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The Contribution of Risk Management According to ISO 31000: 2018 in the Improvement of the Golden Triangle in the Infrastructure Projects: a Case Study of the Algiers Metro Project- Cosider.

Elaborated by:

Imene MOHAMMEDI

Under the supervision of:

Dr. Nadia GAHLAM

Dr. Mehdi BOUCHETARA

Dr. Wissam BELIMANE

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ABSTRACT

The study aims to evaluate the application of risk management in the infrastructure construction industry, focusing on its contribution to the golden triangle of Cost, Quality, and Time, following ISO 31000:2018 guidelines. Using the Algiers M28 metro extension project by Cosider as a case study, 7 interviews with officials were conducted to identify project risks, supplemented by internal documents and site observations. A total of 43 risks were identified.

The qualitative analysis of interview data indicates that current methods can identify risks, but not effectively enough, particularly those that contribute significantly to time, cost, and quality. The study suggests that improving risk management methods could better mitigate or eliminate these risks, offering practical insights into applying ISO 31000:2018 in infrastructure projects and proposing enhanced risk management procedures for the industry.

Keywords: Risk management, ISO 31000:2018, Golden triangle, Infrastructure construction, FMEA.

RESUMÉ

L'étude vise à évaluer l'application de la gestion des risques dans l'industrie de la construction d'infrastructures, en se concentrant sur sa contribution au triangle d'or du Coût, de la Qualité et du Temps, conformément aux directives ISO 31000:2018. En utilisant le projet d'extension du métro M28 d'Alger par Cosider comme étude de cas, 7 interviews avec des responsables ont été menées pour identifier les risques du projet, complétées par des documents internes et des observations sur site. Au total, 43 risques ont été identifiés.

L'analyse qualitative des données d'entrevue indique que les méthodes actuelles peuvent identifier les risques, mais pas de manière assez efficace, en particulier ceux qui contribuent de manière significative au temps, au coût et à la qualité. L'étude suggère qu'une amélioration des méthodes de gestion des risques pourrait mieux atténuer ou éliminer ces risques, offrant des perspectives pratiques sur l'application de l'ISO 31000:2018 dans les projets d'infrastructures et proposant des procédures améliorées de gestion des risques pour l'industrie.

Mots-clés : Management des risques, ISO 31000:2018, Triangle d'or, Construction d'infrastructures, FMEA.

ملخص

الدراسة تهدف إلى تقييم تطبيق إدارة المخاطر في صناعة بناء البنية التحتية، مع التركيز على مساهمتها في المثلث الذهبي للتكلفة والجودة والوقت، وفقاً للمبادئ التوجيهية ISO 31000:2018 باستخدام مشروع توسيع مترو M28 بالجزائر من قبل شركة Cosider كدراسة حالة، تم إجراء 7 مقابلات مع المسؤولين لتحديد مخاطر المشروع، بالإضافة إلى الوثائق الداخلية والملاحظات الميدانية. تم تحديد مجموع 43 مخاطرة.

تشير التحليلات النوعية لبيانات المقابلات إلى أن الأساليب الحالية يمكن أن تحدد المخاطر، ولكن ليست بشكل فعال بما فيه الكفاية، خاصة تلك التي تسهم بشكل كبير في الوقت والتكلفة والجودة. توجي الدراسة بأن تحسين أساليب إدارة المخاطر قد يسهم في التخفيف أو القضاء على هذه المخاطر بشكل أفضل، مما يقدم رؤى عملية حول تطبيق ISO 31000:2018 في مشاريع البنية التحتية ويقترح إجراءات محسنة لإدارة المخاطر في الصناعة.

الكلمات المفتاحية: إدارة المخاطر ISO 31000:2018 ، المثلث الذهبي، بناء البنية التحتية، FMEA.

