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Development of a seismic risk management system for Malmberget underground mine

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ABSTRACT

Mining of iron ore at increasing depth in the LKAB underground mine in Malmberget (MUJ) has lead to an increase in seismic activity in recent years. The Swedish legislation, unlike many other countries, does not require a Seismic Risk Management Plan (SRMP) for seismically active mines. The usefulness of and need for an SRMP has been recognized by the mine management, Due to the increasing problems with seismicity, in 2021 it was decided to start a project called Optimizing Seismic Risk Management MUJ (OSRM MUJ). The project's objectives encompassed the development of a globally standardized seismic risk management (SRM) process covering planning to execution, establishment of an SRM meeting framework for collaboration in MUJ, creation of monitoring routines, tools for transparent risk communication, and an inquiry into necessary personnel adjustments for required staffing modifications essential for the operation of the seismic risk management framework resulting from this project. The scope of this project was to identify all necessary practices for managing seismic risks within MUJ, develop routines for those that were lacking, and create a methodical approach for communicating information of seismic risks in the mine to all stakeholders across various mining processes. Workflows were developed that visually put the routines into context both logically and chronologically. The organized workflow management system was named Seismic Risk Management System MUJ (SRMS MUJ).

The paper describes the structure of the OSRM MUJ project and the SRMS MUJ, detailing their respective organizational frameworks and practices. Additionally, it clarifies the project's methodology and how it generated the observed outcomes.

1 INTRODUCTION

The Malmberget mine owned by LKAB (Sweden) is one of the largest iron ore underground mines in the world. It consists of about 20 orebodies, of which 11 are mined at present. The orebodies vary in size, shape and dip in addition to having different rock mechanical issues related to geology and extraction sequence. The mining method used in the larger orebodies is transverse sublevel caving, while longitudinal sublevel caving is used in some of the smaller orebodies. The increased mining depth in combination with the mining method has lead to an increase in seismic activity.

The Swedish legislation, unlike many other countries, does not require a Seismic Risk Management Plan (SRMP) for seismically active mines. Nonetheless, the usefulness of an SRMP to provide structure and guidance for managing seismic risk has been recognized by the mine management. Due to the increasing problems with seismicity, in 2021 it was decided to start a project called Optimizing Seismic Risk Management MUJ (OSRM MUJ). The project's objectives encompassed the development of a globally standardized seismic risk management (SRM) process covering planning to execution, establishment of an SRM meeting framework for collaboration in MUJ, creation of monitoring routines, tools for transparent risk communication, and an inquiry into necessary personnel adjustments for required staffing modifications essential for the operation of the seismic risk management framework resulting from this project.

2 PROJECT OVERVIEW

The scope of the OSRM project was to identify all necessary practices for managing seismic risks within MUJ, to develop routines if they were lacking, and create a methodical approach for communicating information of seismic risks in the mine to all stakeholders across various mining processes. The objectives were stated as

- Development of a Seismic Risk Management (SRM) process for the whole chain from mine planning to production at the world standard level.
- Establishment of a meeting structure and discussion forum for SRM in MUJ between seismic engineers and stakeholders
- Development of routines and working methods for seismic monitoring.
- Development of routines/tools for clear communication of seismic risks in MUJ.
- Investigation of need for additional personnel needed for new tasks that the project generates.
- Development of non-seismological tools and analyses.

The project objectives were segmented into three distinct subobjectives or phases building on each other.

The first phase consisted of groundwork, i.e. mapping the current status and identifying and prioritizing seismological and non-seismological practices needed for seismic risk management in MUJ (geology, scanning, blasting database, deformation, and stress monitoring etc.), as well as dividing up the work between the members of the team. The practices were organized into categories based on the frequency at which they were required, ranging from daily to bi-annually. Certain practices ended up in a "when necessary" category due to the absence of a predetermined frequency. The practices in these categories were then grouped into short-, medium- and long-term hazards. During some workshops, it became clear that a management system of some sort would be essential to monitor all these practices. The outcome of these workshops revealed the concept of systematically managing seismic risks through well-organized automated and pre-determined workflows and checklists, both before, during, and after specific mining operations and other scenarios where seismic risks needed evaluation across diverse mining procedures. In this phase a questionnaire was sent out to both operators and managers underground to get their view on a) risk management and b) current mine safety.

