUs, extensive RAM, and storage systems like Network-Attached Storage (NAS) or Storage Area Network (SAN) may be necessary to manage GIS databases and support concurrent user access.
8. **Cloud Computing:**
   - Cloud-based infrastructure (e.g., Amazon Web Services, Microsoft Azure, Google Cloud) can be a flexible and scalable solution for GIS-DSS applications. These platforms offer a wide range of computing and storage resources, making them well-suited for handling dynamic workloads and remote data access.
9. **Virtual Reality (VR) Hardware (if implementing VR visualization):**
   - If the project requires VR-based visualization, you will need VR headsets, controllers, and a computer with sufficient GPU and processing power to support VR applications.

The hardware choices should align with the specific needs and scale of the proposed DSS for the POMHAZ project. It's crucial to consider the computational demands of your GIS software, the size of the datasets will be working with, and the level of real-time processing required for post-mining hazards assessment. Additionally, it is worth to mention that hardware requirements may evolve as the project scales and technology advances.

9 Conclusion

The POMHAZ project has meticulously designed the requirements to develop a GIS-based Decision Support System (DSS) in order to address the multifaceted challenges of post-mining hazards.

This report is focused on the requirement of the DSS for post-mine multi-hazard risk assessment.

Key elements include specific data formats like GeoTIFF and shapefiles, rigorous data pre-processing steps, and a comprehensive DSS toolbox featuring databases, qualitative models, and a user-friendly interface. Additionally, the project emphasizes stakeholder engagement through varied front-end interfaces and selects suitable database systems and hardware configurations tailored to its unique requirements.

Overall, these strategic choices aim to create a robust, flexible, and effective tool for post-mining hazard assessment.

As the POMHAZ project advances, the next crucial step, still within Work Package 4 (WP4), involves determining specifications for interfaces and the database system. This preparation is integral to the subsequent implementation of the Decision Support System (DSS).

What is PoMHaz?

The goal of PoMHaz is to improve methodological and practical knowledge for the assessment and management of multi-hazards, at the scale of a coal mining basin, through the active and continuous engagement of key stakeholders involved in or affected by post-mining activities.

PoMHaz is a project funded by the Research Fund for Coal and Steel programme.

Further information can be found under https://www.pomhaz-rfcs.eu.

For feedback on the PoMHaz project or the published deliverables, please contact contact@pomhaz-rfcs.eu.

The PoMHaz Consortium