Post-Mining Multi-Hazards evaluation for land-planning

PoMHaz

WP 3: Post-mining risks assessment methodology and decision support systems

D10 - Deliverable 3.2: DSS specifications related to post-mining hazard management

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Acronyms

AEPO	Approval of Environmental Conditions
DB	Database
DBMS	Database Management System
CERTH	Centre for Research & Technology Hellas
CLI	Command Line Interface
CPU	Central Processing Unit
CRS	Coordinate Reference System
CSV	Comma-separated values
DEM	Digital Elevation Model
DHHN	Deutsches Haupthöhennetz
DMT-THGA	DMT-Gesellschaft für Lehre und Bildung mbH – Technische Hochschule Georg Agricola University
DSS	Decision Support System
EPSG	European Petroleum Survey Group
ETRS89	European Terrestrial Reference System 1989
FGDC	Federal Geographic Data Committee
GDB	Geodatabase
GDPR	General Data Protection Regulation
GeoJSON	Geographic JavaScript Object Notation
GeoTIFF	Geographic Tag Image File Format
GGRS87	Hellenic Geodetic Reference System 1987
GIG	Główny Instytut Górnictwa
GIS	Geographic information system
GPU	Graphics Processing Unit
GUI	Graphical User Interface
Ineris	Institut national de l'environnement industriel et des risques
ISO	International Organization for Standardization
KML	Keyhole Markup Language
NAS	Network-Attached Storage
OGC	Open Geospatial Consortium
POMHAZ	POst-mining Multi-Hazards evaluation for land-planning
PPC	Public Power Company
RAM	Random-Access Memory
RDBMS	Relational Database Management System
RGF93	Réseau Géodésique Français 1993
SAN	Storage Area Network
sDSS	Spatial Decision Support System
SQL	Structured Query Language
SHP	Shapefile
TU BAF	Technische Universität Bergakademie Freiberg
UAV	Unmanned Aerial Vehicle
UI	User Interface
UPS	Uninterruptible Power Supply
UTM	Universal Transverse Mercator
VR	Virtual Reality

WFS	Web Feature Service
WMS	Web Map Service

Executive summary

This deliverable is part of the POMHAZ project, Post-Mining Multi-Hazards evaluation for land-planning. The main objective of POMHAZ is to identify the interaction between the post-mining hazards for coalmines in Europe and to develop tools for facilitate the management of the post-mining hazards in coal region.

In the POMHAZ project, the present deliverable is part of the WP3 that is dedicated to post-mining risk assessment methodology and decision support systems. This WP provides both methodology for assessing post-mining risks and the tools for decision-makers and coal communities facing multi-hazards and multi-risks. This deliverable is related to Task 3.3 “ Development of a DSS for Risk management ”.

The deliverable focuses on the functional and non-functional requirements of the DSS, including its operational capabilities for integrating diverse datasets, analyzing risk scenarios, and supporting informed decision-making. It emphasizes the system's ability to present complex data in accessible formats, such as maps and reports, ensuring its usability by a wide range of stakeholders with varying technical expertise. Furthermore, it addresses constraints in development and usage, including data quality, scalability, compliance with legal and regulatory frameworks, and the need for user training to facilitate widespread adoption.

Deliverable 3.2 also highlights the DSS's planned interoperability with other modules of the POMHAZ project, ensuring seamless integration with GIS platforms and other project components. By establishing the basis for future development phases, this document guarantees that the DSS will be a robust, reliable, and adaptable instrument for post-mining hazard management, contributing to safer land use planning and sustainable redevelopment in affected regions.

1 Introduction

The POMHAZ project aims to enhance hazard assessment and risk management for abandoned coalmines. Its primary goal is to advance methodological knowledge for effectively conducting multi-hazard analyses at the scale of a mining basin, with particular focus on the key hazards associated with post-mining activities [1]. The primary hazards associated with post-mining activities include ground subsidence, contamination of groundwater, soil instability, gas emissions, and underground/surface water pollution [2,3]. These hazards can have significant impacts on urban development, leading to issues such as damage to infrastructure, compromised public safety, and the potential contamination of water sources [4–10]. Addressing these complex risks requires a systematic approach like a Decision Support System (DSS) that integrates various data sources, models hazard interactions, and provides clear decision-making frameworks for effective risk management [11–13]. It aims to:

- **Identify and analyze hazards**: It will scrutinize the hazards of abandoned coalmines in Europe, their interplay, and the resultant impacts on urban development. This examination will utilize multi-criteria approaches and a Decision Support System (DSS).
- **Develop methodology and tools**: The project will create an operational methodology and Geographic Information System (GIS) tools to offer a comprehensive depiction of the hazards.
- **Application to real case studies**: The developed methodology will be applied to European case studies, enabling the practical implementation of the project's findings.