The other part of the mapping was compiling the current seismic risk management in MUJ (point zero for the project describing the current situation in MUJ).

When the seismological and non- seismological practices (measurements and analyses) needed for optimizing SRM in MUJ had been identified they were benchmarked to the practices defined in the study by ACG together with Newcrest "Seismic Risk management Practices in Underground Mines" (2023), see Figure 1. The ACG (2023) paper on seismic risk management practices was used as a starting point.

The second phase of the project was mainly developing the most critical routines and practices. Each routine contained the purpose of the task, who would do it, and in which stage of mining the task was needed. During the work of developing the routines an estimation was made of the resources required when all the routines were implemented. An add on to this phase was to formulate a complete SHMP for the mine, which extended the phase and project deadline with a few months.

In the third phase the workflows forming the seismic risk management system was developed through a number of workshops.

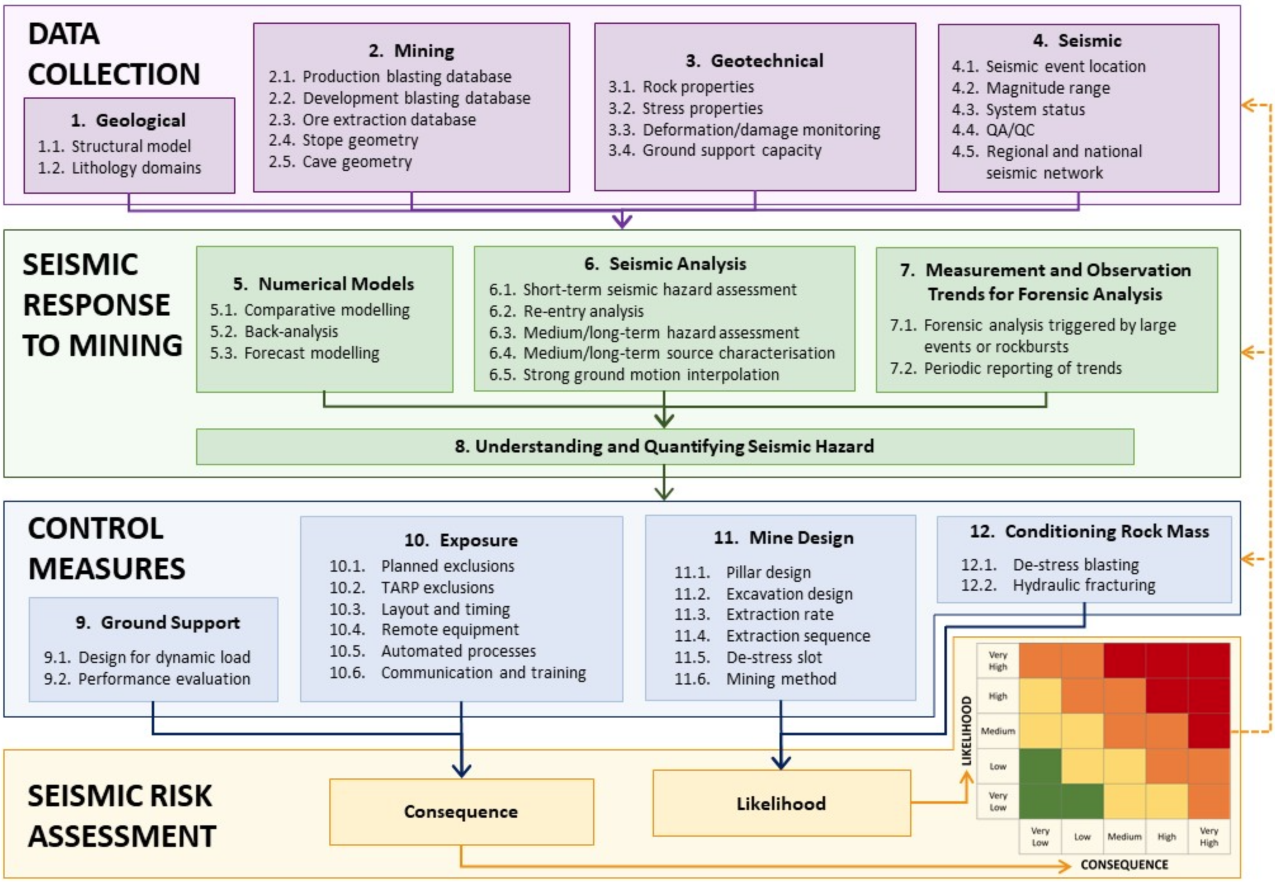

Figure 1 Seismic risk management flowchart (ACG, 2023).

3 METHODOLOGY

The OSRM MUJ project team adopted the Agile methodology, utilizing the Kanban framework for effective project management. They began with collaborative planning, dividing the project into three phases and creating a backlog. A digital Kanban board in Trello was used to visualize workflows, track tasks, and manage deadlines. Biweekly meetings ensured synchronization and discussion of progress and challenges, while continuous improvement was prioritized through regular reviews and feedback. The combination of Agile and Kanban led to increased transparency, collaboration, and efficient workflow management, enabling the team to adapt to changes, address issues promptly, and deliver valuable increments throughout the project lifecycle.

4 ORGANIZATION

The project was overseen by the project sponsor (Malmberget Mine Manager) and key resource managers, including the manager of the mine planning department and the head of the mine research and development department. The project team responsible for execution comprised internal experts, including rock mechanics engineers, geologists, mining engineers, and a seismologist. Additionally, six consultant companies were engaged to handle supplementary tasks and develop some of the routines. The supporting reference group included an internal seismology specialist, an internal research engineer, an internal structural geologist, and two consulting rock mechanics specialists. The purpose of this group is to provide technical guidance and advice for the project group.

