



MAPPING EXTERNAL RISKS USING ONTOLOGIES AND KNOWLEDGE GRAPHS IN THE CONSTRUCTION OF TAILINGS DAMS

MSc. Construction Management and Engineering
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**Mapping external risks using ontologies and knowledge graphs
in the construction of tailings dams**

Graduation Thesis

University	Delft University of Technology
Faculty	Civil Engineering and Geoscience
Master Track	Construction Management and Engineering

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In partial fulfilment of the Master of Science in
Construction Management and Engineering

ABSTRACT

This thesis explores the external risks associated with the construction of tailings dams in the mining industry, focusing on the recent regulatory changes in Mexico. These changes have introduced new complexities and uncertainties in project management, particularly during the tender and construction phases. The aim of this research is to address a gap in traditional risk management methodologies by developing a knowledge graph to identify and manage external risks more effectively, with the specific objective of “How to model an ontology of external risks in the construction of a tailings dam using empirical knowledge.” The scope of the study includes the analysis of external risks in the construction of a tailings dam and the integration of ontologies to enhance contractors' decision-making processes during the tender stage.

The research employs a mixed-method approach, combining a literature review, case study analysis of the Mexican mining industry, and empirical data collection through interviews with industry experts. The methodology involves developing a knowledge graph using the Methontology approach, implemented through Protégé software. The results reveal various external risks, such as social conflicts and activity-related and resource-related issues, that impact tailings dam projects. The knowledge graph created serves as a systematic tool for visualizing and analyzing these risks, with validation processes confirming its logical consistency and applicability.

The study concludes that external risks in the mining industry are multifaceted, encompassing social, financial, and resource-driven factors. The developed ontology provides a practical framework for contractors to identify and mitigate these risks more effectively, especially during the tender stage. The research recommends further development and application of ontology-based models in the industry to bridge the gap between theoretical risk management frameworks and practical, real-world applications, thereby enhancing the overall risk management process in construction projects within the mining sector.

Keywords: Ontology-based model, Risk management, Mining Industry, Construction of tailings dams, Identifying external risks, Knowledge graphs

PREFACE

This research thesis presented a major challenge for me, as it required a combination of critical and analytical thinking, model creation, and report writing, taking more time than I had expected. The subject matter pertains to the mining industry, one of Mexico's most productive industries today. It focuses on using ontologies to establish connections between external risks in the development of construction projects within a knowledge graph, with a specific emphasis on the application of risk management in the construction industry.

I would like to acknowledge my family, especially my parents, for supporting me both mentally and financially as I pursued my studies in the Netherlands. To my wife, Selene, who created a conducive work environment at home and supported me in focusing on completing my master's studies, you are my cornerstone.

I want to express my gratitude to my friends from the master's program, the “Delftse boys,” who provided support and guidance as I navigated the challenges of this process. I also want to thank my Mexican friends who became like family while living abroad.

I am incredibly grateful to my supervisors for their time and invaluable feedback. I want to thank Ranjith for his patience, consistent support, and help organizing this research. At crucial moments, Tong offered insightful analysis and feedback from a different perspective, while Marian's specific feedback was instrumental in identifying areas for improvement. Thank you for helping me see the light at the end of the tunnel.

I hope you enjoy reading this as much as I enjoyed writing it.

*Roberto Gamboa
Delft, August 2024*

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LIST OF ACRONYMS

CQ	Competency Questions
DMP	Data Management Plan
EITI standard	Extractive Industries Transparency Initiative
H&S	Health and Safety
HREC	Human Research Ethics Committee
IRI	Internationalized Resource Identifier
KPIs	Key Performance Indicators
MC	Mechanical Workshop
NGOs	Non-Governmental Organizations
OC	Organized Crime groups
PESTLE	Political, Economic, Social, Technological, Legal, Environmental.
RC	Rural Communities
SCQ	Specific Competency Questions
SEMARNAT	Secretaria de Medio ambiente y recursos naturales (Ministry of Environment and Natural Resources)
SEDENA	Secretaria de la Defensa Nacional (Ministry of National Defense)
SQ	Sub Question
SPARQL	SPARQL Protocol and RDF Query Language
SWOT	Strengths Weakness Opportunities Threats
UK	United Kingdom

GLOSSARY

ATLAS.ti	Qualitative data analysis software used for coding interviews
Chat GPT	Artificial Intelligence program
Derecho de Piso	An extortion fee that criminal groups demand from businesses, communities, or individuals in exchange for protection against the same group
Ejido	Rural communities legally acknowledge as a land ownership form in México
Ejidatarios	Members of an Ejido
Graph DB	Semantic Graph Data based, used for querying specific competency questions in the ontology model
Hermit	Ontology logical reasoner
Knowledge Graph	Semantic network of real-world entities
Methontology	Methodology for developing ontologies
OntoGraf	Interactive graph visualization tool
Ontology	A set of concepts and categories in a subject area or domain that shows their properties and the relations between them.
Pesos	Mexican currency
Protégé	Open-source ontology editor and framework for building intelligent systems
Risk Matrix	Tool for risk management to assess and prioritize risks based on probability of occurrence and impact
Scenario Analysis	Process of analyzing future events by considering alternative possible outcomes
Sensitivity Analysis	Technique used to determine the impact of different input variable values on a specific output variable given certain assumptions.
Silver mine “La Nena”	Hypothetical Case study
SPARQL	RDF query language
SWOT	Planning tool used to identify and analyze internal and external factors impacting the success of a project, business, or organization.
Term pool	Collection or repository of terms that are used within a specific domain or subject area

EXECUTIVE SUMMARY

Introduction & Research Objective

This study centers on the development of tailings dams within the mining sector, with a specific focus on Mexico, and the related external risks. The research underscores the effects of recent regulatory adjustments in Mexico's mining industry, which have heightened the intricacy and unpredictability of project management. The objective is to bridge a notable research void by recognizing and handling these external risks, which are frequently disregarded in conventional risk management methodologies, using Ontologies to enhance a contractor's decision-making during the project's tender stage. This will help to answer the main question and objective of the research :

How to model an ontology of external risks in the construction of a tailings dam using empirical knowledge?

Methodology

The research methodology used in this study follows a mixed-method design. It involves conducting a literature review, collecting empirical data through interviews with experts from both mining companies and contractors, researching specific news articles on events in the Mexican mining industry, and creating and evaluating this knowledge graph to map the external risks that can occur in the construction of a tailings dam. The methodology used for creating the ontology is Methontology, with the assistance of the software Protégé.

Literature Review

The literature explores different perspectives on risk classification, risk management strategies, and the unique external factors that affect infrastructure projects, hydroelectric dam projects, and the mining industry. The review also highlights the key considerations in constructing tailings dams, such as the risks associated with external stakeholders and how environmental impacts may cause discomfort in the rural communities around the project. It also discusses the use of natural resources as materials for construction and how they are more difficult to gather in rural areas where the communities are heavily dependent on them.

The literature review highlights the increasing impact of social events on the mining industry over the past 20 years. It emphasizes the importance of an effective risk identification system for these specific projects in order to reduce cost and schedule impacts. Early identification of risks, ideally before the construction stage, is crucial. It also points out the limitations of traditional risk identification techniques when dealing with complex and evolving external risks. It suggests using ontologies and knowledge graphs as more comprehensive tools for risk management. These tools are focused on identifying clear relationships by utilizing initial knowledge from various stakeholder experiences as a repository of knowledge.

Results

The results are divided into two main parts: analysis of news articles and findings from interviews conducted as part of the case study in Mexico. The news analysis revealed various external events

impacting the mining industry in Mexico, including social conflicts, financial disputes, and natural resources issues. Interviews with industry professionals provided valuable insights into common external risks and the relationships between activities, events, and resources in the construction of tailings dams. The second part of the results cover the process of using the previously mentioned information to develop a model. This involved using quotes from the interviews to create classes and establish relationships between them. The next step was formalizing the model using Protégé software and implementing the process by populating the model with specific classes from the hypothetical case study. This resulted in a robust knowledge base that contains the external risks associated with building tailings dams in Mexico. This model provides a systematic method for visualizing and analyzing these risks.

Also, the evaluation process of the knowledge graph is described through verification and validation. The verification step involves automatic consistency checking using a reasoner, in this case, the Hermit reasoner. It checks for any inconsistencies and illogical connections within the model. There were no inferences, so the model is logically consistent. Next, it evaluates the information based on four criteria through four validation meetings. These meetings involved participants from previous interviews and aimed to assess the knowledge graph's coverage, consistency, clarity, and scalability.

For the validation process, first, the completeness and coherence of the graph was evaluated by manually checking the model for consistency, which was successful. Feedback and opinions from the participants during the validation meeting were gathered as the model was explained, and they were asked if they felt the information covered the entire domain. Then, specific competency questions were developed based on the participants' requirements, which were answered using queries in the software's graph database. The answers were shown to the participants to confirm if they were sufficient and accurate. This successful evaluation process confirmed that the model indeed complied with the objective of mapping external risks in the construction of tailing dams.

Discussion

The most common external risks found in the literature review, news articles, and interviews are discussed, encompassing social, financial, and resource-driven factors, and delves into the advantages and challenges of employing ontologies to enhance external risk management in the construction and mining industry. It specifically examines the implementation and generalizability of the knowledge graph created for this research based on the feedback obtained by participants during validation meetings, as well as the intricacies related to building such a model. Most participants agreed that using ontologies to enhance the contractor's capacity in risk management is a viable option, applicable to various aspects and phases of projects, with positive feedback during the model evaluation stage.

The limitations identified during the model's development and the feedback received during validation meetings were as follows: first, the model was not implemented in a real case; second, the lack of inclusion of quantitative data was a limitation that, if taken into consideration, could improve both the knowledge graph and decision-making regarding external risks. In addition, it also discusses the future use of ontologies in combination with artificial intelligence to support users activities, making the process more user-friendly.

Conclusion

The research concludes by answering the two following sub-questions:

1. *What are the most common external risks in the mining industry, and what is the contractor's perspective on them?*

Answer: The most common external risks in the mining industry may vary depending on the location of the projects and the social intricacies of, but it was found that they fall into four predominant categories which are:

- Social risks
- Resources-related risks
- Financially related risks
- Combination of one or more of the following categories.

The interviews provided valuable insights into how contractors perceive external risks in the mining industry. Contractors tend to prioritize risks associated with their own activities and resources, with trade unions and organized groups such as rural communities or even crime groups identified as the most influential stakeholders. Unlike mining companies, which actively manage external risks daily, contractors typically assess external risks during the tender stage, site visits, and the kick-off meeting before construction commences. Once construction begins, contractors often shift their focus to internal risks within their activities, sometimes overlooking external risk management.

2. *What are the correlations between activities, events, and resources that lead to risks in the construction of tailings dams?*

Answer: The knowledge graph of external risks in the construction of tailings dams was created using 104 classes selected during interviews with the participants, as well as eight object properties (relationships). The model contained 374 logical axioms (correlations). The large number of correlations found, based on a hypothetical case, suggests that using ontologies to analyze such risks holds promise for the future of risk management in the mining and construction industry.

It also encompasses the significance of integrating empirical knowledge through ontologies to enhance the identification and management of external risks in the construction of tailings dams. It proposes further development and application of ontology-based models in the industry to bridge the gap between theoretical risk management frameworks and practical, real-world applications. The study makes theoretical and practical contributions to the field, providing a foundation for future research and implementation in similar projects.



CHAPTER 1

INTRODUCTION

This section provides an introductory background to the primary research objective, which centers around the construction of tailings dams in the mining industry and the associated external risks. It addresses the research gap and states the main objective of the study. Furthermore, the chapter offers a summary of the regulatory changes that have occurred in the Mexican mining industry, with a particular emphasis on their impact on mining externalities.

1.1 RISK MANAGEMENT IN MINING

The mining industry, like many others, has been affected by the constant changes in policies. These policies have resulted in modifications to laws and regulations pertaining to responsible project construction within the industry. The changes have been rapid due to the need for governmental organizations to reduce the environmental impact of mining projects. However, these measures have generated controversy among internal stakeholders due to management changes and the high complexity and risks associated with mining projects. One example of such policies is that mining companies will need to allocate resources to pollution abatement, which can be costly and limit investment in other productive activities (Andersen & Noailly, 2022).

Despite limited information, empirical knowledge within the industry suggests that sustainability concerns significantly influence project decision-making and risk. During the evaluation of the mining industry's impact, new legal regulations at various levels of governance have caused increased complexity and uncertainty, leading to a growing distrust of the industry (Haddaway et al., 2022). Applying regulations, including governmental condonations, special permits, and environmental correction projects, demonstrates this complexity.

1.1.1 Deficiencies of Risk Management in Mining

Managing these projects is challenging due to complex relationships with external stakeholders such as governments, NGOs, and communities, particularly when sustainability is a priority. As a result, external risks in this industry are higher compared to others. Furthermore, the more variables involved, the more difficult it becomes to identify risks in a timely manner.

Risk identification is a crucial process in the construction industry. However, traditional methods like checklists, the Delphi method, interviews, and SWOT analysis still rely on a manual integration of information, which hinders new emerging threats along the way due to the industry's complexity and dynamism (Shaked & Margalit, 2022). As Ding et al. (2016) mention, these tools exclude the relationships between risks. The construction industry involves various external factors like political, environmental, social, technological, legal, and environmental issues, which make it challenging to identify and manage risks (De Azevedo et al., 2014).

1.1.2 External Risks and changing Regulations in Mexico

In 2023, a new mining law reform was imposed, which amended four specific laws that directly affect the environment of the mining industry and its construction projects. As a result, several new general and specific measures have been introduced (De Economía, n.d.-b). Eight measures have been implemented to improve mining activities and protect the environment and communities surrounding mining projects. These measures include the elimination of land expropriation for mining activities, reduction of mining duration to 30 years, and prioritization of the supply of drinking water, meaning

that if the volume of water available is reduced for any reason, the water use permit will be reduced, suspended, or canceled, a 60% water recycling obligation for concessionaires, a social impact study, a minimum of 5% of net profit given to surrounding communities, expanded grounds for cancellation of concessions, the first ground involves not having the necessary water, whereas the second concerns the immediate risk of ecological imbalance and the ban on the disposal of materials, such as tailings dams. It is crucial that these activities do not have an adverse impact on the population, productive areas, or surrounding ecosystems (Day, 2023a).

To sum up, the recent changes have created more ambiguity and uncertainty around the social and environmental issues that a mining project may encounter. These problems can arise at any stage of the project, even if all regulations were followed properly during the documentation stage. The repercussions of such situations are instant and can significantly affect the project. In addition to creating new permits, they also make room for or increase the relevance of three key external factors for any mining project:

- Land (soil, agrarian rights, limitations on the use of land)
- Water (limiting water pollution, water recycling, increasing licensing for different water uses).
- Social (more influence is given to the communities surrounding the mining projects, increase their bargaining power, and in addition to a consent signed by the communities where they accept the project, this consent is negotiable at any time).

The laws that have been modified include (Day, 2023):

- The Mining Law.
- Law on National Waters.
- General Law on Ecological Balance and Environmental Protection.
- General Law for the Prevention and Integral Management of Waste.

1.1.3 Tailings Dams

During the mining operation process, minerals are extracted from the earth along with other materials such as soil and rock. These materials go through a separation process where the minerals are extracted, and the impurities are removed. The remaining materials are referred to as tailings, which are estimated to be produced at an annual rate of anywhere from five to fourteen billion tons. These tailings may contain sulfide minerals that can cause acid drainage, as well as other processing chemicals and process water (Schoenberger, 2016).

As demand for minerals increases and lower-grade deposits are being mined, the amount of waste generated, known as tailings, is also increasing. This is a global issue that needs to be addressed as the burden of tailings is expected to rise steeply. There are various ways to handle and store tailings, including riverine disposal, submarine disposal, wetland retention, backfilling, dry stacking, and storage behind dammed impoundments. Currently, the most widely used method is the construction of tailings dams. The tailings are usually stored underwater to prevent the formation of surface dust and acid mine drainage (Kossoff et al., 2014).

The dams are constructed using coarse tailings material, which is compacted to build the initial wall. It is imperative to waterproof both the initial wall and the foundation soil to prevent any infiltration that can have deleterious effects on the physical stability of the dam or cause groundwater contamination. To minimize saturation of the tailings with process water, surface water, or rainwater, these structures are typically equipped with perimeter channels, subsurface drainage systems, and drainage pipes (Asesorias Tecnicas Geologicas ATG LTDA, n.d.). Attached is an image representing a model of a tailings dam.

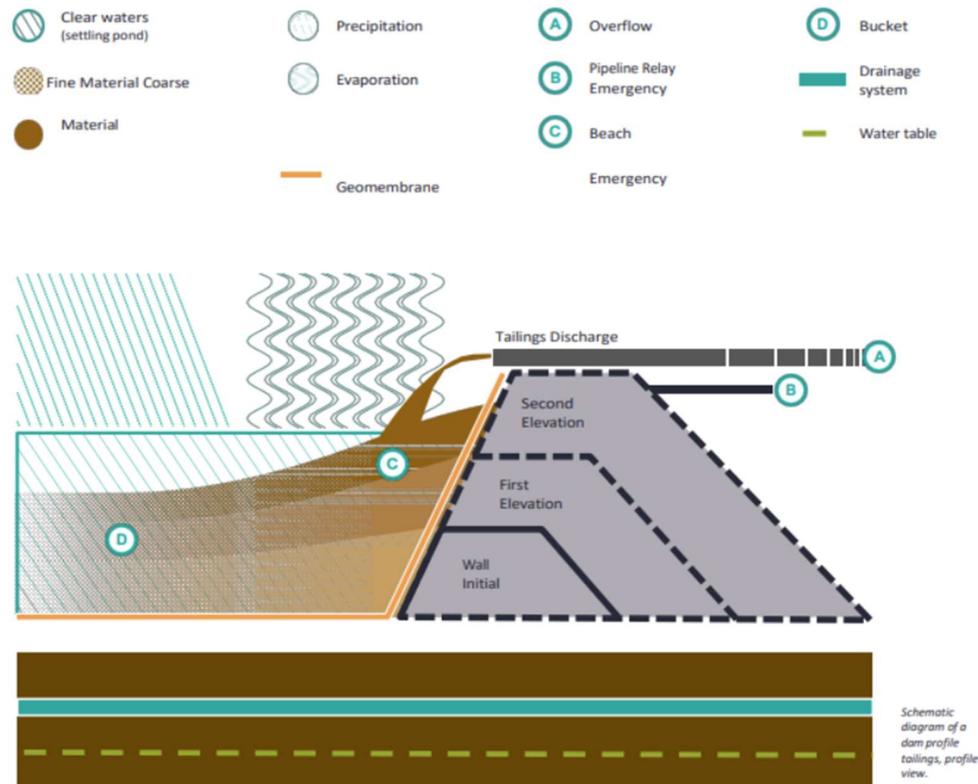


FIGURE 1: SCHEMATIC DIAGRAM OF A TAILINGS DAM (ASESORIAS TECNICAS GEOLOGICAS ATG LTDA, N.D.).

These projects are often constructed using locally available materials, as opposed to the concrete used in water-retention dams (Kossoff et al., 2014); the resources needed from this are truly dependent on the availability of them through local material banks or quarries, which opens the door for external conflicts. It is worth noting that infrastructure projects, particularly those pertaining to the mining industry, are commonly implemented in rural areas where resource availability is limited. In this context, the surrounding communities hold a preference for resource utilization.

Tailings dams are a type of construction project in the mining industry that has been extensively studied around the world. The primary focus of these studies has been on their technical characteristics, methods to achieve greater sustainability in their construction, and the reasons for structural failure. This is because when a tailings dam fails, the impact can be significant. These structures often contain multiple chemicals used to separate minerals from the soil during the mineral recovery process in mines. When these chemicals come into contact with nature, especially water, they can cause contamination over large areas and affect multiple localities. As Kossoff et al. (2014)

state, tailings dams contain a large amount of material that is often harmful to the environment. If they fail, the toxic material can flow into river systems, which can have negative impacts on water and sediment quality, as well as aquatic and human life for hundreds of kilometers downstream. Moreover, the size of these structures is so significant that a tailings dam failure can put the lives of people near the project at risk due to potential landslides.

However, there has been no focus on the construction management of such projects and the external risks to which they are exposed, i.e., the focus has been on the risks of failure, not on the construction process on the part of the contractors and the client.

1.2 PROMISES OF ONTOLOGIES IN RISK MANAGEMENT

Although risk management has been a topic of focus in recent decades, there has been limited implementation of new risk identification techniques in recent years (Hoseini et al., 2019). As a result, risk identification still relies heavily on the qualitative knowledge of specialists. This means that risk identification must be undertaken from the beginning for each new project. To address this challenge, knowledge-based models have been introduced to generate a mapping of events or risks with stakeholders, with the aim of defining the relationships between them systematically and accurately. In recent studies and literature, there have been attempts to use knowledge graphs or ontologies to improve risk management in various industries, applications, and specific projects; however, so far, no ontology has been created for external risks in tailings dam construction.

1.3 RESEARCH GAP

There are several established categories and frameworks for conducting risk management in construction projects. However, if we focus on identifying risk, the models used in the industry only rely on external and subjective information to analyze the context. Delays in construction projects are a common occurrence, often resulting from unforeseen circumstances. Unfortunately, these issues are often identified only after they have already caused significant setbacks (Ansah & Sorooshian, 2017). According to the same author, over 50% of construction project delays are due to a lack of robust management techniques and tools. Traditional methods are not equipped to handle complex project flow management. Even more so when uncontrollable external risks cannot be reduced or avoided, as these risks are generated and grow outside the core organization, so the only option companies have is to base their approach on identifying them, reviewing their potential impact, and figuring out how to mitigate their effects as best as possible should they occur, as most of these risks do not fall into the category of black swan events.

Risk management has evolved over the years, and several techniques have been innovated to assess, plan, and implement risks. Probabilistic risk assessment is one such technique that uses coded models and algorithms to predict the likelihood of specific events occurring. Similarly, frameworks have been developed, shared, and used across different industries like oil and mining to help with risk planning and implementation. Although risk management has been a topic of focus in recent decades, there has been limited implementation of new risk identification techniques in recent years (Hoseini et al., 2019). As a result, risk identification still relies heavily on the qualitative knowledge of specialists. This means that for each new project, risk identification must be undertaken from the beginning. To

address this challenge, knowledge-based models have been introduced to generate a mapping of events or risks with stakeholders, with the aim of defining the relationships between them systematically and accurately.

The research gap addressed in this thesis encompasses four important concepts. Specifically, the methods for identifying risks in risk management need to adapt to the changing industry. For example, the mining industry has experienced regulatory changes that have increased the involvement of external stakeholders in projects, leading to additional external risks in project construction. In contrast, the potential of using ontologies in risk management as an alternative to enhance decision-making needs further exploration. This research gap is depicted in **Figure 2**.

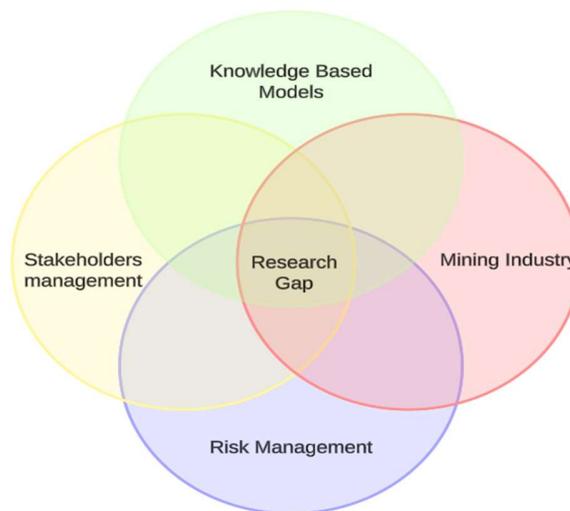


FIGURE 2: VENN DIAGRAM OF RESEARCH GAP

Effective management requires the involvement of all stakeholders, particularly during the project's initial phase. The problem is that risk identification is a process that takes time, quite a lot of time and is normally aligned more to the economic viability of a project, i.e., it is the one who seeks to build a project (the client) who focuses more than ever on the issue of risk identification using the techniques previously mentioned and covering its investment in the transfer of risks in the construction stage to the contractor. The only way to mitigate this risk in the eyes of the contractor is to increase the price of a project, which in many cases is not a good strategy since one of the main objectives at this stage is to find the best possible price to develop the project.

1.4 RESEARCH OBJECTIVE & RESEARCH QUESTIONS

In the context of the present research, emphasis is placed on the Tender (Bidding) and in the construction phase of a tailings dam project due to its critical significance in encompassing two pivotal milestones: the selection and appointment of contractors through a bidding process, and more importantly, the execution of risk assessments. The latter encompasses the evaluation of external risks, notably legal and social factors, which often lead to substantial discord and challenges in project execution. As clarified by Tepeli et al. (2019) and Zhi-Min et al. (2020), the predominant risks

inherent to this phase include alterations in legislative or regulatory frameworks, financial instabilities, and modifications in design instigated by external variables.

Risk identification is a pivotal process in mitigating potential threats, typically performed manually by subject matter experts. However, the integration of data from multiple systems poses a significant challenge, impeding the systematic evaluation of new and emerging risks. As highlighted by Shaked and Margalit (2022), the complexity of this process and the high degree of expertise required to carry it out necessitates more efficient and streamlined approaches to risk identification.

The research aims to create an interface that integrates practical knowledge from stakeholders into a user-friendly platform. The objective is to develop an ontology that can permanently store information about external risks in tailings dam construction using traditional approaches. This model will function as a knowledge repository, allowing contractors to access collective knowledge and establish a framework for future assessments and decision-making. Using ontologies to map external risks in tailings dam construction can be beneficial due to the potential for reusing knowledge graphs in different projects. It is crucial to focus on continuous maintenance of the model by continually incorporating empirical knowledge about projects until the database is as robust as possible. This will enable end users to quickly access comprehensive information in one interface, promoting more effective risk analysis at the project bidding stage.

1.4.1 Main Question

The main question is divided into two sub-questions that will be explored throughout this research.

How to model an ontology of external risks in the construction of a tailings dam using empirical knowledge?

1.4.2 Sub-Questions

Two sub-questions have been formulated to adequately address the main research questions. These sub-questions are based on three sections: a literature review, data collection through interviews, and the use of ontologies to develop a knowledge graph. The methodology for these sub-questions will be explained in the **Chapter 2**.

1. *What are the most common external risks in the mining industry, and what is the contractor's perspective on them?*
2. *What are the correlations between activities, events, and resources that lead to risks in the construction of tailings dams?*

1.5 RESEARCH SIGNIFICANCE AND SCOPE

The mining industry is one of the most risk-vulnerable industries due to the fact that it is a complex human-engineering system, where not only internal (operational) risks significantly affect its development but also ecological, social, and economic risks figure as relevant agents within the risk assessment (Tubis et al., 2020). As regulations continue to prioritize environmental preservation, sustainability, and social protection, mines are facing heightened uncertainty. These changes place greater emphasis on socio-environmental preservation, potentially minimizing the economic impact

of mining projects. As a result, risk assessment has become increasingly complex due to the multitude of variables at play and the corresponding increase in potential risks.

The scope of this research is centered on Mexico as a study area, owing to our unfettered access to a network of subject matter experts in the field and due to recent changes in the regulatory framework of the mining industry. Four laws have been reformed that directly affect the natural and social resources of mining projects. These changes intensify the regulation of compliance in the operation and construction of mines, with the goal of increasing awareness of environmental and social issues. As a result, these issues play a greater role in decision-making and project viability, leading to an increase in potential external risks that may impact projects. It is crucial to identify these risks during all phases of a mining project, including primary and secondary activities. Therefore, having as much information as possible on how various external agents can create risks is important. Risk identification is currently carried out using empirical information, which is then fed into a risk and impact analysis matrix. However, this method takes time and does not capture the relationships that may exist between agents, risks, and activities, resulting in a gap in knowledge and lessons learned.

However, it is important to note that the knowledge-based model can be applied to future projects by utilizing established semantics and relationships between classes, as reusability is one of the significant advantages of knowledge graphs and ontology models (Noy & McGuinness, 2002). This can help bridge the gap between risk management theory, external risks, and the relationship between stakeholders. Ultimately, it can be valuable for the construction sector.



CHAPTER 2

RESEARCH

METHODOLOGY

2 RESEARCH METHODOLOGY

The main goal of this research is to create a knowledge graph of external risks in the construction of a tailings dam using empirical knowledge. This section presents the specific research design and the various sections that comprise the entire thesis research. It begins with collecting information to develop interview questions and understand the most prevalent external risks in the mining industry, including a literature review and analysis of news articles. This is followed by a series of interviews with experts in Mexico and, a summary outlining the plan to create and evaluate the ontological model to answer the second subquestion and, finally, the main question of this research.

2.1 RESEARCH DESIGN

To achieve the main objective, a mixed-method research design consisting of three sections was proposed. These sections aim to comprehensively answer the previously mentioned research questions. The diagram in **Figure 3** shows the link between each sub-question and the three sections of the research methodology. This will provide a better understanding of how the main objective of this research can be achieved.

To begin, first it was decided to research the existing literature to identify the most common issues in construction projects within the mining industry. Since there was a lack of local information for the specific case study in Mexico, there was a need to also analyze news articles from the country to understand the recent events affecting these projects and their underlying causes, and conduct interviews with experts from mining companies and contractors to address SQ1. Using the information gathered, the last step then, is to proceed with creating a knowledge graph for external risks in tailings dam construction in Mexico.

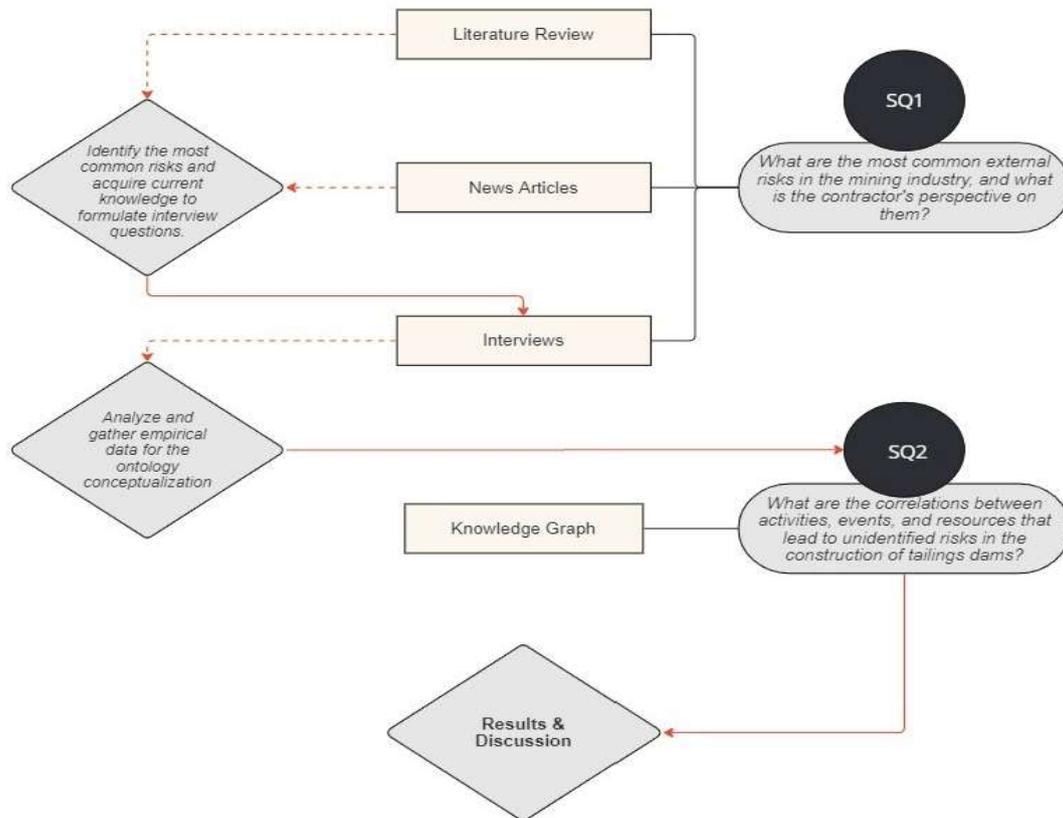


FIGURE 3: RESEARCH DESIGN

2.2 LITERATURE REVIEW

The initial phase of the research involves a literature review that begins with an approach to comprehend the relationship between the mining industry and the risks it currently confronts. This entails distinguishing between risk classifications and exploring the risk management approaches utilized in the industry, including the common tools used for risk identification in civil engineering projects. This introduction sets the stage for addressing the first SQ1, which aims to identify the most prevalent external risks encountered by construction projects in the mining industry. This involves globally identifying these risks in the literature, starting with infrastructure projects that share similarities with the construction of mining dams and considering the critical factors that must be considered for these specific projects.

During the initial stage of this research, an extensive search for papers across various disciplines was conducted. This search aimed to analyze the research objective by focusing on three keywords. The papers accessed during this period were from public databases and those accessible through the TU

DELFT account. This process took approximately six weeks. The following table displays the papers found in one column and those selected for the literature review in another column.

TABLE 1: KEYWORDS, FOUND AND SELECTED PAPERS

Key Words	Papers found	Selected papers for literature review
Risk Management in Construction	22	8
Risks in infrastructure, mining industry, and tailings dams	24	13
Ontologies applied to risk management or construction	11	7
Total	57	28

The decision to analyze practically only 50% of the papers found at the outset was based, firstly, on avoiding redundancy and information saturation and, above all, including only the information that was directly applicable to this research.

2.3 CASE STUDY OF MINING IN MEXICO

To narrow down the information to be studied in the news articles and interviews to a specific country, because external risks vary depending on the location of the projects, mainly due to social issues, this section of the research and the application of the model was decided to focus on the case studies of the mining industry in Mexico.

2.3.1 Analysis of News Articles

As part of the proposed methodology, an analysis of news archives that report events affecting construction projects in the mining industry has been incorporated. This approach allows us to gain a broader understanding of the risks involved in the industry while minimizing the influence of those who prioritize project success over external factors. News articles serve as a valuable source of information, providing the latest updates on current events and often revealing information that mining companies would not make public.

The goal was to collect as many news articles as possible while maintaining the accuracy and reliability of the information. The initial step was to search on Google engine for news in Spanish using the keywords "social events in the mining industry in Mexico". Then, specify reputable newspapers that appeared in the search results, focusing on events such as strikes or work stoppages within Mexico from 10 years ago.

The main exclusion criterion is only considering information from reputable newspapers, avoiding tabloid sources. Only 20 articles were considered to prevent information overload, prioritizing those containing as much information as possible about the events, the stakeholders involved, and an explanation of the reasons behind the events. The analysis of these articles was done manually, and a

tracker in Excel was created that shows the source, the year of publication, the type of risk or reason for which the events were incited, the type of event, and personal comments on this information.

2.3.2 Interviews for Data Collection

To gather empirical data on the correlations between activities, resources, and external risks in constructing tailings dams in Mexico, eight interviews were conducted with professionals experienced in mining construction projects from various backgrounds. As seen in **Table 2**, the list of interviewees comprehends five perspectives from the contractors' eyes and three from the client's perspective as a mining company.

TABLE 2: LIST OF INTERVIEWEES

Interviewee #	ID of Participant	Type of company	Position of employment	Years of experience
1	C-1	Contractor	Chief Operating Officer	36 years
2	C-2	Contractor	Project Manager	15 years
3	MC-1	Mining company	Sustainability Director	10 years
4	MC-2	Mining Company	Planning Manager	25 years
5	C-3	Contractor	Project Manager	28 years
6	C-4	Contractor	Chief Executive Officer	30 years
7	MC-3	Mining Company and Civil servant	Ex-Chief Operating Officer and Ex-Secretary of Economic Development	49 years
8	C-5	Contractor	Project Manager	20 years

A semi-structured interview approach was utilized, asking ten questions with follow-up questions as needed. The open-ended nature of this approach allowed the exploration of the interviewees' experiences and opinions and gather qualitative data more comprehensively. The interview questions were developed to focus on the external risks in Mexico and compare them with the global risks identified in the literature review.. The methods used to identify these risks were also explored to understand if they align with those mentioned in the literature as common. Additionally, insights from events investigated through news articles provided a basis to seek the experiences of the individuals interviewed regarding events related to external risks they have faced.

The interviews also addressed the resources and activities for the construction of projects. The literature review highlighted that resources found near construction sites, such as water and aggregates, or even the transportation of other resources through the areas surrounding the construction site pose external risks when involving external stakeholders. Since risks are uncertain events requiring a premise to exist, and even projects as a whole could be that premise, it was decided to narrow the scope to specific activities necessary for the project to understand the different risks associated with them. Additional follow-up questions were conducted as needed to ensure a thorough understanding of each response. The interview questions are listed below:

TABLE 3: INTERVIEW QUESTIONS

#	Interview Questions	Purpose of Question
1	How many years have you been active in the construction or mining industry? In which sector specifically?	Introduction
2	What kind of external risks do you think the construction of civil engineering projects in the mining industry faces? Follow up: Specifically during the construction phase? Follow up: Specifically in the construction of tailings dams?	To understand the various parameters that are employed to categorize external risks in an inherent manner.
3	What tools or methods do you use to identify risks? Follow up: In your experience, have you encountered any instances where this strategy has been effective or ineffective? Can you recall some examples?	To ensure comprehensive risk identification in the mining sector, it is important to identify any gaps in the process.
4	What are the activities required from winning a tender to the completion of the tailings dam construction? (contractors only) Follow up: In any of these particular activities have you identified any specific risks not previously mentioned?	To confirm the necessary activities to construct tailings dams for creating the term-pool, and reevaluate the effectiveness of the previous risk identification process.
5	What resources are needed to complete such a project? Follow up: How is resource prioritization and management handled during the procurement and construction phases of a project? Follow up: Have you ever encountered unexpected difficulties or conflicts while using or acquiring these resources?	To know the approximate time in which the contractor can carry out a technical and economic evaluation and, therefore, an external risk identification process.
6	What resources are needed to complete such a project? Follow up: How is resource prioritization and management handled during the procurement and construction phases of a project? Follow up: Have you ever encountered unexpected difficulties or conflicts while using or acquiring these resources?	Reaffirm the resources needed for the term-pool and open the way to the question of external risks that may affect resources
7	Have you had any external events that have affected a project like this in terms of time or money? Follow up: If so, what were they and what was the reason for their occurrence? Follow Up: What was the impact of this event on the project and how was it mitigated?	Investigate in a specific way some of the events that have affected the projects to understand why they happened and whether they were budgeted for.
8	What has your experience been in this construction project with the use or management of the following resources: water, land, bank material, roads, explosives, electricity, labour, or machinery?	To ascertain the interviewee's views on the resources identified during the literature review and reassess the possible risks over them.
9	How have you empirically analyzed the correlations between resources, activities, and potential risks?	Establish whether the experience and information involved is sufficient to take into account possible external risks that may arise.

10	<p>What do you think about the relationship between the identification of external problems and decision-making during the bidding process? (Contractor)</p> <p>Follow up :</p> <p>How might additional information about potential project risks influence your quote and decision to enter the bidding process, if at all?</p> <p>Follow up: How might having more information about potential risks affect your ability to negotiate terms or enhance bargaining power with the client for situations beyond the contractor's control, such as including clauses for work stoppage or extraordinary costs?</p>	<p>Know or validate the usefulness of the ontology in the risk identification process</p>
11	<p>How would you perceive a contractor providing a comprehensive analysis of potential external challenges during the tendering stage?? (Mining company)</p> <p>Follow up: Would you consider the contractor's data when negotiating the contract and possible solutions to external challenges that might occur, or would the transfer of risk implicit in contracts normally remain the primary approach?</p>	<p>Know or validate the usefulness of the ontology in the risk identification process</p>

It is essential to conduct interviews with individuals who have prior experience in similar projects to acquire information, requirements, or specifications for developing a knowledge-based model. To gain a comprehensive understanding of Mexico's mining industry, the research will concentrate solely on examining its intricacies. This will involve analyzing external factors, identifying the resources and activities required for constructing a tailings dam, and identifying the key stakeholders who have a direct impact on this industry. The table provided below shows the duration of each interview and the perspectives of the interviewees.