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LISTE OF ABBREVIATIONS AND ACRONYMS

ENSM	Ecole national supérieur de management.
FMEA	Failure Mode and Effect Analysis.
I	Impact.
OCC	OCCURRENCE.
P	Probability.
PLC	Project Life Cycle.
PRA	Probabilistic Risk Assessment
PW	Public works .
RMP	Risk Management Plan .
RNP	Risk Priority Number.
SEV	Severity.
TBM	Building Information Modeling
TBM	Tunnel Boring Machine
TP	Travaux public.

GENERAL INTRODUCTION

1 Context and theme interest:

The rapid development of society is intricately connected to advancements in the construction sector, particularly in infrastructure construction. The underground construction industry plays a crucial and vital role in societal progress through the creation and enhancement of the built environment. This sector not only shapes the physical landscape of our communities but also significantly impacts economic growth, environmental sustainability, and overall quality of life. Innovations in this field support the continuous development and modernization of society (Szymański, 2017).

The current economic downturn and challenges in Algeria's highly competitive construction sector necessitate that contractor manage risks independently. This paper examines the risk analysis and risk management practices in the M28 project of the public works company.

The processes of project risk management encompass planning, identification, analysis, response planning, and risk control. The goal of implementing risk management in projects is to enhance the likelihood and impact of positive occurrences while reducing the probability and impact of negative events (Khairullah et al., 2022).

Safety risk identification in metro construction is a knowledge-intensive task and a critical component of risk management. The knowledge of safety risks is primarily obtained from various sources in unstructured forms, such as specialist experience, risk case bases, construction drawings, construction organization plans, and other project documentation (Ding & Zhou, 2013).

Most organizations employ quality tools for various purposes related to controlling and assuring quality. While many quality tools are specific to certain domains, such as the Bowtie method for the construction industry, some are versatile and can be used across different fields and practices, such as the fishbone diagram. These quality tools are quite generic and can be applied to various conditions. There are seven basic quality tools commonly used in organizations, which can provide valuable insights into organizational problems and assist in deriving effective solutions.

GENERAL INTRODUCTION

Risk management is a prominent topic of discussion among professionals in the design and construction industry who are concerned about the success of their endeavors. Increasingly, professionals engage in risk management even before a project is assigned to them. It is difficult to imagine project management without formal or informal risk management. Effective project management techniques, such as planning and scheduling, are essential tools that can save time, money, and prevent numerous problems. The completion of a construction project requires judicious scheduling and allocation of resources, including manpower, money, equipment, and materials. These resources must be closely managed due to potential seasonal shortages, labor disputes, cash flow issues, equipment breakdowns, competing demands, delayed deliveries, and other uncertainties (Subramani et al., 2014).

Cost management is defined as the processes required to ensure project completion within the approved budget. It includes cost estimating, cost budgeting, and cost control to ensure that projects are completed within the approved budgets. Poor cost performance is a common problem in construction projects worldwide, often resulting in significant cost overruns (cost escalation, budget overrun, or cost increase).

Key projects contributing to this growth include significant investments by Sonatrach, Algeria's national oil company, which plans to invest up to \$42 billion over five years. This includes \$30 billion for natural gas exploration and production, \$7 billion for refining and petrochemical projects, and \$1 billion for renewable energy initiatives (Algeria: Construction Industry to Grow 2.4% in 2024, n.d.). Additionally, Algeria's infrastructure development will be boosted by plans to expand the railway network from 4,200 km in 2022 to 12,500 km by 2030, improving connectivity for mining, gas fields, and construction sites (Algeria Construction Market Analysis, Trends and Forecast Report 2022-2026, 2022).

The construction industry operates in a risk-laden and dynamic environment. In construction projects, time, cost, and quality are the main factors that are interdependent but also interrelated (Rezaian, 2011). Every human endeavor involves risk (Perera, Dhanasinghe, & Rameezdeen, 2009). In many construction projects, the risk is borne by the parties involved. Mahamid (2011) highlighted numerous instances where projects failed to meet targeted time, cost, and quality due to inadequate risk assessments. This paper aims to identify the impact of the construction golden triangle (time, cost, and quality) on project risk in the Sri Lankan

construction industry and suggests proper risk management approaches to improve the performance of infrastructure projects.