5 RESULTS

5.1 Introduction

This section will summarize some of the results from the project as they refer to the objectives stated in the beginning of the project.

The questionnaires to the operators showed that most personnel feels that the mine is safe but that they want more information about seismic and/or rock mechanics issues. The consensus was that text messages (SMS) seems to be the fastest and best way to communicate urgent information regarding seismic events/activity or closed areas. The questionnaire for the management indicated confusion regarding who is responsible and accountable for risk levels, seismic risk management and risk assessments. Many of the concerns identified in the questionnaires have been addressed through the development of the SRM workflows and the routines. The roles, responsibilities and accountabilities for management regarding seismic risk have been clarified in the SHMP.

During the project a huge effort went into identifying the types of instruments, measurements, data collection and analyses that were deemed necessary to have covered all aspects of seismic risk management. Some prioritization had to be made not to overwhelm the project participants. The most necessary practices or routines were developed first, complete with a routine describing the purpose and application. In total 31 seismological routines and 28 non-seismological routines were developed.

The routines were grouped into five different categories: 1) Before opening a new production area for development, 2) After large scale seismic events and/or unusual seismic activity, 3) Analysis and measurements necessary for long term planning, 4) Checklists and 5) Annual update of the SRMP. For each category a workflow was developed that visually put the routines into context both logically and chronologically. This organized workflow management system was named Seismic Risk Management System MUJ (SRMS MUJ), the implementation of which has started in 2024.

5.2 Workflows

Two of the workflows will be described here: Before development of a new production level, and After large seismic event. These two are the most complex since they consist of many different tasks, require input from several different departments and they also contain decision points along the line. Figure 2 and Figure 3 shows the slightly simplified workflows developed by the project for the two cases. Each one of the rectangular boxes in the figures represents one or, in some cases, a few different routines.