TABLE 4: DURATION OF INTERVIEWS

Interview #	Role of Interviewee	Duration
1	Contractor	34 minutes
2	Contractor	49 minutes
3	Mining Company	1 hour 10 minutes
4	Mining Company	40 minutes
5	Contractor	53 minutes
6	Contractor	1 hour 4 minutes
7	Mining Company	49 minutes
8	Contractor	1 hour 8 minutes

To analyze the interviews, first, they were transcribed and translated into English without changing the participants' answers. Then, using **ATLAS.ti** software to create codes based on specific nouns falling into predefined categories such as activities, resources, stakeholders, risks and events, along with quotes about the relationships these nouns have in the current scenario in a explanatory case study. The results section displays the different codes, which were also filtered or combined to create the final model.

In compliance with TU Delft HREC standards, the interviews were conducted in accordance with the parameters and regulations of the Human Research Ethics Committee, **number 4130**, which was approved together with the **DMP** on 10 May 2024. Participants were asked to sign the Informed Consent Form found in **Appendix D**.

2.4 DEVELOPING THE KNOWLEDGE GRAPH

The next step, which is creating a model in the Protege software, is a complex task that requires gathering and analyzing domain knowledge to structure the conceptualization of the model, which will serve as a tool to assess whether such technology and models can aid in creating a more comprehensive system for risk identification. The objective of this model is to help identify the potential risks involved in the construction of tailings dams and provide a more accurate assessment of the external risk profile.

An ontology in computer science is the explicit formal specification of a conceptualization; as simplified by Zheng et al. (2021), ontologies represent the knowledge in specific domains, with a formal description of the concepts and relationships. There exist diverse approaches and techniques to tackle a subject and establish an ontology for it. In the forthcoming section, some methods that may prove relevant to the aim of this thesis have been enumerated. Subsequently, a reference to a data comparison conducted by Iqbal et al. (2013) will be made to ascertain the methodology that is most suitable for this study.

2.4.1 Development Steps

Based on the analysis created by Iqbal et al. (2013), the following table was taken, and based on eight parameters, a comparison of the different methodologies when creating ontologies was made.

Methodologies	Type of development	Collaborative construction	Reusability support	Degree of application dependency	Life cycle recommendation	Strategies for identifying concepts	Methodology details	Interoperability support
TOVE	Stage based	No	Yes	Application semi independent	No	Middle out strategy	Some details	No
Enterprise model approach	Stage based	No	Yes	Application independent	No	Middle out strategy	Some details	No
METHONTOLOGY	Evolving prototype	No	Yes	Application independent	Yes	Middle out strategy	Sufficient details	No
KBSI IDEF5	Evolving prototype	No	Yes	Application independent	No	Not clear	Some details	No
Ontolingua	Modular development	Yes	Yes	Application independent	No	Not clear	Some details	Yes
Common KADS and KACTUS	Modular development	No	Yes	Application dependent	No	Top down strategy	Insufficient details	No
PLINIUS	Guidelines	No	No	Application independent	No	Bottom up strategy	Some details	No
ONIONS	Modular development / Guidelines	No	No	Application dependent	No	Not clear	Insufficient details	Yes
Mikrokosmos	Guidelines	No	No	Application dependent	No	Rule based strategy	Some details	No
MENELAS	Guidelines	No	No	Application dependent	No	Concepts Graphs (CG)	Insufficient details	No
SENSUS	does not mention any preference	Yes	Yes	Application semi independent	No	Bottom up	Some details	Yes
Cyc methodology	Evolving prototype	No	Yes	Application independent	No	Not clear	Some details	No
UPON	Evolving prototype	No	Yes	Application independent	Yes	Middle out strategy	Some details	No
101 method	Evolving prototype	No	Yes	Application independent	No	Developer's consent	Some details	No
On-To-Knowledge	Evolving prototype	No	No	Application dependent	Yes	Middle out strategy	Some details	No

FIGURE 4: COMPARISON OF METHODOLOGIES FOR ONTOLOGIES ENGINEERING (IQBAL ET AL., 2013)

The first parameter is the type of development; in the case of this research, although there is an idea on how the ontology can help to solve the main research question and objective, some requirements or data are not clear or sufficient at the moment, as it is necessary to conduct a series of interviews, so an evolving prototype is more suitable.

The second criterion is the willingness to work collaboratively, and in this case, this does not apply, as the research and modeling will be done individually, and the final product will be an initial version. However, in the future, it would be ideal for this type of model to be friendly to the collaboration of other professionals. Another important criterion and fundamental part of the main objective of the research is the reusability of the ontologies, so it is necessary that this criterion is fulfilled.

In order to achieve independence, it is necessary to find a methodology that allows the disassociation between the application and its reason for being. Since a life cycle assessment is out of the scope of this research, this criterion is not applicable.

Since the identification of concepts is one of the main objectives of this research, it is imperative that the methodology to be used allows for and is specific in different strategies or activities for this purpose. Another fundamental aspect for the development of this ontology is to be very clear about the details of the methodology to be followed, firstly because it must be easy to understand for other users and secondly, because it will be a model made from scratch and without much experience in the development of one. Finally, the interoperability support, which is not included in this research, is not necessary.

TABLE 5: CRITERIA FOR THESIS RESEARCH METHODOLOGY

<i>Criteria for analysis</i>	<i>Criteria Needed</i>
Type of development	Evolving prototype
Support for collaborative construction	Does not apply
Support for Reusability	Preferred
Support for interoperability	Does not apply
Degree of application dependency	Independent
Life Cycle recommendation	Preferred, but does not apply
Strategies for defining Concepts	Top down / middle out
Details of methodology	Necessary

The Methontology approach was deemed most suitable due to its ability to provide in-depth information. Despite some criticism regarding the maturity of all methodologies (Iqbal et al. 2013), Methontology stands out for its inclusion of support activities, which are vital for knowledge acquisition, evaluation, integration, and documentation. These activities run concurrently with development activities, as illustrated in **Figure 5**.

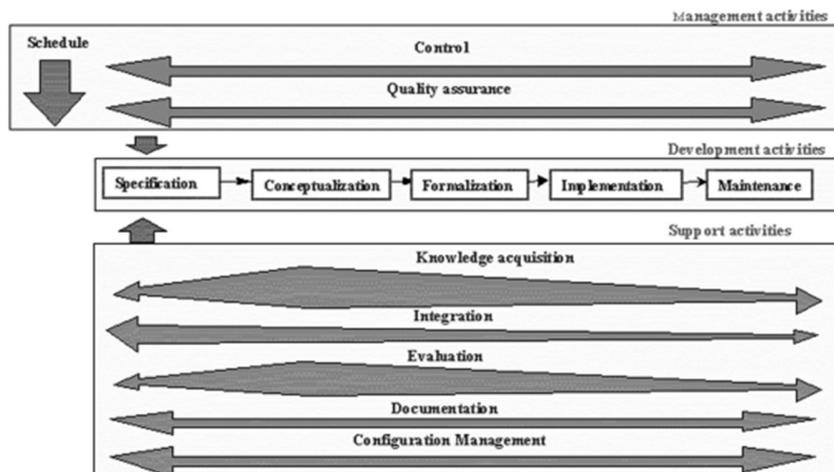


FIGURE 5: METHONTOLOGY APPROACH (FERNÁNDEZ-LÓPEZ & GÓMEZ-PÉREZ, 2002)

According to the Methontology (Fernández-López & Gómez-Pérez, 2002) activities should be divided into two parts. The first part is the development activities which are as follows:

1. Specification: why the ontology is being built.
2. Conceptualization: This is the structure based on the domain knowledge to form the ontology; the domain knowledge is taken mainly by the interview data collection and supported by the news articles and literature review.
3. Formalization: This is the activity where the conceptual model is transformed into a formal model.
4. Implementation: The formal model is then constructed based on a computational language.
5. Maintenance: This is the monitoring of a model to correct, change or update the model so that it continues to fulfill its purpose.

To provide further clarity, this approach proposes that when developing a model or prototype, the initial step involves specifying the ontology. Next or in parallel, one should gather relevant data or knowledge pertaining to the ontology's specific field. Once this stage is complete, the conceptualization phase can commence, which will be succeeded by formalization and implementation. The scope of this research is limited by the first four support activities, meaning that configuration management will not be considered for this model.

2.4.2 Ontology Specification

The first step in developing an ontology is the specification, according to Zheng et al. (2021), to ask three fundamental questions to specify the goal of the ontology:

TABLE 6: ONTOLOGY QUESTIONS

Ontology fundamental questions

What is the objective of the ontology?	Use the information gathered on activities, resources, and events that may generate external risks in different areas of the country as lessons learned.
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What is the scope of the ontology?	Understand the correlations between activities events and resources that lead to unidentified risks in the construction of tailings dams
What are the users of the ontology?	The users are the contractors during the tendering stage, and also after the projects have been completed to apply lessons learned.

In order to address the initial three inquiries, the approach is to establish the foundation of the ontology through the formulation of competency questions. Competency questions serve as a means to evaluate the comprehensiveness of the ontology and its ability to provide relevant information in response to these questions (Noy & McGuinness, 2002). Specifically, the three competency questions outlined aim to address the potential risks or occurrences associated with conducting an activity or utilizing specific resources in the construction of tailings dams within a particular area or project through the contractor's perspective since it should be the user of it. This aligns with the primary objective of the research. These competency questions should be answerable using data derived from literature reviews, news articles, or interview findings.

TABLE 7: LIST OF CQs

Competency Questions

1. **What are the possible risks or events that could trigger the resources needed for building a tailings dam?**
2. **Which external stakeholders are involved in certain activities depending on the location?**
3. **What are the direct and indirect risks of the most common activities in the construction of a tailings dam?**

Displayed below is a visual representation of the ontology creation process, in which the qualitative data gathered during the initial research phase is utilized in the first two steps: the Initiation phase and requirements specification. Since the research pertains to the absence of similar tools, the third step, which involves reusing existing information or models, will be omitted. This allows the research to proceed to the second phase, which focuses on modeling and implementation, which is part of the formalization process.

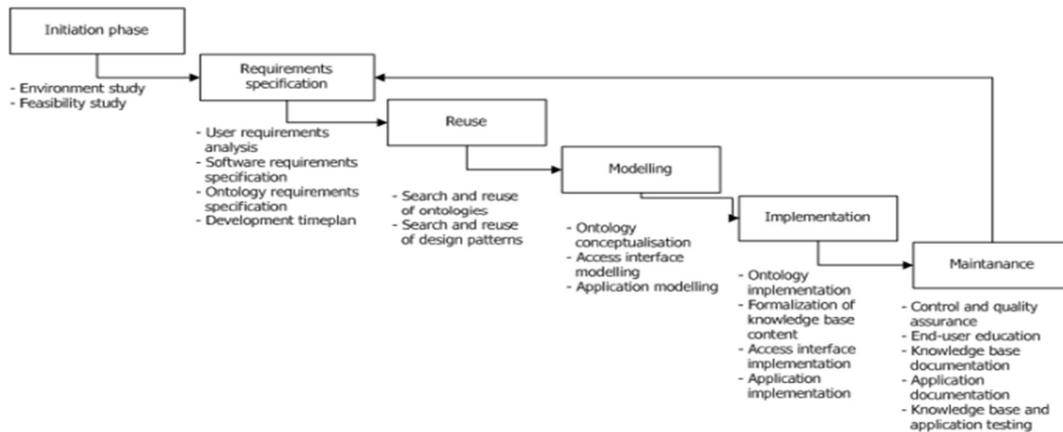


FIGURE 6: PROPOSED METHOD FOR DEVELOPING ONTOLOGY-BASED KNOWLEDGE MANAGEMENT SYSTEMS (WSEAS,2011)

2.4.3 Ontology Conceptualization

In model conceptualization, the information collected is transformed in a structured way according to methontology; one of the first steps to take is to create a glossary of terms in which concepts, relationships and properties are included. At the same time, the literature review and news articles helped to identify concepts within a semantic triple structure or RDF triple (the foundation of the ontology) classes within the ontology domain, while the interview findings were a major source for creating the relationships between subject and object, through the predicate of the RDF semantics as well as in specifically identifying the concepts of the literature review, meaning the definition of the properties. In other words, the ontology conceptualization is a product of the codes retrieved from the interview findings in an organized RDF semantic structure, enumerating the selected terms.

2.4.4 Ontology Formalization

The model was formalized using OWL (Web Ontology Language) since it is the language supported by the Protégé software. This software makes it easy for beginners to quickly edit the knowledge graph information. After conceptualizing the model or classes, the formalization process involves defining the classes and properties of the model to provide more information about a concept. It also entails establishing relationships and constraints between the concepts to create a computational model. This computational model allows for the logical automation and inferences of the conceptual information, which can be implemented in specific cases within the domain and range of the technology. The formalization process heavily relied on the relationships identified in interviews.

2.4.5 Implementation of the Ontology

To address the competency questions and test the model created in Protégé as part of the validation and implementation process, a hypothetical scenario was developed involving a tailings dam project in northern Mexico. This region faces water scarcity for several months, is home to numerous ejido (rural) communities, and is also affected by organized crime that may hinder the project's execution, as well as the necessary resources and activities for constructing the tailings dam. The specific location of the hypothetical mine is depicted in the attached images. This location was chosen due to the region's abundance of silver and the presence of small to medium-sized mines. The precise

coordinates of the case study are 25°12'10"N, 106°33'16"W, with an elevation of 1,717m located in the northwestern region of the State of Durango and close to the state of Sinaloa.



FIGURE 7: HYPOTHETICAL MINE "LA NENA"

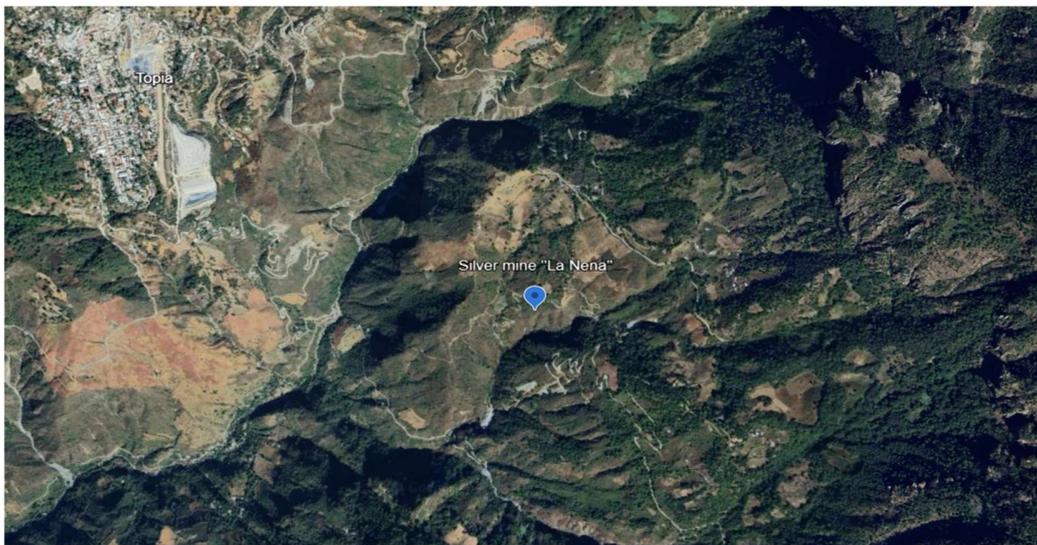


FIGURE 8: CLOSE-UP OF MINE "LA NENA"

The mine is situated in a mountainous area, specifically in the Sierra Madre Occidental. This area is characterized by multiple mountain ranges, making road travel extremely time-consuming. The journey involves passing through steep slopes, curves, and ejido plots from the nearest towns, which are as follows:

TABLE 8: DISTANCE BETWEEN MAJOR CITIES AND CASE STUDY LOCATION

City	Distance in km.	Travel time to the Mine "La Nena" in hours
Durango, Durango	380	7:40
Culiacan, Sinaloa	203	7:15

To provide more context about the location of the case study, the model will utilize the different classes that are part of the hypothetical case study, as mapped in **Figures 9 and 10**. The **Results section** includes a complete list of these classes and their relationships according to the term pool.

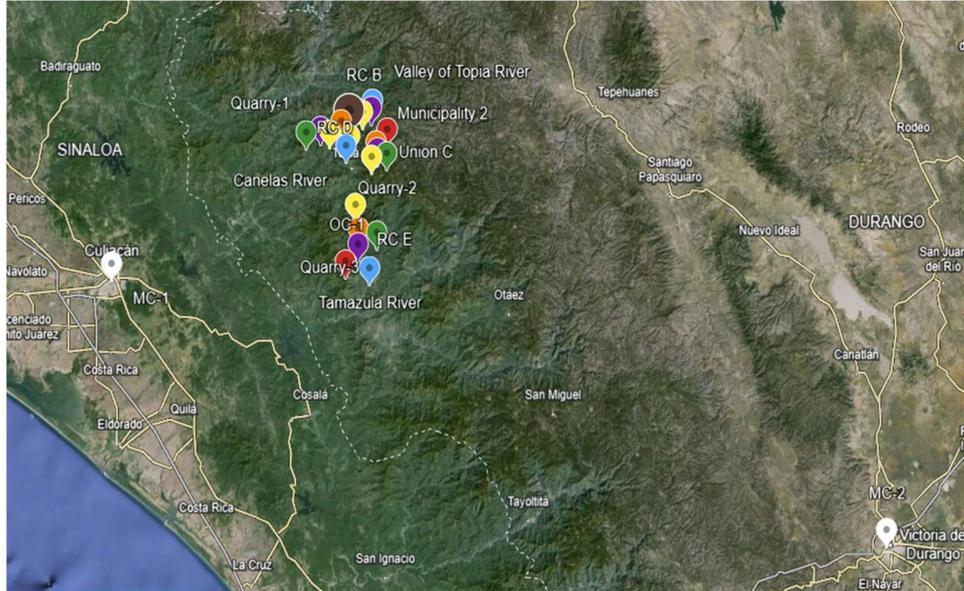


FIGURE 9: MAP OF CLASSES IN CASE STUDY

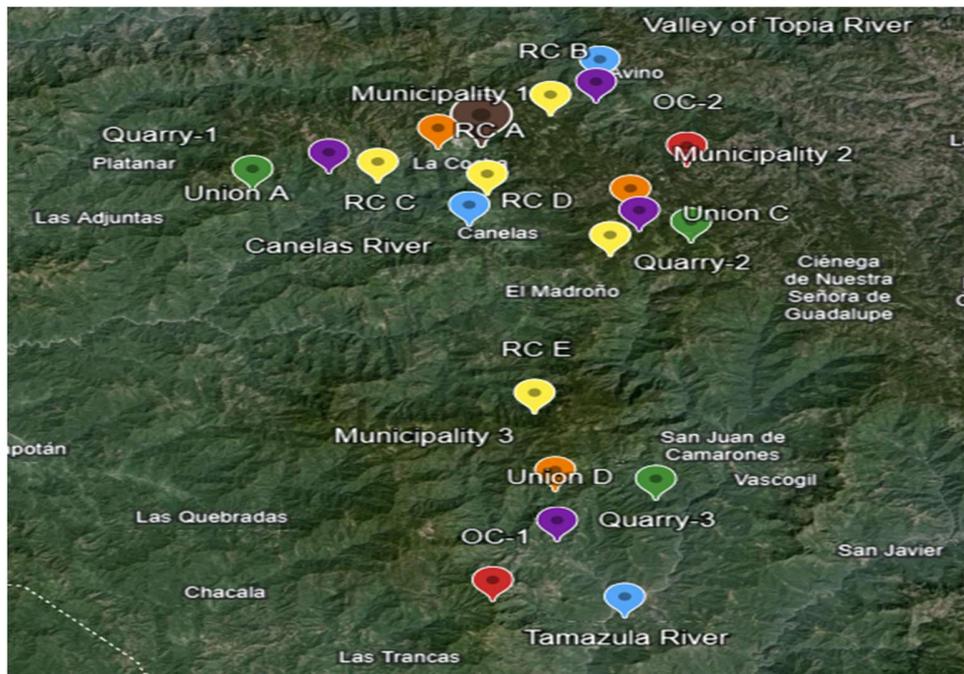


FIGURE 10: ZOOM IN ON THE CASE STUDY MAP

2.4.6 Ontology Verification and Criteria-based Evaluation

The evaluation of an ontology, as outlined by Fernández-López et al. (1997), involves two key steps: verification and validation. Verification ensures the correctness of the model within its logical axioms, such as class relations, and is typically carried out using associated software (Reasoner). Conversely, validation ensures that the model accurately represents the intended system, confirming that its content and purpose align with its objectives and scope. There are several methods for validating knowledge graphs; according to the author Zheng et al. (2021), the approaches for evaluating them can be the following:

- Automated consistency checking: This evaluates the model's description logic and checks for consistency or conflicts between classes.
- Criteria-based evaluation: This evaluates whether the ontology's content is sufficiently clear and can be reused for another purpose.
- Answering competency questions.

For verification, Protégé includes several built-in reasoners to evaluate an ontology model. The most commonly used reasoners are the Pellet and the Hermit reasoners (Farghaly et al., 2024b). In this case the Hermit reasoner was used. The Hermit reasoning can determine whether or not the ontology is consistent and identify subsumption relationships between classes based on the hypertableau calculus which allows the reasoner to avoid some non-deterministic behavior of other reasoners like the Pellet reasoner (HerMiT: An OWL 2 Reasoner, n.d.), also, using direct semantics can test the logical structure of complex ontologies (HerMiT Reasoner: Home, n.d.).

2.4.7 Criteria-based Evaluation

To evaluate the criteria, it was decided to use both an application-based and a manual inspection approach. The application-based method uses information from the model to evaluate the knowledge graph. Specific competency questions are created to determine the scope and robustness of the model. On the other hand, the manual approach involves manually assessing whether the model meets the specification criteria of the knowledge graph (Hooi et al., 2015). Experts answer criteria such as coverage, consistency, clarity, and scalability, while their feedback is used to improve the model. For both processes and to validate the model, four participants were asked to conduct additional meetings via video calls.

2.5 KNOWLEDGE GRAPH VALIDATION

The validation of the knowledge graph involved two processes. The first process checked the coherence and completeness of the model. This was done through an analysis of the participants, showcasing the domain and functionality of the model during the implementation phase. The next step is to develop specific competency questions once the model is finalized and based on the participants' requirements. This tests whether the model can answer them by implementing it in a hypothetical case. The aim is to ensure that the model fulfills its main objective and to identify any gaps, relationships, or classes that need to be included for it to be a successful model.

- *Completeness and coherence*: The knowledge graph is complete when it contains all relevant information about a particular topic, making it useful for end users. This is achieved by analyzing the classes and relationships within the graph, ensuring that the model covers the necessary content to address the objectives of the domain, such as external risks in the construction of tailings dams. On the other hand, coherence involves checking for any contradictions between relationships and ensuring that the relationships themselves are logically sound in the subject-predicate-object structure, which is done manually.
- *Competency Questions development*: To establish the model's competence, it is necessary to verify that the information in the model makes sense and is sufficient to demonstrate whether the model can effectively fulfill its overall purpose. For this purpose, specific competency questions were developed based on the requirements and input from the participants of the validation meetings. These competency questions can vary based on each participant's experience, so this validation method avoids bias toward a single perspective.
- *Answering Competency Questions*: After developing the competency questions, GRAPH DB software was then used to query them. First, we uploaded the knowledge graph created in Protégé was uploaded to the software as a TTL file. Then, we queried the SCQs using the SPARQL language to obtain the answers in table format. However, due to our limited expertise in SPARQL and GRAPH DB, there was a one-day delay in providing the answers to the participants, exacerbated by the time difference between Mexico and the Netherlands. It is important to notice that the participants' feedback on whether the model effectively answered the SCQs was used to make further improvements and ensure the model's robustness.

2.6 SUMMARY OF PROPOSED METHODOLOGY

In summary, the proposed methodology seeks to bridge the gap between conventional techniques and digital technologies, creating a unified knowledge generation and sharing platform. By doing so, it aims to harness the collective expertise of stakeholders, promoting a shared understanding and enabling more informed decision-making towards the construction of tailings dams. The proposed methodology incorporates information from literature reviews, news articles, and interviews with specialists to address SQ1 and a knowledge graph to address SQ2. This approach contains the essential components addressing the primary research question. For the process of creating the knowledge graph, different data-gathering methods will be used to create a complete model, including terms and relationships, as shown in the following figure.

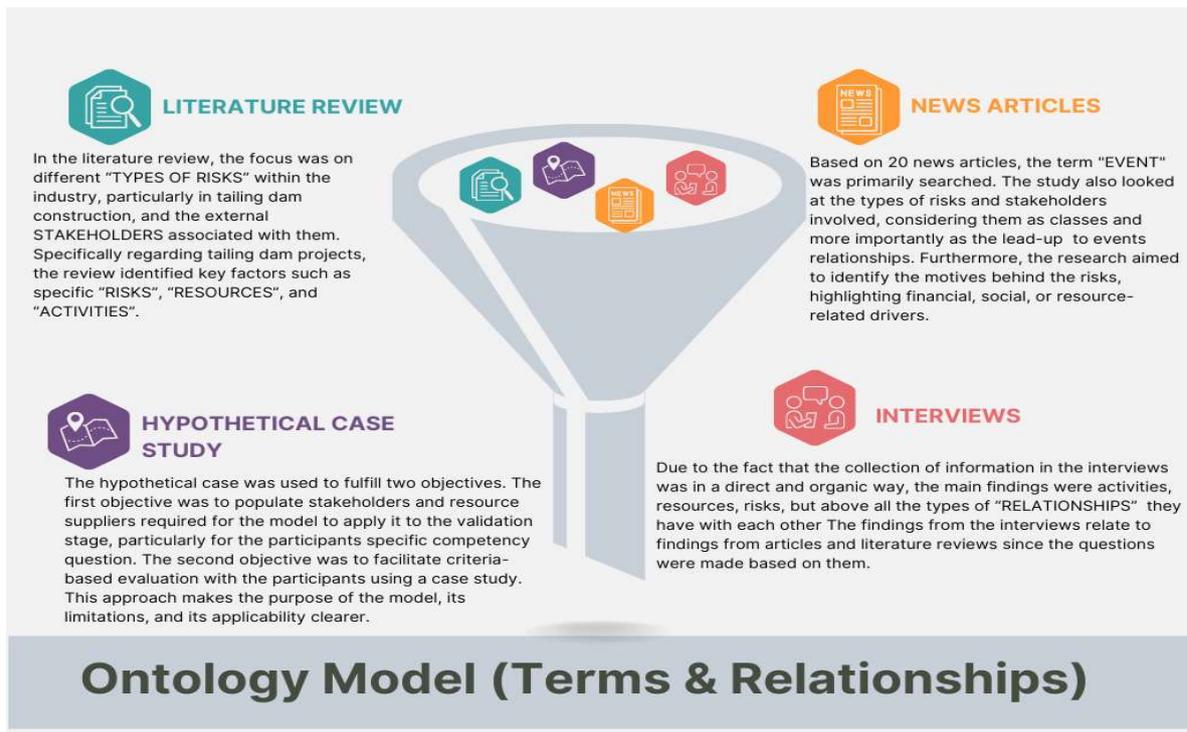


FIGURE 11: FUNNEL DIAGRAM DATA GATHERING= MODEL

In order to better understand the evaluation of knowledge graphically, the following diagram has been designed, which includes the processes of verification and validation, the latter by implementing the model to the previously mentioned hypothetical case.

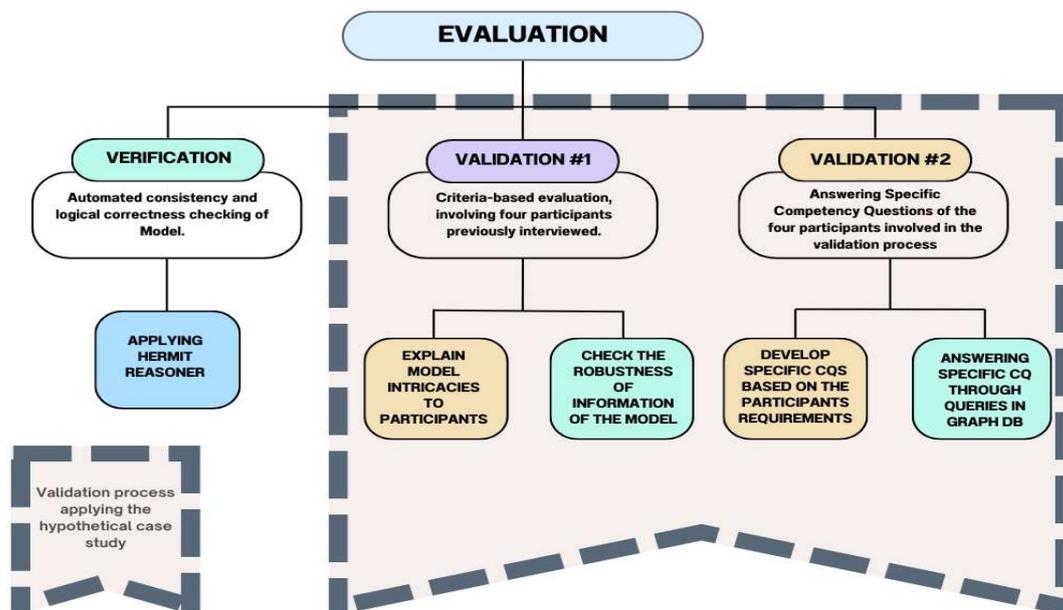
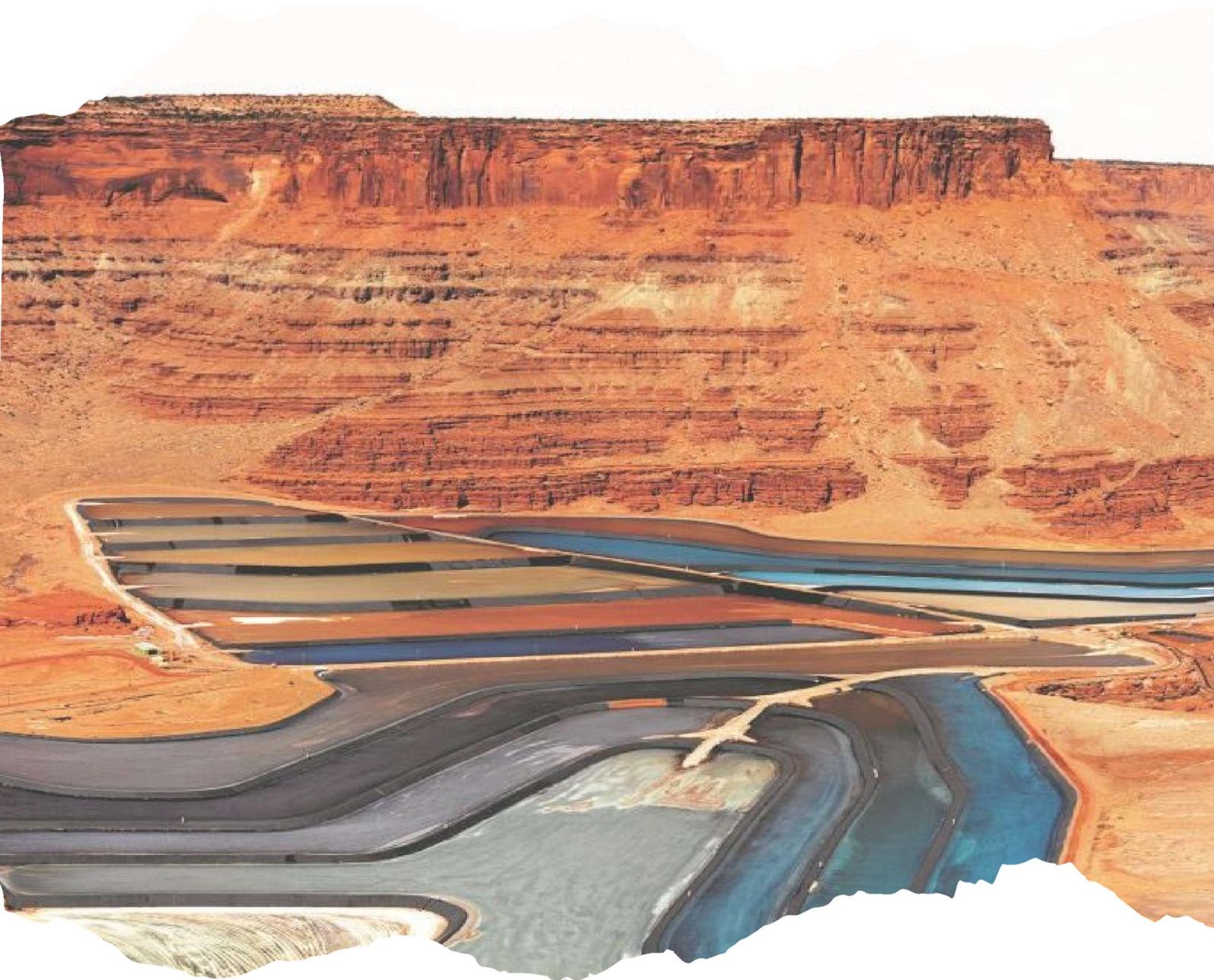


FIGURE 12: EVALUATION OF MODEL (VERIFICATION & VALIDATION)



CHAPTER 3

LITERATURE

REVIEW

3 LITERATURE REVIEW

The literature review examines the external risks and impacts encountered by infrastructure projects with conditions similar to those of a tailings dam project. This was done in order to gain a global understanding of what happens in projects with similar characteristics. It began with a broad study of infrastructure projects worldwide, then narrowed down to hydraulic projects, and finally focused on construction projects within the mining industry. This section also identified how external factors such as resources and external stakeholders play an important role in the current mining industry, the types of risks that are commonly encountered during the construction of these types of projects, and the key drivers to consider in the construction of tailings dams, as shown in **Figure 13**.



FIGURE 13: LITERATURE REVIEW STEPS FOR IDENTIFYING THE MOST COMMON RISKS IN THE MINING INDUSTRY

The literature review's second section discusses the importance of risk identification during the tender stage. This is essential for minimizing the impact of events during construction. Additionally, the section aims to list the methods or techniques commonly used by contractors. In the final section of the literature review, an examination was conducted on how knowledge-based models, specifically those based on ontologies, can improve the efficiency and comprehensiveness of the risk identification process through automation and by leveraging machine learning models.

Since there is not so much specific information in the literature, mainly on external risks in the mining industry, it was decided to follow an integrative literature review to have a holistic view to build the ontology. Initially, it was decided to use keywords in the searches such as uncertainties or classification of risks, and then, as shown in **Figure 13** above, the search went from the general to the specific in terms of external risks, starting with global infrastructure projects, then water infrastructure, mining industry, and finally tailings dams. Finally, a review of risk identification in the bidding process from the contractor's point of view and how ontological models have been applied to risk management. The period of time given for the literature review was initially one month,

collecting data on risks and studies on ontologies applied to risks; however, as the information was gathered, the panorama opened up to a specific type of project, tailing dams, which required one more month to complete the literature review.

3.1 EXTERNAL RISKS IN INFRASTRUCTURE PROJECTS

Risk is an uncertain event that can have positive or negative outcomes. Positive risks represent opportunities, while negative risks are threats that can cause inconvenience or harm. Risk management involves identifying, measuring, and treating risks in the most efficient way possible (Renault & Agumba, 2016).

There are different types of risk and different ways in which risks affect stakeholders, so several risk groups and subgroups have been developed to better understand how they are formed and their effects. Based on the sources concerned with the stakeholders, Zou et al. (2007) have grouped risks into various categories: time-associated, environmentally-associated, cost-associated, and safety-associated.

Mikes and Kaplan (2012) have identified three categories of risk based purely on the approach that must be taken to establish an effective risk management system.

- The first category refers to foreseeable risks, which originate from internal sources and can be controlled, eliminated, or avoided.
- The second category is strategic risks, which companies accept as part of a trade-off where the perceived benefits outweigh the risks. These risks cannot be managed through a rule-based control system but rather by reducing the probability of their occurrence. The higher the likelihood of the risk, the greater the expected benefits should be.
- The third category covers external risks, which are events beyond the control of the stakeholders. These risks require a different approach and should be managed by identifying and mitigating their impact. Although these risks may seem obvious, the absence of a formal tool to analyze and address them often means they are not discussed until it is too late.

Several factors can affect the success of a construction project. These include the project's custom nature, which makes it nonhomogeneous and non-serial in production. Additionally, construction occurs in a complex and uncertain environment, with various stakeholders who may not always agree. The previous factors can lead to increased risks, highlighting the need for swift and clear risk identification for decision-makers (De Azevedo et al., 2014).

Since infrastructure projects impact people's daily lives, external stakeholders, such as local communities and various governmental institutions, are keenly interested. A key factor contributing to the failure of construction projects to meet their estimated timelines and budgets is the level of risk involved. As more parties become involved in these projects, including contractors, subcontractors, owner designers, and external stakeholders, the need to distribute responsibilities and mitigate risks becomes increasingly important. While this new approach can help to reduce risk, it can also make projects more complex and dynamic

While managing infrastructure projects, the focus is primarily on managing work content, timelines, resources, and costs. However, risk management is often overlooked. The project team usually

identifies the most significant risks of the entire project and prepares measures to mitigate their consequences. Unfortunately, contractors often lack the time and motivation to conduct a more comprehensive assessment of the risks associated with individual components of the project. These components can cause risk events that negatively impact the project's progress, particularly regarding execution time and costs. (Rihar et al., 2019)

An extensive search was made for global infrastructure projects where the above has occurred, i.e., external events or conflicts that have impacted a project due to project assessment, their impact, and lessons learned.

In their 2017 study, Shen et al. examined the reasons behind contractors' claims in construction projects in developing countries such as Pakistan, Fiji, Iran, and Zambia. They looked at the impact of various factors, including economic, political, social, and legal issues, as well as the behavior of the client. They found that external risks associated with organizational behavior were a major cause of claims, highlighting the need for cooperation among project participants to mitigate these risks.

The study revealed several events that negatively affected projects, such as conflicts between countries leading to a shortage of explosives, roadblocks that hindered the delivery of necessary materials, organized crime, worker strikes due to political and legal issues, lack of temporary access agreements, and blockades by surrounding communities. However, the study also showed that adopting a partnering strategy to jointly mitigate the impacts of external risks was more effective in dealing with contractual problems and reducing conflicts than litigation (Shen et al., 2017).

The authors suggested several strategies to mitigate the risks mentioned above. First, timely information collection from the complex project environment would help prevent and respond to external risks. Second, promoting partnering among project participants based on equitable risk allocation, trust, and open communication would reduce uncertainties in project implementation and conflicts from opportunistic behavior. Finally, clearly defining the project scope of work and technical specifications would help identify risks.

In Korea, a study was conducted to identify the causes, impacts, and resolutions of external conflicts in 22 mega-projects; the authors Lee et al. (2017b) analyzed social and environmental events that caused delays and increases in project costs. Two projects, the Sapaeo Mountain Tunnel project and the Miryang Transmission Tower, were particularly affected during the construction phase. In the case of the Sapaeo Tunnel, construction work was halted after six months due to strong opposition from a religious organization. Ultimately, the project was completed two years behind schedule and suffered significant financial losses. On the other hand, the Miryang Tower project was delayed for seven years due to objections from the surrounding population regarding its feasibility studies. The study found that conflicts arising from environmental concerns usually escalate during the construction stage rather than the planning stage of a project. Social issues, on the other hand, tend to arise due to increased opposition from local residents who were initially minor shareholders or socially weaker. While most social conflicts are initiated at the planning stage, they often gain momentum over time due to a lack of attention to external risks, leading to greater consequences during the construction stage if not addressed in a timely manner.

Assaf and Al-Hejji (2006) researched the most common causes of delays in construction projects in Saudi Arabia. The study found that the most significant external factors causing delays in construction

projects were labor shortages, an unskilled workforce, delays in material delivery, and inclement weather. Changes in government regulations and laws and social and cultural factors were found to be the least significant factors impacting construction projects in Saudi Arabia.

On the other hand, according to Zou et al. (2007b), the bureaucratic and excessively procedural approval processes in Chinese government agencies pose a significant risk to projects. The study found that the primary concerns of government agencies are project cost, time, and environmental sustainability. Additionally, the study identified several other key risks, including the inability of suppliers to deliver materials on time, the lack of available utilities on site, and the shortage of skilled laborers and professionals. Surprisingly, these risks were not identified as key and significant factors in the early stages of the projects. The authors recommend that contractors develop a solid construction plan that effectively distributes staff and utilities. They also suggest keeping a close eye on the construction progress, ensuring that there are enough professionals, managers, skilled laborers, and utilities available to work on the project.