In the context of the project, this document serves a critical role in the development process of the Decision Support System (DSS). Under the leadership of DMT-THGA and with inputs from partners Ineris and TU BAF, the document compiles and analyzes the DSS's objectives, functional and non-functional requirements, as well as constraints on its development and use:

1. **Identifying DSS specifications**: As the first stage in the DSS development, the document outlines the specifications of the DSS, covering what it is intended to achieve and how it will operate in practice.
2. **Clarifying DSS objectives**: It specifies the intended use of the DSS, the types of decision outcomes it supports, and the decision-making levels it caters to. This includes detailing how the DSS will help in managing post-mining hazards.
3. **Functional and non-functional requirements**: The document defines the operational functionalities of the DSS (functional requirements) and describes its behavior in the operational environment, including reliability, performance and security (non-functional requirements).
4. **Integrating partner knowledge and case studies**: It incorporates insights from all project partners and evaluate the POMHAZ case studies to ensure that the DSS is well suited to the varied geographical areas and decision-making processes involved in post-mining hazard management.

In this project, the proposed DSS will support planning and decision-making processes by providing relevant and scientifically sound information to a wide range of stakeholders as a useful tool leading to effective management by providing guidance and support, alternatives, options and technology comparisons within a reasonable timeframe. These stakeholders can range from local authorities, mining companies, cities and communities.

2 The DSS in the overall concept of the project

The POMHAZ project aims to improve hazard assessment and risk management for abandoned coalmines. This involves developing and implementing a Decision Support System (DSS) with several key deliverables and milestones.

2.1 Purpose and Scope of the DSS

The DSS is designed to support a range of stakeholders, including urban planners, environmental agencies, and local authorities, by providing a comprehensive view of hazard interactions in post-mining areas. Its main purpose is to aid in **informed decision-making** regarding land use, risk mitigation, and sustainable urban development in former coal mining regions. By integrating complex data from multiple sources, the DSS will help identify high-risk zones, optimize resource allocation, and recommend appropriate hazard management strategies.

Specifically, the DSS for post-mining risk management aims to support decisions in the following areas:

- **Hazard mitigation strategies**: Recommending measures to minimize the impact of post-mining hazards such as ground subsidence, water contamination, and gas emissions.
- **Site selection for new developments**: Identifying suitable areas for infrastructure projects based on risk levels.
- **Structure-Infrastructure planning**: Assisting in the planning and maintenance of mining regions structures and infrastructures: roads, buildings, and other infrastructure in post-mining regions.
- **Emergency response planning**: Providing risk scenarios and predictive models to guide emergency preparedness and response efforts.

By addressing these decision-making areas, the DSS will enable stakeholders to proactively manage post-mining risks and contribute to the sustainable redevelopment of affected regions.

2.2 Key deliverables and milestones

1. **Development of methodological knowledge**: The project seeks to enhance the approach to conducting multi-hazard analyses in mining basins. This encompasses understanding the complex interplay of various post-mining hazards and their impacts on urban development.
2. **Decision Support System (DSS)**: A significant deliverable is the creation of a DSS. This system will incorporate multi-criteria approaches to aid in decision-making processes regarding hazard assessment and risk management.
3. **Operational methodology and GIS tools**: The project plans to develop a comprehensive methodology and Geographic Information System (GIS) tools. These tools are intended to provide a global perspective of the hazards associated with abandoned coalmines.
4. **Application to case studies**: Applying the developed methodology and tools to real-world case studies is a crucial milestone. This step will validate the effectiveness of the DSS and the methodologies in practical scenarios.

2.3 Decision Support System (DSS)

The DSS is a central component in achieving POMHAZ's objectives in post-mining hazard management, according to the project plan. Its development and successful implementation are integral to achieving the project's broader goals of sustainable and informed decision-making in areas affected by abandoned coal and lignite mines. The DSS aims to facilitate well-informed decisions based on a thorough analysis of complex data, including natural and post-mining hazards and other risk external factors. These decisions could range from high-level strategic decisions by urban planners and policymakers to more operational decisions by local authorities and hazard management teams.