5.3 Checklists

Many routines that were developed were standalone tasks that did not need a workflow. Some of them are tasks that needs doing daily, like quality checks of the seismic database. Other tasks only need doing infrequently, like installation of stress monitoring cells. These routines were collected in a checklist. Some examples of the routines for each frequency are shown in Table 1.

5.4 Routine template

The following section show the template for writing the routines, complete with instructions to ensure that all routines contain the same basic information.

Title

Summary

Write a short summary of the routine that describes the following: the practice that you are writing, the purpose of the practice, who will be responsible for carrying out the task/practice once it is implemented in the line of work, at what stage in the mining process the practice is needed, how often (frequency) the practice is needed.

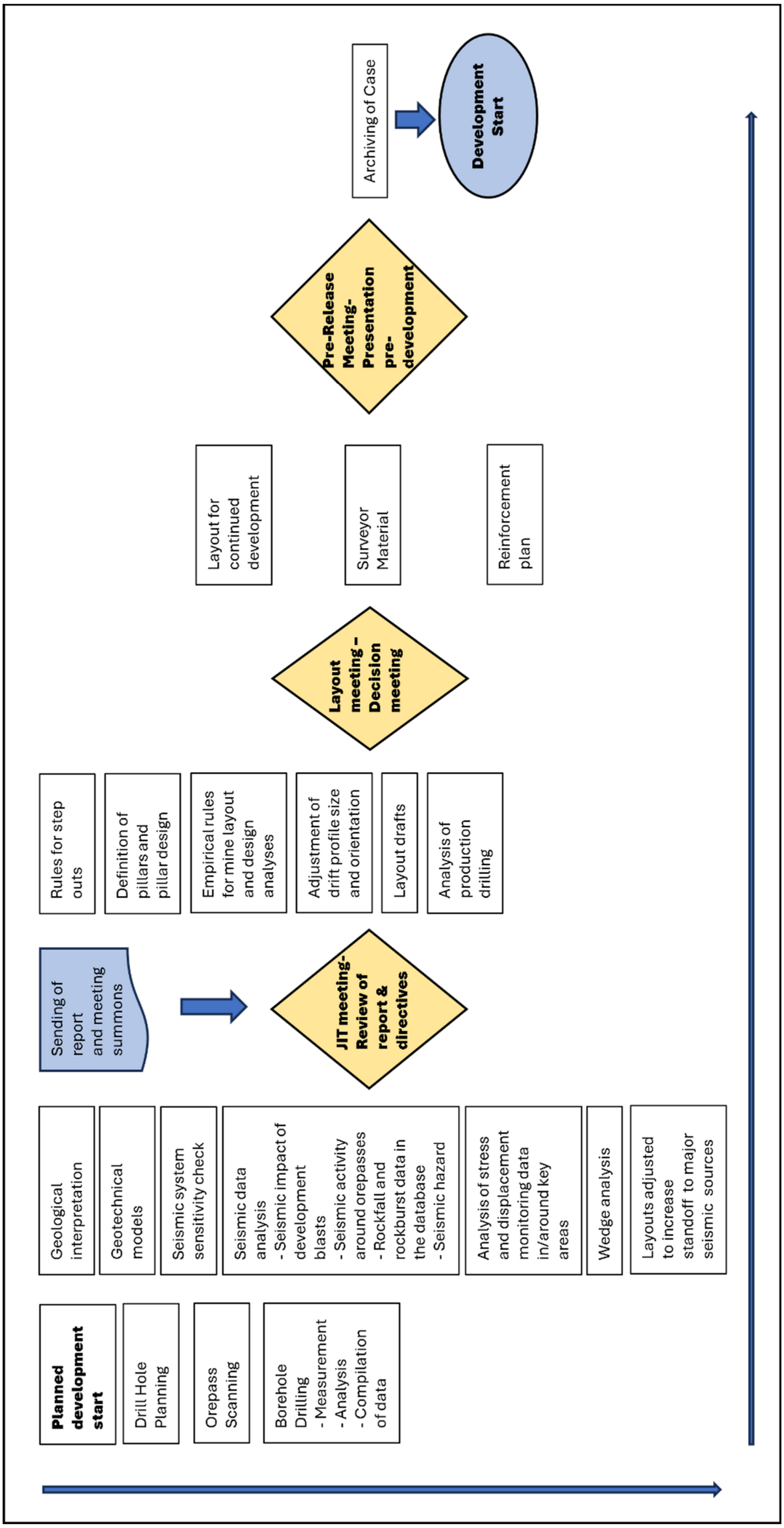

Figure 2 **Workflow of routines before opening of new production level.**

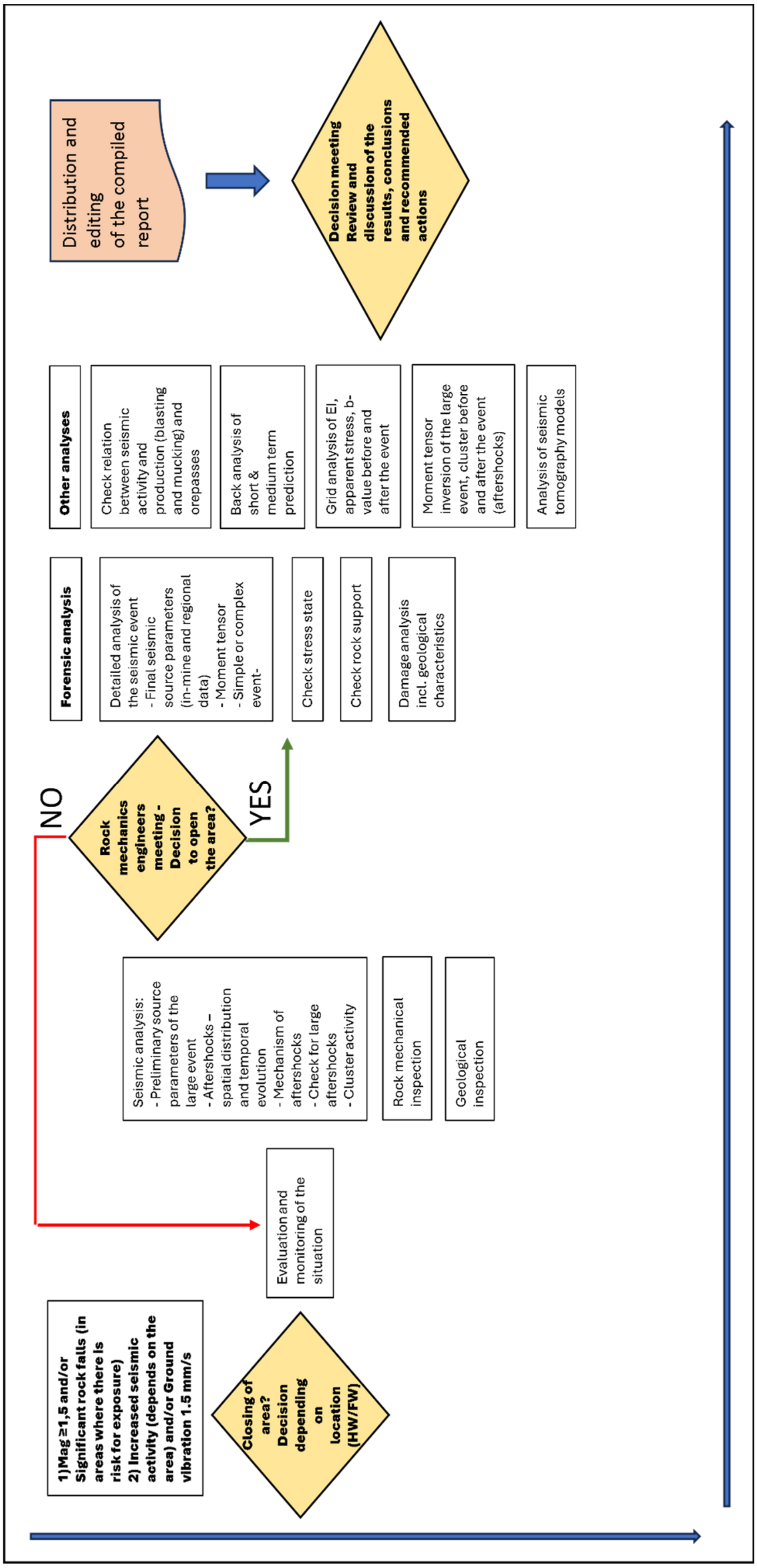

Figure 3 Workflow of routines in case of large seismic event with magnitude M_L > 1.5 or increased seismic activity.

Table 1 Examples of routines to be completed at specific intervals

Daily	Weekly	Monthly	Quarterly	Twice a year	Annually	Biannually	When necessary
Quality check of seismic event database	Displacement monitoring data collection and check	Production follow up with respect to seismic activity	Grid analysis of EI, b-value etc	Update of mine model in MAP3D	Review of rules for layouts	Updating strong ground motion equation	Stress monitoring installation
Re entry check after blasting	Check areas for low/high seismic activity	Check of clusters	General info to the mine		Seismic event rates for the whole mine		1 Hz sensor installation and maintenance