3.1.1 External Risks and Impacts in Hydraulic Infrastructure Projects

Large-scale construction projects, particularly hydraulic infrastructure projects, have negatively impacted surrounding communities in various parts of the world. Andrade Navia and Olaya Amaya (2021) have identified several social impacts that hydroelectric plants have on nearby communities, such as health emergencies caused by water contamination and changes in the water ecosystem, loss of cultural, traditional, or spiritual heritage, forced displacement of communities, and restricted access to natural resources. On the other hand, the most significant environmental impacts are the hydrological changes that occur due to the construction and operation of the plants, which alter the natural river banks, affect the fauna and flora, and deteriorate water quality due to sedimentation and changes in the water flow. In the past, the social and environmental impacts of dam projects have often been underestimated. However, with increasing social awareness, communities have become more informed about these impacts, leading to a rise in conflicts in recent years when such projects are proposed.

Due to the increasing social awareness, construction projects have become more complex, increasing the social and environmental risks associated with them. In a study by Gómez et al. (2014c), it was suggested that communities now have greater access to information, which allows them to make better decisions about new projects. For instance, the Amazonian struggle against megaprojects was largely driven by a media strategy with strong scientific content. This enabled information about the plans and impacts of the megaprojects to reach even the most remote areas of the jungle. The diverse social groups that oppose megaprojects bring together a wide range of knowledge and expertise, resulting in a complex web of ideas and actions. This complexity is due to the different discourses and collective actions that these groups engage in.

3.1.2 External Risks and Impacts in the Mining Industry.

Mining companies frequently extract resources from ecologically and socially vulnerable areas. These areas are typically home to communities, including indigenous ones, who rely on these resources for their livelihoods. Unfortunately, these communities often experience a wide range of impacts, creating conflicts and resistance to these projects that can go from sporadic to sustained collective action by social movements with organized networks. Communities may take action

against mining projects, including canceling a mining project or increasing their bargaining power in negotiations by blockading a mine construction site to increase compensation benefits (Conde & Billon, 2017b). The author refers to the following graph showing the increase of conflicts in the mining industry in recent years, which clearly shows an exponential increase from 2000 to 2016.

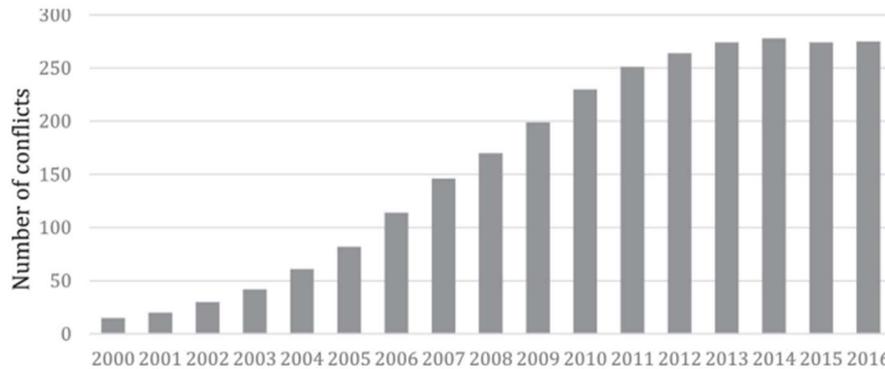


FIGURE 14: NUMBER OF NEW MINING CONFLICTS (CONDE & BILLON, 2017A)

The research suggests that specific factors can increase the likelihood of social events or conflicts. Among these factors is the mining company's inability to fulfill social agreements with communities and provide compensation for the use of necessary resources and land. Additionally, conflicts are more prevalent in communities with territorial cohesion or the ability to unite, such as the Ejido in Mexico, according to the authors' findings. One of the biggest environmental challenges faced by the international mining industry is the management of waste treatment and disposal, particularly tailings dams (Dong et al., 2019).

Governments approach the industry in two conflicting ways. On one hand, they aim to boost their country's economic resources by creating policies that make these projects more profitable than those of other countries. On the other hand, they also regulate the industry's political, environmental, social, and economic aspects to minimize the negative impact on external stakeholders, including the surrounding communities and the environment. The effectiveness of public management is measured by how well it achieves these goals. (Hodge et al., 2022). This very duality makes the social and environmental performance of mining construction projects a wicked problem. Therefore, these external risk factors have a significant weight when assessing the possible impacts on construction projects in the mining sector.

The mining industry is notoriously risky, and construction projects in this field are particularly vulnerable to two types of risks. The first type of risk is internal, relating to health and safety concerns that are inherent in the nature of the industry. Digging below ground level, using explosives, and operating heavy machinery to create infrastructure are all constant hazards. The second type of risk is external and can be categorized under the acronym PESTLE, which stands for Political, Environmental, Social, Technological, Legal, and Environmental factors. These risks can have negative consequences, but they can also present opportunities.

It is important to mention that the external risk mentioned will always be controversial and even biased depending on the stakeholders since they are mainly identified through empirical elements and

are long-term, which translates into a lack of trust among those involved. Especially when the performance of mining companies is not only measured by business KPIs but also by the surrounding environment, such as NGOs, surrounding communities, local and federal government.

According to the World Economic Forum, “Creating real benefits for communities near mine sites will be key for successful new projects. Obtaining the ‘license to operate’ from local communities has been a challenge for the mining industry in recent years.” (Seven Trends That Will Shape the Future of Mining and Metals, 2020). As mining companies digitize and automate, deciding which data to share with stakeholders will be a key discussion point. Governments will want subsidiary structures disclosed to counter tax erosion, while consumers want more transparency in the value chain. Investors will use non-financial data to assess risk, and civil society will push beyond the mandatory EITI Standard. Communities want data on externalities that affect them. Collaboration is essential to determine what data to disclose and how to standardize it. (Seven Trends That Will Shape the Future of Mining and Metals, 2020)

3.1.3 Key Drivers to Consider in the Construction of Tailings Dams

When embarking on a construction project, it is essential to take into account a multitude of factors. In Lammers' (2016) research, several key drivers were identified as important considerations when determining the type of tailings dam to construct. The author highlights the criticality of factoring in environmental risks, including land, water, and air pollution, as well as social issues, land use, public health, political climate, and regulatory requirements, when designing a tailings dam. It's crucial to keep these factors in mind, regardless of the type of dam being constructed, for a successful project outcome.

Among the key drivers to consider in the construction of tailings dams, are the possible risks or impacts that can be created, either in the construction stage or in the operation stage; for this, Denyo and Agyekum (2021) conducted a survey to determine the most significant social and environmental impacts in the area as perceived by the surrounding communities. According to the survey conducted, the top concern among the communities was the loss of farmland. The second most important concern was the lack of job opportunities or the need for new jobs for the rural inhabitants. Additionally, the survey revealed that there was a noticeable impact on air pollution caused by soil particles from the tailings dams. The construction of the project led to the destruction of settlements, resulting in significant negative impacts on the community. Finally, the construction of the dam had severe environmental consequences, such as the destruction of the wetland and terrestrial habitat, which disrupted the habitat of various living organisms.

3.2 RISK IDENTIFICATION DURING THE BIDDING PROCESS OF CONSTRUCTION PROJECTS

Traditionally, contractors in civil engineering projects have employed a high markup to account for potential risks during the tendering/bidding stage. However, this approach is not only inefficient, as the goal of the bidding process is to secure the most competitive price, but it also fails to acknowledge identified uncertainties. In contrast, the mining industry, which is rife with uncertainties, expects contractors to bear such risks, as noted in the preliminary interviews. In construction, it is crucial to establish a realistic estimate of the final cost and duration of the project as early as possible. Thus, at this stage, all potential risks that could impact these estimates should

be identified; as stated by Bahamid and Doh (2017), the risk identification procedure involves continuously analyzing and categorizing the initial importance of risks and the interrelationships that exist between them (Bahamid & Doh, 2017).

The bidding process is usually brief, and contractors primarily focus on studying the project, its technical specifications, and the primary activities to create a budget that covers the project's needs. However, they tend to overlook identifying risks, which the client must have studied for a more extended period, resulting in a disparity in risk management. Therefore, contractors should identify and manage risks in the same process. If risks are identified and managed early on in the project, their impact on the project's final outcome will be less, as the cost of implementing changes is less in the initial stages, as shown in **Figure 15** (Hlaing et al., 2008).

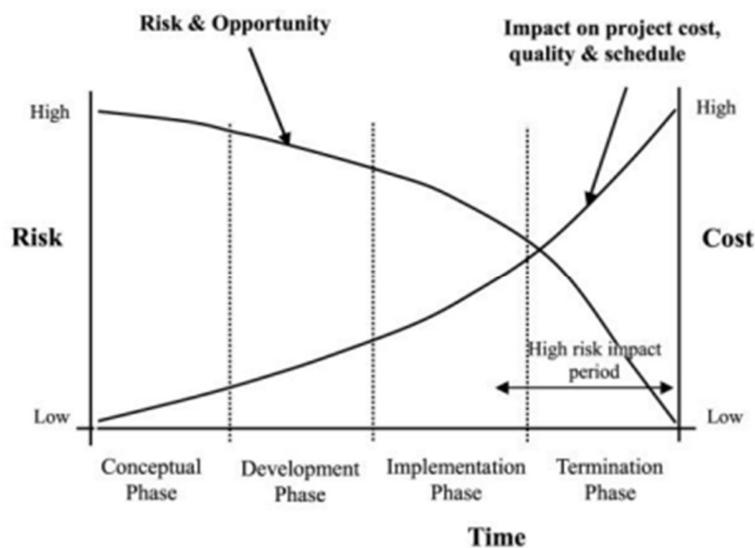


FIGURE 15: RISK-INFLUENCE CURVE FROM HLAING ET AL., 2008

Irrespective of the various stakeholders in a construction project, the contractor, particularly in developing countries, is the party most susceptible to the array of risks that may emerge throughout the project's life cycle. Globally, there exists a plethora of contract types that apportion responsibility differently, yet typically, projects are awarded to a general contractor, a specialist in the field who serves as the coordinator of the various tasks aimed at achieving a set goal.

3.3 RISK IDENTIFICATION TECHNIQUES IN THE CONSTRUCTION INDUSTRY

The identification of potential risks in construction is a process that heavily relies on historical data, experience, and insight, as noted by various authors such as Al-Tabtabai & Diekmann (1992), Bajaj et al. (1997), and Hlaing et al. (2008). In view of this, the industry employs numerous methodologies and approaches that have been identified by scholars across the globe, including Bajaj et al. (1997), Hlaing et al. (2008), and Tharanga (2020) in countries such as Singapore, Australia, South Africa, the UK, Ghana, and Brazil.

The most frequently utilized techniques, according to the previously mentioned authors, in this domain include Checklists, scenario building, expert judgment, brainstorming, Delphi technique, and diagram analysis, encompassing SWOT, flow charts, influence, root cause, and risk breakdown.

According to Bahamid and Doh (2017), the most common risk identification techniques in developing countries include the following approaches:

1. Checklists: By using this technique, project managers can consider risks that have occurred in previous projects.
2. Brainstorming: A brainstorming session is held among key stakeholders to gather information for the checklists.
3. Past experiences and expert interviews: These techniques rely on historical data to avoid repeating past mistakes and learn from previous projects.

Another study conducted by Nawaz et al. (2019) mentions that the most commonly employed techniques for risk identification are those depicted in the subsequent figure.

Techniques	M	R
1. Interviews	2.50	3
2. Scenario analysis	2.33	11
3. Delphi technique	2.40	8
4. Expert judgment	2.43	7
5. Root cause analysis	2.37	10
6. Risk review meetings	2.51	2
7. Cause and effect diagrams analysis	2.45	5
8. Checklists analysis	2.44	6
9. Nominal group techniques	2.31	12
10. SWOT analysis	2.40	8
11. Lesson learned from the past project	2.54	1
12. System or process flow charts	2.33	11
13. Brainstorming	2.38	9
14. Mind mapping	2.49	4

Note: M = Mean, R = Rank.

FIGURE 16: LIST OF MOST USED RISK IDENTIFICATION TECHNIQUES IN CONSTRUCTION PROJECTS (NAWAZ ET AL.,2019)

These techniques are based on subjective information, which can be challenging to manage, especially in developing countries with limited risk management plans. When information is not fully available, this can complicate decision-making processes, especially when dealing with Unknown Known risks, which often go unnoticed due to forgetfulness, negligence, or repression (Perera & Higgins, 2017). Although they can be detected through intuition or empirical knowledge, they are not always accounted for in formal risk management models due to a lack of information; this type of risk is commonly referred to as things you are not aware of but understand, or in other words, risks that some people know about but others do not.

As mentioned by Hlaing et al. (2008), risk identification is paramount in risk management. If a risk is not identified, it cannot be analyzed, and its severity and probability of occurrence cannot be quantified, so a mitigation plan cannot be developed. Therefore, it can be implied that identifying those risks is a key step from Unknown known risk to Known Known risk, as shown in **Figure 17**.

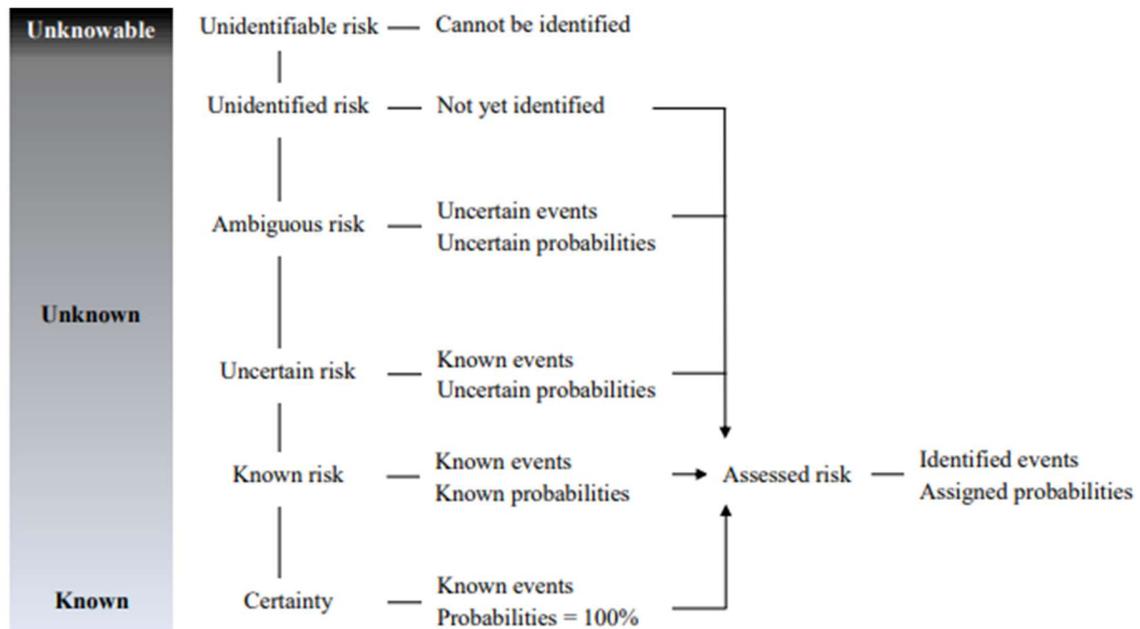


FIGURE 17: DIFFERENT TYPES OF RISK, FROM UNKNOWABLE TO KNOWN (PERERA & HIGGINS, 2017).

3.4 ONTOLOGIES TO IDENTIFY RISKS (KNOWLEDGE GRAPH MODELS)

Research has shown that effective risk management often involves drawing from experience and knowledge gained in similar projects. Knowledge reuse is a key focus of research in construction risk management; However, current risk management tools do not account for causal relationships between risks. Yildiz et al. (2014) emphasize the importance of considering the independencies among risk-related factors. However, this is ignored by the most common tools to identify risk, such as risk checklists. While many risk management systems model interdependencies in a relational database system, semantic relations are not always clearly expressed within traditional relational databases. Representing and identifying the semantics of the field dependencies between complex table structures can be time-consuming, and any changes to interdependence may require recreating the network from the beginning due to complex interaction structures. Therefore, it is necessary to explicitly represent interdependencies among risks and risk factors semantically in a model. Ontology is the formal representation of knowledge in a domain, which allows for semantic reuse of knowledge. (Ding et al., 2016).

As stated by Liu and Zaraté (2014), ontology modeling is the act of collecting and organizing shared knowledge rather than individual opinions. Ontology not only presents information to humans but also analyzes and draws conclusions from it. This is why ontology can offer an impartial, thorough understanding of all stakeholder perspectives and external and internal risks. Furthermore, it offers stakeholders complete visibility of the entire landscape.

Ontologies are a widely recognized means of representing knowledge, providing a clear definition of the domain knowledge shared across multiple systems. Comprised of two fundamental elements, ontologies include classes that signify concepts within the domain of interest, as well as relationships that demonstrate the semantic associations between various concepts (Hassan & Le, 2023).

When there are multiple variables in an environment, identifying risks can become complex, especially if those variables are dynamic and complex themselves, like social issues. In such scenarios, it is crucial to map the implicit and empirical information and put it in an explicit context that shows the relationships between those risks, external agents, and the activities to be carried out in a holistic context. To achieve this, a knowledge model such as ontologies can be used. These models leverage semantic technologies and domain-specific knowledge to provide a comprehensive understanding of risks associated with construction projects.

Risk management in construction projects relies on the expertise of professionals, the experience of stakeholders, and information from various sources. These sources include historical project data, checklists, and other risk identification techniques. A knowledge-based model could capture all this information and knowledge from past projects and reuse them for new projects to improve the decision-making process. By collecting this data and connecting them through semantic relationships, unseen connections can be discovered (Isah & Kim, 2023b).

3.5 POINT OF DEPARTURE / SUMMARY

Upon reviewing the literature, it is evident that early identification of various risks is of paramount importance in project management, especially in the context of construction projects. Traditional risk management techniques often lack the flexibility to effectively address the external risks prevalent in the mining industry, where social dynamics play a significant role. To address this issue, the use of ontologies has been proposed as a solution to enhance risk management practices. By leveraging semantics to establish connections and visualize risks in relation to other factors, ontologies facilitate the documentation of implicit knowledge and enable its reuse and application across diverse projects and domains. Moreover, identifying common risks in the mining industry, including those associated with projects such as tailings dams, serves as a foundation for the subsequent interview questions.

The literature review also revealed that infrastructure projects are most commonly impacted by external risks associated with organizations and social, political, or legal events. Additionally, actions by external stakeholders, particularly communities, have resulted in opposition to projects due to social or environmental concerns. Significant external risks also include changes in government regulations, bureaucratic delays, and a lack of available resources in these areas.

In hydraulic projects, major risks include water contamination, changes to water bodies, and negative environmental impacts. The rise in social awareness indirectly contributes to these risks, as communities are now able to oppose projects or seek higher compensation due to easier access to information. Consequently, there has been an increase in social conflicts in construction projects, particularly in the mining industry. Specifically, in the construction of tailings dams, external risks include environmental contamination, loss of land for cultivation or habitation by communities, and water usage.



CHAPTER 4

CASE STUDY

RESULTS

4 CASE STUDY RESULTS

This chapter is structured into two sections. The first section contains news results specifically related to projects in the mining industry in Mexico. Alongside the findings of the interviews, these results will be utilized to formulate the design of the knowledge graph aimed at identifying events that can significantly impact the mining industry. The second section presents the findings of the interviews and the keywords used to understand the specific risks of the mining industry.

4.1 EXTERNAL EVENTS REGARDING THE MINING INDUSTRY IN MEXICO

As previously discussed, the mining industry and its construction projects are highly intricate due to the geographic location and resources required for operation. One of the external factors that cannot be controlled beforehand are the rural communities, also known as ejidatarios in Mexico. The ejidos and agrarian communities are the form of land tenure that covers the largest area in the Mexican countryside; they offer an important agricultural production, and in their soils are most of the mountains, forest areas, mangroves, coasts, water, mines, and various natural attractions (Morett-Sánchez et al., n.d.). The Ejidos is a form of land ownership among a group of inhabitants in a rural area that dates back to 1915 after the Mexican revolution. Its legal framework is supported by the Mexican Agrarian Law, particularly in articles 9, 10, and 11, which state that an ejido possesses legal personality and its own assets over the land. The only restriction is that it does not conflict with the activities outlined in the Mexican constitution and penal regulations. Therefore, in the case of mining, even if all environmental and social permits have been obtained from the Mexican government and construction companies comply with regulations, they must still obtain ejidal consent to conduct work on their lands, even if they have established a land provision agreement.

Various instances were discovered, particularly in recent times, where social tensions arose between rural communities and the mining industry. In these situations, external risks that were deemed low probability risks due to the lack of power of external stakeholders led to project interruption or mine operation stoppage that lasted even for months. The root causes of these conflicts are part of a complex network of external risks that were either not identified or deliberately omitted, but they are causes that have a significant impact on the project's life if they occur.

The following table lists the news articles with their year of publication and why these events happened, which will be explained in the chapter divided by motives.

TABLE 9: LIST OF ARTICLES NEWS ANALYZED

Author(s), Title, Newspaper	Year Published	Risks
Maldonado, S. (2024, March 29). Minera San Agustín reanuda labores; agradece al Estado por proteger empleos. www.elsiglodedurango.com.mx . https://www.elsiglodedurango.com.mx/noticia/2024/minera-reanuda-labores-agradece-al-estado-por-protoger-empleos.html	2024	Social risk (financially driven)

De Durango, E. U. / E. S. (n.d.). Ejidatarios recibirán 2 patrullas y despensas por acuerdo con empresa minera. El Sol De Durango Noticias Locales, Policiacas, Sobre México, Durango Y El Mundo. https://www.elsoldedurango.com.mx/local/ejidatarios-recibiran-2-patrullas-y-despensas-por-acuerdo-con-empresa-minera-11455733.html	2024	Social risk
Bessi, R. (2023, September 6). Oaxaca: Comunidades denuncian colusión de la Procuraduría Agraria con proyecto minero. Avispa Midia. https://avispa.org/oaxaca-comunidades-denuncian-colusion-de-la-procuraduria-agraria-con-proyecto-minero/	2023	Social risk
Corresponsal, S. O. A. (2022, September 6). Ejidatarios bloquean mina de Carrizalillo por incumplimiento de contrato. La Jornada. https://www.jornada.com.mx/notas/2022/09/06/estados/ejidatarios-bloquean-mina-de-carrizalillo-por-incumplimiento-de-contrato/	2022	Social and legal risks (Financially and resource-driven)
https://www.elsiglodedurango.com.mx/noticia/2021/persiste-desacuerdo-entre-la-mina-y-ejidatarios-de-la-parrilla.html	2021	Social Risks (Financially Driven)
Medina, M. (2021, December 28). Ejidatarios toman Minera Capstone por incumplimiento en acuerdos. Imagen Zacatecas. https://imagenzac.com.mx/capital/ejidatarios-toman-minera-capstone-por-incumplimiento-en-acuerdos/	2021	Social Risks (Financially Driven)
https://www.jornada.com.mx/notas/2021/01/17/estados/ejidatarios-bloquean-mina-de-manganeso-en-hidalgo/	2021	Social en environmental risks (Use of Dynamite)
De Durango, M. R. E. S. (n.d.). Problema con mina en San José de Avino enfrenta al pueblo de Pánuco de Coronado. El Sol De Durango Noticias Locales, Policiacas, Sobre México, Durango Y El Mundo. https://www.elsoldedurango.com.mx/local/municipios/problema-con-la-mina-en-san-jose-de-avino-enfrenta-al-pueblo-de-panuco-de-coronado-durango-10042833.html	2023	Environmental risks
Ollaquindia, R. O. (2014, February). Ante falta de respuesta, ejidatarios continúan protesta en inmediaciones de la mina Camino Rojo. La Jornada Zacatecas. Retrieved April 1, 2024, from https://ljz.mx/02/02/2014/ante-falta-de-respuesta-ejidatarios-continuan-protesta-en-inmediaciones-de-la-mina-camino-rojo/	2014	Social Risks (financially driven)
Rocha, C. (2016, December 30). El estado de Puebla mantiene cuatro conflictos mineros, según el OCMAL. La Jornada De Oriente. https://www.lajornadadeoriente.com.mx/puebla/estado-puebla-mantiene-cuatro-conflictos-mineros-segun-ocmal/	2016	Social and environmental risks (water-driven)
Huicholes en pie de guerra. (n.d.). vanguardia.com.mx. https://vanguardia.com.mx/noticias/nacional/2860836-huicholes-en-pie-de-guerra-NXVG2860836	2015	Social and environmental risks (water-driven)
Corresponsal, C. G. L. (2023, October 21). Defensores del río Sonora cierran acceso a mina de Cananea. La Jornada. https://www.jornada.com.mx/noticia/2023/10/21/estados/defensores-del-rio-sonora-cierran-acceso-a-mina-de-cananea-8669	2023	Social risks
Mayorga, P. (n.d.). Inseguridad generada por el narco obliga al cierre de minera en la Sierra Tarahumara. Proceso. https://www.proceso.com.mx/nacional/2018/5/25/inseguridad-generada-por-el-narco-obliga-al-cierre-de-minera-en-la-sierra-tarahumara-205723.html	2018	Social risks (organized crime)

Exigen cerrar mina en Solosuchiapa. (2019, February 26). Cuarto Poder Chiapas. https://www.cuartopoder.mx/chiapas/exigen-cerrar-mina-en-solosuchiapa/277210	2019	Social risk
Mariscal, Á. (2016, November 10). En Chiapas piden cierre definitivo de minas a cielo abierto. Chiapasparalelo. https://www.chiapasparalelo.com/noticias/chiapas/2016/11/habitan-tes-de-chiapas-piden-cierre-definitivo-de-minas-a-cielo-abierto/	2016	Environmental risks
Sánchez, A. (2020, February 21). Bloqueos a minas opacan extracción de oro y plata en México. El Financiero. https://www.elfinanciero.com.mx/empresas/bloqueos-a-minas-opacan-extraccion-de-oro-y-plata-en-mexico/	2019	Social Risks
De Zacatecas, R. G. / E. S. (n.d.). Candidato a alcalde bloquea mina en Sombrerete; Grupo México interpone denuncia penal. El Sol De Zacatecas Noticias Locales, Policiacas, Sobre México, Zacatecas Y El Mundo. https://www.elsoldezacatecas.com.mx/elecciones-2024/candidato-a-alcalde-bloquea-mina-en-sombrerete-grupo-mexico-interpone-denuncia-penal-11810449.html	2024	Political Risks
De Morelia, D. M. E. S. (n.d.). ArcelorMittal da su postura ante bloqueo en la Mina Las Truchas. El Sol De Morelia Noticias Locales, Policiacas, Sobre México, Michoacán Y El Mundo. https://www.elsoldemorelia.com.mx/local/arcelormittal-da-su-postura-ante-bloqueo-en-la-mina-las-truchas-11112799.html	2023	Environmental risks
Canedo, F. P. (2024, May 7). Rechazan mineros bloqueos. www.elsiglodetorreon.com.mx . https://www.elsiglodetorreon.com.mx/noticia/2024/rechazan-mineros-bloqueos.html	2024	Financial Risk
Martínez, J. C. (2021, January 17). Minera denuncia pasividad de Fiscalía de Sinaloa en investigación de bloqueos que la mantienen cerrada. El Universal. https://www.eluniversal.com.mx/estados/minera-denuncia-pasividad-de-fiscalia-de-sinaloa-en-investigacion-de-bloqueos-que-la/	2021	Social Risks

The primary factors that have triggered these events are financial, a combination of financial and environmental factors, and environmental and social risks, including organized crime. The following case studies, categorized by the primary reason for the conflicts, will illustrate these factors.

4.1.1 Financially-driven Events

Social events always have a different background or motive, and the consequences are social movements or demonstrations of the population. A series of news articles in Mexico was compiled to analyze the causes of social events that have escalated to become news. Usually, the events that gain enough social force to gain visibility are the ones that appear in the news and, therefore, have a greater impact on the projects.

In Durango, Mexico, recently, in a mine owned by Argonaut Company, the operations and construction of secondary infrastructure faced an inactivity period due to blockades and demonstrations by ejidatarios. By September 2023, the ejidatarios' complaints went through the legal process and courts, where the Argonaut Gold mining group was found innocent and cleared of any

wrongdoing, the conflict began when a family claimed that the payment they had agreed upon for the use of a plot of land was not enough, even though it had already been paid and agreed upon from the beginning. The family argued that the mine was extracting far more value from the land than they had originally agreed upon, which led to blockades by the population that lasted for about six months (Maldonado, 2024).

The conflict was resolved by fulfilling three of the family's requests, the first being the allocation of two extra patrols for the protection of the ejidal population, an increase in the amount of the subsidies granted, and the paving of a stretch of road (E. U. / E. S. De Durango, n.d.). Although the demands have a lower cost, the work was stopped for 6 months, which resulted in much higher lost costs. The social problems in this case went further even though the mining company and the civil engineering subcontractors were not at fault. Even though the court had ordered the ejidatarios to stop taking over the access roads to the mine, they did so.

Another event in the same state was that a group of approximately thirty people blocked the accesses to the Roble de Velardeña mine, as the union demanded profit payments; however, the mining company presented its annual report where it mentioned that it had not made any profits. The union then blocked the entrance and the mine's workers and contractors demanded that the state help them resolve the blockade, as it is illegal and unfounded. Between the union and the staff there was even a small encounter where there was some aggression and threats from the protesters (Canedo, 2024).

In another state, Zacatecas recently had two events of social conflicts in different projects, the ejidatarios of Hacienda Nueva in Zacatecas took over the main entrance of Capstone Gold mining company due to their dissatisfaction with the mutual agreements for the benefit of the community. These agreements included providing work opportunities to the community, fixing roads and highways, and compensating for any contamination. The ejidatarios demanded that more people from the community be hired and fewer outsiders, better road repairs, and they were unhappy with the passage of machinery destined for secondary works of the operation because they caused damage. The main trigger for the takeover was that the mine made an electrical connection from a substation that passed through ejidos without providing the same benefits of connection to the ejidatarios (Medina, 2021). Certain rural dirt roads, lacking in concrete or steel infrastructure, were affected by the passage of new machinery. This is due to the increased stresses posed by heavy equipment, oil spillages, and even rainfall. Furthermore, upon discovering that a mining company had installed a temporary power line, people chose sides and demanded the same benefit.

The other protest in Zacatecas, was against the Goldcorp company. The agrarian inhabitants demanded to renegotiate the "Goods other than land" payments, which are extra payments requested by the ejidatarios in addition to the rent of their plots. The company wanted to start the construction of a new tailings dam, but the inhabitants noticed that there were monetary resources available for this. As a result, they decided to request an additional twelve million pesos for the common good of society (Ollaquindia, 2014).

It is common practice in Mexico for ejidatarios to renegotiate financial support when they believe they have more bargaining power. This serves as an example of how a social event could lead to the postponement of mining dam construction projects, even if the projects have complied with regulations and pre-existing agreements with society. The new regulation in Mexico provides more bargaining power to these communities, and the more information they possess about past projects,

the higher their demands become. In Durango, in another project owned by the company First Majestic, the local community decided to halt their work. This decision was made due to a lack of agreement between the company and the communities. The ejidatarios have had a change of opinion and wished to modify the social responsibility contracts. These contracts involve the support offered by companies to improve the quality of life of the communities surrounding the mining projects (Barrientos, 2021b).

4.1.2 Financially and Resource-driven Events

In the state of Guerrero in Mexico, ejido communities blocked access to the mine of the Canadian company Equinox Gold due to social non-compliance. Specifically, the ejidatarios comment that one of the clauses of the contract refers to the fact that the mining company must give preference to the rental of equipment, machinery and complementary services used for the operation and construction of secondary works, which has not been fully complied with due to the fact that foreign construction companies from other states of the republic have been contracted. The inhabitants of the area have closed the access roads for vehicles transporting fuel and supplies for the mine works. Due to the drought, the ejidatarios complain of scarce water and request mining company relief irrigation for agricultural areas (Corresponsal, 2022).

4.1.3 Resources-driven Events

In southern Mexico, in Chiapas, thousands of demonstrators closed roads and access routes to the Santa Fe mine. They also went to the municipal town hall to demand the cancellation of the mining concession. They argued that there is significant water contamination and demonstrated that nature was being destroyed. They also pointed out that the surrounding villages were suffering damage due to the mine's activity (Exigen Cerrar Mina En Solosuchiapa, 2019). In Chiapas as well, ejido communities from two different municipalities marched and demonstrated for the definitive closure of 5 mines. The reason according to the demonstrators is environmental pollution, specifically 3 rivers that supply water to the municipalities. The mines have not been operating for months, but the companies had hoped that the concessions would be returned to them.

The Las Truchas mine in Michoacan was blocked by inhabitants of neighbouring communities because access to the river next to it was limited. This was due to the fact that the mining company was doing some renovations in order to continue with the operation of the mine. The ejidatarios complained and requested that an alternative route to access the water body be extended; however, since the river is federal property, the mining company needed permission from the authorities to create one (De Morelia, n.d.). In this case, the main reason why the communities protested was because they wanted to have better access to a body of water next to the mine, but the company, although it agreed to build an alternative road, needed state and federal permits to do so, and although the communities were informed, the blocking of access continued (Mariscal, 2016).

In 2010, the federal government granted a concession for a mine in Cerro Quemado, San Luis Potosi. The project faced opposition due to concerns about water supply, environmental impact, potential loss of cultural heritage, and protests from indigenous communities arguing that the land and soil was sacred to them (Huicholes En Pie De Guerra, n.d.). One of the interviewees mentioned this project, suggesting that the lack of communication between the indigenous communities and certain external stakeholders was inadequate. This lack of communication led to problems and irrational fears, despite

the fact that the project was not going to affect the cultural heritage of the Wixaritari, the indigenous community in question.

Since 1980, there have been 37 social conflicts related to mining activity in the state of Puebla. One of the most significant conflicts was caused by the Autlan mining company, which destroyed two water deposits supplying three communities through the use of authorized explosives. More recently, in 2012, the Frisco mining company's project was halted because local inhabitants discovered that the construction and operation of tunnels would consume around 190 liters of water per second (Rocha, 2016).

In Panuco, Colorado, the local residents are protesting against the construction of a tailings dam. The construction has changed the course of the water, contaminating their land. These protests have resulted in violent clashes between the residents, as some of them are employees of the mining company. The tailings dam is necessary to comply with environmental regulations. Therefore, if the dam is not completed, the mining company has stated that they will be forced to shut down the operation, leaving hundreds of people unemployed (M. R. | E. S. De Durango, n.d.).

Water is a crucial resource for rural areas that lack large infrastructures to supply them. In these areas, water supply depends on natural wells or even rivers that flow into the region. However, water is also essential for mining and the construction of tailings dams. This creates a major problem when water is scarce, as it is a natural resource that can become scarce at any time, and its flow is neither continuous nor predictable.

4.1.4 Socially-driven Events

Fortuna Silver Mines has been building a gold and silver mine in Oaxaca since 2009. However, local communities have been protesting against the project, particularly the planned construction of ventilation shafts. Despite the company having valid concessions for these lands, the communities have opposed these works. The mining company has concessions for the land where they are excavating underground, but conflicts arise when they need to do secondary construction work on the land, as the ejidatarios do not respect the agreements and protest (Bessi, 2023).

In Hidalgo state, local residents have blocked access to a manganese mine for three main reasons. First, the use of dynamite weakened the walls of some houses and classrooms of a secondary school, according to the residents. Second, the ejidatarios needed to use a portion of the land to dispose of used tires from heavy machinery, which, combined with the area's rainfall and high temperatures, led to a proliferation of mosquitoes that transmit dengue fever. Third, the company needed to build a new dam, but due to a lack of resources, they had to settle for creating dykes to prevent the overflow of contaminated water, which did not effectively do the job (Montoya, 2021b). The use of dynamite for mining or road construction, as well as building dams, has had a detrimental effect on the homes of the neighboring communities. Despite the requirement for a special permit from SEDENA and environmental institutions to use explosives, it was unexpected that the resulting explosions would cause damage to the property of local residents.

A big blockade was formed in the five entrances of the mine by 300 former workers and members of a community near the Buenavista mine in Cananea, Sonora. They protested against the unjustified dismissals of some workers fifteen years ago and are demanding payment of reinstatement fees and

medical insurance. The blockades have been strategically placed on ejido plots and secondary roads leading to the mines to avoid confrontations; however, they have affected the passage of more than six thousand workers. The union and strike leader stated that they were not going to allow supplies into the mine. Their goal is to strand all the contractors and suppliers in their towns and communities in order to apply pressure and increase their bargaining power (C. G. L. Corresponsal, 2023).

In 2019, one of the biggest news companies wrote an article regarding the continuous social problems that big mining companies had in that year. The news covers five social blockades in big mines all over Mexico. One of the mines mentioned lasted 130 days without activity, allegedly because the company Newmont-Goldcorp disregarded the community and did not fulfill some of their commitments. In another mine in Coahuila, there was a blockade at the Silver Bull mine because workers were demanding payments. Another mine in Oaxaca was stopped because parents were demanding support for housing and schools. In another case in Zacatecas, there was also a stoppage because the community of Boquillas wanted new agreements for housing support to be fulfilled (Sánchez, 2020).

One social factor that also creates social risks in this industry is the involvement of political actors as is the case of the mine San Martin, where a candidate for mayor of the town, blocked the entrances to the mine, in conjunction with a small truckers' union, as this candidate is also the leader of the union. The blockade lasted more than a week. The mining company filed a criminal complaint against the candidate, while the state government called on the mining company and the candidate to reach a mutually beneficial agreement (De Zacatecas, n.d.).

4.1.5 Organized Crime as a Social Risk

In the mining industry, organized crime poses a significant threat. Mines are often located in remote, mountainous areas, making it difficult for the government to control them. This allows criminal groups to operate freely, extorting money from nearby communities and companies. For example, Americas Gold and Silver has been facing challenges since 2020, with armed groups stealing over forty tons of material from the mine. Additionally, a local union has blocked access to the mine and even attacked vehicles transporting materials and personnel. Despite multiple attempts to negotiate with the union and armed groups, the company has been unable to reach an agreement and is now seeking assistance as they have exhausted all other options (Martínez, 2021).

4.2 INTERVIEW FINDINGS

In accordance with the methodology outlined, eight interviews were conducted to collect data and define the terminology for the Protégé model. The interviews were recorded, transcribed, and stored on the TU Delft server using Microsoft Teams. They were then translated into English from Spanish and coded using Atlas.TI software, resulting in the creation of 150 codes and quotations. These codes and quotations were used to build a term pool, which in turn was used to create the knowledge graph. The complete codes and the frequency with which they were mentioned can be found in **Appendix A**. Below are some quotes from the interviewees and some formulated codes.

TABLE 10: #1 C-2 PROOF QUOTE AND CODES (FROM ATLAS.TI)

Interviewees Proof Quotes	Codes
<p><i>There may be some threat in this case of, I don't know, for example, there are certain points in Mexico where there is organized crime, there may be some issue of, I tell you openly, of a quota, a quota that has to be paid, so that expense, well no, it was not considered, in the issue of property or physical security for all the workers and for the project.-</i></p>	<ul style="list-style-type: none"> • Stakeholders: Organized Crime Groups • Social Risk: Extraordinary fees to Criminal groups • Social Risk: Delinquency • Relationship: The mitigation strategy to delinquency involving organized crime groups is paying an extraordinary fee.