Deliverable D3.2 establishes the detailed specifications for the DSS, defining the functionalities, data sources, interfaces, and constraints that guide the development and implementation phases. In Deliverable D3.3, the implementation of the specific DSS for project POMHAZ will be explained in detail, including a documentation on its usage. D4.2, D4.3 and D4.4 are dedicated to the linking of DSS and GIS system and the validation of the system, while D5.3 will test all component on real case studies.

This deliverable also outlines the specific user requirements derived from stakeholder consultations, ensuring that the DSS meets the needs of all intended users. Additionally, it provides a roadmap for testing and validation of the DSS to ensure it is fit for purpose in real-world applications.

2.4 Interaction with other modules of the project

The Decision Support System (DSS) will have multiple points of contact and active interfaces with other parts of the project, making it a central component. Data for the decision-making process is sourced from various channels, including the graphical user interface (GUI, e.g. weights for the process), GIS (e.g. hazard maps), knowledge database (e.g. information on hazards or process documentation), model database (e.g. models for calculating risk classes), and open data sources (e.g. elevation models, if not otherwise available). Figure 1 provides a schematic representation of these interfaces.

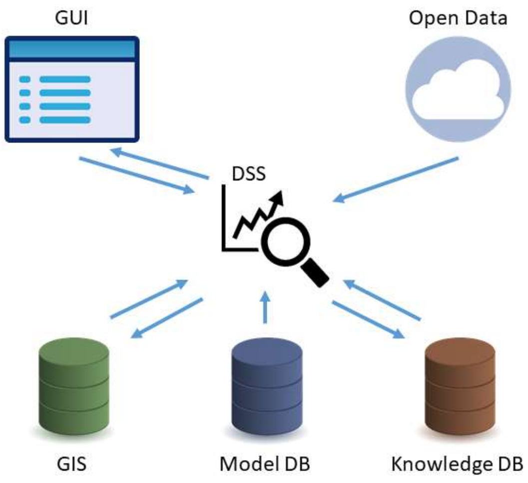

Figure 1: Interactions of the DSS tool with other modules in the POMHAZ project, highly simplified representation.

There will also be interfaces in the opposite direction. The DSS output will be presented to the user through the GUI in different formats such as maps, reports, and diagrams. Additionally, the analysis results will be written back to the corresponding databases, enabling an iterative process with modified parameters.

To ensure maximum interoperability between GIS, DSS and GUI, the same programming languages and database systems should be used wherever possible. Python is ideal for creating the individual tools, as many freely available libraries with GIS and analysis functions are already available for this purpose. The databases (Knowledge Database, Model Database) could run on PostgreSQL; the PostGIS extension exists for the geodatabase in the GIS.

3 Literature review

A Decision Support System (DSS) is a computer-based information system designed to assist decision-makers by analyzing data and generating informed decisions [14–17]. These systems are crucial across various industries such as disaster management, healthcare, finance, and logistics, providing structure, analysis, and optimization for complex decision-making processes. Key components of DSS include:

- **Database Management Systems (DBMS)**: These systems store and manage relevant data, providing the foundational information needed for effective decision-making. A well-designed DBMS allows for efficient access to large datasets, which is essential for accurate analysis in real time.
- **Model-Based Components**: These components facilitate data analysis through the use of algorithms, simulations, and mathematical models. By leveraging these models, DSS can generate potential scenarios and predictions, which are particularly valuable in uncertain or high-stakes environments.
- **User Interfaces (UI)**: The UI is how decision-makers interact with the system, access reports, visualize results, and run simulations. A well-designed UI enables users to intuitively access critical insights, making the decision process smoother and more effective.

DSS are applied for data analysis, simulation of scenarios, and risk management, proving critical in environments like healthcare, disaster management, and finance. For instance, in healthcare, DSS are used to optimize resource allocation, guide diagnostic decisions, and assist in treatment planning. In finance, these systems are used to manage risks, predict market trends, and provide insights for investment strategies [18–21].

One specific type of DSS is the Spatial Decision Support System (sDSS), which integrates geographic or spatial data for decision-making [22]. This specialization of DSS has proven invaluable in fields such as urban planning, emergency response, and environmental management. Sugumaran and DeGroote's book (2011) [22], *"Spatial Decision Support Systems: Principles and Practices"*, offers a detailed exploration of sDSS, including how spatial analysis can improve decision outcomes in complex geographic contexts. For example, sDSS can help city planners assess the suitability of land for development, assist emergency services in allocating resources during a disaster, or support environmental managers in conserving sensitive ecosystems.