Purpose and end user of practice

Describe the purpose of practice for seismic risk management and explain the end user, i.e., the person who will use the outcome of this practice in the line of work. (Technician, rock mechanics engineer, mining engineer, or the like).

Procedure

Explain how the task is to be executed in the line of work (Where to find the needed data, software, app)? Note! DO NOT WRITE A DETAILED STEP-BY STEP DESCRIPTION. Instead insert link to step-by-step guide in the routine (in case you have done or are intending to make a step-by-step guide).

Executor of practice

Describe what knowledge (knowledge and skill in software) and which department and the role (technician, rock mechanics engineer, mining engineer, seismologist, geologist or the like) that is needed to be able to perform the task.

Frequency for the need of the practice

Describe how often the practice is needed.

Stage of mining when the practice is needed

Describe at what stage of the mining process the practice is needed.

Improvement suggestions for the future

Explain how the task can/should/will be changed/improved in the future.

6 ONGOING WORK

At the Malmberget mine there is a case management system in place to handle cases where different roles have to do things in a certain order. This existing system (developed in-house) did not have capacity to add more complex workflows where several things need to happen at the same time. Also the person who developed and maintained the system has moved on to different tasks. It was therefore decided to look into commercial management systems.

A list of specifications was sent out to several suppliers. The requirements were:

- Sufficient data storage capacity
- Data security
- Automated workflows
- Advanced checklists
- Possibility to attach documents
- Parallel tasks
- Visual
- Compatible with Microsoft Teams
- Revision and history management
- User friendly
- Support 24/7

The specifications along with one example workflow were sent out. After meeting with several suppliers and evaluation of the offers one software has been chosen for a trial. The trial will be conducted by a small group of personnel for a limited time period, starting in February

2024. After the trial is completed, implementation of the seismic risk management system will commence.

7 GENERAL LEARNINGS FROM THE PROJECT

The OSRM MUJ project achieved its goals and objectives, with regular reviews at Steering Committee and Reference Group meetings. Deviations from the original plan were carefully analyzed and documented in a decision log. A major deviation involved writing the SHMP for MUJ, ordered by the sponsor, leading to a three-month delay in phase 2. The project faced delays due to factors identified by the project manager (PM): inadequate resource management system, understaffing, team members working in shifts, and personnel changes. These challenges resulted in difficulties prioritizing tasks, halts in project advancement, communication issues, and minor delays in phase 2. The PM emphasizes the need for an internal resource management system and fully available team members dedicated to the project. An essential factor contributing to the project's success lies in the PM's ability to dedicate ample working hours to identifying and addressing deficiencies that arose throughout the project's duration, as well as to oversee the project.

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