TABLE 11: #2 MC-2 PROOF QUOTES AND CODES (FROM ATLAS.TI)

Interviewees Proof Quotes	Codes
<p><i>Yes, look, in some places and here it has also happened that sometimes communities are very close to the operations, and as we need to use machinery, trucks, they make a lot of noise, raise a lot of dust, pollution that bothers these people, and that are also important points that we have to respect and of course improve so that it does not affect, at least in the Community, either with noise, pollution, etc.</i></p>	<ul style="list-style-type: none"> • Stakeholders: Rural Communities • Resource: Machinery and transportation trucks • Activity Risk: Dust pollution • Activity Risk: Noise pollution • Relationship: The use of machinery and trucks creates dust and noise pollution that affects communities.
<p><i>First in a certain mine, we did some blasting, but it was very close to the surface. So, that generation of energy, of that magnitude, from the blasting broke some glass, some windows of some nearby houses and we had problems. So because of the energy that was dissipated, the energy reached some houses and broke several windows, but at those points we supported the people, we reconstructed the damage that we generated and of course in the blasting control we had to use a softer explosives, which did not cause damage in the process.</i></p>	<ul style="list-style-type: none"> • Activity: Blasting • Activity Risk: Damaging Surrounding Buildings • Resource: Explosives • Relationship: Blasting NEEDS explosive as RESOURCE. • Relationship: There is a risk coming directly from the blasting activity, which is damaging the surrounding buildings of the communities.

TABLE 12: C-4 PROOF QUOTES AND CODES (FROM ATLAS.TI)

Interviewees Proof Quotes	Codes
<p><i>Well, first what we would have to see is that before the mining projects have to be developed they must be authorized by the Secretary of Environment in the federal area, from there proceed to them to bid such works and already being notified that you are going to enter to develop such construction or this reinforcement so to speak of different works, Especially in the tailings dams, there are times when the communities sometimes get upset because of some situation, either environmental or because of the dust generated by the activities during the construction process and they are right, they are right, so you have to be very careful. As a builder you must carry out your activities in accordance with the official norms and guidelines requested by the</i></p>	<ul style="list-style-type: none"> • Stakeholders: SEMARNAT • Stakeholders: Rural communities • Activity Risk: Dust pollution • Social Risk: Communal Complains • Legal conflict: Permits • Stakeholders: Organized Crime groups • Stakeholders: Unions • Mitigation strategy or Social Risk: Extraordinary fees to organized crime groups or Unions • Social Risk: Defiance of Law • Social Risk: Union Conflicts <p>Relationships:</p>

<p><i>contracting company in order to develop and carry out the works; practically that is it.</i></p> <p><i>The other very recurrent one, I do not know if I can comment on it, but lately, here in Mexico, organized crime sometimes requests quotas to be able to work, many times this happens and frankly these quotas are disguised through unions.</i></p> <p><i>The unions also sometimes cause a series of problems because even if you sign agreements with them, they feel absolutely free, violating all Mexican laws and regulations to increase these quotas and this affects everything that has been quoted and budgeted and that you have within that project</i></p>	<ul style="list-style-type: none"> • As in the literature review and news is mentioned, communal complains to governmental institutions may lead to permits conflicts. (Can lead to event, Has Social Risk) • Some activities have inherent risks within society (Has activity Risk) (Has Stakeholders) • Some Risks can be mitigated through “Quotas or Fees” (Has Mitigation strategy)
<p><i>Except that, for example, they tell you that you should use local labor as much as possible, even if they are working within the client 'scompany.</i></p> <p><i>However, there are times when it does impact you because indirectly you stop handling a possible amount of foreign transportation, that is, because you are going to, you are supposed to hire local people and the truth is that local people are not used to it and when the time comes they do not work properly, they themselves leave the job and then it impacts you that you have to hire foreign people, and that is what impacts you.</i></p>	<ul style="list-style-type: none"> • Resource: Labour • Activity: Labour Mobilisation • Resource Risk: Incompetence of Local Labour • Has Social Risk: Communities desire to Replace Contractor <p>Relationships:</p> <ul style="list-style-type: none"> • Some resources have their own risk; in this case, local labour has the risk of being incompetent, and in some cases, it is compulsory to hire them by law or by the client to avoid more problems with ejidatarios.(Has Resource Risk) (Has Social Risk)
<p><i>And you have to start or the company has to have the necessary resources to start mobilization. what do I mean?</i></p> <p><i>Mobilization is the transfer of the necessary equipment, which is usually large construction equipment.</i></p> <p><i>Tractors, excavators, motor graders and sending the right people to the site where the work is going to be executed, to try to find campings sites especially and where you are going to supply certain issues such as spare parts, details that you require within the work, then also sending the mobile</i></p>	<ul style="list-style-type: none"> • Activity: Transportation of Machinery to site • Resource Risk: Heavy Machinery Breakdown • Has Mitigation Strategy: Buying Spare parts in advance • Resource: Machinery and Transportation trucks <p>Relationships:</p> <ul style="list-style-type: none"> • To buy spare parts in advance, it is advisable to find specialized works hops nearby where you can order those parts, so these workshops become external stakeholders as well (Has stakeholders) (Has Mitigation Strategy) • The activity transportation of machinery to site has the relationship of (Needs Resource) to conducted, such as Machinery and transportation trucks
<p><i>In general there is one, the first one, even if you comply with all the federal regulations for the transportation of heavy machinery on federal roads, unfortunately in Mexico we still have a federal highway police that commits a lot of crimes, I mean they ask for resources unduly, that is one of them. The other is the theft of machinery, that is why you must have all</i></p>	<ul style="list-style-type: none"> • Stakeholder: State Highway patrols • Social Risk: Defiance of law • Social Risk: Corruption • Social Event: Theft of machinery • Resource: Machinery and transportation trucks

<p><i>the equipment, vehicles and heavy machinery insured in case of this eventuality, practically these two issues.</i></p>	<p>Relationships</p> <p>While transporting machinery, state highway patrol may incur in corruption or defiance of law (Has Social Risk), the other risk or event is the theft of Machinery (Can lead to Event) which can happen if you don't comply with the fees of the patrols or organized crime groups.</p>
<p><i>Ah, water is very important because there are few reservoirs generally in the mining areas, sometimes we have had to bring or carry, sorry, the required water to distances of several kilometers from different wells. I am talking about sometimes up to 30 to 40 km away.</i></p>	<ul style="list-style-type: none"> • Resource : Water • Resource Risk: Insufficient water supply • Mitigation Strategy: Hauling water tanks <p>Relationships:</p> <p>Water is one of the most important resources in the construction of tailing dams; because Mexico is an arid country, there is always the risk of not having enough supply of water, so the mitigation strategy is to carry water from other recollection points. (Has resource Risk) (Has Mitigation Strategy)</p>
<p><i>Sometimes the client has conflicts with the communities where they are located and the communities themselves, in order to pressure the client, in this case, obstruct the contractor. We have had to consider that in the indirect costs of saying: We are going to consider, out of all the direct costs you have, to consider 15 days, for example, of periods of strikes or stoppages, and you have to consider that because the client in their contracts they totally disassociate themselves from these anomalous situations. This has happened to us, not once, I think 7 or 8 times has happened to us</i></p>	<ul style="list-style-type: none"> • Stakeholders: Client • Stakeholders: Rural Communities • Social Event: Strikes • Social Events: Problems with ejidatarios <p>Relationships:</p> <p>If the client does not have a proper communication strategy with communities which is a social risk, can lead to events like problem with the ejidatarios, strikes or roadblocks. (Has Social Risk) (Has Stakeholders) (Can lead to Event)</p>

The previous excerpt provides evidence from quotes, codes, and relationships obtained during the interviews with participants. Different colors separate the various codes and relationships to which the comments and answers refer.

The interviewees' responses focused on the perceived risks faced by contractors and mining companies when building tailing dams in Mexico. The interviews were conducted in an organic manner, and nouns and verbs were collected and coded to create a glossary with different relationships between them. However, it was decided to include only three examples of such findings to avoid information overload.

The codes represented words and implicit relations, which constituted raw data and a conceptual model in a semi-structured form. In the next chapter, it will be shown how the information from **Appendix A** was transferred to a term pool with established relations and annotations within the Protégé software, since not all the codes were specifically used in the construction of the knowledge graph, firstly, because some risks such as weather incidents were outside the scope of the ontology, or in some cases the mining companies focused on responding to other factors such as technical factors when planning a project; while in other cases certain terms such as machinery and trucks were

included in the same class or all the civil works and earthworks necessary, this was to ensure that the model was consistent.

Although the contractors' responses regarding the activities and resources needed for building a tailings dam were similar, some specified recent problems they had encountered, which varied based on their experiences. Some interviewees provided specific cases of events resulting from these risks, while others only mentioned risk mitigation strategies. These problems, which can be translated into external risks, specifically focus on the aforementioned activities and resources. On the other hand, the interviewees from the mining company focused more on the social risks and external stakeholders involved in the project's development, from planning to construction, in a general manner.

One of the main findings from the interviews was an increase in the time required to address social issues in recent years. This was attributed to increased access to information in rural communities, changes in the mining law in Mexico, and the growing presence of criminal groups. These factors have led to an increase in the bargaining power of stakeholders, resulting in greater social complexity and associated risks in the industry, as stated in the following proof quote.

Proof Quote of interviewee MC-3

“Well, look, fundamentally the mining industry has been evolving, the relationship with external factors that we have had, political risks, social, labor, legal risks have been evolving and they are becoming more and more complex. People are becoming more and more educated.

Regulations have become more demanding and, therefore, the mining industry has had to evolve to a change in which we have to take into account the communities, the environment and in the last 30 years this political risk has been increasing.

The labor risk has been increasing, so these are factors that have to be taken into account when you are going to develop a project, fundamentally that giving you the opportunity to develop the project or to build a new project requires much more effort at this time than it did 30 or 40 years ago, for example, in the water administration, in the risk of the communities, and the labor risk became very, very important in the last 10 years.

Before, as a CEO in the past, you used 80% of your time for operations and 20% for financial administrative aspects; now you use 80% to solve social issues and 20% for operations and finance. So, this issue is evolving”

4.3 SUMMARY

Based on the analysis of 20 articles, it is clear that roadblocks, work stoppages, and strikes are the most common occurrences and external risks in Mexico's mining sector. The primary participants in these events are unions, ejidatarios, and, in rare cases, organized crime groups. These events are typically caused by financial issues, including disputes over agreements between mining companies and local communities and disputes over the use of natural resources. Reports indicate that these situations are often resolved through monetary payments, corruption, or coercion, although not all cases are resolved favorably for the success of the project.

The interviews also confirmed and largely aligned with the information presented in the news articles and literature review regarding the most prevalent external risks encountered by the mining industry. The participants referred to specific examples from their own experiences, which were reflected in direct quotes and codes. To answer **SQ1**, the most common external risks can be categorized into

Activity, Resource, and Social Risks. The events identified in the news articles were influenced by financial, resource, and social factors, individually or in combination. Below are the most common external risks based on the insights obtained from the key interviews.

TABLE 13: MOST COMMON EXTERNAL RISKS IN THE MINING INDUSTRY

Activity Risks	Resources Risk	Social Risk
Damaging community plots	Heavy Machinery breakdown	Communities desire to replace contractor
Damaging Roads or power lines	Incompetence of local labor	Communal complains
Damaging surrounding buildings	Inflation of local prices	Communities refuse to sign permits
Dust pollution	Insufficient hauling trucks	Communities desire to control resources
Exploiting Unlicensed Quarries	Insufficient water supply	Corruption
Material Spillage	Lack of aggregates in quarries	Defiance of law
Noise Pollution	Lack of construction materials in the zone	Delinquency
	No concrete plants nearby	Miscommunication with communities
		Union conflicts

In conclusion, the contractors' perspective on risks revolves around specific cases where conducting an activity or procuring a resource involves unique external risks that only manifest at the time of execution, cases that, although they knew could happen, it was difficult to foresee if they were not presented explicitly or as lessons learned, especially at the time of the bidding process and procurement. The primary stakeholders include rural communities, government institutions, and, at times, the client itself in the communication process with rural communities. In Mexico, the mining company engages with these stakeholders through its community and government relations departments. It is important to note that not all risks are consistent; rather, they depend on various factors, such as the regional differences in the acquisition of certain resources and the social dynamics in the surrounding areas.



CHAPTER 5

DEVELOPING THE

KNOWLEDGE GRAPH

5 KNOWLEDGE GRAPH RESULTS

This chapter will outline the process of building the model using the established methodology. The first section will focus on conceptualizing the ontology, showing examples of how the interview key findings were included in the knowledge graph and how the classes and relationships were structured using some examples, quotes, and graphs using the OntoGraf tab.

The second part shows how the model was formalized by using the developed model and the specific information gleaned from interview participants to refine the general layout of the knowledge graph using the OWL language, define the taxonomy of the classes, and establish their object properties using Protégé software.

5.1 CONCEPTUALIZATION OF THE ONTOLOGY

After gathering the necessary data to create the term pool, the next step is to establish connections between the classes, which is crucial for shaping the model's semantics and ensuring its logic and functionality. During interviews, the information and knowledge provided by the interviewees were used to define these relationships. This process can be complex without the right tools since linking the classes may result in a confusing and time-consuming task. Ontologies, specifically the Protégé software, enable the creation of object properties between classes based on RDF triples (semantic triples). This involves creating connections between subjects and objects using predicates and organizing them logically and automatically into a knowledge graph. In this context, the subjects and objects are all the classes listed in **Appendix B**, while the predicates are the object properties, forming a comprehensive knowledge graph.

While the primary focus of analyzing this object's properties was to identify risks associated with building tailings dams, the stakeholders involved were also considered, as well as the mitigating factors and potential events stemming from these risks. The central foundation of the model was to focus on and analyze the activities required to build these projects, connecting them to potential risks. Next, the resources required to carry out these activities and the associated risks were outlined. Finally, the risks posed by various stakeholders were assessed, categorizing them into the following three distinct object properties linked to risks:

- Has Activity Risk
- Has Resource Risk
- Has Social Risk

To clearly illustrate the process of model building, some quotes from the interviews will be shown from where the different classes and relationships were created to build the model. After conducting a literature review, analyzing news articles, and formulating specific questions to explore likely events, mitigation strategies, activities, resources, and risks to uncover relationships between different terms.

5.1.1 Classes

The model's classes were derived directly from interviews and divided into subsections. This section displays the quotes that influenced the decision to include specific nouns or verbs in the knowledge

graph. Each subsection provides a brief explanation for one class to avoid redundancy, but the same process applies to the other classes; a more detailed explanation of each class can be found in **Appendix B under the Annotations column**. The main criterion for selecting the classes was the number of frequencies mentioned in the interviews or the emphasis given by the participants to the coded nouns or verbs. The tables and subsections below display the chosen classes and quotes from the interviews where they are referenced. The words translated into codes and then into classes are highlighted in red.

5.1.1.1 Activities

The activities were selected based on the contractors' perception of the risks. According to the interviews, participants mentioned that risks arise once the construction of the tailings dams has begun. The first criterion for selecting activities was the number of mentions in the interviews and the emphasis and context in which they were mentioned based on the predetermined questions.

For example, the transportation of materials to the site was mentioned 21 times in the interviews as shown in **Appendix A**. This activity also includes related activities, such as predecessor activities like quarrying or acquiring aggregates, and successive activities like earthworks. This activity is typically carried out using dump trucks owned by trade unions, and it takes place on rural routes where there are communities, which can also pose external risks.

TABLE 14: SELECTED ACTIVITIES AND QUOTES FROM INTERVIEWS

#	Activities	Quotes
1-	Blasting	But what happens, when you are exploiting that cut, those bases, that rock, you make detonations, explosives , whatever you want and you start crushing. C-5
2-	Building secondary roads	Then, because of the issue of accesses, if at the beginning you have to start with a bridge because there is a river or something, you have to go further ahead and the issue of heavy machinery is whether there are accesses or you have to build them. C-5
3-	Earthworks	The issue of the union, of transporters, for the earthworks, that you need to move materials and that is the biggest concept that is the movement and it is the first thing, is the issue of the transportation union. C-5
4-	Hammering	Two projects, one project that we did 80,000 square meters of earthworks, where unfortunately the soil mechanics where they did the borings was a type 1 and type 2 material and when we were doing the earthworks, very hard type 3 rock appeared and we had to use almost 10 excavators with hammers that we had not considered. C-1
5-	Labour mobilization	We first handle a phase of, well we call it preliminary works in what we are doing, first organizing the planning of the logistics of the arrival of the equipment. Likewise, seeing the arrival of the personnel , the technical personnel starts to do the work in order to detonate the good start of the work. C-3
6-	Material crushing	the client hires the engineering firm as supervisor and they realized that during the process they had to change the diameters of a material that we had not considered. Ah, and the process of taking from a larger diameter of rock to a smaller diameter and it was clean rock , let's put it that way, we did not have the machinery at that time on site, which yes, there was because of the engineering firm where we had to stop for approximately 3 weeks. C-4
7-	Quarrying	Well, now that you have your market study and everything, you have already located the land where you are going to be able to buy or exploit the materials necessary materials such as gravel, sand, gravel, tepetate. C-1
8-	Transportation of machinery to site	Yes, especially, well in the machinery, well, the issue of security is very important, physical security in the transfers at the beginning, there is always a very strong mobilization of machinery. And in that mobilization we need to carry it out safely. C-2

9-	Transportation of materials to site	We are handling this as something preliminary, the arrival of the Campers, the arrival of the supplies, the procurement of the materials, and to formalize an agreement with the people who are going to give us the service of transportation and Haulings. <u>C-3</u>
10-	Civil Works	First of all, the planning of how you are going to attack your project, not initially, because any project starts with earthworks, once you have the necessary earthworks, platforms or excavations, then you move on to the civil works stage where you start making your foundations, the structures and whatever is necessary. <u>C-1</u>

5.1.1.2 Resources

As with activities, resources were chosen as classes because obtaining these resources involves external risks. This is mainly because tailings dams are constructed near mine operating plants, which are often located in remote areas with few suppliers or sources of natural resources. Furthermore, these suppliers or sources are often controlled by rural communities, trade unions, or organized crime groups, leading to additional social risks.

The resource of water, which was mentioned 25 times, is a clear example of the challenge in obtaining this resource, either due to scarcity or because of rural communities' control over it. Additionally, a law reformed in 2023 prioritized the use of water for community activities, making obtaining water sometimes require sending water pipes from other locations, sometimes many kilometers away from where the tailings dam is being built, which demands a significant amount of water for the earthworks.

TABLE 15: SELECTED RESOURCES AND QUOTES FROM INTERVIEWS

#	Resources	Quotes
1-	Aggregates	In our industry basically, it is to look for good supplies of filler and stone materials for construction. <u>C-3</u>
2-	Good quality materials	So, there, in that matter, yes, yes. It was somewhat complicated, we brought the stone from Oaxaca, the base from Puebla, because there were no materials in the area, there were no materials that were required. <u>C-5</u>
3-	Machinery and transportation trucks	Mobilization is the transfer of the necessary equipment, which is usually large construction equipment. Tractors, excavators, motor graders and sending the right people to the site where the work is going to be executed, to try to find campings sites especially and where you are going to supply certain issues such as spare parts, details that you require within the work, then also sending the mobile offices to the site, you are usually assigned, the client assigns you a camping area and then in that area you install mobile dormitories if necessary. <u>C-4</u>
4-	Water	Ah, water is very important because there are few reservoirs generally in the mining areas, sometimes we have had to bring or carry, sorry, the required water to distances of several kilometers from different wells. <u>C-4</u>
5-	Explosives	Yes, well, first in the use of explosives, in Mexico to be able to request a permit from the secretary of national defense, which is the SEDENA from now on. You have to bring the authorization, either from the client if you are in the polygon owned by the client, or from the Ejido in case you have to make some access or road, that you have to use explosives. <u>C-4</u>
6-	Labour	Well, the personnel, you must have trained people, first the engineering staff that knows what we are going to develop. Generally, it is based on civil engineers, although in my company I also have architects who understand perfectly well what earthworks are.. <u>C-4</u>
7-	Concrete	Obviously the initial machinery would be tractors, motor graders, compactors, backhoes.

		That would be the initial to start with and later, depending on the project, you can implement concrete plants depending on the region, because there are regions where they do not exist. C-1
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5.1.1.3 Stakeholders

It is crucial to consider stakeholders when evaluating external risks. These stakeholders can significantly impact the project and are typically located near the project area or have a stake in the project resources and activities.

Rural communities or ejidatarios are important external stakeholders, as emphasized by participants 58 times. This is because government institutions and mining companies have legal obligations and social responsibilities to these communities, which are then passed on to the construction company. The bargaining power of these rural communities has increased over time due to factors such as enhanced legal protection and access to information. For instance, in order to obtain permits for activities like explosive use or mining, the communities must provide their consent. Moreover, they have control over natural resources such as water, quarries, and rural roads.

TABLE 16: SELECTED STAKEHOLDERS AND QUOTES FROM INTERVIEWS

#	Stakeholders	Quotes
1-	Client Mining Company	On one occasion, for example, in a mining company we were going to enter to work, we already had the project, we had a quotation. And these laws practically prevented the mining company from working on the project to date. I am saying that this happened 15 years ago and to date the law of uses and customs totally prohibited the mining company to develop that work there and they have not been able to solve that situation. C-4
2-	Governmental Institutions	In most of the projects nowadays, the permits before the environmental companies (Institutions) are very important, that is the main thing that has to be arranged, to get and have the corresponding environmental permit, whether it is the permits for the use of soil change of the geographic area where you are working and the environmental permits, which is the main thing that the Government asks for in order to be able to carry out a construction project, and that is the most difficult thing together with the area of ejido relations. MC-2
3-	Organized crime groups	There is organized crime, the Community is going to threaten me with machetes, are they going to extort me? And once they extort me, do I pay them or do you pay them, or nobody pays them? I think it is a co-responsibility, of the company to give the scope to the contractor and of the contractor to ask for it, no? MC-1
4-	Rural communities (Ejidatarios)	Regularly, yes frequently in every project, especially in the mines, there are always the communities that are linked to the client and that is where the problems arise. C-2
5-	Unions	Yes, and you really have to go and look for the local unions and the people that are necessary, right? you know that here in Mexico there are many side interests? C-1
6-	Mechanical Workshops	Starting the investigation of all the personnel, immediately it is in the mechanical supply centers. C-4

5.1.1.4 Events and Legal Conflicts

Social events or legal conflicts are the potential outcome when risks are not addressed promptly. These events, as mentioned in interviews, are similar to those reported in news analysis. It's not surprising, as they are the only options stakeholders involved in external risks have.

For example, strikes or work stoppages were grouped together under the concept of strikes in the model, as they are essentially the same event. This was mentioned 26 times during the interviews. The reason why this event can impact the contractor is that while mining companies are required to hire local personnel for their operations, this obligation is transferred to the contractor. Therefore, any social issue, regardless of the cause, has the potential to hinder progress and result in unnecessary expenses and waste of time and money for the contractor.

TABLE 17: SELECTED EVENTS OR LEGAL CONFLICTS AND QUOTES FROM INTERVIEWS

#	Events or legal conflicts	Quotes
1-	Problems with ejidatarios	That's right, we did have that social claim and since it was an indigenous community in the Sierra de Jalisco area, that is, they are people that have their own system of laws, uses and customs, they limited us a little with their general regulations, because even though we already had a permit from Sedena or the State Government and all the paperwork that we had to have, they still restricted our activities. C-3
2-	Roadblocks	Yes, yes, as you were saying, the community is always there to put pressure on the company, the mine company. But there have always been occasions of road blockades, they block us there where we are hauling and if there is only one route, they block everything, and that is where it is going to be, that is where the money ends up being spent, in stopping our ability to work. C-2
3-	Strikes	Then in 2009 there was a stoppage where they took over the project, they stopped the construction of the mine, but not only the people of the Community took it over, they were also involved with the people of the other neighboring Communities, and when the mine and the Federal Government decided to evict the people, they went and hid in the neighboring Community and for the Federal Authority went inside the communities and made a mess, because for them there are no limits from community to community, So, I believe that this was an inadequate approach to the crisis because it was definitely a crisis and a way had to be found to resolve it. It was not easy because there were threats, violence and so on. It was a very, very complicated context. MC-1
4-	Water intake blockage	Yes, yes, you can have your construction permits and everything in order according to the governmental regulations and the people of the Community have stopped us, they blocked our water intakes, they have blocked our drains, they have closed our roads and they do not allow them to travel on their streets, so it is quite a strong problem that you have to give them something in return. C-1
5-	Theft of machinery	Yes, yes, yes, yes. We have had machinery stolen in the course of the work site, in the transfers, right now no more and no less, about two months ago a motor grader and a vibrocompactor were stolen from the highway from Guadalajara to Morelia and the driver at night went out to a stretch of a free highway, to cut the road to Mexico City and was assaulted, fortunately the equipment was recovered in about a month and a half, but we have had problems like these. C-3
6-	Harming personnel	Yes, look, well, yes, yes, yes. The norm has changed, and it has been deficient, because actually the ejidatarios many times and in many areas in many states have become more difficult. Then, they even kidnap and hurt someone. So I think that the norm is one thing, but it is not really respected 100%, the ejidatarios are owners of their lands, we know that, we try to do the best for everyone in the

		negotiation, but there comes a time when these people do not get what they ask for, what they need, they are asking and asking and asking and asking and it is a very difficult situation because they can end up damaging or harming the production of a company. That is the most difficult thing that can happen in an agreement between the ejido and the company. MC-2
7-	Land conflicts	That's right, because you know that here, in Mexico, when we have projects in sight, there are a lot of louts that start buying the land before the projects come out and then that is another legal problem , because when the ejidatarios find out, they become more problematic in strikes, in work stoppages or situations that have happened here in Mexico, like in the airport, the macheteros and all that. C-1
8-	Permit conflicts	We have had both legal and social problems, we have had work stopped for up to a year due to construction permits and political problems. Directly from the Government they have stopped and another socially that the Community does not agree with the works that you are doing and they riot and ask you for works in exchange or improvements to the Community that neither the client nor you have considered and it is quite a strong problem. C-1

5.1.1.5 Risks

As previously mentioned, risk classes were categorized into three main categories. This was mainly based on feedback from contractors, who indicated that once activities begin, certain risks and resource-related issues can arise. We also included a separate category for social risks in the model to account for indirect factors that stakeholders can introduce.

5.1.1.6 Activity Risks

The activities selected carry inherent risks. Some risks are specific to certain activities, for example, noise pollution from blasting, while others, like dust pollution, are shared among different activities such as crushing and quarrying.

One common issue is damage to access points, community roads, or power lines. During interviews, this was mentioned 16 times. The damage is mainly caused by the frequent movement of heavy machinery and dump trucks used to transport materials to the site. The roads are typically made of untreated earth without concrete reinforcement, and the power lines are overhead on poles with a small surface area, making them susceptible to damage from the passage of heavy vehicles.

TABLE 18: SELECTED ACTIVITY RISKS AND QUOTES FROM INTERVIEWS

#	Activity Risks	Quotes
1-	Dust pollution	So, the bank of materials, that is another factor, a lot of dust was emitted, we were shredding materials as a primary or secondary, so all the dust that was generated, it covered or reached the trees. C-2
2-	Material spillage	Let me give you an example, the communities would ask us: hey, a dump truck is passing by here and it dropped a little sand; or a little concentrated material or whatever material we were using , so they would tell us: I need you to sweep it immediately and then we would do it, right? So sometimes it was a problem to do it directly and not to notify the mine, and sometimes, if we notified the mine, it would take up to two days, it would take up to two days for the response. and that generated a social problem, no? C-2
3-	Noise pollution	Yes, look, in some places and here it has also happened that sometimes communities are very close to the operations, and as we need to use machinery, trucks, they make a lot of noise , raise a lot of dust, pollution that bothers these people, and that are also important points that we have to respect and of course improve so that it does not affect, at least in

		the Community, either with noise, pollution, etc. We have to review all those points so that we do not have problems with that. MC-2
4-	Damaging surrounding buildings	First in a certain mine, we did some blasting, but it was very close to the surface. So, that generation of energy, of that magnitude, from the blasting broke some glass, some windows of some nearby houses and we had problems. So it is because of the energy that was dissipated, the energy reached some houses and broke several windows, but at those points we supported the people, we reconstructed the damage that we generated and of course in the blasting control we had to use a softer explosives, which did not cause damage in the process. MC-2
5-	Exploiting unlicensed quarries	Well yes, we also have projects in Monterrey, we have projects in those regions of the country and because of the water issue, basically we have very limited water and sometimes we lack water as well. Also, it will be the issue of the exploitation of banks (quarrying) close to the urban areas. We are having the problem of the dust and the environmental pollution that these generate and sometimes we can also see that these people who are involved in the unions, suddenly exploit quarries that sometimes do not have, well, the corresponding permits with the ecology norms and that is what we sometimes complain about. C-3
6-	Damaging roads or power lines	We drove a big tractor to a small road. Well, it had concrete, but well, it was a local road, a 15 cm concrete, without a structure underneath that concrete, so that, it would support, is the weight? Well, you can imagine the concrete, it was damaged, it broke and yes, there were altercations and well, you always have to do this social work, that is to say, to reach an agreement, you tell them. C-5
7-	Damaging community plots	Then what happened to us that, well, a stone fell outside our bank, a stone went to the other plot. We already had our correct delimitation, but the material went, even with the protection of the slope, it went and then the owner of the plot took advantage of it, she said it was a serious affectation to her plot, which were just some stones, so a whole legal process was set up and well, especially with the client, it did not affected us directly, but in that case it happened that way. C-2

5.1.1.7 Resource Risks

The model included resource risks due to the challenges of obtaining materials in rural areas. These areas typically focus on agriculture and mining and do not have a skilled workforce or easy access to construction materials. The mining law reforms now require mining companies to hire a certain percentage of local labor, and they comply by providing training. However, when it comes to building tailings dams, most of the work involves heavy machinery and specialized construction, which is unfamiliar to rural communities. This incompetence of labor poses a significant risk for the contractor, as it has been documented 14 times.

TABLE 19: SELECTED RESOURCES RISKS AND QUOTES FROM INTERVIEWS

#	Resources Risks	Quotes
1-	Heavy machinery breakdown	To have a stock of the most important things, for example, cutting parts, which is what wears out the most. But in the mechanical area, you also have to know where you are going to supply a particular part, how long it takes to have that physical response and generally we as a company, to avoid that kind of risk, so we have one or two extra machines to take over, while the repair of the downed machine is being done. C-4
2-	Inflation of local prices	But when we made the offer, the study was done, we had prices relatively, maybe double those of Mexico City, but as the work progressed, it became more expensive. Everythng became more expensive, even the workers' food and your own food doubled to 50% or 60%.

		<p>So, what happens?</p> <p>There is the construction boom, there is a lot of construction, a lot of construction.</p> <p>It becomes very expensive, people abuse it and when they start to finish the work, prices start to go down again, so it is supply and demand and you cannot control how much you can raise your prices. <u>C-1</u></p>
3-	No concrete plants nearby	<p>Obviously the initial machinery would be tractors, motor graders, compactors, backhoes.</p> <p>That would be the initial to start with and later, depending on the project, you can implement concrete plants depending on the region, because there are regions where they do not exist. <u>C-1</u></p>
4-	Lack of aggregates in quarry	<p>Yes, I am also telling you to make sure of the material banks, of the capacity of exploitation of the banks, because suddenly, you arrive at a bank and they already have it very exploited and they are not able to give you the amount of material required for the project, so depending on the volume of stone materials is to see the feasibility or to see that the material banks will have the capacity to give you the volume required for the work program that you want to implement. <u>C-3</u></p>
5-	Lack of materials in zone	<p>We usually organize our projects in two stages, which could be preliminary or pre-project, where we usually call, we try to find information about the site, and when we see formality or that the project is going to materialize we go to the site and we do local marketing, we look for local unions, we usually look for 2 or 3 different people from different unions to see the working conditions, we go and visit material banks near the construction site, where we try to see if they are owners, if they are in ejidos, especially if they are controlled by these people from the unions, and we try to see the quality of the material, see the quantity we require to avoid the possibility of not having enough material. <u>C-3</u></p>
6-	Insufficient water supply	<p>Yes there were changes in this, the client told us, there is no water ,there is no water here in the locality there is no water nearby.</p> <p>So you need to consider this in your quotation. <u>C-2</u></p>
7-	Insufficient hauling trucks	<p>There have been times when there have been up to three construction sites of different companies at the same time.</p> <p>So, neither the bank nor the transporters are able to keep up, nor is the bank enough, so no, practically, even though we do not know each other, we are fighting among the 3 builders. <u>C-5</u></p>
8-	Incompetence of local labour	<p>As for the union personnel, well, we have had to deal with local personnel, we have struggled, we have struggled with the fact that sometimes there is no locally qualified labor, sometimes there is, sometimes there is not. <u>C-2</u></p>

5.1.1.8 Social Risks

Social risks are different from other types of risks because they involve two main areas: resources and activities. These areas help us understand how likely the risks are to happen. Social risks become important when a stakeholder creates a risk based on their own views or decisions, regardless of what the contractor does.

For example, unions and ejido communities may want to control resources because they are afraid of change, have limited resources like water, or want to make more money from selling materials. Both groups want to benefit more, following the law of supply and demand. When they notice more activity, especially from outsiders, these marginalized groups start taking action. Even though this risk was not repeated often, it was highlighted by the participants.

TABLE 20: SELECTED SOCIAL RISKS AND QUOTES FROM INTERVIEWS

#	Social Risks	Quotes
1-	Miscommunication with communities	Yes, yes, in other mines I have had some issues, where people do stoppages or roadblocks, one of them was because the way the human resources manager handled the negotiations because the ejidatarios did not like how those negotiations were handled, because according to them it was not very fair, whether it was fair or not, they should also understand that we also require a certain benefit, not just give them satisfaction, right? MC-2
2-	Communal complains	Yes, look, right now in the current mine there is a town that is at the top of the site (mine), you go to the northern part of the mine and there is a town that has many workers who work here in the company, before, the main road went through the industrial areas of the mine, and due to some risk that we wanted to avoid, we built a road outside the mine, made of earthworks only. Ah, but some of their personal use trucks that apparently required a better road, although the road is very accessible, they requested it for several days, they did not striked or did a stoppage, but they did have several complaints that the road had to be improved, and finally, we had to give them that requirement so they would not take other actions. MC-2
3-	Community desire to control resources	Yes, also here, for example, here in the stream bed we have several permits to remove gravel and sand material, some ejidatarios, well they take over certain parts and do not allow us to quarry that material, we have to reach another agreement so that they give us permission, although with the authority we already have that permission, well with the ejidatarios we also have to respect their area of properties, right? MC-2
4-	Corruption	Yes, yes there are. In general there is one, the first one, even if you comply with all the federal regulations for the transportation of heavy machinery on federal roads, unfortunately in Mexico we still have a federal highway police that commits a lot of crimes, I mean they ask for resources unduly, that is one of them. C-4
5-	Delinquency	Another problem is the unions here in Mexico, which are by region and which unfortunately are now in the hands of groups that are very closeminded, and they ask you almost for an extraordinary and unlawful fee (derecho de piso) so that you can work peacefully and they do not bother you and do not kidnap your engineers, your residents, so you have to have a deal with them. C-1
6-	Communities desire to replace contractors	For example, we had a contractor that did the welding of the Geomembrane for the tailings dam and a local supplier said, I am going to do it, he trained himself, bought his equipment, did everything he had to do, the truth is, I don't know how he did it, I was not there. And he said, look, I already have the training, the certification, I have the machines and I have the personnel, get your contractor out, I am going to do the work because I have already spent some money on it. And so, obviously at the end of the day we had to make the change, because our sourcing priority starts locally. MC-1
7-	Defiance of law	Look, if we look at how we work in Mexico, most of them do not even comply with the law, it is a reality and if apart from that the law does not even establish something properly, that is, with the proper scope, we leave an open risk in the industry, right? MC-1
8-	Union Conflicts	Sometimes the strategy is that in the selection of the union or the people we work with at the site, they are not the strongest or the most consolidated and that is why I tell you we usually go to the site to make sure we work with people who are owners of the dump trucks or with people who actually earn money from the service of the dump trucks, that gives us a lot of certainty when we find a service provider that has a vehicle fleet, that is, dump trucks to provide the service, we know they are honest people, that is why they are honest, right? And we try to distance ourselves from those who try to live off the service of the owners and the workers. Yes, it has given us problems,

		Likewise, there are areas where, even in Mexico City, even if you choose a person, sometimes the law of the strongest prevails, more structured unions, which eat up the smaller unions. C-3
9-	Communities refuse to sign permits	No, because for explosives, generally, a Letter of Prior Authorization is issued; otherwise, the permit is not issued. -By the communities, right? Yes, you cannot get a permit without a letter from El Ejido signed. C-2

5.1.1.9 Risk Mitigation Strategies

The initial plan did not include integrating the knowledge graph with this category of classes, as it was considered to be outside the domain. However, when participants discussed risks and events, they often mentioned the measures they had in place to avoid or mitigate them.

In Mexico, it is unfortunately common practice to impose extraordinary fees on different stakeholders, and in some cases, these fees are obligatory. These fees are not considered as part of corruption but rather as a monetary transfer to protect the common good of the project, machinery, or even the welfare of the staff. This class was divided into three categories based on the stakeholders involved, as the motives behind these fees varied according to the risks. This strategy was cited multiple times and was used as an example to illustrate the social landscape of the case study in Mexico.

TABLE 21: SELECTED MITIGATION STRATEGIES AND QUOTES FROM INTERVIEWS

#	Risk mitigation strategies	Quotes
1-	Buying spare parts in advance	That it is very important that the machinery is at 100% that we lacked from the previous work in terms of the mechanical engineering staff. If we missed, what we missed, was it two or three days to get some special piece of machinery, to have enough stock and above all to select capable mechanical personnel to avoid downtime of machinery on standby. C-4
2-	Change supplier of resource	Mhm then when the work starts and without knowing, the second one starts and the third one starts and the third one starts and we fight for the material, fortunately for us, unfortunately for others, a second bank opens on one side of that bank, a second bank. C-5
3-	Contracting more unions	Mhm then when the work starts and without knowing, the second one starts and the third one starts and the third one starts and we fight for the material, fortunately for us, unfortunately for others, a second bank opens on one side of that bank, a second bank. C-5
4-	Extraordinary fees to communities	That's right, by rule and by regulation, also depending on the region, the union asks for a percentage of more or less 60% of the labor force. It has to be local to the community, but often, the problem we have is that they are people who are not specialized or dedicated to the field, and it doesn't really work for you, right? So we had to give them more money to allow you to bring your specialized people. C-1
5-	Extraordinary fees to criminal groups	There may be some threat in this case of, I don't know, for example, there are certain points in Mexico where there is organized crime, there may be some issue of, I tell you openly, of a quota, a quota that has to be paid, so that expense, well no, it was not considered, in the issue of property or physical security for all the workers and for the project. C-2
6-	Extraordinary works requested by ejidatarios	By agreements, by agreements, the last one that happened to us was by long-term agreements, they blocked an access, because they wanted the improvement of a road, a road of theirs from the same community that they had promised them and since we

		were already there, well, we did a part and that was it, but in the end they wanted everything, the whole road, right? So they wanted concrete in everything, in all their, in all the street and that was one of the reasons that are the agreements with communities and social commitments that the client himself has. <u>C-2</u>
7-	Hauling water tanks	And that for me is particular in Monterrey, yes, yes, yes, yes, it is something that now we have even reinforced, we have sent water tanks from Guadalajara to have water supplies and I mean now we have a good work, now in this project, what we have already implemented, due to other previous experiences in Monterrey, we have already found a formula to be able to get in price with the locals. <u>C-3</u>
8-	Removing spillage from roads	The way we solve it was hiring more local personnel as road agents or bandoleros as we call them in Mexico, I had to immediately send a sweeper with water to avoid pollution and the schedule was delimited. <u>C-4</u>
9-	Restriction on work shifts	Well, sometimes the social issue of the environmentalists, the ecology issue, there are areas in the Republic where there is a lot of surveillance and a lot of observation of the environmental issues, for example not to generate dust, not to be able to use certain equipment because of the noise, because of the proximity to residential areas that, suddenly they restrict the working hours so as not to interfere with the people's resting time. <u>C-3</u>
10-	Hiring security	The other is the theft of machinery, that is why you must have all the equipment, vehicles and heavy machinery insured in case of this eventuality, practically these two issues. <u>C-4</u>
11-	Installing concrete plant at site	Obviously the initial machinery would be tractors, motor graders, compactors, backhoes. That would be the initial to start with and later, depending on the project, you can implement concrete plants depending on the region, because there are regions where they do not exist. <u>C-1</u>
12-	Dust suppression	I don't know why they have not designed this type of machinery for dust mitigation. You have to engineer it for that mitigation. We had to put on the belt where the crushed material comes out. So to speak, I had to design a little roof without touching the shredding equipment because if you don't lose guarantees, if you lose everything, if not at the end of the belt I had to put a flute. We call it a flute because it is a tube with perforations, like a flute. And injecting water so that when the material falls, it does not generate that pollution and that helped us a lot in dust mitigation. <u>C-4</u>
13-	Ensuring quarry permits	In a bidding process in which we are participating right now, which is in Zitácuaro, Michoacán, we did the research, we went, we went to the material banks, we have to take into account the permits, as I was telling you, but we have to take into account the unions, that is another one, a union of workers is always an issue to be treated with tongs because in that project, for example, it happened to us that all the material banks in the zone are unionized and all of them, let's say that they do not have a permit, they do not have an official permit, what they have is a permit of uses and customs, that is, it is based on, let's say, a format, nothing more than a meeting that they hold, because they are indigenous communities, they hold a meeting and before the Government, that is their permit, right? <u>C-2</u>
14-	Extraordinary fees to unions	Another problem is the unions here in Mexico, which are by region and which unfortunately are now in the hands of groups that are very closeminded, and they ask you almost for an extraordinary and unlawful fee (derecho de piso) so that you can work peacefully and they do not bother you and do not kidnap your engineers, your residents, so you have to have a deal with them. <u>C-1</u>

5.1.2 Relationships

To ensure clear and concise representation, it was opted to include 8 direct relationships, avoiding redundancies and aiming to maintain a balance of information and clarity within the model. As with

classes, the following table will display a quote to illustrate the information source influencing the decision to include these relationships in the model. This will be followed by a brief explanation of the concepts and a graph connecting the classes in the current model.