This paper is about risk management in the infrastructure sector, identify the contribution of project risks to the golden triangle: cost, quality and time and evaluate them according to the instructions of ISO 31000, 2018v. Focus on effectively managing these risks and improving project success.

2 Objectives:

2.1 General Objective:

The purpose of this master thesis is to evaluate how the risk management process is used in the construction industry and how the, determine the contribution of project risks to golden triangle: cost, quality and time and evaluate them in accordance with ISO 31000, 2018v instructions. To focus on the effective management of these risks and enhance project success.

2.2 Specific objectives:

- **Analyze Risk Management in the Infrastructure Sector:**
 - Identify and assess the types of risks commonly encountered in infrastructure projects.
 - Explore current risk management practices and methodologies used in the sector.
- **Evaluate Risks According to ISO 31000:2018 Guidelines.**
- **Determine the Contribution of Project Risks to the Golden Triangle:**
 - Examine how risks impact project cost, quality, and time.
 - Quantify and categorize the influence of different types of risks on each of these three key project parameters.
- **Evaluate Risks According to ISO 31000:2018 Guidelines:**
 - Apply the principles, framework, and process for risk management as outlined in ISO 31000:2018.
 - Ensure compliance with international standards to provide a structured approach to managing risks.
- **Focus on Effective Management of Risks:**
 - Develop strategies and recommend best practices for mitigating identified risks.
 - Improve the efficiency and effectiveness of procedures for managing risks.
- **Enhance Project Success:**

- Measure the impact of improved risk management on project outcomes.
- Suggest improvements based on case studies and real-world applications.

3 Problematic:

To evaluate the contribution of risk management in relation to the golden triangle in infrastructure projects, according to the ISO 31000:2018 procedures, this research aims to address the research question based on the works of various authors (Ding et al., 2012; (Sharafat et al., 2021; Amini et al., 2023; Daoud et al., 2023; Banerjee Chattopadhyay et al., 2021; Mussa et al., 2023; Sousa et al., 2012; Zhao, 2024)), is the following :

How can effective risk management, guided by ISO 31000t standards, address the contributions of project risks to cost, quality, and time in infrastructure projects, thereby improving overall project success?

4 Method:

My study aimed to gain an in-depth understanding of the risk management processes and practices employed in a real-world construction project. According to (Gajewska & Ropel, n.d.) Qualitative methods are well-suited for exploring complex phenomena in context.

The underground metro project represented a complex, high-risk construction endeavor. Qualitative research is valuable for investigating such complex projects where quantitative data may be limited or difficult to obtain.

Scientific research is a rational approach to examining phenomena and problems to be solved and obtaining precise answers from investigations.

The use of a methodological approach is essential in all scientific research, the specific methods implemented to collect and analyze the data on which our memory is based. A method is defined as a set of procedures that follow specific steps to arrive at a result. In science, the original method and process used during research to determine results.

Qualitative methods of data analysis are essentially based on induction; propositions relating to meaningful relationships are drawn, induced, from observations. They are called qualitative because the analysis of data and their interpretation are done through analogies,

metaphors, representations and means linked to discourse rather than calculation. The goal here is to understand what is specific to a specific environment. (Pierre, 2008).

The reason we judged the qualitative approach to be appropriate in our case is the complexity of our theme and its importance in creating value for the host organization. This approach requires a permanent presence in the field to make interpretations and collect as much information as possible, using a certain sense of observation, close interaction with staff and senior management to diagnose the existing context, as well as the content of the method was adapted in our research topic, and in order to better study this research work, we used the necessary data collection tools and techniques.

5 Plan announcement:

The introduction of this document provides an overview of risk management within the infrastructure sector, highlighting the research objectives and areas of interest. It proceeds to outline the development of the research question forming the basis of the analysis model.

In the theoretical section of the first chapter, literature related to the core concepts of the topic is examined, delving into risk management, its facets, and its implications. Subsequently, an experiential learning mode is introduced, assessing its relevance in the realm of construction. This section aims to adopt a cognitive approach, bridging foundational elements to construct the analysis model under scrutiny.