Additionally, a recent review by Elkady et al. (2024) [23] titled *"Decision-making for community resilience: A review of decision support systems and their applications"* provides a comprehensive overview of how DSS, including sDSS, have been applied across various sectors to enhance community resilience. Sahar emphasizes the role of DSS in supporting complex decision-making, especially during emergencies where rapid, well-informed decisions are crucial. This review highlights several case studies where DSS have been implemented to mitigate disaster impacts and improve community preparedness, reinforcing the systems' relevance in public safety and resilience initiatives.

Further, several significant RFCS projects have advanced knowledge in hazard assessment and risk management, which are highly relevant to the development of DSS in post-mining contexts:

- **RFCS-CT-2007-00004 (PRESIDENCE)**: This project focused on predicting and monitoring subsidence hazards above coal mines. The tools developed, such as telemetry systems and laser-scanning techniques, can be valuable for identifying subsidence risks in abandoned coal mines.
- **RFCR-CT-2010-00014 (MISSTER)**: MISSTER contributed to the security of mine shafts by enhancing the identification of failure modes, particularly those that lead to sinkholes, through laboratory investigations and numerical modeling.
- **RFCR-CT-2012-00003 (COMEX)**: This project addressed optimizing mine design and reducing the impact of ground movement hazards. The advanced geotechnical modeling techniques for subsided rock developed during COMEX can complement the multi-hazard assessment capabilities of DSS.
- **RFCR-CT-2015-0004 (MERIDA)**: MERIDA dealt with managing environmental risks during and after mine closure. The methodologies from MERIDA for hazard interactions provide a foundation for multi-hazard analysis, aligning well with the objectives of DSS in managing post-mining risks.
- **RFCS Project TEXMIN 847250 (2019)**: TEXMIN explored the impact of extreme weather events on mining operations. The findings regarding the influence of climate change and extreme weather on post-mining landscapes are crucial for incorporating environmental changes into DSS.
- **RFCS Project METHENERGY PLUS 754077 (2017):** This project examined methane recovery in coal mines. The techniques developed in METHENERGY PLUS are significant for assessing and managing gas emissions from abandoned mines, which can be integrated into the hazard analysis of the DSS.

Looking towards future advancements, the integration of artificial intelligence (AI) and real-time data processing presents significant potential for DSS. AI can enhance predictive capabilities by learning from historical data and recognizing patterns that might not be immediately apparent to human decision-makers. When combined with real-time processing, AI-driven DSS could provide faster and more precise insights, allowing for adaptive decision-making in rapidly changing situations—such as tracking the spread of an infectious disease, responding to financial market fluctuations, or managing resources during a natural disaster.

By expanding the literature review and referencing works such as Sugumaran and DeGroote's foundational book on sDSS [22], as well as Elkady's recent review of DSS applications [23], alongside insights from various European projects, we can better understand both the current utility and future potential of these systems. The ongoing evolution of DSS, driven by technological advancements, continues to make them a cornerstone of effective decision-making in increasingly complex environments.

4 Summary of questionnaire responses

To meet the requirements of all project partners and describe the specifications of the DSS, TU BAF created a questionnaire for Deliverable D4.1 (Report on system requirements, system design and architecture) with the support of DMT-THGA. Three partners with case studies according to the project proposal answered the questionnaire by the extended submission date. The synthesis of key points from the answered questionnaires provides valuable insights into the specifications for the DSS and GIS for post-mining hazard management. The following is a comparative analysis of the responses from **DMT-THGA**, **Ineris**, and **PPC**, highlighting both their differences and commonalities.

4.1 Coordinate Reference System (CRS) and geospatial data formats

- **DMT-THGA**: ETRS89/UTM32N DHHN2016. Data formats include different vector (e.g. .shp) and raster data formats (e.g. GeoTIFF).
- **Ineris**: RGF93 EPSG 2154, compatible with ETRS89. Data formats are shapefile (.shp) and GeoJSON.
- **PPC**: GGRS87/Greek Grid, compatible with ETRS89. Data formats include shapefile (.shp) and Keyhole Markup Language (.kml).

→ All of these can be easily transformed to a common format and CRS.