TABLE 22: SELECTED RELATIONSHIPS AND QUOTES FROM INTERVIEWS

#	Relationship	Quotes
1-	Needs resource	Well, the work itself, we already know how to carry it out, that is why I tell you, a construction process is carried out, but you have to see both the water supplies as we mentioned before and also the human resources team if there is one in the zone or in the area, start investigating both for the engineering staff and the staff of the rest of the personnel. <u>C-4</u>
2-	Has risk	In fact, risk management rather than we saw risks, for example, in the water administration, in the risk of the communities, and the labor risk became very, very important in the last 10 years. The reality is that, as conditions have evolved, my vision is that at some point a risk assessment will have to be made for new projects, especially if you are investing, 300 or 500 million dollars, investors and companies that are willing to invest, will have to identify the risks that will have to be evaluated, right now in Mexico there are at least 10 projects that are already being explored but they are stopped precisely because of the evaluation of how they are going to do it and with what permit they are going to do it. Right now the most important risk that we have is that we do not have permits or to generate a permit for a new project, they do not give it to you for the mining industry, it is very limited, so even if you have already explored a project as there is a case here near Durango called Vizsla in Cosalá. <u>MC-3</u>
3-	Has activity risk	Also, it will be the issue of the exploitation of banks (quarrying) close to the urban areas. We are having the problem of the dust and the environmental pollution that these generate and sometimes we can also see that these people who are involved in the unions, suddenly exploit quarries that sometimes do not have, well, the corresponding permits with the ecology norms and that is what we sometimes complain about. <u>C-2</u>
4-	Has resource risk	Starting the investigation of all the personnel, immediately it is in the mechanical supply centers. This is very important and I am sorry, it is redundant and I have seen many companies that do not take this into account and sometimes have machinery stopped for weeks. So you have to foresee those risks to avoid them, as I mentioned before. To have a stock of the most important things, for example, cutting parts, which is what wears out the most. But in the mechanical area, you also have to know where you are going to supply a particular part, how long it takes to have that physical response and generally we as a company, to avoid that kind of risk, so we have one or two extra machines to take over, while the repair of the downed machine is being done. <u>C-4</u>
5-	Has social risk	Look, I think we are facing a more interconnected society, where whatever you do or do not do, not only has an impact locally, but also on the reputation and therefore also has repercussions on your economic projections, with your investors and your other stakeholders of interest and both socially and environmentally. I believe that this is the great challenge, because this communication, precisely, has allowed that beyond the interaction and also from the political point of view, agendas are established that could promote or stand in your way for the construction of your project. Yes, yes, I believe that the construction process from the preparation of the construction and the construction has the fine thread that will help you to have fewer social and environmental problems in your operation and that you can really focus on extracting the mineral or whatever you are looking for. <u>MC-1</u>
6-	Has stakeholder	The other problem it had, is just what I was telling you, it did not adequately take into account the surrounding communities, those that are not necessarily in the project and other third party agents. I think the world we live in today is very interesting, because it

		forces us to be much more careful, much more aware and proactively involve all interested parties before you have a problem and even if in the process you have a problem because we are not exempt, you also have to have your strategies for how to present it to all stakeholders , in which times and in which ways. Finally, there are communities that have manifested themselves and in fact, currently all these years that I have been here, the complaints and claims about the operation and what came from the process of the construction of the project, today they come mainly from the surrounding communities , because with the host community we have a constant relationship, but with the others, that relationship has had its ups and downs and I think the main reason was the wrong start that generated distrust in the environment, <u>MC-1</u>
7-	Can lead to event	For example, if you are going to install a new tailings dam, you have to have a lot of negotiation capacity to negotiate with the surrounding communities because if they oppose the authority, they will never give you the permit. Do you understand me? So, there are common factors or facts that complicate the process, which is a little bit going back to what I was telling you in the past. <u>MC-3</u>
8-	Has mitigation strategy	So what we had to do was to use a water pipe to mitigate that, not that problem, but you have to do it. What do I tell you at the end of the day? You don't consider it, but we are learning. These are the lessons learned, all those fine details and to avoid in the future, which is the important thing, to avoid in future works that you have these types of claims or complaints. <u>C-4</u>

5.1.2.1 Needs Resource

The relationship needs resources is straightforward. Each selected activity requires resources to be completed. For example, activities such as blasting require explosives, while earthworks and civil works in the tailings dam require labor, water, materials, and heavy machinery. The image below illustrates these relationships, showing how activities are linked to the resources they need. For instance, it demonstrates the activity of blasting, which needs the resource of explosives to be done.

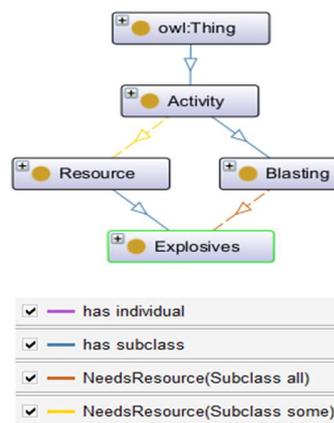


FIGURE 18: NEEDS RESOURCE GRAPHIC RELATIONSHIP

5.1.2.2 Has Risk

The "Has Risk" relationship is used to connect activities and resources (domain) to the three selected types of risks (range). The accompanying image illustrates this connection and specifies the chosen risks. It sets the stage for other relationships and serves as a precursor connection.

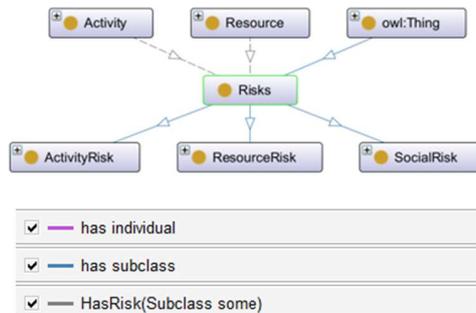


FIGURE 19: HAS RISK GRAPHIC RELATIONSHIP

5.1.2.3 Has Activity Risk

The domain of this object properties is activities, and the range is the previously mentioned activity risks. As the participating contractors mentioned, according to their perspective, the risks they face start once they carry out an activity. Therefore, such a subclass of risks was decided. In this case, it displays the graphical connections of the material crushing activity and its associated risks, such as dust and noise pollution.

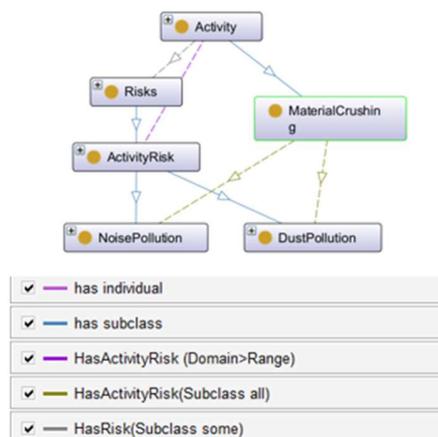


FIGURE 20: HAS ACTIVITY RISK GRAPHIC RELATIONSHIP

5.1.2.4 Has Resource Risk

The resource risk relationship has the domain of resources and the range of resource risks. Resource risks can include issues such as the risk of water scarcity, lack of nearby resources, or the breakdown of specialized machinery used for earthworks or material crushing. This relationship is exemplified by the connection between three resources: machinery and transportation trucks, water and concrete, and the resource risks identified in interviews.

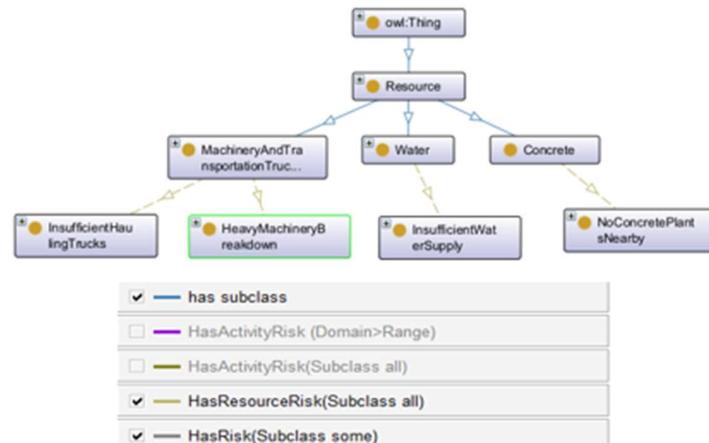


FIGURE 21: HAS RESOURCE RISK GRAPHIC RELATIONSHIP

5.1.2.5 Has Social Risk

Social risks, which are generated by various stakeholders, can impact an operation, the collection of resources, or general protection, and in some cases, even if the contractor is not directly involved. This category was included based on feedback from interviews, particularly from participants in the mining industry who placed greater emphasis on these types of risks. As highlighted by participant MC-1, social risks are closely linked to stakeholders, which is another relationship that has been incorporated into the knowledge graph. The figure below shows this relationship with two activities, such as quarrying and transportation of machinery to the site, and two resources, such as aggregates and labor.

Proof Quote of Interviewee MC-1

“But at the end, for example, when you identify your social risks, well, that is going to derive in a relationship plan. And in this relationship plan you are going to be establishing the type of communication, the frequency of agreements you can have with different stakeholders, which may not even be, well, not only the type of communication, but also the type of agreements you can have with the different stakeholders. stakeholders, which can be not only individuals, but also municipalities or organizations or the local, state or even federal government.”

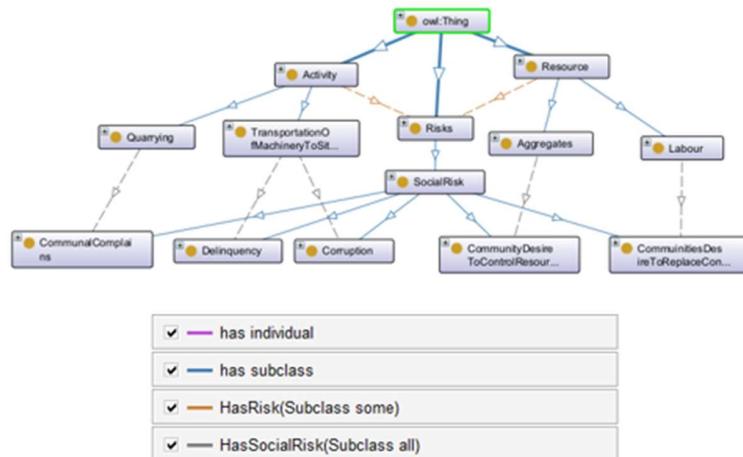


FIGURE 22: HAS SOCIAL RISK GRAPHIC RELATIONSHIP

5.1.2.6 Has Stakeholder

In this research, the focus is on external risks, which involve different stakeholders. Thus, the relation Has Stakeholder was chosen. This object property applies to four classes as its domain: Activity, Resource, Risk, or Social Event. Consequently, this class and relation are present in nearly all connections within the model. To illustrate, various examples of activities, resources, and social risks were chosen to showcase their relationships with the included stakeholders. As depicted in the image, an increase in relationships directly correlates with the expansion of the knowledge graph.

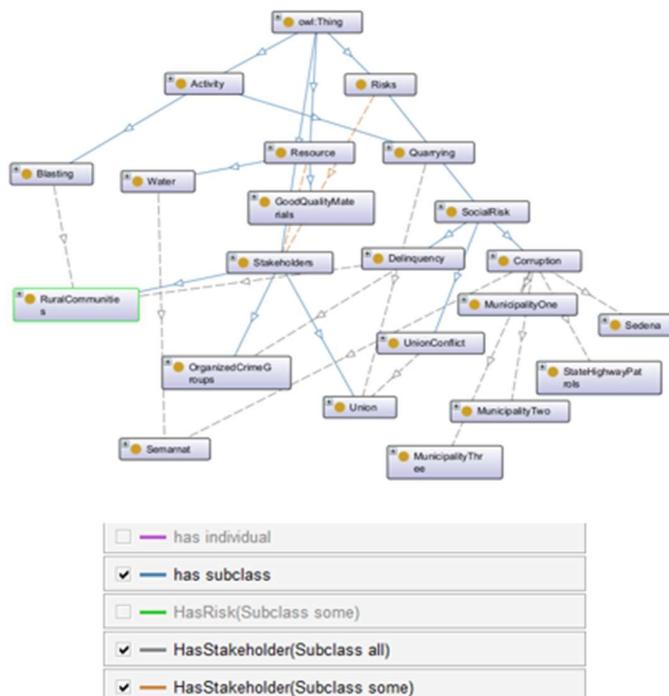


FIGURE 23: HAS STAKEHOLDER GRAPHIC RELATIONSHIP

5.1.2.7 Can Lead to Event

The construction of tailings dams carries inherent risks that can lead to two potential outcomes. If these risks are not adequately prevented or mitigated, they may result in social or legal conflicts. This connection directly ties the risks to the eventual consequences. In this context, the example demonstrates how social risks can lead to various social events.

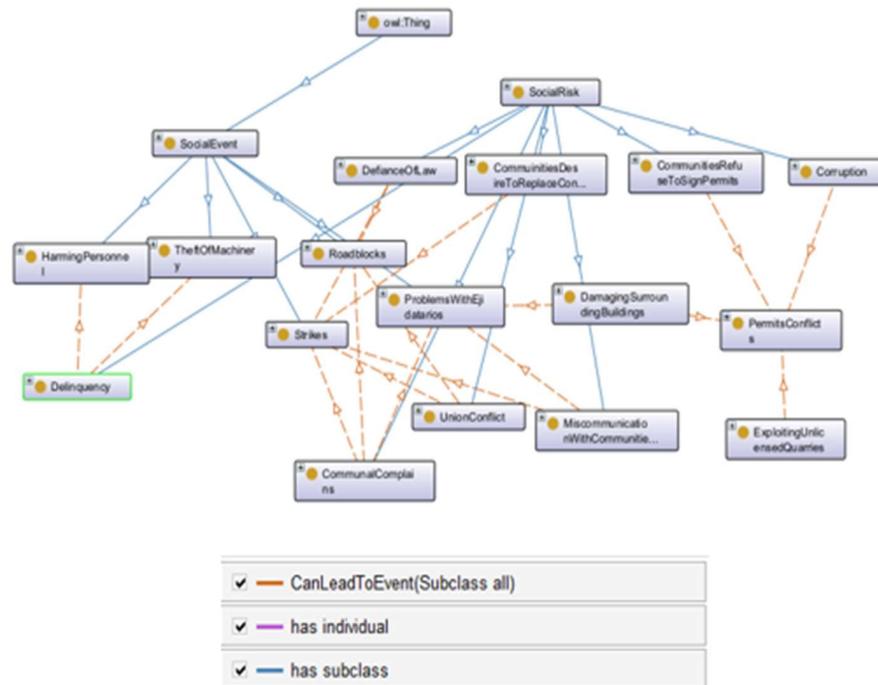


FIGURE 24: CAN LEAD TO EVENT GRAPHIC RELATIONSHIP

5.1.2.8 Has Mitigation Strategy

The next relationship to explore and describe is the Has mitigation strategy. One possible outcome of the presented risks is their mitigation in various ways by the contractor. While these strategies can help mitigate the risks, some may require a financial investment from the builder. Therefore, it is important to be clear about potential risks and how to mitigate them from the bidding process stage in order to make informed decisions about budget allocation for the client. The image below displays some mitigation strategies for various risks, legal conflicts, and social events.

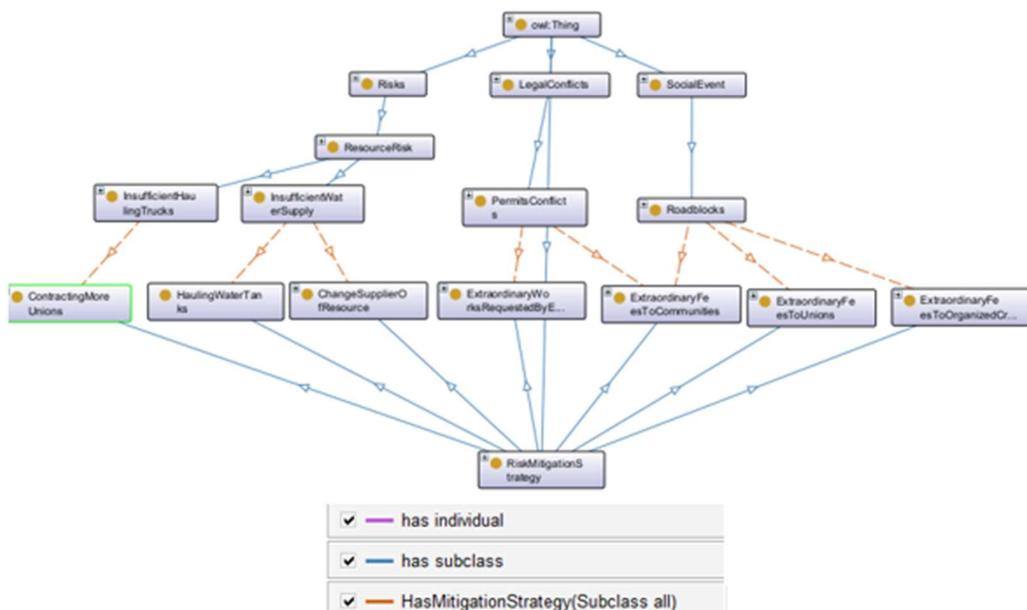


FIGURE 25: HAS MITIGATION STRATEGY GRAPHIC RELATIONSHIP

5.2 FORMALIZATION OF ONTOLOGY

The following excerpt provides evidence from quotes, codes, and relationships obtained during the interview with Participant C-1 as an example of how the formalization of the model was done. Different colors separate the various codes and relationships to which the comments and answers refer. **Figure 26** displays a portion of the model, using only the information gathered from these quotes, while **Figure 27** illustrates each relationship between the classes, color-coded for clarity.

TABLE 23: C-1 PROOF QUOTES, CODES AND RELATIONSHIPS

Interviewees Proof Quotes from Participant C-1	Codes
<p><i>Well, look. I've run into problems with ejidatarios. When looking for land from developers for any type of industrial work, whether private or federal, the first issue we run into is with the ejidatarios, because of the power to bring together all that society so that they can sell you the land, that is one of the basic problems here in Mexico, when you are not in a region that already has authorization, industrial parks, oh or within the city, then the first issue is the ejidatarios, you have to hire a person who can negotiate the price of the land, it is with the ejidatarios, with the Community and that is a problem because it can take several years.</i></p>	<ul style="list-style-type: none"> Stakeholders: Communities Social Risk: inadequate communication strategy with communities. Social Event: Problem with ejidatarios <p>Relationships:</p> <ul style="list-style-type: none"> Ejidatarios (rural communities) can create a risk if an inadequate communications strategy is not followed. (Has Social Risk)
<p><i>Well, in social matters, many times the neighboring landowners ask you, or they give you a lot of objections because they say that their buildings are damaged when you are carrying out your work or you affect their roads, their accesses to their lands.</i></p>	<ul style="list-style-type: none"> Activity Risk: Damaging Surrounding Buildings Activity Risk: Damaging Roads Activity Risk: Damaging community plots Stakeholders: Unions

<p><i>And they want to take advantage of everything, right?</i></p> <p><i>Another problem is the unions here in Mexico, which are by region and which unfortunately are now in the hands of groups that are very close minded, and they ask you almost for an extraordinary and unlawful fee (<i>derecho de piso</i>) so that you can work peacefully and they do not bother you and do not kidnap your engineers, your residents, so you have to have a deal with them.</i></p> <p><i>Basically, you have to give them the union fees and work with their machinery and their transport trucks.</i></p>	<ul style="list-style-type: none"> • Mitigation strategy: Extraordinary fees to criminal groups or communities. • Social Risk: Delinquency • Social Risk: Union Conflict • Resource: Machinery and transport truck <p>Relationships:</p> <ul style="list-style-type: none"> • Doing certain activities can create specific risks. (Has Activity Risk) • Unions are stakeholders that can be involved in social Risk (Has Social Risk) • Some social risks have a mitigation strategy of providing extraordinary fees to communities, organized crime groups, or Unions. (Has Mitigation Strategy). • Some activities need resources like machinery and transport trucks, and stakeholders may be involved in obtaining these resources as well. (Needs Resource, Has Stakeholders)
<p><i>Well, look, Eh?</i></p> <p><i>Normally when you make these visits, well, you try to go to the right people who have control of the area, both material and labour, transportation, and all that, and from the beginning you reach an agreement, on a quota, either for the entire project or a weekly or biweekly quota depending on how the negotiation is done.</i></p>	<ul style="list-style-type: none"> • Resources: Good quality materials • Resources; Labour • Resources: Transportation trucks • Activity: Transportation of materials to site • Stakeholders: Unions (since they have the control of this activities and resources. • Social Risk: Communities desire to control resources <p>Relationships:</p> <ul style="list-style-type: none"> • Unions usually have the control of transportation and resources in rural areas, this creates social risks for the transportation of materials as well as collecting material, and hiring labour. (Has Social Risk) • These stakeholders usually ask for some extraordinary fees to let contractors work without union conflict. (Has mitigation strategy)
<p><i>Well, now that you have your market study and everything, you have already located the land where you are going to be able to buy.</i></p> <p><i>Or exploit the materials necessary materials such as gravel, sand, gravel, tepetate, obviously the initial machinery would be tractors, motor graders, compactors, backhoes.</i></p> <p><i>That would be the initial to start with and later, depending on the project, you can implement concrete plants depending on the region, because there are regions where they do not exist.</i></p> <p><i>So, you have to look at the whole situation and look for the mines or rent?</i></p> <p><i>And to buy, even the ejidatarios is the exploitation of the land.</i></p>	<ul style="list-style-type: none"> • Activity: Quarrying • Resources: Aggregates • Resources: Machinery and transportation truck • Resources: Concrete • Resource Risk: No concrete plants nearby <p>Relationships:</p> <ul style="list-style-type: none"> • Concrete is needed as a resource, and there is a risk that there are no plants nearby.(Has Resource Risk)

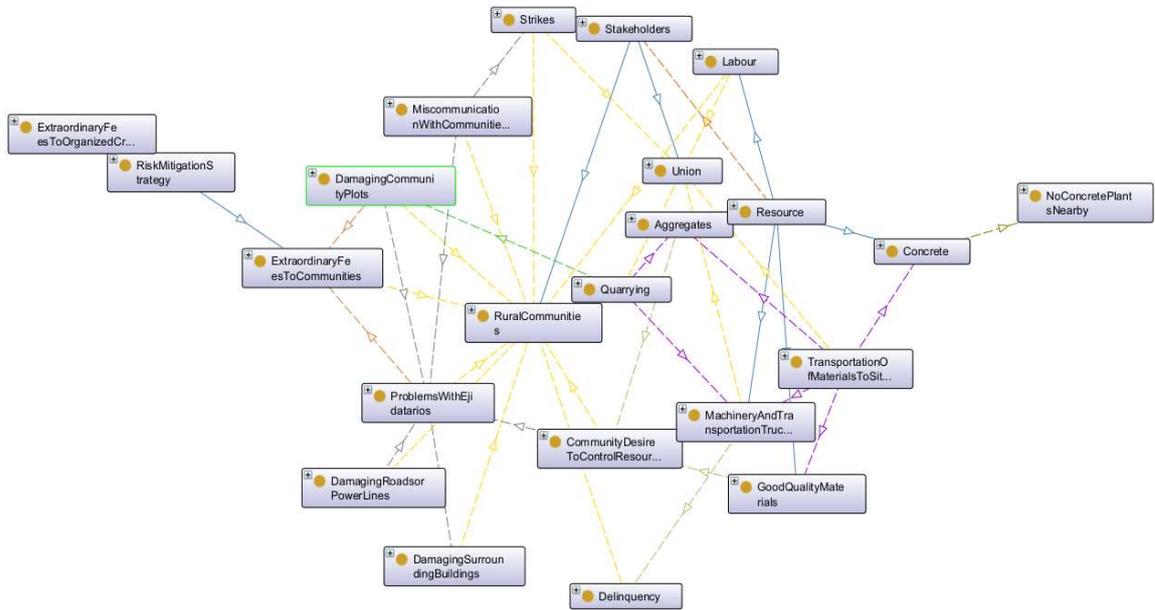


FIGURE 26: C-1 EXAMPLE OF BUILDING MODEL

Arc Types	
type filter text	
<input checked="" type="checkbox"/>	— CanLeadToEvent(Subclass all)
<input checked="" type="checkbox"/>	— has individual
<input checked="" type="checkbox"/>	— has subclass
<input checked="" type="checkbox"/>	— HasActivityRisk(Subclass all)
<input checked="" type="checkbox"/>	— HasMitigationStrategy(Subclass all)
<input checked="" type="checkbox"/>	— HasResourceRisk(Subclass all)
<input checked="" type="checkbox"/>	— HasSocialRisk(Subclass all)
<input checked="" type="checkbox"/>	— HasStakeholder(Subclass all)
<input checked="" type="checkbox"/>	— HasStakeholder(Subclass some)
<input checked="" type="checkbox"/>	— NeedsResource(Subclass all)

FIGURE 27: C-1 OBJECT PROPERTIES EXAMPLE



CHAPTER 6

IMPLEMENTATION

OF THE ONTOLOGY

6 IMPLEMENTATION OF THE ONTOLOGY.

The implementation of the model and incorporation of data from a hypothetical case study will culminate in the completion of the knowledge graph development process. This chapter also includes the verification and validation process of the model as per the methodology outlined in **Chapter 2**. The verification of the model was done in two parts: first, by using the Hermit reasoner to check the model's consistency automatically, and second, through a criteria-based evaluation. The validation process is divided into three parts: first, checking for completeness and coherence of the model; second, developing specific competency questions and answering them.

The methodology section details the practical application of the knowledge graph, including specifying suppliers and stakeholders and validating the model with specialists. To accomplish this, a hypothetical case study in northern Mexico was developed to simulate the construction of a tailings dam at a silver mine. This case study was necessary since access to an actual project and its information during this thesis's research and development stage was limited. This helped create more relations and classes to populate the model.

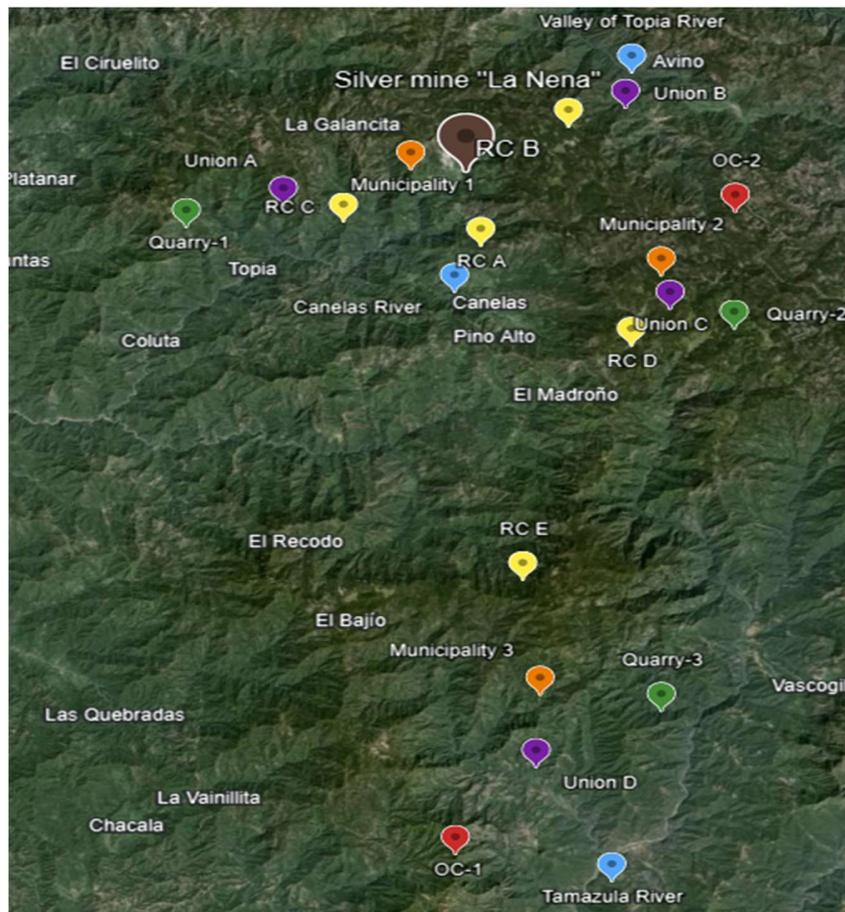


FIGURE 28: HYPOTHETICAL CASE STUDY

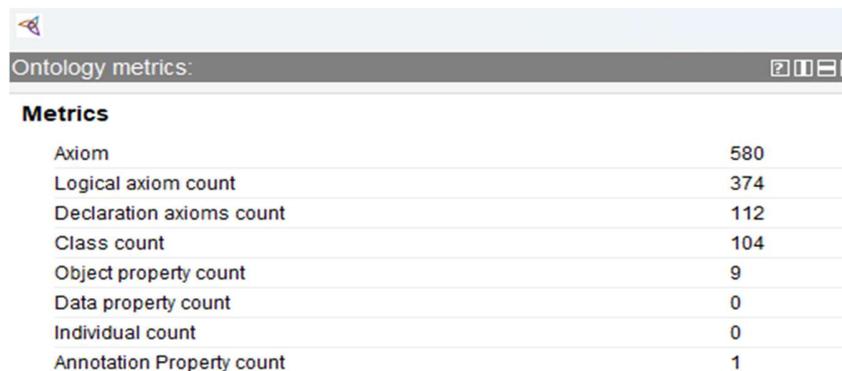
To provide more context about the location of the case study, the model utilizes the following classes for the term pool that are part of the hypothetical case study. These terms have been included in the knowledge graph.

TABLE 24: LIST OF CLASSES BELONGING TO CASE STUDY

Type of class	Class and color code	Color code	Name
Resource	Waterbody	Blue	Canelas River
Resource	Waterbody	Blue	Valley of Topia River
Resource	Waterbody	Blue	Tamazula River
Resource	Quarry	Green	Quarry-1
Resource	Quarry	Green	Quarry-2
Resource	Quarry	Green	Quarry-3
Resource	Machine Workshop	White	MC-1
Resource	Machine Workshop	White	MC-2
Stakeholder	Union	Purple	Union A
Stakeholder	Union	Purple	Union B
Stakeholder	Union	Purple	Union C
Stakeholder	Union	Purple	Union D
Stakeholder	Government	Orange	Municipality 1
Stakeholder	Government	Orange	Municipality 2
Stakeholder	Rural Community (Ejido)	Yellow	RC A
Stakeholder	Rural Community (Ejido)	Yellow	RC B
Stakeholder	Rural Community (Ejido)	Yellow	RC C
Stakeholder	Rural Community (Ejido)	Yellow	RC D
Stakeholder	Rural Community (Ejido)	Yellow	RC D
Stakeholder	Organized crime group	Red	OC-1
Stakeholder	Organized crime group	Red	OC-2

6.1 DEVELOPING THE KNOWLEDGE GRAPH: APPLYING ONTOLOGIES IN PROTÉGÉ

After conducting interviews, gathering news, and drawing from experience in the construction industry in Mexico, as well as incorporating stakeholders from a hypothetical case study, a term pool with object properties (relationships) was developed to illustrate the classes and connections between them used in creating the knowledge graph. Using the Protégé software, relations (object properties) were established between the identified classes and to document the model as explained in the Methontology subchapter properly, annotations explaining each concept employed (classes) for visualizing the semantics of this information. In total and answering **SQ2**, eight relations (object properties) and 104 classes, meaning that 374 correlations were created between activities, events resources, risks, events and stakeholders in constructing a tailings dam as shown in the Ontology metrics figure below.



Ontology metrics:	
Metrics	
Axiom	580
Logical axiom count	374
Declaration axioms count	112
Class count	104
Object property count	9
Data property count	0
Individual count	0
Annotation Property count	1

FIGURE 29: ONTOLOGY METRICS

To improve readability, **Table 25** shows only a part of the term pool, featuring at least one Child Class (Subclass) of each entity type, along with their relationships and class-specific comments. The complete term pool utilized in the model can be found in **Appendix B (- COMPLETE TERMPPOOL FOR CONSTRUCTING THE KNOWLEDGE GRAPH)**.

TABLE 25: EXTRACT FROM THE TERM POOL AND RELATIONSHIPS FOR THE DEVELOPMENT OF THE KNOWLEDGE GRAPH

Classes:	Object Properties (Relations)	Annotations
<i>Activities:</i>		
Quarrying	Activity HasActivityRisk only DamagingCommunityPlots HasActivityRisk only ExploitingUnlicensedQuarries HasSocialRisk only CommunalComplains HasStakeholder only Union NeedsResource only Aggregates NeedsResource only MachineryAndTransportationTrucks	"Quarrying is a basic but complicated activity in the areas where the mines are normally located. This is because there are few quarries. In addition, these quarries sometimes do not have the necessary permits from SEMARNAT (Environmental Institution), and the owners (Ejidatarios) normally hide behind the law of Usos y Costumbres (Uses and Customs)."
Quarry Three	Quarrying HasStakeholder only EjidoE HasStakeholder only MunicipalityThree HasStakeholder only OrganizedCrimeGoupOne HasStakeholder only UnionD	"This Quarry and the stakeholders that are involved, are shown in the Hypothetical Case Study"
Transportation of machinery to Site	Activity HasActivityRisk only DamagingRoadsorPowerLines HasSocialRisk only Corruption HasSocialRisk only Delinquency HasStakeholder only OrganizedCrimeGroups HasStakeholder only StateHighwayPatrols NeedsResource only MachineryAndTransportationTrucks	"The tailings dams are primarily composed of aggregates, requiring a large amount of heavy machinery for earthworks, such as backhoes, tractors, irrigation tankers, and motor graders."
<i>Resources:</i>		
Aggregates	Resource HasResourceRisk only InflationOfLocalPrices HasResourceRisk only LackOfAggregatesInQuarry HasSocialRisk only CommunityDesireToControlResources	"Aggregates are crucial for earthworks. Suppliers must be quarries with Semarnat permits, and the aggregates are transported to the site using dump trucks."

Water	Resource HasResourceRisk only InsufficientWaterSupply HasSocialRisk only CommunityDesireToControlResources HasStakeholder only Semarnat	"Water is one of the most precious resources in rural locations in Mexico, as depending on the season, the scarcity of water increases. There are some parts of Mexico where it only rains two months a year. Sometimes, communities claim the water available is theirs, or even some municipalities may impose some restriction on the usage of water for construction, as is the case of Monterrey, where in some periods they can not use potable water for construction purposes."
<u>Tamazula River</u>	Water HasStakeholder only EjidoE HasStakeholder only MunicipalityThree HasStakeholder only UnionD	"This river is located and shown in the Hypothetical Case Study"
Explosives	Resource HasSocialRisk only CommunitiesRefuseToSignPermits HasSocialRisk only Corruption HasSocialRisk only Delinquency HasStakeholder only OrganizedCrimeGroups HasStakeholder only RuralCommunities HasStakeholder only Sedena HasStakeholder only Semarnat	"The use of explosives is restricted by SEDENA (Military) in Mexico, in order to get a permit for acquiring and using explosives, SEDENA requires a signed permit of the surrounding communities. Also, it is a resource appreciated by Criminal groups, so stealing it or demanding some explosives is common in Mexico by these groups. Since it needs special permits, corruption is also an inherent social risk"
Activity Risks:		
Dust pollution	ActivityRisk CanLeadToEvent only Roadblocks HasMitigationStrategy only DustSuppression HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"Like Noise Pollution, certain activities generate dust. This can lead to complaints from ejidatarios and a major event."
Resource Risk:		
Incompetence of Local Labour	ResourceRisk HasMitigationStrategy only ExtraordinaryFeesToCommunities HasStakeholder only ClientMiningCompany HasStakeholder only RuralCommunities	"In mining industry projects, the contractor must hire a certain percentage of local personnel as per agreements between the mining company and the ejido communities. Often, these personnel may lack specialized skills or motivation, resulting in reduced productivity. To address this issue, some contractors opt to pay a fee to the communities, akin to salary payments, in order to ensure that only trained personnel are engaged."
Social Risk:		
Community desire to control resources	SocialRisk CanLeadToEvent only ProblemsWithEjidatarios CanLeadToEvent only WaterIntakeBlockage HasStakeholder only RuralCommunities	"Due to the bargaining power of communities, there is a risk that they may seek to control federal or natural resources, such as water, federal land, or roads, even if they do not own them, in order to exploit the client and the contrasts."
Social Events:		

Roadblocks	SocialEvent HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryFeesToOrganizedCrimeGroups HasMitigationStrategy only ExtraordinaryFeesToUnions HasStakeholder only ClientMiningCompany HasStakeholder only OrganizedCrimeGroups HasStakeholder only RuralCommunities HasStakeholder only Union	"Roadblocks in secondary roads or at the accesses to the site are a common practice in the mining industry, involving communities, Unions and Organized Crime Groups"
Risk Mitigation Strategy:		
Extraordinary Fees to Union	RiskMitigationStrategy HasStakeholder only Union	"As with communities, some disputes with the union can be resolved by giving a fee in return."
Stakeholders:		
Rural Communities	Stakeholders	"Rural communities, known as Ejidos, are a form of land ownership where many people reside. Some of the residents, known as ejidatarios, are involved in agriculture or the extraction of natural resources. However, some of the land is not suitable for farming, which limits the communities' ability to generate income. Despite this, this stakeholders hold significant bargaining power, especially following the new mining law reform, as they have the authority to grant land exploitation permits to mining companies and influence the use of natural resources. The mining companies handle communication with the ejidatarios, and these communities often view the mining company contractors as outsiders or adversaries."
EjidoA	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
Legal Conflicts:		
Permit Conflicts	LegalConflicts HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only MunicipalityOne HasStakeholder only MunicipalityThree HasStakeholder only MunicipalityTwo HasStakeholder only Sedena HasStakeholder only Semarnat	"Conflicts over permits is a legal event that can jeopardise the continuity of the project."

To build the model, information from the term pool in Protégé was utilized. Concepts from the entities tab (indicated by the blue circle) were employed and connected using the object properties tab in the software interface (shown in the green rectangle in **Figure 30**). Additionally, brief descriptions of each class were provided in the Annotations tab (depicted in red) to document and elucidate them for the end users or potential users of the model.