Following the literature review, there are inclusive definitions of key concepts central to the research, notably construction risk management, particularly within mega projects such as metro construction.

Chapter Two outlines the methodological framework, detailing the entire methodological approach developed. This segment elucidates sampling and data collection methods, alongside the analytical tools and techniques employed during the pilot study.

The concluding chapter encompasses the practical framework, presenting and interpreting the results of statistical analyses in alignment with the study's objectives. Further, observations and discussions are juxtaposed with the literature analysis.

GENERAL INTRODUCTION

Finally, the conclusion encapsulates the research's findings and its constraints. It concludes by projecting the implications of the present study onto future academic discourse.

CHAPTER I: THEORETICAL FRAM WORK

Risk management in infrastructure projects, particularly in construction, is a multifaceted domain crucial for project success. Extensive literature has explored various aspects of risk management, linking factors like time, cost, and quality with other variables. Recent studies have utilized scientific analysis to uncover productivity trends, influential authors, and key research topics in construction risk management. This literature review underscores the complexity of risk management, emphasizing its dual aim of risk avoidance or minimization and the transformation of risks into competitive advantages. This introduction sets the stage for a comprehensive examination of risk management practices, focusing on two specific areas: underground construction project management and strategic risk management.

Section1: Literature Review

Previous studies have explored the literature on risk management in infrastructure projects, with a focus on linking time, cost, and quality factors with other variables. The objective of these studies includes identifying and analyzing risk management models, case studies, and dimensions of variables, as well as the methodology for studying them. Recent research has used scientific metric analysis to reveal the most productive countries, authors, and journals in the field of construction risk management, as well as the main research topics and their relationships. «The results of these studies demonstrate that risk management is a broad and complex subject, especially when its management aims to both avoid or minimize risk and guide the organization to a level where the risks can be transformed into competitive advantages». (A Review of Risk Management in Construction: Opportunities for Improvement, n.d.) (Osei-Kyei et al., 2022)

1 Underground construction project management:

A study conducted by Iqbal and al focuses on the significance of various types of risks, Different types of risks, the overall responsibility for their management, and how effective it is of commonly practiced risk management techniques in the industry The researchers examined two categories of risk management techniques preventive techniques, which are employed before project initiation to address anticipated risks and remedial techniques, which are implemented during project execution after a risk has already occurred The findings of the study indicate that financial issues on-site accidents, and defective design are the major risks observed in projects Furthermore the analysis reveals that the most effective preventive risk

management techniques involve the development of accurate project schedules based on updated data and insights gained from previous similar projects. On the other hand, close supervision and coordination within projects are identified as the most effective remedial risk management techniques (Iqbal et al., 2015).

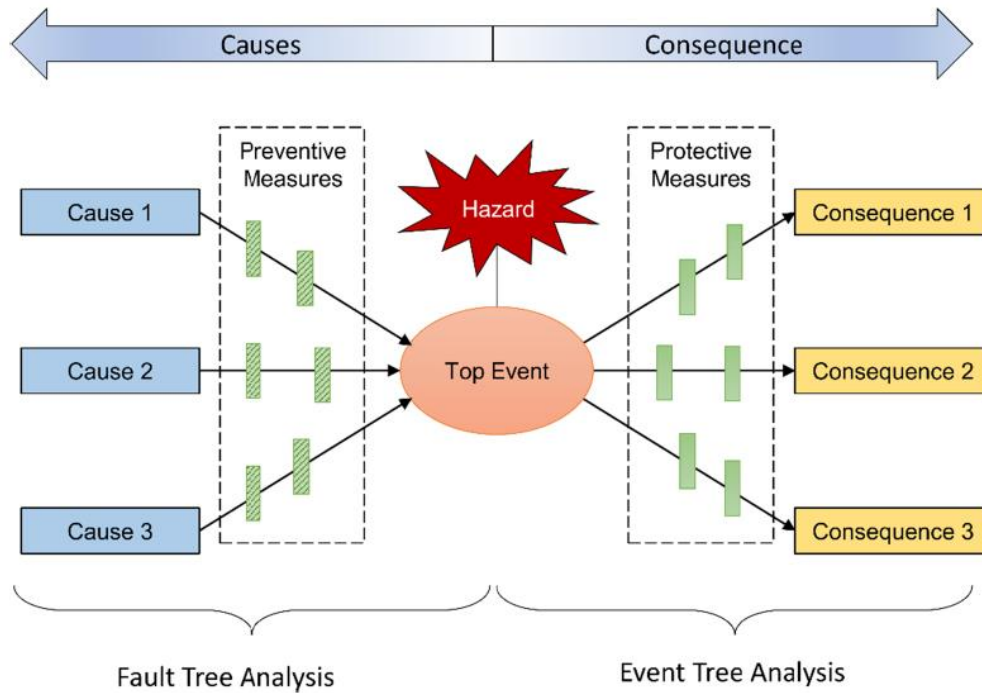
1.1 Metro construction project management:

«A metro project involves complicated and high-risk construction work»(Ding et al., 2012)

In the paper of Mr. Ding and colleagues, he encapsulates the safety hazards and determining factors associated with metro construction. Additionally, he elucidates the process of acquiring risk identification rules, expanding upon these rules, and the organization of rule structures that form the foundation of the knowledge database for risk identification. (Ding et al., 2012)

Shaaf's paper introduces a new methodology for analyzing and managing risks associated with tunnel boring machines in challenging ground conditions. This methodology is based on a generic bowtie method, which combines fault tree and event tree analyses to assess the causes and consequences of undesired events. By focusing on the common undesired event, this approach provides a systematic and comprehensive risk assessment framework. The proposed risk analysis technique can be a valuable tool for professionals working with tunnel boring machines

Figure 1: Generic bow-tie risk analysis diagram



Source: (2021) 103860

In a separate article, Gofer suggests using the Analytic Hierarchy Process of the Analytic Hierarchy Process (AHP) method to analyze and quantify risks in infrastructure construction projects. This method involves calculating global priority weights for various aspects, including cost, time, and quality, in both lump sum contracts and unit price contracts. By applying the AHP method, the study aims to identify the most influential risk factors in each type of contract and offer recommendations to effectively mitigate these risks.(Sharafat et al., 2021).

2 Strategic risk management: (the golden triangle)

2.1 Time:

The paper aim of Mr. Khalid is to review the impact of poor planning and management on the duration of construction projects This research adopts a descriptive methodology, focusing on reviewing prior studies and literature to elucidate the correlation between inadequate project planning and management and the incidence of delays in construction projects. Literature’s analysis discloses that poor project planning and management is cited by several researchers as a delay factor in the construction projects. The researcher's findings

CHAPTER I: THEORETICAL FRAM WORK

suggest that inadequate planning and management in construction projects can have detrimental effects on project timelines and completion. It is observed that construction delays and duration concerns often turn potentially profitable projects into unprofitable ones. However, these delays can be mitigated or avoided through enhanced pre-project planning and effective project management, which are deemed as pivotal factors contributing to project success.

The paper of Saeed Identify and evaluate the business risk (Cost and time overruns) management in construction projects to control and minimize such risk is the aim of this research Across various construction sites, skilled professionals were engaged through an online questionnaire to gather a wide range of perspectives for comparative analysis. This questionnaire served as a tool to enhance the research by gathering more nuanced, accurate, and reliable data regarding risk management in the construction business.

Frequent occurrences of subpar business performance, evidenced by time delays and cost overruns, are prevalent in construction endeavors. Mitigating such setbacks can be notably achieved through meticulous initial construction planning, precise project estimation, minimization of mid-construction alterations, and enhancement of contract management practices. And improving communication between construction parties. (Saeed, 2018)

The purpose of the paper of Zidane & Andersen is to identify the universal delay factors from an intensive literature review, complemented by delay factors in major Norwegian construction, they found 104 articles covering 45 countries to determine the delay factors in construction projects. The research identifies several factors contributing to delays in the Norwegian construction sector, including inadequate planning and scheduling, sluggish or ineffective decision-making processes, internal administrative red tape within project organizations, shortages of resources such as manpower and equipment, inadequate communication and coordination among stakeholders, delays in quality inspection procedures, design alterations during construction, lack of commitment or clarity from sponsors/owners/clients regarding project goals and objectives, tardy or incomplete design submissions, office-related challenges, and issues related to end-users.