4.2 Data licensing and restrictions

- **DMT-THGA**: No restrictions, data used in the case study is publicly available.
- **Ineris**: Mining data is not publicly accessible at the study stage, requiring authorization from state services.
- **PPC**: Some data published in papers and public Environmental Permitting Approval (AEPO). Raw data provided after administration approval.

→ The data restrictions are not affecting their use in the project environment.

4.3 Spatial, temporal, and spectral resolution

- **DMT-THGA**: High-resolution vector data, historical maps dating back to the mid-19th century, and supportive data depending on the sensor.
- **Ineris**: Vector format maps with long-term behavior analysis over 100 years.
- **PPC**: Both raster and vectorial representation, with long-term temporal resolution.

→ Spatial, temporal and spectral resolution suit the projects scope.

4.4 Attribute schema and metadata

- All partners will include attributes where applicable and metadata if available.

4.5 Focus of risks and data types

- **DMT-THGA**: Focus on sinkholes, hydrological issues, environmental pollution, and gas emissions. Various types of data, including historical maps, DEM, land use, and geodata.
- **Ineris**: Emphasis on ground movements like subsidence and sinkholes. Data includes mining activities, environmental data, topography, etc.

- **PPC**: Focused on ground movement. Data encompasses DEM, land use patterns, geological, geotechnical, and hydrogeological data.

→ The provided data correlates with the focus of the risks in the case study areas.

4.6 IT-Infrastructure, GIS Software, and User Interface/API Needs

- **DMT-THGA**: GIS with a database backend, backup storage, and webserver as frontend. Uses ArcGIS Pro, ArcGIS Online, QGIS and Geoserver.
- **Ineris**: IT infrastructures are shared at the national level. Uses QGIS and requires a web interface for visualization.
- **PPC**: Needs cloud storage and uses QGIS open source. Requires Windows API for risk assessment visualization.

→ The software is interoperable, needs for IT-Infrastructure and APIs can be met.

4.7 Commonalities and Differences

- **Commonalities:** All partners emphasize the importance of interoperable CRS and geospatial data formats. Open-Source software and Open Data are widely used.
- **Differences**: Data accessibility and licensing vary among partners. DMT-THGA has no restrictions on data use, due to Open Data policies and the old age of the adits to be examined. Ineris and PPC have certain limitations, that will however not affect the use in the project.

5 Functional Requirements of the DSS

In order for the DSS to function as intended, it is essential to consider a range of functional requirements during the design process. These requirements were derived from a synthesis of literature, the project proposal, and the project consortium.

5.1 Operational Functionalities of the DSS

- **Data Integration and Management:** Ability to integrate and manage diverse data sets, including topographical, geological, hydrological and remote sensing data (e.g. Land Use/Land Cover or elevation models derived from satellite images). Efficient handling, homogenization and reclassification of vector and raster data with various formats.
- **Risk Assessment and Analysis:** Functionality to assess risks associated with post-mining, natural and technical hazards using multi-criteria analysis (e.g. -method). Capabilities for modeling and simulating different hazard scenarios and their potential impacts.
- **Decision Support Tools:** Tools for aiding decision-making, including scenario analysis, decision trees and cost-benefit analysis modules. Visualization tools for representing complex data in non-technical formats.
- **Reporting and Documentation:** Automated report generation that includes analysis results, decision logs, and methodology used. Documentation features to ensure transparency and traceability of decisions made using the DSS.
- **User Interface and Accessibility:** Intuitive and user-friendly interface usable by stakeholders with varying levels of technical expertise.

5.2 Requirements derived from project partners:

- **Customization and Scalability:**
    - The DSS should be customizable to suit the specific needs of different project partners and geographical areas.
    - Scalability to handle varying scales of analysis, from localized site-specific assessments to broader regional analyses.
- **Interoperability and Compatibility:**
    - Compatibility with existing systems and software used by project partners.
    - Interoperability with various GIS platforms and data formats.
- **Reliability and Accuracy:**
    - High reliability and accuracy in data processing and analysis.
    - Robust error-checking and validation mechanisms to ensure the integrity of the analysis.
- **Security and Data Privacy:**
    - Strong security protocols to protect sensitive data.
    - Roles/rights concept.
    - Compliance with data privacy laws and regulations, particularly in handling data related to urban development and individual properties.
- **Local and Regional Specificities:**
    - Incorporation of local and regional factors in risk assessment, acknowledging the unique characteristics of each geographical area and mine.