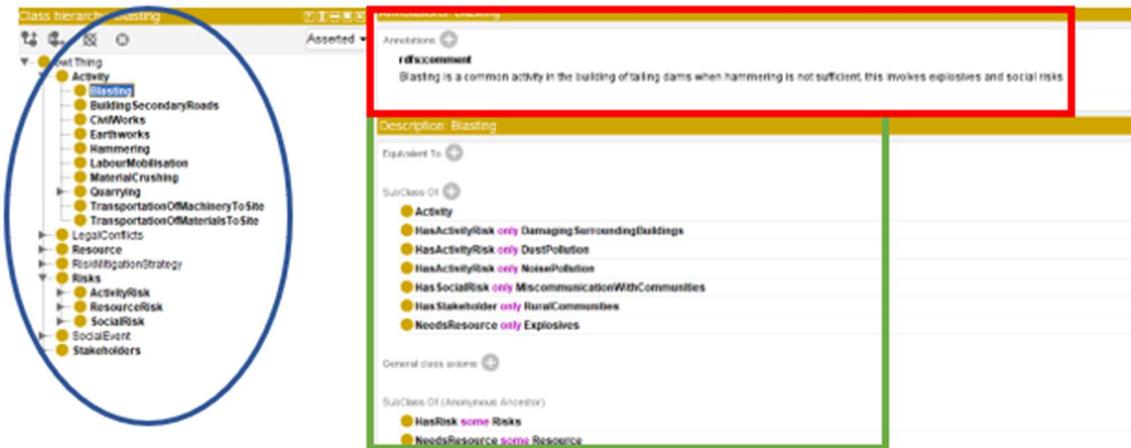


FIGURE 30: EXPLANATION OF BUILDING THE MODEL IN PROTÉGÉ

The model's final output can be visually displayed using the OntoGraf plug-in. This interactive interface showcases all class correlations and allows users to reorganize classes and their relationships in a structured manner. Below is an example of multiple classes and relations graphs to illustrate the numerous relationships and classes in the model. Each relationship is differentiated using various patterns and colors to enhance user visualization.

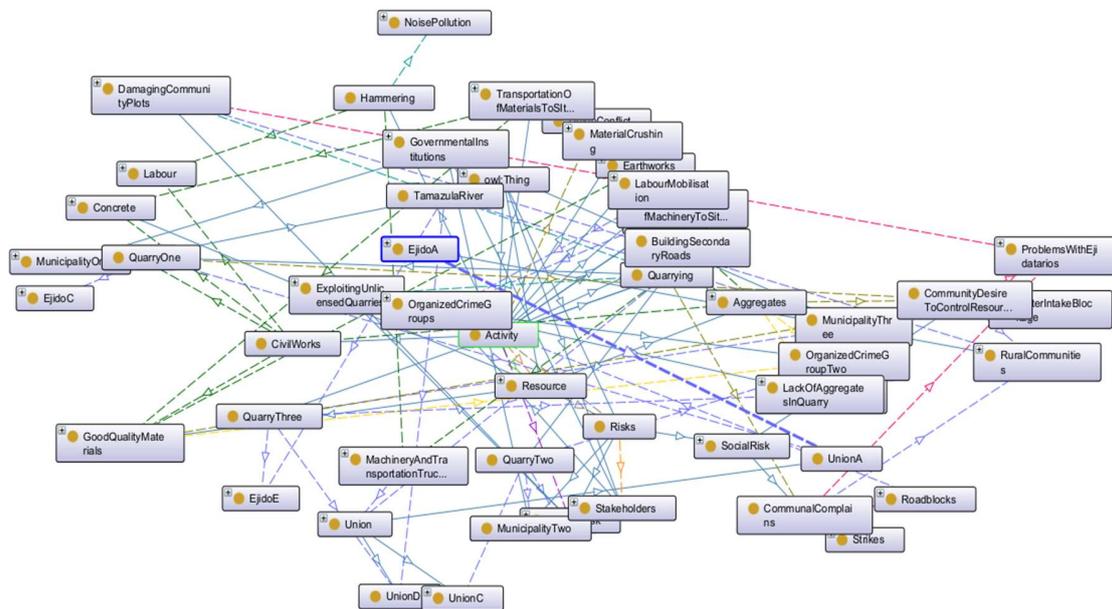


FIGURE 31: EXAMPLE OF THE CORRELATION BETWEEN CLASSES (ONTOGRAF)

6.2 ONTOLOGY VERIFICATION

Following the outlined methodology, the knowledge graph was verified in two key steps. The first step is automated consistency checking using a reasoner. The second step involves a criteria-based evaluation conducted through manual revision and validation meetings with the participants.

6.2.1 Verification using Reasoner

Several reasoners can be used in Protégé software by default or as a plug-in to verify the model. However, the Hermit reasoner was chosen to check the model's consistency to ensure no conflicts between the classes and the object properties assigned to each one. As shown in **Figure 32**, after running the reasoner, the log shows no inconsistencies in the model. Thus, it can be inferred that the model verification was successful.

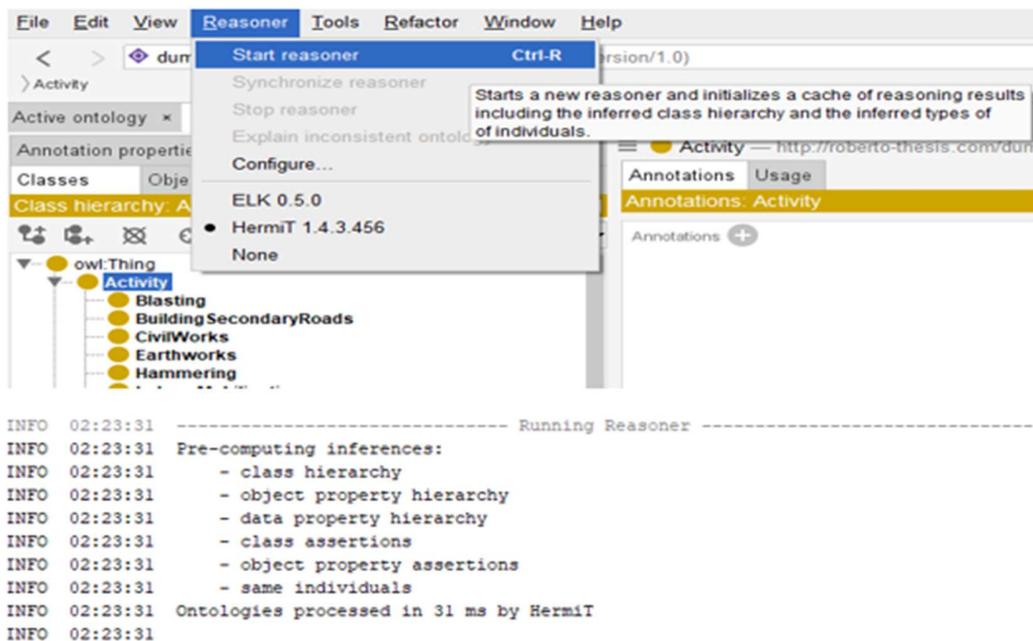


FIGURE 32: PROTÉGÉ LOG, APPLYING REASONER TO MODEL

6.2.2 Criteria-Based Evaluation

The criteria-based evaluation involved conducting four validation meetings with previously interviewed contractors using Teams. The interviews from these meetings were recorded.

TABLE 26: VALIDATION MEETING DETAILS

Validation meeting #	ID of Participant	Duration
1	C-2	1 hour 3 minutes
2	C-3	39 minutes
3	C-5	57 minutes
4	C-4	1 hour 2 minutes

In the validation meetings, the model was presented to the participants. The purpose of the model, along with the relationships between classes and object properties, was explained using various examples with the help of Tab OntoGraf. These meetings usually lasted around 55 minutes since each concept and its relationships were thoroughly explained.

Despite the model's limitations, such as its reliance on quantitative data and absence of real stakeholders due to the hypothetical nature of the case, all participants acknowledged that the activities, resources, and external risks associated with tailings dam construction were explicitly identified and interconnected in a meaningful way.

TABLE 27: CRITERIA-BASED EVALUATION RESULTS

Criteria-based evaluation	Feedback from participants
Coverage	The participants agreed that the classes and relationships in the model covered the possible external risks in the construction of tailing dams.
Consistency	The logical consistency of the model made sense and no contradictions in relationships or definitions were found.
Clarity	The participants understood the model's purpose and functionality, regardless of their position in the company.
Scalability	Participants shared their opinions on how the knowledge graph could be easily adjusted for various purposes. These included using it for decision-making on project locations, incorporating it into kick-off meetings, and not limiting its use to just the bidding process. They also discussed using it as a repository of lessons learned for projects beyond tailing dams, leveraging the semantic core of the model, and adapting it to other instances.

6.3 ONTOLOGY VALIDATION

The validation of the ontology starts with the evaluation of the completeness and coherence of the model, followed by the development of competency questions based on the requirements of the participants and finally, ensuring that the model can answer these questions in a complete, clear, and accurate way.

6.3.1 Completeness and Coherence

During the validation meetings, we explained the model and showed and described each of the classes and object properties. Participants asked questions and provided feedback, sometimes suggesting additional relationships to make the model more comprehensive. The feedback that fell outside the limitations of the model, such as quantitative data like material prices, distances and routes of resource collection to the site, H&S risks, or the application of information on a real case, was not included. However, the participants understood that while the model could contain such information, it was beyond the scope of the knowledge graph. All four participants agreed that the model effectively highlighted external risks associated with activities, resources, and stakeholders in the construction of tailings dams.

Finally, several manual reviews were conducted to ensure the consistency of the model. Some relationships that were incorrectly made due to human error were adjusted until the model was fully consistent.

6.3.2 Competency Questions Development

In the final and arguably most crucial step of the model validation stage, participants were asked to provide input on the information they required regarding the hypothetical case study of constructing a tailings dam in the silver mine "La Nena." Google Earth was used to display the case's location, the stakeholders involved, and the resource collection sites. The following specific competency questions were developed based on the participant's requirements.

TABLE 28: SPECIFIC COMPETENCY QUESTIONS

Participant	Specific CQs
C-2	<ul style="list-style-type: none"> Which risks are involved in blasting and the use of explosives? What are the potential outcomes of an activity-related material spill, and what measures can be taken to mitigate the risk?
C-3	What are the risks associated with machinery and transportation trucks, specifically in the case of breakdowns and theft of machinery? What are the mitigation strategies?
C-5	What are the risks and stakeholders involved in Quarrying Quarry 1?
C-4	What are the risks associated with water collection, and how do the stakeholders differ for each body of water?

The specific CQs were gathered and addressed using Graph DB software with the SPARQL query language. However, this approach was limited by the lack of expertise in using this software. Hence, the query for specific CQs was not done during the meetings, leading to a subsequent review by participants to confirm the correctness and robustness of the answers. The competency questions were developed only for the previously interviewed contractors, as the model focuses on them as the end users.

6.3.3 Answering Competency Questions

The first participant, C-2, had two requirements; the first question was about the risks associated with the blasting activity and the use of explosives. To provide a more comprehensive perspective on this question, it was also decided to consider the stakeholders involved in each of these risks, the possible events that could occur for each risk, and the mitigation strategy for each event or risk. The query and the results are presented in a tabular format. To enhance visibility, the stakeholder column in **Table 29** has been removed. The results of each query in a clearer format can be found in **Appendix C**. The query identified the types of risk related to both activity and resources.

```

PREFIX rdfa: <http://www.w3.org/2000/01/rdfa-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX : <http://roberto-thesis.com/final/>
SELECT DISTINCT ?Activity ?Relation ?Risk ?Resource ?ResourceRiskRelation ?ResourceRisk ?Event
?MitigationStrategy
WHERE {
  {
    # Direct risks related to Blasting
    :Blasting rdfa:subClassOf ?restriction .
    ?restriction owl:onProperty ?Relation .
    ?restriction owl:allValuesFrom ?Risk .
    FILTER (?Relation IN (:HasActivityRisk, :HasResourceRisk, :HasSocialRisk))
    BIND(:Blasting AS ?Activity)
    OPTIONAL {
      ?Risk rdfa:subClassOf ?riskRestriction .
      ?riskRestriction owl:onProperty :CanLeadToEvent .
      ?riskRestriction owl:allValuesFrom ?Event .
      BIND(:CanLeadToEvent AS ?EventRelation)
    }
    OPTIONAL {
      ?Risk rdfa:subClassOf ?mitigationRestriction .
      ?mitigationRestriction owl:onProperty :HasMitigationStrategy .
      ?mitigationRestriction owl:allValuesFrom ?MitigationStrategy .
      BIND(:HasMitigationStrategy AS ?MitigationRelation)
    }
  }
  OPTIONAL {
    ?Event rdfa:subClassOf ?eventMitigationRestriction .
    ?eventMitigationRestriction owl:onProperty :HasMitigationStrategy .
    ?eventMitigationRestriction owl:allValuesFrom ?MitigationStrategy .
    BIND(:HasMitigationStrategy AS ?MitigationRelation)
  }
  OPTIONAL {
    ?Risk rdfa:subClassOf ?stakeholderRestriction .
    ?stakeholderRestriction owl:onProperty :HasStakeholder .
    ?stakeholderRestriction owl:allValuesFrom ?Stakeholder .
    BIND(:HasStakeholder AS ?StakeholderRelation)
  }
  OPTIONAL {
    ?Event rdfa:subClassOf ?eventStakeholderRestriction .
    ?eventStakeholderRestriction owl:onProperty :HasStakeholder .
    ?eventStakeholderRestriction owl:allValuesFrom ?Stakeholder .
    BIND(:HasStakeholder AS ?StakeholderRelation)
  }
}
UNION
{
  # Risks related to the resources needed by Blasting
  :Blasting rdfa:subClassOf ?resourceRestriction .
  ?resourceRestriction owl:onProperty :NeedsResource .
  ?resourceRestriction owl:allValuesFrom ?Resource .
  # Fetching the risks of the resources needed by Blasting
  ?Resource rdfa:subClassOf ?resRiskRestriction .
  ?resRiskRestriction owl:onProperty ?ResourceRiskRelation .
  ?resRiskRestriction owl:allValuesFrom ?ResourceRisk .
  FILTER (?ResourceRiskRelation IN (:HasActivityRisk, :HasResourceRisk, :HasSocialRisk))
  OPTIONAL {
    ?ResourceRisk rdfa:subClassOf ?resourceRiskRestriction .
    ?resourceRiskRestriction owl:onProperty :CanLeadToEvent .
    ?resourceRiskRestriction owl:allValuesFrom ?Event .
    BIND(:CanLeadToEvent AS ?EventRelation)
  }
  OPTIONAL {
    ?ResourceRisk rdfa:subClassOf ?resourceMitigationRestriction .
    ?resourceMitigationRestriction owl:onProperty :HasMitigationStrategy .
    ?resourceMitigationRestriction owl:allValuesFrom ?MitigationStrategy .
    BIND(:HasMitigationStrategy AS ?MitigationRelation)
  }
  OPTIONAL {
    ?Event rdfa:subClassOf ?eventResourceMitigationRestriction .
    ?eventResourceMitigationRestriction owl:onProperty :HasMitigationStrategy .
    ?eventResourceMitigationRestriction owl:allValuesFrom ?MitigationStrategy .
    BIND(:HasMitigationStrategy AS ?MitigationRelation)
  }
  OPTIONAL {
    ?ResourceRisk rdfa:subClassOf ?resourceStakeholderRestriction .
    ?resourceStakeholderRestriction owl:onProperty :HasStakeholder .
    ?resourceStakeholderRestriction owl:allValuesFrom ?Stakeholder .
    BIND(:HasStakeholder AS ?StakeholderRelation)
  }
  OPTIONAL {
    ?Event rdfa:subClassOf ?eventResourceStakeholderRestriction .
    ?eventResourceStakeholderRestriction owl:onProperty :HasStakeholder .
    ?eventResourceStakeholderRestriction owl:allValuesFrom ?Stakeholder .
    BIND(:HasStakeholder AS ?StakeholderRelation)
  }
}
}
}

```

QUERY 1: RISKS OF BLASTING AND EXPLOSIVES (C-2 #1 SCQ)

TABLE 29: C-2 QUERY #1 RESULTS WITHOUT STAKEHOLDERS

Activity	Relation	Risk	Resource	ResourceRiskRelation	ResourceRisk	Event	MitigationStrategy
Blasting	HasActivityRisk	DamagingSurroundingBuildings				PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios
Blasting	HasActivityRisk	DamagingSurroundingBuildings				ProblemsWithEjidatarios	ExtraordinaryWorksRequestedByEjidatarios
Blasting	HasActivityRisk	DustPollution				Roadblocks	DustSuppression
Blasting	HasActivityRisk	DustPollution				Roadblocks	ExtraordinaryWorksRequestedByEjidatarios
Blasting	HasActivityRisk	NoisePollution				ProblemsWithEjidatarios	RestrictionOnWorkShifts
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryWorksRequestedByEjidatarios
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryFeesToUnions
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryWorksRequestedByEjidatarios
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	LandConflicts	ExtraordinaryFeesToCommunities
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	PermitsConflicts	ExtraordinaryFeesToCommunities
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios
			Explosives	HasSocialRisk	Delinquency	HarmingPersonnel	HiringSecurity
			Explosives	HasSocialRisk	Delinquency	TheftOfMachinery	HiringSecurity

The second SQC was about the potential consequences if material spillage occurred during the transportation of materials to the site. The query is shown below; the results can be found in **Appendix 5: C-2 Query #2 Results**. The results of both queries were considered satisfactory by participant C-2, with the exception of the limitation of risks regarding H&S.

```

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX : <http://sobae-to-thesis.com/final/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT DISTINCT ?ActivityRisk ?ActivityRiskRelation ?RelatedEntity ?Event ?EventRelation
?RelatedEntity2
WHERE {
  {
    # Relations of MaterialSpillage
    :MaterialSpillage rdfs:subClassOf ?restriction1 .
    ?restriction1 owl:onProperty ?ActivityRiskRelation .
    ?restriction1 owl:allValuesFrom ?RelatedEntity .
    BIND(:MaterialSpillage AS ?ActivityRisk)
  }
  UNION
  {
    # Relations of ProblemsWithEjidatarios
    :ProblemsWithEjidatarios rdfs:subClassOf ?restriction2 .
    ?restriction2 owl:onProperty ?EventRelation .
    ?restriction2 owl:allValuesFrom ?RelatedEntity2 .
    BIND(:ProblemsWithEjidatarios AS ?Event)
  }
}

```

QUERY 2: WHAT ARE THE POTENTIAL OUTCOMES OF AN ACTIVITY-RELATED MATERIAL SPILL, AND WHAT MEASURES CAN BE TAKEN TO MITIGATE THE RISK? (C-2 #2 SQC)

Participant C-3 wanted to understand the risks associated with machinery and transportation trucks, particularly in the case of breakdowns and theft, and the potential mitigation strategies. For the purpose of addressing the three queries, the initial step involved the examination of the risks linked to the utilization of machinery and transportation trucks. By employing the UNION clause, the query incorporated mitigation strategies for both machinery theft and the potential breakdown of heavy machinery. Furthermore, the query successfully identified the stakeholders involved and pinpointed prospective workshops where spare parts could be sourced in the event of machinery breakdown in the case study, as shown in the following query and result table.

```

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX : <http://roberto-thesis.com/finai/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT DISTINCT ?Resource ?Risk ?Event ?MitigationStrategy ?Stakeholder ?CaseStudyEntity
WHERE {
  {
    # Risks related to MachineryAndTransportationTrucks
    :MachineryAndTransportationTrucks rdfs:subClassOf ?restriction .
    ?restriction owl:onProperty ?Relation .
    ?restriction owl:allValuesFrom ?Risk .
    BIND(:MachineryAndTransportationTrucks AS ?Resource)
    FILTER (?Relation IN (:HasActivityRisk, :HasResourceRisk, :HasSocialRisk))
  }
  UNION
  {
    # Mitigation strategies and stakeholders for HeavyMachineryBreakdown
    :HeavyMachineryBreakdown rdfs:subClassOf ?mitigationRestriction .
    ?mitigationRestriction owl:onProperty :HasMitigationStrategy .
    ?mitigationRestriction owl:allValuesFrom ?MitigationStrategy .
    BIND(:HeavyMachineryBreakdown AS ?Risk)
    OPTIONAL {
      ?MitigationStrategy rdfs:subClassOf ?stakeholderRestriction .
      ?stakeholderRestriction owl:onProperty :HasStakeholder .
      ?stakeholderRestriction owl:allValuesFrom ?Stakeholder .
    }
  }
  UNION
  {
    # Subclasses of MechanicalWorkshops
    ?CaseStudyEntity rdfs:subClassOf :MechanicalWorkshops .
    BIND(:MechanicalWorkshops AS ?Stakeholder)
  }
  UNION
  {
    # Mitigation strategies for TheftOfMachinery
    :TheftOfMachinery rdfs:subClassOf ?mitigationRestriction .
    ?mitigationRestriction owl:onProperty :HasMitigationStrategy .
    ?mitigationRestriction owl:allValuesFrom ?MitigationStrategy .
    BIND(:TheftOfMachinery AS ?Event)
    BIND(:Delinquency AS ?Risk)
  }
  UNION
  {
    # Stakeholders for TheftOfMachinery
    :TheftOfMachinery rdfs:subClassOf ?stakeholderRestriction .
    ?stakeholderRestriction owl:onProperty :HasStakeholder .
    ?stakeholderRestriction owl:allValuesFrom ?Stakeholder .
    BIND(:TheftOfMachinery AS ?Event)
    BIND(:Delinquency AS ?Risk)
  }
  UNION
  {
    # Subclasses of OrganizedCrimeGroups
    ?CaseStudyEntity rdfs:subClassOf :OrganizedCrimeGroups .
    BIND(:OrganizedCrimeGroups AS ?Stakeholder)
  }
}

```

QUERY 3: RISKS OF MACHINERY AND TRANSPORTATION TRUCKS, SPECIFIC CASE OF BREAKDOWN AND THEFT OF MACHINERY MITIGATION STRATEGIES (C-3 SCQ)

TABLE 30: C-3 QUERY RESULTS

Resource	Risk	Event	MitigationStrategy	Stakeholder	CaseStudyEntity
MachineryAndTransportationTrucks	HeavyMachineryBreakdown				
MachineryAndTransportationTrucks	InsufficientHaulingTrucks				
MachineryAndTransportationTrucks	DefianceOfLaw				
MachineryAndTransportationTrucks	Delinquency				
MachineryAndTransportationTrucks	UnionConflict				
	HeavyMachineryBreakdown		BuyingSparePartsInAdvance	MechanicalWorkshops	
				MechanicalWorkshops	MechanicalWorkshopOne
				MechanicalWorkshops	MechanicalWorkshopTwo
	Delinquency	TheftOfMachinery	ExtraordinaryFeesToOrganizedCrimeGroups		
	Delinquency	TheftOfMachinery	HiringSecurity		
	Delinquency	TheftOfMachinery		OrganizedCrimeGroups	
				OrganizedCrimeGroups	OrganizedCrimeGroupOne
				OrganizedCrimeGroups	OrganizedCrimeGroupTwo

Participant C-5 requirements were based on the case study: What are the risks and stakeholders involved in Quarrying Quarry 1? In this case, the query was created to identify the types of risks and specific risks associated with Quarry One, located west of the project area. The query also included possible events linked to these risks and aimed to identify the stakeholders involved in these risks and events specific to the quarry in question. The results can be found in **Appendix 7: C-5 Query Results**,

which includes the specific stakeholders that may be involved in the risks and events of exploiting Quarry One.

```

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX : <http://roberto-thesis.com/final/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT DISTINCT ?Quarrying ?Relation ?Risk ?Event ?Stakeholder ?CaseStudyStakeholders
WHERE {
  {
    # Risks related to QuarryOne
    :QuarryOne rdfs:subClassOf ?restriction1 .
    ?restriction1 owl:onProperty ?Relation .
    ?restriction1 owl:allValuesFrom ?Risk .
    BIND(:QuarryOne AS ?Quarrying)
    FILTER (?Relation IN (:HasActivityRisk, :HasResourceRisk, :HasSocialRisk))
    OPTIONAL {
      ?Risk rdfs:subClassOf ?riskStakeholderRestriction1 .
      ?riskStakeholderRestriction1 owl:onProperty :HasStakeholder .
      ?riskStakeholderRestriction1 owl:allValuesFrom ?Stakeholder .
    }
    OPTIONAL {
      ?Risk rdfs:subClassOf ?eventRestriction1 .
      ?eventRestriction1 owl:onProperty :CanLeadToEvent .
      ?eventRestriction1 owl:allValuesFrom ?Event .
    }
  }
  UNION
  {
    # Specific stakeholders for QuarryOne
    :QuarryOne rdfs:subClassOf ?generalStakeholderRestriction1 .
    ?generalStakeholderRestriction1 owl:onProperty :HasStakeholder .
    ?generalStakeholderRestriction1 owl:allValuesFrom ?CaseStudyStakeholders .
    BIND(:QuarryOne AS ?Quarrying)
  }
}

```

QUERY 4: WHAT ARE THE RISKS AND STAKEHOLDERS INVOLVED IN QUARRYING QUARRY 1? (C-5 SCQ)

Participant C-4 was interested in understanding the risks associated with water collection and how different stakeholders are involved in each body of water in the case study. Two queries were made to gain insights into the relationships, risks, and stakeholders related to the water resources and various bodies of water in the case study. The first query sought to identify the risks of the water resource, the potential events of those risks, and the mitigation strategies. The second query aimed to determine the potential sources of water collection and which stakeholders could be involved in these risks. Due to the large response size of the Graph DB, a **GROUP** clause was included for the risks and event mitigation strategies, as well as for the stakeholders and water bodies.

```

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX : <http://sobarto-thesis.com/final/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT DISTINCT ?Resource ?Relation ?Risk (GROUP_CONCAT(DISTINCT ?RiskMitigationStrategy;
separator="," ) AS ?RiskMitigationStrategies) (GROUP_CONCAT(DISTINCT ?Stakeholder; separator="," ) AS
?) AS ?Stakeholders) ?Event (GROUP_CONCAT(DISTINCT ?EventMitigationStrategy; separator="," ) AS
?) AS ?EventMitigationStrategies) ?BodyOfWater (GROUP_CONCAT(DISTINCT ?BodyOfWaterStakeholder;
separator="," ) AS ?BodyOfWaterStakeholders)
WHERE {
  {
    # Risks related to Water
    :Water rdfs:subClassOf ?restriction1 .
    ?restriction1 owl:onProperty ?Relation .
    ?restriction1 owl:allValuesFrom ?Risk .
    BIND(:Water AS ?Resource)
    FILTER (?Relation IN (:HasActivityRisk, :HasResourceRisk, :HasSocialRisk))
    OPTIONAL {
      ?Risk rdfs:subClassOf ?riskStakeholderRestriction1 .
      ?riskStakeholderRestriction1 owl:onProperty :HasStakeholder .
      ?riskStakeholderRestriction1 owl:allValuesFrom ?Stakeholder .
    }
    OPTIONAL {
      ?Risk rdfs:subClassOf ?eventRestriction1 .
      ?eventRestriction1 owl:onProperty :CanLeadToEvent .
      ?eventRestriction1 owl:allValuesFrom ?Event .
    }
    OPTIONAL {
      ?Event rdfs:subClassOf ?eventMitigationRestriction1 .
      ?eventMitigationRestriction1 owl:onProperty :HasMitigationStrategy .
      ?eventMitigationRestriction1 owl:allValuesFrom ?EventMitigationStrategy .
    }
  }
  OPTIONAL {
    ?Risk rdfs:subClassOf ?riskMitigationRestriction1 .
    ?riskMitigationRestriction1 owl:onProperty :HasMitigationStrategy .
    ?riskMitigationRestriction1 owl:allValuesFrom ?RiskMitigationStrategy .
  }
}
UNION
{
  # General stakeholders for Water
  :Water rdfs:subClassOf ?generalStakeholderRestriction1 .
  ?generalStakeholderRestriction1 owl:onProperty :HasStakeholder .
  ?restriction1 owl:onProperty ?Relation .
  ?generalStakeholderRestriction1 owl:allValuesFrom ?Stakeholder .
  BIND(:Water AS ?Resource)
  FILTER (?Relation IN (:HasStakeholder))
}
UNION
{
  # Where can the contractor collect Water and its stakeholders
  ?BodyOfWater rdfs:subClassOf :Water .
  OPTIONAL {
    ?BodyOfWater rdfs:subClassOf ?bodyOfWaterStakeholderRestriction .
    ?bodyOfWaterStakeholderRestriction owl:onProperty :HasStakeholder .
    ?bodyOfWaterStakeholderRestriction owl:allValuesFrom ?BodyOfWaterStakeholder .
  }
  BIND(:Water AS ?Resource)
}
}
GROUP BY ?Resource ?Relation ?Risk ?Event ?BodyOfWater

```

QUERY 5: WHAT ARE THE RISKS ASSOCIATED WITH WATER COLLECTION, AND HOW DO THE STAKEHOLDERS DIFFER FOR EACH BODY OF WATER? (C-4 SCQ)

TABLE 31: C-4 QUERY RESULTS PART 1

Resource	Relation	Risk	RiskMitigationStrategie	Stakeholders	Event	EventMitigationStrategies
Water	HasResourceRisk	InsufficientWaterSupply	ChangeSupplierOfResource, HaulingWaterTanks	GovernmentalInstitutions, MunicipalityOne, MunicipalityThree, MunicipalityTwo, RuralCommunities	ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities, ExtraordinaryWorksRequestedByEjidatarios
Water	HasResourceRisk	InsufficientWaterSupply	ChangeSupplierOfResource, HaulingWaterTanks	GovernmentalInstitutions, MunicipalityOne, MunicipalityThree, MunicipalityTwo, RuralCommunities	WaterIntakeBlockage	ChangeSupplierOfResource, ExtraordinaryFeesToCommunities
Water	HasSocialRisk	CommunityDesireToControlResources		RuralCommunities	ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities,
Water	HasSocialRisk	CommunityDesireToControlResources		RuralCommunities	WaterIntakeBlockage	ChangeSupplierOfResource, ExtraordinaryFeesToCommunities
Water	HasStakeholder			Semarnat		

Like others, Participant C-4 agreed that the answers correctly diagnosed potential risks at various water intakes. However, he also suggested including the distances from the water collection sites to the project area and assessing the conditions and dimensions of the roads connecting the project to the different water bodies. To show the results properly in this report, the table from the query was divided into two parts; the full result table can be found in **Appendix C**.



CHAPTER 7

DISCUSSION

7 DISCUSSION

The discussion chapter reviews and discusses the research questions outlined in **section 1.4**. It then proceeds, based on the research design shown in **Figure 3**, to discuss the results of these methods and findings. This section will also analyze the feedback received from the participants of the validation meetings, outlining the pros and cons of the model. The limitations of both the research and the knowledge graph presented will be listed in the final section of this chapter.

7.1 MOST COMMON EXTERNAL RISKS IN THE MINING INDUSTRY

To accomplish the research objective of modeling an ontology of external risks in construction projects within the mining industry, it was initially referred to relevant literature to gain an understanding of the various types of uncertainties and the significance of identifying them, as discussed by Hlaing et al. (2008). Additionally, it examined different approaches to risk classification proposed by various researchers, with a particular focus on external risks within the PESTLE framework, which is utilized to analyze and pinpoint external macro-environmental factors influencing an organization (Kansongue et al., 2023).

A two-pronged approach was taken to identify the risks involved in constructing tailings dams. First, looking at risks associated with similar construction projects and then at risks specific to the mining industry. This combined approach aimed to provide a comprehensive overview of the risks involved in tailings dam construction.

Given the limited information available on external risks in tailings dams, a literature review of infrastructure projects as a general starting point was conducted. This was due to the similarities in constants and variables, such as the remote project locations and the involvement of external stakeholders and the risks they bring. This literature review was expanded to include Hydraulic infrastructure project risks, such as water dams, as they share similarities in construction activities and environmental and community impacts. The current global risks in the mining industry were also investigated, focusing on the main factors generating these risks and their influence on stakeholders like governments and social groups.

Lastly, key considerations were reviewed for the planning and construction of a tailings dam. To better illustrate the progression from the general to the specific, we have included a diagram outlining the steps mentioned above.



FIGURE 33: LITERATURE REVIEW STEPS FOR IDENTIFYING THE MOST COMMON EXTERNAL RISKS IN THE MINING INDUSTRY

The difference between uncertainty and risk lies in the fact that uncertainty refers to a lack of information or knowledge about a specific situation. In contrast, risk relates to the potential impact of an event, whether positive or negative (Pmp, 2024). The study also considered events that have had a negative impact on the mining industry in Mexico. **Section 4.1** analyzed twenty news items from reputable newspapers to understand the reasons behind social events involving stakeholders such as rural communities (Ejidos), trade unions, and organized crime in various parts of the country. The key drivers of these events were classified into four categories:

1. Financially driven events.
2. Events driven by a combination of financial and resource factors.
3. Resource-driven events.
4. Socially driven events.

An important insight from the interviews is that both contractors and mining companies have observed a rise in social risks within the mining industry, which aligns with the significant increase in mining conflicts reported by Conde and Billon (2017b). Some of these incidents have been exacerbated by recent changes in mining law regulations. These changes have granted external project stakeholders greater leverage to negotiate and even halt ongoing projects, even if all legal requirements were previously met. As a result, stakeholders now have a more pronounced influence, leading to increased social complexities and associated risks within the industry.

In the existing literature on specific risks in the construction of infrastructure projects, risks vary considerably depending on the geopolitical environment of the country or area where they occur because external risks are, in most cases, social risks, regardless of the motive, rooted in the social perception of external stakeholders, while this case study specifically focuses on the risks involved

in building tailings dams in a particular country, which can offer valuable insights for future studies in developing countries like Mexico.

7.2 USING ONTOLOGIES TO MAP EXTERNAL RISKS IN THE CONSTRUCTION OF TAILINGS DAMS

To successfully address research question #2, which explores the correlation between activities, events, and resources leading to external risks in tailings dam construction, the knowledge graph presented was developed. This model also serves as a response to the main research question. The process of developing the ontology model, once the data pool was available, was illustrative in order to understand and analyze the potential consequences of each activity and resource, i.e. the semantics of the model. Although Protégé has a user-friendly interface compared to other machine languages, creating a model from scratch that extends beyond the limitations of the domain and scope itself is complex. This complexity lies mainly in ensuring the robustness and correctness of the model, as the more concepts and relationships it contains, the more complicated it is to verify. Nevertheless, the use of the Hermit reasoner integrated into the software and the OntoGraf visualization tab helps to mitigate potential contradictions. After completing the model, four validation meetings were conducted, and the validation was successfully completed based on the proposed methodology, which centered around answering specific competency questions.

The participants fully grasped the limitations and purpose of the model and also supported its potential application to real-life projects. One of the main limitations in the validation stage was the use of Graph Db and SPARQL for creating queries, as the lack of expertise in this tool and language required greater effort. Finally, despite these challenges, new trends and Artificial Intelligence programs such as Chat GPT can be utilized to find answers simply by attaching the file in Turtle Syntax and correctly articulating the question. To demonstrate this, below it shows the ChatGPT answer in the plain text regarding the relationships of the activity risk “material spillage.” Where the AI was able to recognize the model effectively, explaining the previously mentioned **activity risk** and all its relationships within the model. As depicted in **Figure 34**, the results of the risk material spillage relationships align with the findings of **Query 2**.

Here are the detailed restrictions related to `MaterialSpillage`:

1. `MaterialSpillage` is a subclass of various restrictions. Each restriction is defined using an `owl:Restriction` and has specific properties.

Restrictions Found:

1. Restriction 1:
 - onProperty: `HasMitigationStrategy`
 - allValuesFrom: `RemovingSpillageFromRoads`
2. Restriction 2:
 - onProperty: `HasStakeholder`
 - allValuesFrom: `Union`
3. Restriction 3:
 - onProperty: `HasResourceRisk`
 - allValuesFrom: `ProblemsWithEjidatarios`
4. Restriction 4:
 - onProperty: `HasStakeholder`
 - allValuesFrom: `RuralCommunities`

Additional Information:

- The class `MaterialSpillage` is also a subclass of `ActivityRisk`.
- It has a comment describing its context: "As the Unions are the ones in charge of transportation of material, spillage can happen."

FIGURE 34: EXAMPLE OF HOW AI CAN EXTRACT INFORMATION FROM AN ONTOLOGY

7.3 IMPLEMENTATION AND GENERALIZABILITY OF THE ONTOLOGY

In the validation process, participants were asked for their opinions on the model and for feedback that could improve the model design or add variables to create a more comprehensive ontology. The generalizability of the knowledge graph was also discussed, exploring more possible uses for it, as the scope of this research was only to map external risks to improve decision-making at the bidding stage of projects. Participant C-5 commented that, in addition to this use, there was also the possibility of using it for kick-off meetings held before the start of the project and once the tender has been won. The objective would be to educate all those involved in the project, such as engineers, safety, and cost personnel, on the possible social and external implications that could occur during the construction stage of the tailings dams.

The same participant also mentioned that such a model could be used by the client to review the social feasibility of the projects, i.e., to map the external risks but from the client's perspective. Although it sounds logical that it could be used in this way for permitting and mine operation risks, it would be interesting to know the possible application of this model, as the risk management of mining companies is usually very complete and with much information collected throughout the experience. However, this same robust risk management of the client could mean that it is not necessary to use knowledge graphs, as it could be redundant. Nevertheless, one of the possible applications of knowledge graphs in the client's perspective would be to assess the feasibility of tailings dams by focusing on the location of the dams, i.e., mapping the stakeholders, in this case, rural communities in the different possible areas where the dam could be designed.

After receiving an explanation of the model and having his CQs addressed, Participant C-2 remarked that the model effectively covered most external risks, emphasizing the importance of considering all relevant stakeholders. He also expressed satisfaction with the visualization of the OntoGraf tab and the representation of object properties and relationships through color coding. The participant also mentioned that he would have preferred the model to cover the risks related to H&S as well.

Participant C-3 provided positive feedback on using this model for project feasibility studies, particularly for housing or commercial building developers. The participant noted that the model would benefit decision-making, especially for smaller companies without access to comprehensive decision-making tools. Comparing different options can be complex and confusing in the construction environment, where information is often based on tacit knowledge rather than documented data.

Participant C-4 suggested that having quantitative information, such as distances between quarries and the construction site or water collection points, could significantly improve decision-making. This includes assessing the quality of materials from different quarries. C-4 gave an example that even if quarry 1 were closer to the site but had lower quality materials, it would be more beneficial to use the materials from quarry 2, even if it was further away. Additionally, C-4 highlighted the importance of capturing and consolidating knowledge gained from past projects to apply it to new projects, as this knowledge is often forgotten or overlooked.

In light of the previous comments, it can be inferred that the implementation of the knowledge graph upon the main objective was successful. Nevertheless, to examine deeper and extract further value, it would be advantageous to integrate quantitative data and account for internal risks. This could be accomplished through a detailed examination of specific cases and the internal processes of the contractors and mining companies. The knowledge graph could also focus on other fields of construction management. With a conceptualized model, it could be adjusted to change object relationships or classes after defining its scope and objective.

Incorporating ontologies in identifying construction risks allows for the reuse of empirical knowledge shared among colleagues within a company. This enables the discovery of interdependencies between risk factors as stated by Yildiz et al. (2014), particularly in the case of Unknown Known risks where some staff may lack certain knowledge that their colleagues possess. Ontology modeling involves consolidating and structuring collaborative knowledge (Liu & Zaraté, 2014), providing a more efficient approach compared to traditional techniques such as checklists, brainstorming, and expert interviews, which often demand significant time and effort from participants. Therefore, using ontologies in risk management can significantly improve time efficiency, especially during the tendering phase of a project. By identifying risks at this stage, we can proactively implement solutions to mitigate their impact during the construction phase.

7.4 LIMITATIONS OF RESEARCH AND MODEL

This research had several limitations. Firstly, there was a lack of specific literature on external risks in the mining industry, especially in tailings dam construction. The focus on risks of these projects is mostly on technical risks, such as structural failure of the dam, due to the high impacts they can have on the environment. The lack of access to specific projects to assess the real risks and stakeholders, as well as quantitative data, limited the feasibility of the model response, creating the need to

formulate a hypothetical case. In addition, data collection became more challenging and time-consuming, as it relied on interviews of different stakeholders from different companies. This time constraint also meant that the focus of the model, especially on activities, was more general and could not delve into more specific activities.

One of the main comments made by interviewees at the validation meetings was whether the model could contain quantitative data on the case study, such as river and quarry distances and travel times in order to get an idea of the costs involved in choosing where to take the resources; although Protégé does have the capacity to relate quantitative data, due to time constraint and that it was a hypothetical case study, it was not included. Another comment was whether it was possible to include the costs of resources from different suppliers and even the properties of the aggregates to be exploited.