6 Non-Functional requirements of the DSS

Non-functional requirements are critical for ensuring the effectiveness, reliability, and user trust in the DSS. They encompass aspects like performance, security, and usability that define the quality of the system. The DSS in the POMHAZ project is designed to be a reliable and adaptable tool that meets various essential requirements for its efficient operation.

Firstly, the reliability and availability of the system are paramount. The system is designed to offer consistent performance with high transparency and minimal failures, ensuring that it remains available with minimal downtime for maintenance.

The DSS is designed to handle large datasets and complex analyses with efficiency and speed. The system requires efficient processing capabilities to ensure fast data analysis in a variety of scenarios. Usability, accessibility, and scalability are key aspects of the DSS interface. It is intuitive and user-friendly, accommodating users of varying technical expertise. Accessibility features are included to ensure wide-ranging stakeholder usability. The DSS is also built to accommodate growing data volumes and evolving analysis requirements, making it adaptable to changes in project scope or technological advancements.

The security measures in place are robust and effectively protect sensitive data from unauthorized access, breaches, and other cyber threats. User authentication, access controls, and data encryption protocols are firmly established. Strict adherence to data privacy and compliance is necessary, especially when dealing with personal, company, or public sensitive information. The mechanisms in place ensure that data usage complies with legal and ethical standards, such as the European General Data Protection Regulation (GDPR).

Interoperability is a key focus of the DSS, as it is compatible with various data formats and can seamlessly integrate with the project GIS and software used by project partners. This is facilitated by standardized data exchange protocols.

Comprehensive documentation covers the functionality, configuration, and maintenance of the system. Training materials or programs are provided to assist users in effectively utilizing the DSS. Disaster recovery and data backup plans are in place to ensure data integrity and system functionality in the event of unforeseen circumstances. Regular data backups are performed to prevent data loss and facilitate quick recovery. These features collectively ensure that the DSS is a reliable, efficient, user-friendly, and secure tool, capable of meeting the complex demands of post-mining hazard management.

7 DSS-Constraints in development and usage

In the development, use, and evolution of the DSS several constraints and limitations can arise. Understanding these challenges is crucial for devising effective strategies to mitigate their impact. Key constraints include:

1. **Technical Constraints**:

    - **Data Quality and Availability**: In some post-mining regions, relevant data may be scarce or outdated, affecting the accuracy of hazard assessments. Ensuring access to high-quality data is essential for the reliability of the DSS.

    - **Integration of Diverse Data Sources**: The DSS must integrate data from various formats and sources (e.g., GIS, databases, spreadsheets). Variability in data quality and format can pose challenges for seamless integration.

2. **Scalability and Flexibility Constraints**:

    - **System Performance**: As the volume of data increases, the DSS must maintain performance and response times. Scalability is necessary to accommodate expanding datasets and evolving analytical requirements.
    - **Adaptability to Changing Conditions**: The system should be flexible enough to incorporate new hazard data, methodologies, and user feedback as they arise.

3. **Legal and Regulatory Constraints**:

    - **Compliance with Data Protection Laws**: Adherence to regulations regarding data privacy (e.g., GDPR) is crucial, particularly when handling sensitive information related to individuals or communities affected by mining hazards.
    - **Environmental Regulations**: The DSS must comply with local and international environmental regulations when suggesting land use changes or risk mitigation strategies.

4. **User Acceptance and Training**:

    - **Resistance to Change**: Users accustomed to traditional methods may resist adopting the DSS. Comprehensive training and clear communication about the benefits of the system will be necessary to foster acceptance.
    - **Usability Issues**: The design of the user interface must accommodate users with varying levels of technical expertise to ensure effective engagement with the system.

5. **Interoperability with Existing Systems**:

    - **Compatibility with Current Tools**: The DSS must work seamlessly with existing software and systems used by stakeholders. Ensuring compatibility can be challenging and may require standardizing data formats and protocols.

By addressing these constraints proactively, the project team can develop targeted strategies to enhance the DSS's effectiveness and ensure its successful implementation in post-mining hazard management.

7.1 Technical constraints

In some post-mining regions, relevant data might be scarce or outdated, affecting the accuracy of hazard assessments. Historical data, remote sensing information, and local surveys may vary significantly in quality. Variability in data quality and format across different sources can pose integration challenges. Robust data validation and standardization processes will have to be implemented to ensure reliability. Techniques such as cross-validation with existing databases and adherence to established metadata standards will be critical. All data must be validated and homogenized in a preprocessing step before being integrated into the DSS.

7.2 Scalability and flexibility constraints

As data volume grows, the system might struggle to maintain performance metrics such as response time and processing speed. The DSS must be flexible to adapt to evolving hazard scenarios, data models, technical advancements, and user needs. It will be designed with scalability in mind, employing a modular architecture that allows for the independent upgrading of components. For instance, separate modules could handle data ingestion, analytical processing, and user reporting, facilitating updates and expansions without disrupting overall system functionality. Modular architecture and open-source libraries will be used to facilitate updates and expansions.

7.3 Legal and regulatory constraints

Compliance with data protection laws (such as GDPR) is critical when handling sensitive information. Different data types, such as personal data, company data, and municipal data, have varying confidentiality levels that must be respected. This is particularly important when sharing data across jurisdictions, which may have their own legal frameworks governing data protection. The DSS will have to comply with all relevant legal requirements, and clear data handling and sharing protocols, such as encryption standards and access control measures, will be established to safeguard sensitive information.

7.4 User acceptance and Training

Users accustomed to traditional methods may resist adopting a new system, necessitating extensive training to effectively utilize the DSS. The development of user-friendly interfaces will be crucial in fostering acceptance and enhancing the system's effectiveness. Comprehensive training programs, including workshops, online tutorials, and user manuals, will be provided. Moreover, engaging users early in the development process through feedback mechanisms will ensure that their needs and concerns are addressed, ultimately leading to a more intuitive and effective system.

7.5 Interoperability with existing systems

Ensuring that the DSS works seamlessly with existing software and systems used by stakeholders is a vital component of its design. The integration process will involve utilizing standard geodata formats and exchange protocols, such as those defined by the Open Geospatial Consortium (OGC), to facilitate interoperability. Additionally, open-source code will be leveraged to ensure that integration is both easy and transparent. The DSS will aim to integrate with existing GIS tools (e.g., ArcGIS, QGIS**)** and databases (e.g., PostgreSQL, MySQL) to provide a comprehensive risk management solution.

8 Integration and analysis of data Sources

The DSS has to be able to integrate and analyze different data sources, as indicated by the literature and questionnaire responses. This can include historical, topographic, geological, hydrological, socioeconomic and several other data sets in various format. Their integration and analysis will be explained in detail in POMHAZ deliverable D3.3.

9 IT Infrastructure and software requirements

Based on the "POMHAZ Deliverable D3.1" report, the IT infrastructure and software required for the DSS and GIS are comprehensive and multi-faceted. They include hardware, software, data formats, and various technologies necessary to support the system's functionalities.

9.1 Software requirements

- Geospatial Data Formats: Shapefile (.shp), GeoTIFF (.tif), and geodatabases like Esri File Geodatabases (.gdb) or Spatialized databases (.sqlite).
- Attribute Data Formats: Formats such as CSV and GeoJSON for encoding geospatial data.
- Database Systems: Options include relational database management systems (RDBMS) like PostgreSQL with PostGIS, MySQL with spatial extensions, NoSQL databases like MongoDB and Cassandra, and spatial databases like SpatiaLite and Oracle Spatial.
- Data Warehousing and Graph Databases: For extensive data analytics, reporting, and managing complex relationships between geospatial entities.
- Data Quality and Interoperability Standards: Adherence to metadata standards like ISO 19115 or FGDC, and utilization of data exchange formats like WMS, WFS, or KML.

9.2 DSS components

- Database: Functions as a repository for both historical and current data.
- Model Base: Houses quantitative, statistical, financial, optimization, or simulation models.
- Knowledge Base: Repository for specialized expertise.
- Graphical User Interface (GUI): For interaction between the user and the DSS.
- User: The individual or entity using the DSS for decision-making.

9.3 Front-End Interaction Options

- Web-Based Dashboards: For accessibility from different locations.
- Mobile Applications: For real-time access in the field.
- Desktop Applications: For in-depth data manipulation and modeling.
- GIS Interfaces: For direct work with geospatial data.
- Command-Line Interfaces (CLI): For advanced functionalities and data manipulation.
- Chatbots and Conversational Interfaces: For natural language interaction.
- Customized Reporting Tools: For generating tailored reports and summaries.
- Interactive Data Visualization Platforms: For non-technical stakeholders.