Since the model is a knowledge graph, any information that can be known can be included. However, the constraint is to have the empirical information of the people involved in the projects. In order to have a complete model of the risks, it would also have to include the intrinsic risks of the operation, such as health and safety risks, construction process risks, and inherent costs.

The limitation of an ontology lies in the time and information provided. However, in specific cases and over years, applying lessons learned, a model could be multiplied among its relationships and classes, as long as sufficient time is devoted to it. As with any decision-making, the more information available, the better and more effective the decision can be.

A final restriction of the model is that it needs a person with experience using the software so that it can be shaped and modified with the information gathered from the end users. The more complex and specific the model is, the more time is needed to make it, but also the more functional it will be.



CHAPTER 8

CONCLUSIONS

8 CONCLUSIONS

8.1 RESEARCH CONCLUSION

In this research, the primary aim was to explore how to model an ontology of external risks in the construction of a tailings dam project using empirical knowledge and by following the Methontology approach, specifically focusing on the support activity of knowledge acquisition through a combination of literature review, news analysis, and the findings from interviews, the necessary database was successfully constructed and implemented it within the model.

The use of a knowledge graph, as exemplified in this research, is not intended to function as the exclusive tool for identifying risks, whether they are external or internal. Despite possessing comprehensive operational or project-related technical specifications, external and particularly social risks involve stakeholders situated in the project's operational milieu. Notably, according to the interviewees, site visits are among the prevalent activities to gather specific information about a project located in a rural area.

During the terminal phases of the bidding process, the contractor dispatches personnel to conduct diagnostic or analytical assessments of potential suppliers and resource procurement sources essential for the project's tasks. These visits typically entail the evaluation of distributor pricing and identification of local union entities, communities, and governmental bodies necessitating mediation to preclude prospective impediments. Nonetheless, the information derived from these visits is commonly disseminated verbally and is contingent upon the individuals undertaking the visits. This information may be overlooked or omitted if not effectively communicated to the construction company's personnel.

Notwithstanding, a knowledge graph can function as a repository for such information, resembling a database employing semantics to foster enhanced comprehension and explicate potential interrelationships, thereby streamlining the comprehensive structuring and visualization of the data. Moreover, this approach can supplant alternative methodologies for risk-informed decision-making, such as SWOT analysis, Scenario Analysis, Sensitivity Analysis, or a Risk Matrix, by amalgamating the distinct functionalities of these methodologies into a knowledge graph capable of interlinking the information derived from these varied approaches.

8.2 ANSWERING RESEARCH QUESTIONS

8.2.1 Sub-Question #1: What are the most common external risks in the mining industry, and what is the contractor's perspective on them?

In the literature review, it was found that external risks related to social, political, legal, economic, or environmental factors can create various risks depending on the project area or the social and political environment in which the project will be developed. The research focused on three types of external risks within construction projects and the mining industry: risks linked to carrying out an activity, direct or indirect risks in the acquisition of resources for such activities, and the most important within the mining industry, social risks. The specific events that affected the operations of the mining

industry and/or related construction projects showed that the main reasons were the reactions of different stakeholders due to various factors, including financial, resource-related, and social motives.

Financial reasons encompassed monetary demands from communities for work permits, land, and mining companies' social responsibility programs. Resource-related reasons involved disputes regarding the misuse of natural resources like water or land, pollution resulting from mine operations, and issues arising from the involvement of external entities such as foreign contractors. Social motives included instances where political actors intervened for personal gain, and community leaders influenced communities to demand more money or infrastructure improvements to enhance the quality of life.

The interviews revealed both similarities and differences in the perceptions of external risks from the perspectives of clients and contractors in the industry. One significant similarity is the increased bargaining power of stakeholders in recent years, leading to greater potential risks. Contractors primarily view clients as a source of risk, especially in terms of communication with communities and the transfer of risks outlined in the contract. This puts contractors in a challenging position with limited options for managing this type of risk. On the other hand, clients primarily focused on mine operations tend to prioritize construction projects less and see contractors as temporary outsiders.

During the interviews with contractors, a focus on the risks associated with activities and resources was evident, with trade unions or organized groups identified as the most influential stakeholders in these risks. In contrast, interviews with mining companies predominantly concentrated on social risks, with ejidatarios and governmental institutions identified as the most influential stakeholders. One notable difference is that mining companies practice external risk management on a daily basis, whereas contractors, who are more focused on internal risks within their activities, tend to overlook this process once construction begins. External risks are typically analyzed during the tender stage, site visits, and at the kick-off meeting before construction commences.

In summary, the interviews provided specific insights into the types of external risks in the mining industry and in the construction of tailings dams. Participants shared real examples of problems they encountered and how they resolved them, in some cases incurring significant costs.

8.2.2 Sub-Question #2: What are the correlations between activities, events, and resources that lead to risks in the construction of tailings dams?

To answer sub-question #2 of this research, the data collected from previous sub-questions, along with the findings from the interviews, news, and experience in the construction industry, were utilized to develop the knowledge graph discussed in the results section. To address this question, the classes were divided as shown below:

TABLE 32: SUMMARY OF CLASSES

Classes	# of Subclasses
Activities	13
Resources	10
Risk	3

Activity-related risks	7
Resources-related risks	8
Social-related risks	9
Social Events	6
Legal conflicts	2
Risk mitigation strategies	14
Stakeholders	25

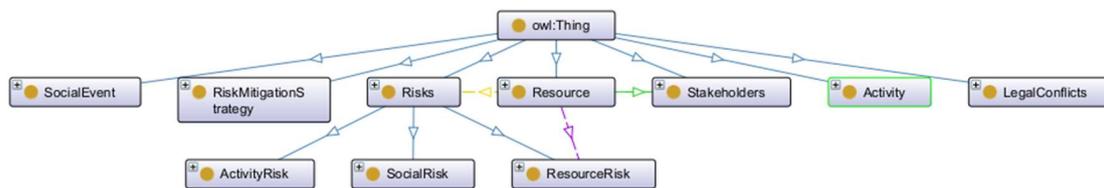


FIGURE 35: CLASS HIERARCHY (UPPER LEVEL)

Eight object properties were used in the model to correlate all the classes mentioned, as shown in the following table, resulting in 374 correlations between the classes and the object properties.

TABLE 33: SUMMARY OF OBJECT PROPERTIES

Object properties	Domains	Ranges
Needs resource	Activities	Resources
Has Stakeholder	Activities, Resources,Risks, Social events	Stakeholders
Can lead to event	Risks	Legal conflict or social event
Has mitigation strategy	Legal conflicts,Risks, Social events	Risk mitigation strategy
Has risk	Activities or resources	Risks
Has activity risk	Activities	Activities risks
Has resource risk	Resources	Resources risks
Has social risk	Activity or resources	Social risks

In conclusion, the model effectively complied with the evaluation processes described in the methodology chapter, as shown in the following table.

TABLE 34: SUMMARY OF MODEL EVALUATION

Evaluation	Comments
Verification through reasoner	No inferences were found using Hermit reasoner
Criteria based evaluation	According to the participants, the coverage, consistency, and clarity of the knowledge graph were completely satisfactory. There were positive comments regarding the scalability of the knowledge graph, mentioning how the information in the graph could be adjusted for use in other areas.
Completeness and coherence	Participants confirmed the completeness of information in the knowledge graph and manually verified the consistency of relationships until it was accurate.
Answering competency questions	According to the participants, the specific competency questions developed in the validation meetings were successfully answered within the limitations of the knowledge graph. As with the completeness of the model and criteria-based evaluation, some feedback was provided that would enhance the model while also expanding its domain for future applications in the construction of tailing dams.

To understand these correlations more fully and visualize the whole knowledge graph, the reader can refer to **Appendix B** or import the IRI from <http://roberto-thesis.com/final/1.0> into the Protégé software.

8.3 THEORETICAL CONTRIBUTIONS AND RESEARCH RECOMMENDATIONS

In the existing literature, there is a substantial amount of research on how to enhance risk management and apply new analyses or tools in the construction and mining industry. Some ontologies have been applied to risk management or processes in the construction industry. However, one of the key objectives of this research is to bridge the gap between risk management, specifically external risks, and the construction of tailings dams. This primary contribution is crucial as it illustrates how to build an ontology that can be used for risk management in construction projects, specifically in industries such as mining and, more specifically, in projects like tailings dams, to enhance decision-making in the bidding process.

It also contributes to outlining the steps for gathering information from two different perspectives, in this case, the client and the contractor, to integrate this knowledge into a model or graph. This database can be self-mapped, updated, and tailored to various projects using the same established set of meanings.

When undertaking future research related to this study, it is advisable to utilize this or another ontology, if it exists, as a foundation. This will enable its application to a specific real-life scenario within a company, where project information can be collected more efficiently, especially if there is documentation on lessons learned. It is essential to explore the use of quantitative data in order to make more informed decisions based on the model.

8.4 PRACTICAL CONTRIBUTIONS AND IMPLICATIONS

Using ontologies in any field may initially seem complex but with a semantic structure aligned with the model's objective and an individual proficient in using software, the process becomes more manageable. As previously mentioned, having the necessary information for the term pool is vital in creating the model. For instance, if a company possesses a comprehensive analysis of lessons learned and documentation from each project, this foundational task is largely accomplished. However, construction companies seeking to implement this type of modeling will need to designate a specific role dedicated to maintaining the models and documentation. The individual responsible for these activities should be well-informed about potential events or risks and have access to a site logbook containing relevant information. Furthermore, the efficacy of a knowledge graph relies on consistent upkeep; the more robust and updated it is, the better it can foresee potential risks. It is important to note that one of the main objectives of ontologies is reusability. With the model's core, it can be adapted and utilized more efficiently across various projects, ultimately saving time.

This research focused on external risks in the construction of tailings dams. However, based on the semantics already established in the model, it could be used in the future as a basis to apply it to a specific case or to add internal risks, including to other types of infrastructure or building projects.

9 REFERENCES

- Al-Tabtabai, H., & Diekmann, J. E. (1992). Judgemental forecasting in construction projects. *Construction Management and Economics*, 10(1), 19–30. <https://doi.org/10.1080/01446199200000003>
- Alexandropopescu. (2023, May 24). México: las recientes reformas a la Ley Minera están en riesgo de ser imputadas por legisladores. *Noticias Ambientales*. <https://es.mongabay.com/2023/05/reformas-ley-minera-en-riesgo-de-ser-imputadas-mexico/>
- Amponsah-Tawiah, K., & Dartey-Baah, K. (2011). The Mining Industry in Ghana Blessing or Curse. *International Journal of Business and Social Science*. https://www.researchgate.net/profile/Kwasi_Dartey-Baah/publication/280557496_The_Mining_Industry_in_Ghana_A_Blessing_or_a_Curse/links/55b9045c08aed621de084c6c.pdf
- Andersen, M., & Noailly, J. (2022). Environmental regulations in the mining sector and their effect on technological innovation. In Cambridge University Press eBooks (pp. 142–171). <https://doi.org/10.1017/9781108904209.007>
- Andrade Navia, J. M., & Olaya Amaya, A. (2021). IMPACTOS ECONÓMICOS, SOCIALES Y AMBIENTALES GENERADOS POR LAS GRANDES HIDROELÉCTRICAS. UNA REVISIÓN. *Interciencia*, 46, 10378-1844/14/07/468-08. https://www.interciencia.net/wp-content/uploads/2021/02/02_6537_A_Andrade_v46n1_7.pdf
- Ansah, R. H., & Sorooshian, S. (2017). Effect of lean tools to control external environment risks of construction projects. *Sustainable Cities and Society*, 32, 348–356. <https://doi.org/10.1016/j.scs.2017.03.027>
- Asesorías Técnicas Geológicas ATG LTDA. (n.d.). Propuesta de lineamientos técnicos de política de buenas practicas para estandarizar los procesos relacionados con presas de relaves. Ministerio De Minas Y Energía Dirección De Minería Empresarial Asesorías Técnicas Geológicas ATG Ltda. Retrieved March 9, 2024, from https://www.minenergia.gov.co/documents/9582/Cartilla_Lineamientos_Presas_Relaves.pdf
- Assaf, S., & Al-Hejji, S. (2006). Causes of delay in large construction projects. *International Journal of Project Management*, 24(4), 349–357. <https://doi.org/10.1016/j.ijproman.2005.11.010>
- Badri, A., Nadeau, S., & Gbodossou, A. (2012). A mining project is a field of risks: a systematic and preliminary portrait of mining risks. *International Journal of Safety and Security Engineering*, 2(2), 145–166. <https://doi.org/10.2495/safe-v2-n2-145-166>
- Bahamid, R. A., & Doh, S. I. (2017). A review of risk management process in construction projects of developing countries. *IOP Conference Series*, 271, 012042. <https://doi.org/10.1088/1757-899x/271/1/012042>
- Bajaj, D., Oluwoye, J., & Lenard, D. (1997). An analysis of contractors' approaches to risk identification in New South Wales, Australia. *Construction Management and Economics*, 15(4), 363–369. <https://doi.org/10.1080/014461997372917>
- Barrientos, C. (2021b, April 13). Persiste desacuerdo entre la mina y ejidatarios de La Parrilla. www.elsiglodedurango.com.mx. <https://www.elsiglodedurango.com.mx/noticia/2021/persiste-desacuerdo-entre-la-mina-y-ejidatarios-de-la-parrilla.html>

Bessi, R. (2023, September 6). Oaxaca: Comunidades denuncian colusión de la Procuraduría Agraria con proyecto minero. Avispa Midia. <https://avispa.org/oaxaca-comunidades-denuncian-colusion-de-la-procuraduria-agraria-con-proyecto-minero/>

BMI Macroeconomic & Industry Megatrends. (2023, July 21). https://www.fitchsolutions.com/topic/megatrends?utm_campaign=megatrends&utm_medium=pc&utm_source=google&utm_content=target&utm_term=global%20industry%20reports&gclid=CjwKCAjw4P6oBhBsEiwAKYVvkq8Ss59XyeSjDRAYGP6wicMUHFNsyOyQvquET8udpvMpo0JceFlmSbBoCSwgQAvD_BwE

Canedo, F. P. (2024, May 7). Rechazan mineros bloqueos. www.elsiglodetorreon.com.mx. <https://www.elsiglodetorreon.com.mx/noticia/2024/rechazan-mineros-bloqueos.html>

Casti, J. 2011. Four faces of tomorrow [Online]. Laxenburg: OECD. Available: <http://www.oecd.org/governance/risk/46890038.pdf>.

Conde, M., & Billon, P. L. (2017b). Why do some communities resist mining projects while others do not? the Extractive Industries and Society/ the Extractive Industries and Society, 4(3), 681–697. <https://doi.org/10.1016/j.exis.2017.04.009>

Corresponsal, C. G. L. (2023, October 21). Defensores del río Sonora cierran acceso a mina de Cananea. La Jornada. <https://www.jornada.com.mx/noticia/2023/10/21/estados/defensores-del-rio-sonora-cierran-acceso-a-mina-de-cananea-8669>

Corresponsal, S. O. A. (2022, September 6). Ejidatarios bloquean mina de Carrizalillo por incumplimiento de contrato. La Jornada. <https://www.jornada.com.mx/notas/2022/09/06/estados/ejidatarios-bloquean-mina-de-carrizalillo-por-incumplimiento-de-contrato/>

Day, J. (2023, June 15). Reforma minera: principales modificaciones, efectos e implicaciones para los inversionistas extranjeros. Jonesday.com. <https://www.jonesday.com/es/insights/2023/06/mining-reform-in-mexico-amendments-and-impact>

De Azevedo, R. C., Ensslin, L., & Jungles, A. E. (2014). A Review of Risk Management in Construction: Opportunities for Improvement. *Modern Economy*, 05(04), 367–383. <https://doi.org/10.4236/me.2014.54036>

De Economía, S. (n.d.). Reforma integral a la actividad minera. gob.mx. <https://www.gob.mx/se/prensa/reforma-integral-a-la-actividad-minera>

De Durango, E. U. / E. S. (n.d.). Ejidatarios recibirán 2 patrullas y despensas por acuerdo con empresa minera. El Sol De Durango | Noticias Locales, Policiacas, Sobre México, Durango Y El Mundo. <https://www.elsoldedurango.com.mx/local/ejidatarios-recibiran-2-patrullas-y-despensas-por-acuerdo-con-empresa-minera-11455733.html>

De Durango, M. R. | E. S. (n.d.). Problema con mina en San José de Avino enfrenta al pueblo de Pánuco de Coronado. El Sol De Durango | Noticias Locales, Policiacas, Sobre México, Durango Y El Mundo. <https://www.elsoldedurango.com.mx/local/municipios/problema-con-la-mina-en-san-jose-de-avino-enfrenta-al-pueblo-de-panuco-de-coronado-durango-10042833.html>

De Morelia, D. M. | E. S. (n.d.). ArcelorMittal da su postura ante bloqueo en la Mina Las Truchas. El Sol De Morelia | Noticias Locales, Policiacas, Sobre México, Michoacán Y El Mundo. <https://www.elsoldemorelia.com.mx/local/arcelormittal-da-su-postura-ante-bloqueo-en-la-mina-las-truchas-11112799.html>

De Zacatecas, R. G. / E. S. (n.d.). Candidato a alcalde bloquea mina en Sombrerete; Grupo México interpone denuncia penal. *El Sol De Zacatecas | Noticias Locales, Policiacas, Sobre México, Zacatecas Y El Mundo*. <https://www.elsoldezacatecas.com.mx/elecciones-2024/candidato-a-alcalde-bloquea-mina-en-sombrerete-grupo-mexico-interpone-denuncia-penal-11810449.html>

Denyo, P. K., & Agyekum, K. (2021). Examining the social and environmental impact of tailings Dam Projects in Ghana: a case study of Perseus Mining TSF Project. <http://129.122.16.11/handle/123456789/14106>

Ding, L., Zhong, B., Wu, S., & Luo, H. (2016). Construction risk knowledge management in BIM using ontology and semantic web technology. *Safety Science*, 87, 202–213. <https://doi.org/10.1016/j.ssci.2016.04.008>

Dong, L., Tong, X., Xi-Bing, L., Zhou, J., Wang, S., & Liu, B. (2019). Some developments and new insights of environmental problems and deep mining strategy for cleaner production in mines. *Journal of Cleaner Production*, 210, 1562–1578. <https://doi.org/10.1016/j.jclepro.2018.10.291>

Exigen cerrar mina en Solosuchiapa. (2019, February 26). *Cuarto Poder Chiapas*. <https://www.cuartopoder.mx/chiapas/exigen-cerrar-mina-en-solosuchiapa/277210>

Farghaly, K., Soman, R. K., & Whyte, J. (2024). cSite ontology for production control of construction sites. *Automation in Construction*, 158, 105224. <https://doi.org/10.1016/j.autcon.2023.105224>

Fernández-López, M., & Gómez-Pérez, A. (2002). Overview and analysis of methodologies for building ontologies. *The Knowledge Engineering Review*, 17(2), 129–156. <https://doi.org/10.1017/s0269888902000462>

Fernández-López, M., Gómez-Pérez, A., & Juristo, N. (1997). METHONTOLOGY: From ontological art towards ontological engineering. *National Conference on Artificial Intelligence*. <http://oa.upm.es/5484/>

Gómez, A., Wagner, L., Torres, B., Martín, F., & Rojas, F. (2014c). Resistencias sociales en contra de los megaproyectos hídricos en América Latina. *Revista Europea De Estudios Latinoamericanos Y Del Caribe/European Review of Latin American and Caribbean Studies*, 0(97), 75. <https://doi.org/10.18352/erlacs.9797>

Granger, C. W. J. (2010). 2. Risk: a decision Maker’S perspective. In *Princeton University Press eBooks* (pp. 31–46). <https://doi.org/10.1515/9781400835287-003>

Haddaway, N. R., Smith, A., Taylor, J. J., Andrews, C. R., Cooke, S. J., Nilsson, A. E., & Lesser, P. (2022). Evidence of the impacts of metal mining and the effectiveness of mining mitigation measures on social–ecological systems in Arctic and boreal regions: a systematic map. *Environmental Evidence*, 11(1). <https://doi.org/10.1186/s13750-022-00282-y>

Hassan, F., & Le, T. (2023). Ontology-Based approach to Risk-Factor identification to support the management of provisions in bridge design. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 15(1). [https://doi.org/10.1061/\(asce\)la.1943-4170.0000574](https://doi.org/10.1061/(asce)la.1943-4170.0000574)

HerMiT: an OWL 2 reasoner. (n.d.). <https://www.cs.ox.ac.uk/people/boris.motik/pubs/ghmsw14Hermit.pdf>

HerMiT Reasoner: Home. (n.d.). <http://www.hermit-reasoner.com/>

Heuberger, R. H. (2005). Risk analysis in the mining industry. *The Journal of the South African Institute of Mining and Metallurgy*, 75–79.

- Hlaing, N., Singh, D., Tiong, R. L. K., & Ehrlich, M. (2008). Perceptions of Singapore construction contractors on construction risk identification. *Journal of Financial Management of Property and Construction*, 13(2), 85–95. <https://doi.org/10.1108/13664380810898104>
- Hodge, R. A., Ericsson, M., Löf, O., Löf, A., & Semkowich, P. (2022). The global mining industry: corporate profile, complexity, and change. *Mineral Economics*, 35(3–4), 587–606. <https://doi.org/10.1007/s13563-022-00343-1>
- Hooi, Y. K., Hassan, M. F., & Shariff, A. M. (2015). Ontology Evaluation — a criteria selection framework. *International Symposium on Mathematical Sciences & Computing Research (iSMSC)*. <https://doi.org/10.1109/ismsc.2015.7594069>
- Hoseini, E., Hertogh, M., & Bosch-Rekveltdt, M. (2019). Developing a generic risk maturity model (GRMM) for evaluating risk management in construction projects. *Journal of Risk Research*, 24(7), 889–908. <https://doi.org/10.1080/13669877.2019.1646309>
- Huicholes en pie de guerra. (n.d.). vanguardia.com.mx. <https://vanguardia.com.mx/noticias/nacional/2860836-huicholes-en-pie-de-guerra-NXVG2860836>
- Hussain, C. M., Paulraj, M. S., & Nuzhat, S. (2022). Source reduction and waste minimization in the mining industries. In *Elsevier eBooks* (pp. 169–176). <https://doi.org/10.1016/b978-0-12-824320-6.00011-3>
- Isah, M. A., & Kim, B. (2023). Development of knowledge graph based on risk Register to support risk management of construction projects. *KSCE Journal of Civil Engineering*, 27(7), 2733–2744. <https://doi.org/10.1007/s12205-023-2886-7>
- Iqbal, R., Murad, M. a. A., Mustapha, A., & Sharef, N. M. (2013). An Analysis of Ontology Engineering Methodologies: A Literature review. *Research Journal of Applied Sciences, Engineering and Technology*, 6(16), 2993–3000. <https://doi.org/10.19026/rjaset.6.3684>
- Junega, P. J. (n.d.). The Known-Unknown classification of risk. *Management Study Guide*. <https://managementstudyguide.com/known-unknown-classification-of-risk.htm>
- Kansongue, N., Njuguna, J., & Vertigans, S. (2023). A PESTEL and SWOT impact analysis on renewable energy development in Togo. *Frontiers in Sustainability*, 3. <https://doi.org/10.3389/frsus.2022.990173>
- Kossoff, D., Dubbin, W. E., Alfredsson, M., Edwards, S., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. *Applied Geochemistry*, 51, 229–245. <https://doi.org/10.1016/j.apgeochem.2014.09.010>
- Lammers, H. (2016). Qualitative risk assessment and identification of key drivers for consideration during selection of a copper tailings disposal technology, A [MA thesis, Colorado school of mines]. <https://mountainscholar.org/handle/11124/171601>
- Lee, C., Won, J. W., Jang, W., Jung, W., Han, S. H., & Kwak, Y. H. (2017b). Social conflict management framework for project viability: Case studies from Korean megaprojects. *International Journal of Project Management*, 35(8), 1683–1696. <https://doi.org/10.1016/j.ijproman.2017.07.011>
- Liu, S., & Zaraté, P. (2014). Knowledge Based Decision Support Systems: A survey on technologies and application domains. In *Lecture notes in business information processing* (pp. 62–72). https://doi.org/10.1007/978-3-319-07179-4_7

- Lykourantzou, I., Papadaki, K., Kalliakmanis, A., Djaghoul, Y., Latour, T., Charalabis, I., & Kapetanios, E. (2011). Ontology-based Operational Risk Management. 2011 IEEE Conference on Commerce and Enterprise Computing. <https://doi.org/10.1109/cec.2011.18>
- Maheshbhai, P. K., Bhatt, R., & Bhavsar, J. J. (2014). A study of risk factors affecting building construction projects. *International Journal of Engineering Research and Technology*, 3(12). <https://www.ijert.org/research/a-study-of-risk-factors-affecting-building-construction-projects-IJERTV3IS120480.pdf>
- Maldonado, S. (2024, March 29). Minera San Agustín reanuda labores; agradece al Estado por proteger empleos. www.elsiglodedurango.com.mx. <https://www.elsiglodedurango.com.mx/noticia/2024/minera-reanuda-labores-agradece-al-estado-por-proteger-empleos.html>
- Mariscal, Á. (2016, November 10). En Chiapas piden cierre definitivo de minas a cielo abierto. *Chiapasparalelo*. <https://www.chiapasparalelo.com/noticias/chiapas/2016/11/habitantes-de-chiapas-piden-cierre-definitivo-de-minas-a-cielo-abierto/>
- Martínez, J. C. (2021, January 17). Minera denuncia pasividad de Fiscalía de Sinaloa en investigación de bloqueos que la mantienen cerrada. *El Universal*. <https://www.eluniversal.com.mx/estados/minera-denuncia-pasividad-de-fiscalia-de-sinaloa-en-investigacion-de-bloqueos-que-la/>
- Medina, M. (2021, December 28). Ejidatarios toman Minera Capstone por incumplimiento en acuerdos. *Imagen Zacatecas*. <https://imagenzac.com.mx/capital/ejidatarios-toman-minera-capstone-por-incumplimiento-en-acuerdos/>
- Mikes, A., & Kaplan, R. S. (2012). Managing Risks: A New Framework. *Harvard Business Review*. <http://eureka.sbs.ox.ac.uk/7457/>
- Montoya, J. R. (2021b, January 17). Ejidatarios bloquean mina de manganeso en Hidalgo. *La Jornada*. <https://www.jornada.com.mx/notas/2021/01/17/estados/ejidatarios-bloquean-mina-de-manganeso-en-hidalgo/>
- Morett-Sánchez, J. C., Cosío-Ruiz, C., Morett-Sánchez, J. C., & Cosío-Ruiz, C. (n.d.). Panorama de los ejidos y comunidades agrarias en México. https://www.scielo.org.mx/scielo.php?pid=S1870-54722017000100125&script=sci_arttext
- Nawaz, A., Waqar, A., Shah, S. a. R., Sajid, M., & Khalid, M. I. (2019). An Innovative Framework for Risk Management in Construction Projects in Developing Countries: Evidence from Pakistan. *Risks*, 7(1), 24. <https://doi.org/10.3390/risks7010024>
- Noy, N. F., & McGuinness, D. L. (2002). Ontology Development 101: A Guide to Creating Your First Ontology. Knowledge System Laboratory. <http://ce.sharif.edu/~daneshpajouh/ontology/ontology-tutorial-noy-mcguinness.pdf>
- Ollaquindia, R. O. (2014, February). Ante falta de respuesta, ejidatarios continúan protesta en intermediaciones de la mina Camino Rojo. *La Jornada Zacatecas*. Retrieved April 1, 2024, from <https://ljz.mx/02/02/2014/ante-falta-de-respuesta-ejidatarios-continuan-protesta-en-intermediaciones-de-la-mina-camino-rojo/>
- Perera, T. P., & Higgins, D. H. (2017). THEORETICAL OVERVIEW OF KNOWN, UNKNOWN AND UNKNOWABLE RISKS FOR PROPERTY DECISION MAKINGS. In 23RD ANNUAL PACIFIC RIM REAL ESTATE SOCIETY CONFERENCE (1st ed.). https://www.researchgate.net/publication/320943325_Theoretical_Overview_of_Known_Unknown_and_Unknownable_Risks_for_Property_Decision_Makings#full-text

- Pmp, F. U. (2024, March 5). Risk vs uncertainty in project Management | PM Study Circle. PM Study Circle. <https://pmstudycircle.com/risk-vs-uncertainty/>
- Pretty, M. M. P. (2021). Identification of external risks affecting the South African mining sector and their mitigation strategies [Master's Dissertation, University of Johannesburg]. <https://ujcontent.uj.ac.za/esploro/outputs/9912875107691/filesAndLinks?index=0>
- Renault, B. Y., & Agumba, J. N. (2016). Risk management in the construction industry: a new literature review. MATEC Web of Conferences, 66, 00008. <https://doi.org/10.1051/matecconf/20166600008>
- Rihar, L., Žužek, T., Berlec, T., & Kušar, J. (2019). Standard Risk Management Model for infrastructure projects. In IntechOpen eBooks. <https://doi.org/10.5772/intechopen.83389>
- Rocha, C. (2016, December 30). El estado de Puebla mantiene cuatro conflictos mineros, según el OCMAL. La Jornada De Oriente. <https://www.lajornadadeoriente.com.mx/puebla/estado-puebla-mantiene-cuatro-conflictos-mineros-segun-ocmal/>
- Sánchez, A. (2020, February 21). Bloqueos a minas opacan extracción de oro y plata en México. El Financiero. <https://www.elfinanciero.com.mx/empresas/bloqueos-a-minas-opacan-extraccion-de-oro-y-plata-en-mexico/>
- Schoenberger, E. (2016). Environmentally sustainable mining: The case of tailings storage facilities. Resources Policy, 49, 119–128. <https://doi.org/10.1016/j.resourpol.2016.04.009>
- Seven trends that will shape the future of mining and metals. (2020, February 8). World Economic Forum. <https://www.weforum.org/agenda/2019/03/seven-trends-shaping-the-future-of-the-mining-and-metals-sector/>
- Shaked, A., & Margalit, O. (2022). Sustainable risk identification using formal ontologies. Algorithms, 15(9), 316. <https://doi.org/10.3390/a15090316>
- Shen, W., Tang, W., Yu, W., Duffield, C., Hui, F. K. P., Wei, Y., & Fang, J. (2017). Causes of contractors' claims in international engineering-procurement-construction projects. Journal of Civil Engineering and Management, 23(6), 727–739. <https://doi.org/10.3846/13923730.2017.1281839>
- Taylan, O., Bafail, A. O., Abdulaal, R. M. S., & Kabli, M. R. (2014). Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. Applied Soft Computing, 17, 105–116. <https://doi.org/10.1016/j.asoc.2014.01.003>
- Tepeli, E., Taillandier, F., & Breyse, D. (2019). Multidimensional modelling of complex and strategic construction projects for a more effective risk management. International Journal of Construction Management, 21(12), 1218–1239. <https://doi.org/10.1080/15623599.2019.1606493>
- Tharanga, Dhanusha. (2020). CRITICAL REVIEW OF RISK IDENTIFICATION TECHNIQUES. 10.13140/RG.2.2.18209.22886.
- Topic: Mining. (2023, August 31). Statista. <https://www.statista.com/topics/1143/mining/#topicOverview>
- Tubis, A., Werbińska-Wojciechowska, S., & Wróblewski, A. (2020). Risk Assessment Methods in Mining Industry—A Systematic Review. Applied Sciences, 10(15), 5172. <https://doi.org/10.3390/app10155172>
- Wseas. (2011). Applications of mathematics and computer engineering: American Conference on Applied Mathematics (AMERICAN-MATH 11) : 5TH WSEAS International Conference on Computer Engineering and Applications (CEA 11)

- Yildiz, A. E., Dikmen, İ., Birgönül, M. T., Ercoskun, K., & Alten, S. (2014). A knowledge-based risk mapping tool for cost estimation of international construction projects. *Automation in Construction*, 43, 144–155. <https://doi.org/10.1016/j.autcon.2014.03.010>
- Zheng, Y., Törmä, S., & Seppänen, O. (2021). A shared ontology suite for digital construction workflow. *Automation in Construction*, 132, 103930. <https://doi.org/10.1016/j.autcon.2021.03.009>
- Zhou, M., Zhang, R., Li, Q., & Zhou, Y. (2014). High frequency phenotyping with unmanned aerial vehicles in paddy rice. *Remote Sensing*, 6(7), 6427–6441. <https://doi.org/10.3390/rs6076427>
- Zhi-Min, W., Liu, Z., & Liu, J. (2020). Risk Identification and Responses of Tunnel Construction Management during the COVID-19 Pandemic. *Advances in Civil Engineering*, 2020, 1–10. <https://doi.org/10.1155/2020/6620539>
- Zou, P. X., Zhang, K., & Wang, J. (2007). Understanding the key risks in construction projects in China. *International Journal of Project Management*, 25(6), 601–614. <https://doi.org/10.1016/j.ijproman.2007.03.001>

10 APPENDICES

10.1 APPENDIX A-INTERVIEWS KEY CODES.

Activities	Frequency
• Bidding process	8
• Blasting	6
• Building secondary roads	9
• Buying Land	9
• Transportation of aggregates to site	21
• Civil works	2
• Installing concrete plants	2
• Drainages	1
• Drilling wells	3
• Earthworks	10
• Environmental permits procedures	7
• Foundations	1
• Hammering	2
• Hauling water tanks	15
• Hiring personnel	10
• Identification of risks	14
• Installing camping sites	1
• Installing field offices	2
• Labour mobilization	8
• Maintenance program for equipment	4
• Material crushing	6
• Platforms	1
• Preliminary activities	11
• Procurement of resources	7
• Quarrying	19
• Renting land	7
• Renting Machinery	4
• Structures	1
• Tools to identify risks	5
• Transportation of machinery	15
• Welding of geomembrane	2

Activities Risks	Frequency
• Damaging buildings surrounding t	3
• Damaging community plots	5
• Affecting access to community plo	10
• Damaging or affecting roads	6
• Diverting bodies of water	3
• Environmental pollution	2
• Exploiting an unlicensed quarries	4
• Delimited work shifts	3
• Noise pollution	4
• Pollution of dust	7
• Short periods to bid	4
• Spillage from transporting materia	1

Environmental risks	Frequency
• Excessive rain	6
• Impacting bodies of water	5
• Tailing spillages	2

Social conflicts or events	Frequency
• Strikes	10
• Theft of machinery	8
• Work stoppages	16
• Drain blockages	1
• Communities desire to replace co	7
• Roadblocks	16
• Problems with ejidatarios	29
• Water intake blockage	3

Legal conflicts or risks	Frequency
• Land	17
• Permits	20
• Political	8
• Increase of regulations demand	2

APPENDIX 1: INTERVIEW KEY FINDINGS #1

Resources	Frequency
Aggregates	20
Concrete	2
Concrete plants	1
Diesel (Fuel)	3
Energy	1
Explosives	7
Field offices	4
Food	5
Good quality materials	13
Heavy equipment workshops	4
Labour	25
Land acquisition	14
Machinery and transportation trucks	29
Steel	2
Water	25
Wood	3

Resources Risk	Frequency
Tight budget	1
Community desire to control resources	5
Heavy machinery breakdown	2
Imposition of rental machinery	1
Incompetence of Labour	14
Insufficient Machinery	3
Lack materials in the zone	9
Insufficient water supply	19
Lack of aggregates in quarries	8
Local inflation of prices	5
Machinery transportation (theft of machinery)	15
Supply of diesel (fuel)	2

Social Risk	Frequency
Bargaining power of social groups	52
Communal conflicts	9
Communities are afraid of change	8
Communities have better access to information	3
Corruption	4
Defiance of the law	17
Delinquency including kidnapping, and assassination	14
Distant relationship between Client and communities	7
Extraordinary fees to criminal groups	6
Extraordinary fees to social groups	37
Extraordinary fees to Unions	19
Extraordinary works requested by ejidatarios	21
Inadequate communication strategy with communities	9
Increase of political risks	4
Increment on prices	10
Management Change in government	8
Miscommunication between client and communities	13
Organized crime	10
Political agendas	13

Stakeholders	Frequency
Client (Mining Company)	13
Communities	58
Governmental institutions	21
Organized crime	12
Political actors	12
Unions	20

APPENDIX 2: INTERVIEW KEY FINDINGS #1

10.2 APPENDIX B- COMPLETE TERMPPOOL FOR CONSTRUCTING THE KNOWLEDGE GRAPH

<u>Classes:</u>	Object Properties (Relations)	Annotations
Activities:		
Blasting	Activity, HasActivityRisk only DamagingSurroundingBuildings HasActivityRisk only DustPollution HasActivityRisk only NoisePollution HasSocialRisk only MiscommunicationWithCommunities HasStakeholder only RuralCommunities NeedsResource only Explosives	"Blasting is a common activity in the building of tailing dams when hammering is not sufficient. this involves explosives and social risks"
Building secondary roads	Activity HasActivityRisk only CommunalComplains HasActivityRisk only DamagingCommunityPlots HasActivityRisk only DamagingRoadsorPowerLines HasActivityRisk only DefianceOfLaw HasActivityRisk only MiscommunicationWithCommunities HasStakeholder only RuralCommunities NeedsResource only Labour NeedsResource only MachineryAndTransportationTrucks NeedsResource only Water NeedsResource only Aggregates	"This activity refers to the creation of temporary accesses to the project in the construction process. Some of these accesses usually pass through ejido communities, which requires permits. The accesses are usually made in order to bring machinery to the site and to bring the necessary resources to the site."
Earthworks	Activity NeedsResource only Aggregates NeedsResource only GoodQualityMaterials NeedsResource only Labour NeedsResource only MachineryAndTransportationTrucks NeedsResource only Water	"Earthworks is practically the main activity at site, it depends on the competition of another activities and having the resources ready."
Hammering	Activity HasActivityRisk only NoisePollution NeedsResource only Labour NeedsResource only MachineryAndTransportationTrucks	"Depending on the soil, Hammering is needed to create the basin that the Tailings dams need. THis involves heachy machinery, which can create social risks"
Labour mobilization	Activity HasSocialRisk only CommunitiesDesireToReplaceContractor HasSocialRisk only Delinquency HasSocialRisk only UnionConflict HasStakeholder only OrganizedCrimeGroups HasStakeholder only RuralCommunities HasStakeholder only Union NeedsResource only Labour NeedsResource only MachineryAndTransportationTrucks	"Mobilising personnel is a crucial preliminary activity, especially in the mining industry where work sites are often remote from urban areas. The necessary personnel usually include machine operators, flaggers, masons, engineers, safety personnel, and surveyors."
Material crushing	Activity HasActivityRisk only DustPollution HasActivityRisk only NoisePollution NeedsResource only Aggregates NeedsResource only MachineryAndTransportationTrucks	"In order to achieve the grades and sizes specified for the construction of tailings dams, material crushing is necessary, which requires specialized machinery for rock crushing."