9.4 Hardware Requirements

- Workstation or Server: With adequate CPU, RAM, storage, and GPU capabilities.
- Multiple Monitors: For enhanced productivity.
- Network Infrastructure: For seamless data transfer.
- Mobile Devices: For field data collection.
- Data Storage and Backup: Implementing NAS or SAN solutions.
- Power Backup: UPS or power generators.
- Cloud Computing: For scalable and remote data access.

- VR Hardware: If VR-based visualization is required.

10 User Interface and Accessibility

The user interface of the Decision Support System should be designed to be intuitive, user-friendly, and accessible for a wide range of stakeholders. These stakeholders may include technical experts, decision-makers, and local authorities. To ensure effective use of the DSS, the following aspects should be considered:

- **Usability and Design**:
    - The UI should be structured clearly and easy to navigate.
    - Key features and tools should be easily accessible for the user.
    - Color schemes and icons must be consistent and comprehensible.

- **Adaptability**:
    - The UI should be flexible, allowing customization to meet the needs of different user groups.
    - Users with varying technical backgrounds should be able to adjust the complexity of displayed data and functionalities (e.g., expert mode vs. basic mode).

- **Accessibility**:
    - The system must be accessible to users with disabilities (e.g., visual impairments). This could be achieved through screen reader compatibility, adjustable contrast settings, and keyboard navigation support.

- **Multilingual Support**:
    - Since the DSS is intended for use by international partners, the UI should support multiple languages that are used in the European Union. Starting with English as a baseline, modern translation software can be used for translation to French, Greek, German and Polish e.g.

- **Interactive Visualizations**:
    - The system should provide various visualization options, such as interactive maps, charts, and reports, to present complex data and analyses in an understandable manner.
    - These visualizations should be easily customizable and exportable for use in reports and presentations.

- **Mobile Accessibility**:
    - A mobile version of the UI or a dedicated app should be considered to enable users to access the system on the go, particularly during on-site inspections.

Considering these aspects will ensure that the DSS is accessible, adaptable, and user-friendly for a broad audience, enhancing its overall effectiveness.

11 Conclusion

In conclusion, the POMHAZ project highlights the significance of a comprehensive Decision Support System (DSS) for managing post-mining hazards and associated risks. By integrating multi-hazard data and leveraging advanced methodologies, the DSS will provide a robust framework for informed decision-making. Moving forward, continued collaboration with stakeholders and the refinement of this system will ensure its applicability across diverse geographical areas, ultimately contributing to safer urban development and environmental protection.

In the POMHAZ project, the primary aim is to enhance hazard assessment and risk management in post-mining coal mine areas through the development of a Decision Support System (DSS). This innovative system integrates various data sources to facilitate informed decision-making, specifically tailored for post-mining contexts. The DSS is designed to focus on comprehensive multi-hazard analysis and support, emphasizing transparent and informed decision-making processes.

The system encompasses a wide array of operational functionalities, including advanced data integration, risk assessment, and interactive visualization tools. These are complemented by essential non-functional requirements such as reliability, performance, and stringent security measures. However, the development process faces several challenges, including technical limitations, varying data availability and quality, budget constraints, and the need for widespread user acceptance and training. A significant aspect of the DSS is its approach to data integration and analysis, where different methods are employed to ensure the integrity and quality of diverse datasets. The IT infrastructure and software requirements for the DSS are comprehensive, necessitating advanced hardware and software capabilities to manage and analyze large, complex datasets efficiently.

User interface and accessibility are also pivotal aspects of the DSS design. The system prioritizes an intuitive user interface and accessible features, ensuring ease of use for a diverse range of stakeholders, from technical experts to local community members.

Looking ahead, the next steps in the development process involve finalizing the DSS specifications, informed by ongoing stakeholder feedback. This will be followed by the prototyping and development phase, where an initial version of the DSS will be created. An iterative process of testing and refinement will be crucial, involving user feedback to identify and address areas for improvement. Comprehensive training materials and documentation will be developed to assist users in effectively utilizing the system.

The implementation phase will see the DSS deployed in a controlled environment, with gradual expansion and continuous monitoring of its performance and user feedback. Establishing ongoing support and maintenance systems is essential for the long-term viability of the DSS. Continuous evaluation and enhancement of the system will ensure it remains effective and adapts to evolving requirements and technological advancements.

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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.

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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