Quarrying	Activity HasActivityRisk only DamagingCommunityPlots HasActivityRisk only ExploitingUnlicensedQuarries HasSocialRisk only CommunalComplains HasStakeholder only Union NeedsResource only Aggregates NeedsResource only MachineryAndTransportationTrucks	"Quarrying is a basic but complicated activity in the areas where the mines are normally located. This is because there are few quarries. In addition, these quarries sometimes do not have the necessary permits from SEMARNAT (Environmental Institution), and the owners (Ejidatarios) normally hide behind the law of Usos y Costumbres (Uses and Customs)."
<u>Quarry One</u>	Quarrying HasStakeholder only EjidoC HasStakeholder only MunicipalityOne HasStakeholder only UnionA	"This Quarry and the stakeholders that are involved, are shown in the Hypothetical Case Study"
<u>Quarry Two</u>	Quarrying HasStakeholder only EjidoD HasStakeholder only MunicipalityTwo HasStakeholder only OrganizedCrimeGroupTwo HasStakeholder only UnionC	"This Quarry and the stakeholders that are involved, are shown in the Hypothetical Case Study"
<u>Quarry Three</u>	Quarrying HasStakeholder only EjidoE HasStakeholder only MunicipalityThree HasStakeholder only OrganizedCrimeGoupOne HasStakeholder only UnionD	"This Quarry and the stakeholders that are involved, are shown in the Hypothetical Case Study"
Transportation of machinery to Site	Activity HasActivityRisk only DamagingRoadsorPowerLines HasSocialRisk only Corruption HasSocialRisk only Delinquency HasStakeholder only OrganizedCrimeGroups HasStakeholder only StateHighwayPatrols NeedsResource only MachineryAndTransportationTrucks	"The tailings dams are primarily composed of aggregates, requiring a large amount of heavy machinery for earthworks, such as backhoes, tractors, irrigation tankers, and motor graders."
Transportation of materials to site	Activity HasActivityRisk only MaterialSpillage HasSocialRisk only UnionConflict HasStakeholder only Union NeedsResource only Aggregates NeedsResource only Concrete NeedsResource only GoodQualityMaterials NeedsResource only MachineryAndTransportationTrucks	"It is crucial to consider the logistics of transporting materials to project sites like tailings dams. Adequate dump trucks are required to transport aggregates from the quarries, concrete, water, timber for formwork and steel. In Mexico, this activity is carried out by trade unions, which entails risks beyond the contractor's reach."
Civil Works	Activity NeedsResource only Aggregates NeedsResource only Concrete NeedsResource only GoodQualityMaterials NeedsResource only Labour NeedsResource only Water	"This activity includes all constructions of concrete structures (Foundations, Platforms and Retention Walls)"
Resources:		
Aggregates	Resource HasResourceRisk only InflationOfLocalPrices HasResourceRisk only LackOfAggregatesInQuarry HasSocialRisk only CommunityDesireToControlResources	"Aggregates are crucial for earthworks. Suppliers must be quarries with Semarnat permits, and the aggregates are transported to the site using dump trucks."

Good quality materials	Resource HasResourceRisk only InflationOfLocalPrices HasResourceRisk only LackOfMaterialInTheZone HasSocialRisk only CommunityDesireToControlResources	"This resource refers to all materials necessary for construction works other than water, aggregates, and concrete, such as good quality timber, reinforcing steel, and any other necessary supplies."
Machinery and transportation trucks	Resource HasResourceRisk only HeavyMachineryBreakdown HasResourceRisk only InsufficientHaulingTrucks HasSocialRisk only DefianceOfLaw HasSocialRisk only Delinquency HasSocialRisk only UnionConflict HasStakeholder only Union	"This category encompasses two resources: transport trucks and heavy machinery. They are grouped together due to similar risks and include the necessary diesel or gasoline for operation."
Water	Resource HasResourceRisk only InsufficientWaterSupply HasSocialRisk only CommunityDesireToControlResources HasStakeholder only Semarnat	"Water is one of the most precious resources in rural locations in Mexico, as depending on the season, the scarcity of water increases. There are some parts of Mexico where it only rains two months a year. Sometimes communities claim the water available is theirs, or even some municipality may impose some restriction on the usage of water for construction, as is the case of Monterrey, where in some periods they can not use potable water for construction purposes."
<u>Tamazula River</u>	Water HasStakeholder only EjidoE HasStakeholder only MunicipalityThree HasStakeholder only UnionD	"This river is located and shown in the Hypothetical Case Study"
<u>Valley of Topia River</u>	Water HasStakeholder only EjidoB HasStakeholder only MunicipalityOne HasStakeholder only UnionB	"This river is located and shown in the Hypothetical Case Study"
<u>Canelas river</u>	Water HasStakeholder only EjidoA HasStakeholder only EjidoC HasStakeholder only MunicipalityOne HasStakeholder only UnionC	"This river is located and shown in the Hypothetical Case Study"
Explosives	Resource HasSocialRisk only CommunitiesRefuseToSignPermits HasSocialRisk only Corruption HasSocialRisk only Delinquency HasStakeholder only OrganizedCrimeGroups HasStakeholder only RuralCommunities HasStakeholder only Sedena HasStakeholder only Semarnat	"The use of explosives is restricted by SEDENA (Military) in Mexico, in order to get a permit for acquiring and using explosives, SEDENA requires a signed permit of the surrounding communities. Also it is a resource appreciated by Criminal groups, so stealing it or demanding some explosive is common in Mexico by these groups. Since it needs special permits, corruption is also an inherent social risk"
Labour	Resource HasResourceRisk only IncompetenceOfLocalLabour HasSocialRisk only CommunitiesDesireToReplaceContractor HasStakeholder only RuralCommunities HasStakeholder only Union	"The management of construction personnel is complex as it can lead to social problems and risks, especially when working in rural areas where social norms may differ from those in urban areas. This resource includes engineers, masons, machine operators, etc."

Concrete	Resource HasResourceRisk only NoConcretePlantsNearby	"Concrete is used in civil construction. If concrete plants are more than two hours away from the site, an on-site plant must be implemented to maintain concrete characteristics."
Activity Risks:		
Dust pollution	ActivityRisk CanLeadToEvent only Roadblocks HasMitigationStrategy only DustSuppression HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"Like Noise Pollution, certain activities generate dust. This can lead to complaints from ejidatarios and a major event."
Material spillage	ActivityRisk HasMitigationStrategy only RemovingSpillageFromRoads CanLeadtoEvent only ProblemsWithEjidatarios HasStakeholder only RuralCommunities HasStakeholder only Union	"As the Unions are the one in charge of transportation of material, spillage can happen"
Noise Pollution	ActivityRisk CanLeadToEvent only ProblemsWithEjidatarios HasMitigationStrategy only RestrictionOnWorkShifts HasStakeholder only RuralCommunities	"Noise pollution is a factor that can create problems, because some activities generate it, this risk may be more likely to occur if there are communities close to where the related activities are taking place."
Damaging Surrounding Buildings	ActivityRisk CanLeadToEvent only PermitsConflicts CanLeadToEvent only ProblemsWithEjidatarios HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"During the blasting activity, nearby houses of ejidatarios may be damaged, such as windows or walls."
Damaging community plots	ActivityRisk CanLeadToEvent only LandConflicts CanLeadToEvent only ProblemsWithEjidatarios HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"Two Interviewees claimed that while quarrying material, some of the rocks fell to a community plot, damaging their property"
Exploiting Unlicensed quarries	ActivityRisk CanLeadToEvent only PermitsConflicts HasMitigationStrategy only EnsuringQuarryPermits HasStakeholder only RuralCommunities HasStakeholder only Semarnat	"Some quarries are owned by ejidatarios. Because certain Ejidos are governed by the Ley de Usos y Costumbres rather than the legal framework of Mexico, some do not have permits from Semarnat. However, according to their law, they are allowed to operate the quarries. However if a contractor acquires aggregates from such quarries, they could face legal trouble."
Damaging roads or power lines	ActivityRisk CanLeadToEvent only ProblemsWithEjidatarios HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"Rural roads can be damaged by heavy machinery, as these roads are not designed to handle such vehicles. In Mexico, all electrical infrastructure is overhead, so oversized vehicles

		transporting machinery can collide with the lines."
Resource Risk:		
Heavy machinery breakdown	ResourceRisk HasMitigationStrategy only BuyingSparePartsInAdvance HasStakeholder only MechanicalWorkshops	"Due to the extended working hours that machinery is exposed to during the construction of tailings dams, there is always a risk of breakdown or damage to a part, which would render the machine unusable until it is fixed. This could potentially affect the contractor's ability to carry out the necessary work. Additionally, due to the remote location of these projects, moving the machinery to a workshop or the contractor's headquarters involves transporting the machinery over long distances."
Inflation of local prices	ResourceRisk HasMitigationStrategy only ChangeSupplierOfResource HasStakeholder only RuralCommunities	"Following the law of supply and demand, when suppliers or ejido communities realise that a project is starting, they often increase the prices of inputs, such as timber, water, food, lodging, diesel and aggregates."
No concrete plants nearby	ResourceRisk HasMitigationStrategy only InstallingAConcretePlantAtSite	"If there are no concrete plants nearby, remote plants have to be placed. Once the concrete comes out of production, there is only about two hours to transport and pour it on site. Otherwise, the concrete may set or lose its properties."
Lack of aggregates in quarry	ResourceRisk HasMitigationStrategy only ChangeSupplierOfResource	"There is always a risk that a quarry may not be providing enough material to meet the needs of the client and the contractor. This could be due to the quarry not extracting enough aggregates, or because there is high demand from other projects."
Lack of material in zone	ResourceRisk HasMitigationStrategy only ChangeSupplierOfResource	"Due to the location of mining projects, some materials or resources may need to be brought in from elsewhere, which can increase costs and reduce contractor productivity."
Insufficient water supply	ResourceRisk CanLeadToEvent only ProblemsWithEjidatarios CanLeadToEvent only WaterIntakeBlockage HasMitigationStrategy only ChangeSupplierOfResource HasMitigationStrategy only HaulingWaterTanks HasStakeholder only GovernmentalInstitutions HasStakeholder only MunicipalityOne HasStakeholder only MunicipalityThree HasStakeholder only MunicipalityTwo HasStakeholder only RuralCommunities	"In Mexico, there are periods of drought, where months pass without rain, which can create problems such as depletion of the aquifers and ejido communities or municipalities limiting access to water for contractors."

Insufficient Hauling Trucks	ResourceRisk CanLeadToEvent only Roadblocks CanLeadToEvent only UnionConflict HasMitigationStrategy only ContractingMoreUnions HasStakeholder only Union	"Hauling Trucks usually belongs to Unions, when one Union does not have sufficient trucks, you have to contract another union to help"
Incompetence of Local Labour	ResourceRisk HasMitigationStrategy only ExtraordinaryFeesToCommunities HasStakeholder only ClientMiningCompany HasStakeholder only RuralCommunities	"In mining industry projects, the contractor must hire a certain percentage of local personnel as per agreements between the mining company and the ejido communities. Often, these personnel may lack specialized skills or motivation, resulting in reduced productivity. To address this issue, some contractors opt to pay a fee to the communities, akin to salary payments, in order to ensure that only trained personnel are engaged."
Social Risk:		
Miscommunication with Communities	SocialRisk CanLeadToEvent only ProblemsWithEjidatarios CanLeadToEvent only Strikes HasStakeholder only ClientMiningCompany HasStakeholder only RuralCommunities	"Usually, all the communication with the rural communities is done by the Mining company rather than the actual contractor. This can create some misunderstandings while gathering resources or carrying out activities"
Communal complains	SocialRisk CanLeadToEvent only ProblemsWithEjidatarios CanLeadToEvent only Roadblocks CanLeadToEvent only Strikes HasStakeholder only RuralCommunities	"The risk of communal complaints involves formal complaints from the community that can escalate into a major issue if not addressed. This creates a significant problem for the client, as they are the ones interacting with the communities, and reflects poorly on the contractor."
Community desire to control resources	SocialRisk CanLeadToEvent only ProblemsWithEjidatarios CanLeadToEvent only WaterIntakeBlockage HasStakeholder only RuralCommunities	"Due to the bargaining power of communities, there is a risk that they may seek to control federal or natural resources, such as water, federal land, or roads, even if they do not own them, in order to exploit the client and the contrasts."
Corruption	SocialRisk CanLeadToEvent only LandConflicts CanLeadToEvent only PermitsConflicts HasStakeholder only MunicipalityOne HasStakeholder only MunicipalityThree HasStakeholder only MunicipalityTwo HasStakeholder only Sedena HasStakeholder only Semarnat HasStakeholder only StateHighwayPatrols	"Corruption is unfortunately common in Mexico, so the risk of corruption of the authorities is part of the social risks to get the necessary permits with governmental institutions and patrols."

Delinquency	SocialRisk CanLeadToEvent only HarmingPersonnel CanLeadToEvent only TheftOfMachinery HasMitigationStrategy only HiringSecurity HasStakeholder only OrganizedCrimeGroups HasStakeholder only RuralCommunities	"Delinquency as a risk means that one of the stakeholders involved may do something outside the law to take advantage, such as harming personnel or theft of machinery."
Community desire to replace contractors	SocialRisk CanLeadToEvent only Strikes HasStakeholder only RuralCommunities HasStakeholder only Union	"In some activities and resources, both communities and Union may want to impose labour, for example welding, or the machinery operators"
Defiance of Law	SocialRisk CanLeadToEvent only Roadblocks CanLeadToEvent only Strikes HasStakeholder only RuralCommunities HasStakeholder only StateHighwayPatrols HasStakeholder only Union	"Defiance of law means that some stakeholders will operate outside of their rights"
Union Conflicts	SocialRisk CanLeadToEvent only Roadblocks CanLeadToEvent only Strikes HasMitigationStrategy only ExtraordinaryFeesToUnions HasStakeholder only Union	"Typically, unions engage in disputes over contracts, leading to friction between them. Therefore, utilizing more than one union carries a risk of potential issues. Additionally, as a significant stakeholder, the contractor relies on them to transport aggregates, making them capable of demanding specific quotas or price increases to sustain their collaboration."
Communities refuse to sign permits	SocialRisk CanLeadToEvent only LandConflicts CanLeadToEvent only PermitsConflicts HasMitigationStrategy only ExtraordinaryFeesToCommunities HasStakeholder only GovernmentalInstitutions HasStakeholder only RuralCommunities	"Under the new mining law regulation, the surrounding communities must agree to and sign permits allowing the use of resources or activities in the mining industry. Without this signature, other government bodies will not grant the necessary permits."
Social Events:		
Problems with ejidatarios	SocialEvent HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only ClientMiningCompany HasStakeholder only RuralCommunities	"Problems with ejidatarios (Rural Communities) is an event that has not escalated enough to create a movilization, instead is a verbal event that includes the Mining company because they are the ones who carry the communication with them. This can range from a formal complaint to threats, which can affect the contractor in the eyes of the mining company."
Roadblocks	SocialEvent HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryFeesToOrganizedCrimeGroups HasMitigationStrategy only ExtraordinaryFeesToUnions HasStakeholder only ClientMiningCompany HasStakeholder only OrganizedCrimeGroups	"Roadblocks in secondary roads or at the accesses to the site are a common practice in the mining industry, involving communities, Unions and Organized Crime Groups"

	HasStakeholder only RuralCommunities HasStakeholder only Union	
Strikes	SocialEvent HasMitigationStrategy only ExtraordinaryFeesToUnions HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only ClientMiningCompany HasStakeholder only RuralCommunities HasStakeholder only Union	"Strikes and work stoppages may be done by Unions or Rural Communities. If this event happens it usually affects the mining operations as well."
Water intake blockage	SocialEvent HasMitigationStrategy only ChangeSupplierOfResource HasMitigationStrategy only ExtraordinaryFeesToCommunities HasStakeholder only RuralCommunities	"Water intake blockages are usually a strategy that rural communities use to enhance their bargaining power or when they have a conflict with contractors."
Theft of Machinery	SocialEvent HasMitigationStrategy only ExtraordinaryFeesToOrganizedCrimeGroups HasMitigationStrategy only HiringSecurity HasStakeholder only OrganizedCrimeGroups	"Machinery theft is also one of the events that is driven by social risks and organised crime."
Harming Personnel	SocialEvent HasMitigationStrategy only HiringSecurity HasStakeholder only OrganizedCrimeGroups	"Harming personnel means endangering the integrity of workers, such as robbery, kidnapping or extortion."
Risk Mitigation Strategy:		
Buying Spare parts in advance	RiskMitigationStrategy HasStakeholder only MechanicalWorkshops	"In order to ensure that spare parts are in stock, there are two options: keeping them in the HeadQuarters or having them in advance at specialized workshops or shops. Typically, the parts need to be ordered directly from the supplier, which can result in a long wait time."
Change supplier of resource	RiskMitigationStrategy	"Even if its a mitigation strategy, changing from supplier in rural zone may lead to other risks (out of the scope of this model) like the increase of time to bring the supplies, which can translate to more money and the involvement of more stakeholders"
Contracting more Unions	RiskMitigationStrategy HasStakeholder only Union	"If one union is not providing enough to transport material to the site, contracting with another union can help mitigate the problem."

Extraordinary Fees to communities	RiskMitigationStrategy HasStakeholder only RuralCommunities	"In many cases, communities will generate risks or events with the aim of getting something in return. It is common for these problems to be solved by means of an extraordinary fee."
Extraordinary Fees to Union	RiskMitigationStrategy HasStakeholder only Union	"As with communities, some disputes with the union can be resolved by giving a fee in return."
Extraordinary fees to criminal groups	RiskMitigationStrategy HasStakeholder only OrganizedCrimeGroups	"One way of keeping organised crime groups under control is by means of fees called " (Derecho de Piso)"."
Extraordinary works requested by ejidatarios	RiskMitigationStrategy HasStakeholder only RuralCommunities	"Sometimes, the rural communities "Ejidatarios" request some extraordinary construction works as a condition or a remedy for their claims"
Hauling water tanks	RiskMitigationStrategy	"If water is not available nearby, the only possible option to continue to have water is to transport water tankers from other cities or water intakes where there is sufficient water."
Removing Spillage from roads	RiskMitigationStrategy	"If communities start complaining about material spillage, hiring a cleaning crew on a daily basis can help mitigate that risk"
Restriction on work shift	RiskMitigationStrategy	"One way to mitigate noise pollution and make communities more comfortable is to reduce working hours where activities generate this impact. Reducing the amount of work only mitigates the risk of community action, however it reduces the contractor's productivity."
Hiring Security	RiskMitigationStrategy	"Hiring security can be beneficial when transporting machinery or for guarding personnel in case they are threatened."
Installing a concrete plant at site	RiskMitigationStrategy	"Installing a remote concrete plant is an additional cost, however this cost can be foreseen from the tendering stage."
Dust suppression	RiskMitigationStrategy	"Suppressive irrigation to control the dust generated by certain activities is the only way to mitigate this pollution."
Ensuring Quarry Permits	RiskMitigationStrategy HasStakeholder only Semarnat	"In addition to signing contracts with the quarries, the contractor must ensure that all permits are in order, regardless of whether the mine operates without them."
Stakeholders:		
ClientMiningCompany	Stakeholders	"The mining company is a significant stakeholder as it not only hires construction companies but also acts as a mediator between rural communities and the contractor. If an issue arises between the contractor and any other stakeholders, the client may also face consequences beyond the project itself."

		Therefore, contractors face severe penalties if such events occur."
Governmental Institutions	Stakeholders	"Some governmental institutions are involved in both the acquisition of resources and in some activities. There are permits that have to be applied for in some cases, but there are also social risks where these stakeholders can create problems."
<u>MunicipalityOne</u>	GovernmentalInstitutions	"This Municipality is located and shown in the Hypothetical Case Study"
<u>MunicipalityTwo</u>	GovernmentalInstitutions	"This Municipality is located and shown in the Hypothetical Case Study"
<u>MunicipalityThree</u>	GovernmentalInstitutions	"This Municipality is located and shown in the Hypothetical Case Study"
<u>Sedena</u>	GovernmentalInstitutions	"SEDENA is the military institution in Mexico, which gives the permits for the use and acquiring explosives"
<u>Semarnat</u>	GovernmentalInstitutions	"SEMARNAT is Mexico's environmental ministry, responsible for granting permits for natural resources, such as water intakes, quarries, and explosives."
<u>State highway Patrol</u>	GovernmentalInstitutions	"Some risks regarding the transportation of machinery lies within the State Highway patrols as a stakeholder. Since the transportation of heavy machinery requires permits due to the excessive dimensions of the trailers that carry them, some federal police officers try to extort the drivers of the transport by citing non-existent or inapplicable laws, due to corruption."
OrganizedCrimeGroup	Stakeholders	"Currently, there are numerous criminal groups in Mexico primarily engaged in drug trafficking to the United States, extortion, and kidnapping. These groups tend to operate in the mountainous and rural areas of Mexico, where it is more challenging for the Federal Government to restrict their activities. In these areas, these groups also exert significant influence over social control, thereby granting them substantial leverage and creating additional external risks."
<u>OrganizedCrimeGroupOne</u>	OrganizedCrimeGroups	"This Organized Crime group is located and shown in the Hypothetical Case Study"
<u>OrganizedCrimeGroupTwo</u>	OrganizedCrimeGroups	"This Organized Crime group is located and shown in the Hypothetical Case Study"

Rural Communities	Stakeholders	"Rural communities, known as Ejidos, are a form of land ownership where many people reside. Some of the residents, known as ejidatarios, are involved in agriculture or the extraction of natural resources. However, some of the land is not suitable for farming, which limits the communities' ability to generate income. Despite this, these stakeholders hold significant bargaining power, especially following the new mining law reform, as they have the authority to grant land exploitation permits to mining companies and influence the use of natural resources. The mining companies handle communication with the ejidatarios, and these communities often view the mining company contractors as outsiders or adversaries."
<u>EjidoA</u>	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
<u>EjidoB</u>	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
<u>EjidoC</u>	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
<u>EjidoD</u>	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
<u>EjidoE</u>	RuralCommunities	"This Ejido is located and shown in the Hypothetical Case Study"
Union	Stakeholders	"In Mexico, the unions are in charge of material transport and, therefore, own their dump trucks. There are many unions, but in rural areas, the unions have more bargaining power because there are few of them. Unions are also usually made up of ejidatarios."
<u>UnionA</u>	Union	"This Union is located and shown in the Hypothetical Case Study"
<u>UnionB</u>	Union	"This Union is located and shown in the Hypothetical Case Study"
<u>UnionC</u>	Union	"This Union is located and shown in the Hypothetical Case Study"
<u>UnionD</u>	Union	"This Union is located and shown in the Hypothetical Case Study"
Mechanical Workshops	Stakeholders	"This stakeholder refers to the workshops that may have the machinery parts that are needed when they break down. (It was requested by an interviewee in the validation stage)."
<u>Mechanical Workshop One</u>	MechanicalWorkshops	"This Workshop is located and shown in the Hypothetical Case Study"
<u>Mechanical Workshop two</u>	MechanicalWorkshops	"This Workshop is located and shown in the Hypothetical Case Study"

Legal Conflicts:		
Land Conflicts	LegalConflicts HasStakeholder only ClientMiningCompany HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only RuralCommunities	"Some land use conflicts can also create a legal issue, which should be avoided at all costs, as resolving them can take months or years."
Permit Conflicts	LegalConflicts HasMitigationStrategy only ExtraordinaryFeesToCommunities HasMitigationStrategy only ExtraordinaryWorksRequestedByEjidatarios HasStakeholder only MunicipalityOne HasStakeholder only MunicipalityThree HasStakeholder only MunicipalityTwo HasStakeholder only Sedena HasStakeholder only Semarnat	"Conflicts over permits is a legal event that can jeopardise the continuity of the project."

APPENDIX 3: COMPLETE TERM POOL FOR THE DEVELOP OF THE KNOWLEDGE GRAPH

10.3 APPENDIX C – COMPLETE QUERIES RESULTS FOR VALIDATION.

Activity	Relation	Risk	Resource	ResourceRiskRelation	ResourceRisk	Event	MitigationStrategy	Stakeholder
Blasting	HasActivityRisk	DamagingSurroundingBuildings				PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	RuralCommunities
Blasting	HasActivityRisk	DamagingSurroundingBuildings				ProblemsWithEjidatarios	ExtraordinaryWorksRequestedByEjidatarios	RuralCommunities
Blasting	HasActivityRisk	DustPollution				Roadblocks	DustSuppression	RuralCommunities
Blasting	HasActivityRisk	DustPollution				Roadblocks	ExtraordinaryWorksRequestedByEjidatarios	RuralCommunities
Blasting	HasActivityRisk	NoisePollution				ProblemsWithEjidatarios	RestrictionOnWorkShifts	RuralCommunities
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities	ClientMiningCompany
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities	RuralCommunities
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryWorksRequestedByEjidatarios	ClientMiningCompany
Blasting	HasSocialRisk	MiscommunicationWithCommunities				ProblemsWithEjidatarios	ExtraordinaryWorksRequestedByEjidatarios	RuralCommunities
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryFeesToUnions	ClientMiningCompany
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryFeesToUnions	RuralCommunities
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryWorksRequestedByEjidatarios	ClientMiningCompany
Blasting	HasSocialRisk	MiscommunicationWithCommunities				Strikes	ExtraordinaryWorksRequestedByEjidatarios	RuralCommunities
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	LandConflicts	ExtraordinaryFeesToCommunities	GovernmentalInstitutions
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	LandConflicts	ExtraordinaryFeesToCommunities	RuralCommunities
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	GovernmentalInstitutions
			Explosives	HasSocialRisk	CommunitiesRefuseToSignPermits	PermitsConflicts	ExtraordinaryFeesToCommunities	RuralCommunities
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	MunicipalityOne
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	MunicipalityThree
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	MunicipalityTwo
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	Sedena
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	Sernarnat
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryFeesToCommunities	StateHighwayPatrols
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityOne
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityThree
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityTwo
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	Sedena
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	Sernarnat
			Explosives	HasSocialRisk	Corruption	LandConflicts	ExtraordinaryWorksRequestedByEjidatarios	StateHighwayPatrols
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	MunicipalityOne
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	MunicipalityThree
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	MunicipalityTwo
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	Sedena
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	Sernarnat
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryFeesToCommunities	StateHighwayPatrols
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityOne
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityThree
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	MunicipalityTwo
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	Sedena
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	Sernarnat
			Explosives	HasSocialRisk	Corruption	PermitsConflicts	ExtraordinaryWorksRequestedByEjidatarios	StateHighwayPatrols
			Explosives	HasSocialRisk	Delinquency	HarmingPersonnel	HiringSecurity	OrganizedCrimeGroups
			Explosives	HasSocialRisk	Delinquency	HarmingPersonnel	HiringSecurity	RuralCommunities
			Explosives	HasSocialRisk	Delinquency	TheftOfMachinery	HiringSecurity	OrganizedCrimeGroups
			Explosives	HasSocialRisk	Delinquency	TheftOfMachinery	HiringSecurity	RuralCommunities

APPENDIX 4: COMPLETE C-2 QUERY #1 RESULTS

ActivityRisk	ActivityRiskRelation	RelatedEntity1	Event	EventRelation	RelatedEntity2
MaterialSpillage	CanLeadToEvent	ProblemsWithEjidatarios			
MaterialSpillage	HasMitigationStrategy	RemovingSpillageFromRoads			
MaterialSpillage	HasStakeholder	RuralCommunities			
MaterialSpillage	HasStakeholder	Union			
			ProblemsWithEjidatarios	HasMitigationStrategy	ExtraordinaryFeesToCommunities
			ProblemsWithEjidatarios	HasMitigationStrategy	ExtraordinaryWorksRequestedByEjidatarios
			ProblemsWithEjidatarios	HasStakeholder	ClientMiningCompany
			ProblemsWithEjidatarios	HasStakeholder	RuralCommunities

APPENDIX 5: C-2 QUERY #2 RESULTS

c	Risk	Event	MitigationStrategy	Stakeholder	CaseStudyEntity
MachineryAndTransportationTrucks	HeavyMachineryBreakdown				
MachineryAndTransportationTrucks	InsufficientHaulingTrucks				
MachineryAndTransportationTrucks	DefianceOfLaw				
MachineryAndTransportationTrucks	Delinquency				
MachineryAndTransportationTrucks	UnionConflict				
	HeavyMachineryBreakdown		BuyingSparePartsInAdvance	MechanicalWorkshops	
				MechanicalWorkshops	MechanicalWorkshopOne
				MechanicalWorkshops	MechanicalWorkshopTwo
	Delinquency	TheftOfMachinery	ExtraordinaryFeesToOrganizedCrimeGroups		
	Delinquency	TheftOfMachinery	HiringSecurity		
	Delinquency	TheftOfMachinery		OrganizedCrimeGroups	
				OrganizedCrimeGroups	OrganizedCrimeGroupOne
				OrganizedCrimeGroups	OrganizedCrimeGroupTwo

APPENDIX 6: C-3 QUERY RESULTS

Quarrying	TypeOfRisk	Risk	Event	Stakeholder	CaseStudyStakeholders
QuarryOne	HasActivityRisk	DamagingCommunityPlots	LandConflicts	RuralCommunities	
QuarryOne	HasActivityRisk	DamagingCommunityPlots	ProblemsWithEjidatarios	RuralCommunities	
QuarryOne	HasActivityRisk	ExploitingUnlicensedQuarries	PermitsConflicts	RuralCommunities	
QuarryOne	HasActivityRisk	ExploitingUnlicensedQuarries	PermitsConflicts	Semarnat	
QuarryOne	HasSocialRisk	CommunalComplains	ProblemsWithEjidatarios	RuralCommunities	
QuarryOne	HasSocialRisk	CommunalComplains	Roadblocks	RuralCommunities	
QuarryOne	HasSocialRisk	CommunalComplains	Strikes	RuralCommunities	
QuarryOne					EjidoC
QuarryOne					MunicipalityOne
QuarryOne					UnionA
QuarryOne					Union

APPENDIX 7: C-5 QUERY RESULTS

Resource	Relation	Risk	RiskMitigationStrategies	Stakeholders	Event	EventMitigationStrategies	BodyOfWater	BodyOfWaterStakeholders
Water	HasResourceRisk	InsufficientWaterSupply	ChangeSupplierOfResource, HaulingWaterTanks	GovernmentalInstitutions, MunicipalityOne, MunicipalityThree, MunicipalityTwo, RuralCommunities	ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities, ExtraordinaryWorksRequestedByEjidatarios		
Water	HasResourceRisk	InsufficientWaterSupply	ChangeSupplierOfResource, HaulingWaterTanks	GovernmentalInstitutions, MunicipalityOne, MunicipalityThree, MunicipalityTwo, RuralCommunities	WaterIntakeBlockage	ChangeSupplierOfResource, ExtraordinaryFeesToCommunities		
Water	HasSocialRisk	CommunityDesireToControlResources		RuralCommunities	ProblemsWithEjidatarios	ExtraordinaryFeesToCommunities, ExtraordinaryWorksRequestedByEjidatarios		
Water	HasSocialRisk	CommunityDesireToControlResources		RuralCommunities	WaterIntakeBlockage	ChangeSupplierOfResource, ExtraordinaryFeesToCommunities		
Water	HasStakeholder			Semarnat				
Water							CanelasRiver	EjidoA, EjidoC, MunicipalityOne, UnionC, Semarnat
Water							TamazulaRiver	EjidoE, MunicipalityThree, UnionD, Semarnat
Water							ValleyOfTopiaRiver	EjidoB, MunicipalityOne, UnionB, Semarnat

APPENDIX 8: C-4 QUERY RESULTS

10.4 APPENDIX D – HREC CONSENT FORM.

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT TEMPLATES AND GUIDE
(English Version: January 2022)

The following templates have been developed by the Human Research Ethics Committee (HREC) to assist you in the design of your Informed Consent materials for non-medical research involving human Research Subjects. **It is important to adapt this template to the outline and requirements of your particular study, using the notes and suggestions provided.**

For additional information or specific expertise on preparing your Informed Consent materials you can consult the following:

- The TU Delft [Research Ethics webpages](#),
- Your faculty Data Steward, the TU Delft Privacy Team
- Our brief guide on Completing the HREC checklist
- Our [Risk-Planning tool, Managing Risk in Human Research](#)

If you have any questions about applying for HREC approval which are not dealt with on the [Research Ethics webpages](#), please contact HREC@tudelft.nl

You can find **Dutch versions** of the Informed Consent templates in the Informed Consent section of the [Research Ethics webpages](#).

Informed Consent as a legal and ethical agreement

The key function of the Informed Consent (IC) process is that this is where you (the Responsible Researcher) come to an agreement with your participants about what they will do for your research and what you will do, both legally and ethically, to ensure their physical, emotional and reputational security. It is key that they know exactly what – and particularly what potential risks – they are agreeing to, and that this is clear in your agreement, and executed in practice.

Two types of Informed Consent

“Informed Consent” covers two distinct, if overlapping, elements of a participant’s agreement to participate in scientific research. These are essentially: consent to participate in the research and consent to the way in which any personal data will be processed and managed.

- **Research Participation** – obtaining a participant’s consent to participate is essential for any research involving human “subjects”. It requires researchers to flag the potential physical, emotional or other risks they might be exposed to by virtue of the research process or its findings.
- **Data Processing and Privacy** – at the same time, under the European General Data Protection

Regulation (2016) Informed Consent is the most common (but not only) legal basis for collecting Personal Data (including both Personally Identifiable Information and/or Personally Identifiable Research Data) from “human subjects”. Within the context of scientific research specifically it is important that research participants (“human subjects”) understand what potential risks they might face as a consequence of the collection of any Personal Data, as well as what steps will be taken to mitigate those risks. The development and execution of a robust **Data Management Plan** constitutes one of those mitigating steps.

Structure and content of your Informed Consent materials

Your Informed Consent materials can be considered as a legal and ethical contract between you and the people who will be providing you with your research data. In most cases this agreement will comprise of Participant Information and Explicit Consent points. The Participant Information is normally a short, clear summary that informs your participant of anything that might affect their willingness to participate in your research. The specific Explicit Consent points list specific points with which your participants can choose to agree or disagree. Bear in mind, when you are giving participants particular choices, that you will need to execute these agreements with precision.

Standard structure of Informed Consent materials

Participant Information • Your **Participant Information** should clearly summarise what your research aims to do, what participants are asked to do, what risks might arise – including identification – and what steps you will take to mitigate them. Remember to include not just the personally identifiable research data (PIRD) you collect, but also how you will store the Informed Consent forms and any personally identifiable information (PII) therein.

- See [TEMPLATE 1](#)

Explicit Consent points • In addition to the Participant Information it is best practice (and sometimes a legal requirement) to include a list of specific **Consent Points** with which your participants can agree or disagree.

- Bear in mind that where your participants disagree, you will need to have **practical plans** in place to comply with these specific points.
- See [TEMPLATE 2](#)

Alternative approaches to Informed Consent

Depending on your research methods and goals, the standard approach outlined above may not be appropriate or possible. For example, if you are gathering your research data using an anonymous online survey, the option of removing specific datasets may not be possible – and so this is not something you can offer in your Informed Consent process. In such cases, the Participant Information and Explicit Consent points are replaced by an **Opening Statement** with which participants demonstrate their agreement by clicking the link to the survey (see [TEMPLATE 1](#)).

Alternative Informed Consent materials

Opening Statement • Where your participants are asked to, for example, complete an anonymous online survey, a signed Informed Consent form is not an option. Instead, the Participant Information and Explicit Consent points might be replaced by an **Opening Statement**. In this case a participant's agreement with the terms and conditions of your research can be signified by clicking through to the survey.

- Your Opening Statement should ensure that your participants are aware of what your research is about, and what is expected of them before they click through to the survey.
- Make sure that your participants can leave the survey or skip questions in line with your Opening Statement –

APPENDIX 10:HREC CONSENT FORM PART 2

- and that your Opening Statement is clear on this.
- Make it clear that by clicking through to the survey participants are agreeing to conditions.
- Verbal Consent**
 - In some circumstances it might be necessary to use other Informed Consent approaches – such as verbal consent and/or consent of a Gatekeeper.
- Debriefing Information**
 - Where deception is required for your research, Informed Consent has technically not been given. In such cases you are advised to debrief your participants, explaining why they were deceived and how, and seek Informed Consent again after the debrief.

Where it is not possible to seek Informed Consent at all – e.g.: because your method involves covert observation, relies on existing datasets, or is collected from the public domain – steps to ensure the safety of your participants are nevertheless required. For example, you can make sure that the party or parties providing your data are permitted to do so, collect information on the original informed consent process, or demonstrate that you understand how combining multiple datasets might lead to unintended consequences and the steps you will take to avoid this.

Please contact your Faculty Data Steward or the TU Delft Privacy Team, or consult our Guidance Notes on [completing the HREC checklist](#) for more information.

Executing Informed Consent agreements

Like any contract between parties, your Informed Consent agreement needs to be managed and executed in perpetuity, so make sure that you have plans in place to honour the agreements you have made – including what happens if you or another member of the research team moves elsewhere. Bear in mind also what is and is not executable in practical terms. For example, if you are seeking approval to use personal names with quotes in any publications, then it is unlikely that you can assure anonymity of stored data. Equally, if you agree with participants to use actual names in any kind of publication, it is best practice to obtain additional, specific approval from named participants prior to publication.

It is critical here that the risks and mitigating steps you identify in your HREC checklist and Data Management Plan are consistent with the agreement you make with your participants. It is your job as the (Responsible) Researcher to ensure that your participants are made aware of any potential risks which they may not themselves foresee. In relation to any Personal Data you may be gathering for administrative purposes and/or as research data, it's equally important that this agreement is in line with how you will manage your data in practice.

To this end, you must make sure that the information across your HREC application documents is consistent and aligned.

TEMPLATE 1: Participant Information/Opening Statement

You are being invited to participate in a research study titled *Assessing the Robustness of Risk Identification in the mining industry*. This study is being done by Roberto Gamboa Andrade from the TU Delft.

The purpose of this research study is to enhance risk management for mining construction projects through the contractors eyes during the bidding phase by developing an ontology-based framework, which will serve as an information bridge between tailing dams activities, their resources and the potentially external risks. and will take you approximately 30 minutes to complete. The data will be used to complete the thesis research in the MSc Construction management and Engineering programme which will be published in the student repository of TU Delft

University. We will be asking you to answer a series of questions about your construction experience in the mining industry, specifically about unidentified risks when carrying out the activities necessary to complete tailing dams projects.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by anonymising all personally identifiable information (PII) as well as personally identifiable research data (PIRD) prior to the publication of the written report, as well as storing such information in a secure space in the TU DELFT University cloud (OneDrive). Only specific data on events, risks and activities collected in the interviews will be used in the publication of the project, therefore the transcripts will not be published.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. If you want to maintain your anonymity within the study, you can request to remove any data that you do not wish to disclose. We will ensure that the information you want to remove from the transcript is deleted within two weeks after the interview.

Corresponding Researcher: Roberto Gamboa Andrade (rgamboaandrade@tudelft.com)

Responsible Researcher: Ranjith Kuttantherappel Soman (r.soman@tudelft.com)

TEMPLATE 2: Explicit Consent points

Please make sure that you select (and amend as necessary) any Explicit Consent points which are relevant to your study and exclude those which do not apply. You should also add further points and necessary to address your specific research situation.

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICIPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [26/03/2024], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	<input type="checkbox"/>	<input type="checkbox"/>
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	<input type="checkbox"/>	<input type="checkbox"/>
3. I understand that taking part in the study involves: <ul style="list-style-type: none"> The interview and data will be captured by means of an audio-recorded interview, where information about the construction activities along with their risks and external events will be sought. Also, during the interview, notes, video and audio will be taken to gather the necessary information. The interview will be transcribed using Microsoft Teams software and then analysed by coding using ATLAS.ti software. All personally identifiable information will be anonymised before being used in the written report. 	<input type="checkbox"/>	<input type="checkbox"/>
4. I understand that I will not be compensated for my participation by.	<input type="checkbox"/>	<input type="checkbox"/>
5. I understand that the study will end in the month of June -2024		

B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks: Discomfort and data/information leakage. I understand that these will be mitigated by ensuring that the information will be stored in TU DELFT's One Drive cloud, as well as anonymized prior to publication of the research, and if there is discomfort on the part of the interviewee, the interviewee may request that the interview be stopped.	<input type="checkbox"/>	<input type="checkbox"/>
7. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) Age, occupation and associated personally identifiable research data (PIRD) and years of experience in the construction sector with the potential risk of my identity being revealed	<input type="checkbox"/>	<input type="checkbox"/>
8. I understand that some of this PIRD is considered as sensitive data within GDPR legislation, specifically political views, which are beyond the scope of this research and will not be discussed.	<input type="checkbox"/>	<input type="checkbox"/>
9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach. Firstly, the information will be stored in a secure space such as One Drive. Secondly, the information will be anonymized after transcription and will remain so for the purposes of publication of the thesis.	<input type="checkbox"/>	<input type="checkbox"/>
10. I understand that personal information collected about me that can identify me, such as <i>my name, age and years of experience</i> will not be shared beyond the study team.	<input type="checkbox"/>	<input type="checkbox"/>
11. I understand that the (identifiable) personal data I provide will be destroyed by the end of the month of July-2024.	<input type="checkbox"/>	<input type="checkbox"/>
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for the student thesis repository,	<input type="checkbox"/>	<input type="checkbox"/>
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	<input type="checkbox"/>	<input type="checkbox"/>

Signatures

Name of participant [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Roberto Gamboa Andrade  26/03/2024
Researcher name [printed] Signature Date

Study contact details for further information: Roberto Gamboa Andrade, Phone number:
+31619931995. Rgamboaandrade@tudelft.nl