And the top 10 universal delay factors are: design changes during construction/change orders; delays in payment of contractor(s); poor planning and scheduling; poor site management and supervision; incomplete or improper design; inadequate contractor experience/building

methods and approaches; contractor's financial difficulties; sponsor/owner/client's financial difficulties; resources shortage (human resources, machinery, equipment); and poor labor productivity and shortage of skills. (Zidane & Andersen, 2018)

The study of Rivera aims to determine the ten principal causes of delay in road construction projects in 25 developing countries across the globe. The study involves two steps. Initially, the authors gathered data concerning the most common delays encountered in road construction projects. Subsequently, they evaluated the severity of each delay factor in these projects. Employing a quasi-meta-analysis methodology for greater precision, the researchers processed the data due to the nuanced nature of the information. Half (50%) of the countries have similar causes of delay, and delay in road construction projects based on the intensity results. This study uses the results of the intensity. As per the findings of the validation process, the inexperience of the construction manager, deficient planning/scheduling, and issues related to land acquisition for the road construction project (expropriation for project construction) exerted greater impacts compared to the frequent design changes, despite the latter being listed as the most common cause of delay. (Rivera et al., 2020)

The study of Amini et al highlights the causes of cost overrun in Iranian construction projects. The paper also reviews the findings of similar studies conducted in several Asian countries. The present study utilized a questionnaire developed from 43 prevalent factors identified through an extensive literature review. Data collection involved representatives engaged in overseeing construction operations in Iran. Using the SPSS software package, the collected data underwent analysis based on the Relative Importance Index (RII). The outcomes highlighted poor site management, inadequate planning, material price fluctuations, lack of experience, and adverse economic conditions as key contributors to cost overruns in Iranian construction endeavors. Furthermore, the research findings revealed that, among studies conducted in Asian nations, the foremost three factors were most commonly observed.. (Amini et al., 2023)

2.2 Cost:

The study of Abdel-Monem first identified the most critical factors affecting the accuracy of cost estimates. A specially crafted questionnaire was administered to construction experts, revealing their inclination towards enhancing cost estimation through the implementation of a well-defined risk management strategy. Drawing from respondents' insights, this study

identified 51 risk factors along with their underlying causes, subsequently proposing a response strategy tailored to address the most significant risks that could impact project costs. (Abdel-Monem et al., 2022)

Daoud et al focused on the Egyptian construction sector and identifies the top six factors that lead to cost overruns and delays in mega construction projects. These factors are inadequate project planning, poor communication and coordination, changes in project scope, lack of skilled labor, insufficient budget allocation, and payment delays. The study recommends strategies to mitigate these factors, The study also suggests managing changes in project scope through effective change management processes and ensuring sufficient budget allocation by conducting accurate cost estimates and setting aside contingency funds. These suggestions offer valuable insights for both practitioners and policymakers within the construction sector, aiding in the mitigation of the adverse effects of cost overruns and project delays. Overall, the study emphasizes the importance of identifying and addressing the key factors contributing to cost overruns and delays in mega construction projects. (Daoud et al., 2023)

The main goal of the Hussein and Moradinia study is to evaluate the impact of Earned Value Management (EVM) and risk management on factors such as project schedule, project costs, and de-sign defects. For this research, a questionnaire was designed and disseminated to subject matter experts in Iran. Geographically, the participation rates were 38.49% in East Azerbaijan, 31.65% in West Azerbaijan, and 26.86% in the Tehran Province. Data was analyzed using SPSS and AMOS software. Structural equation modeling results indicate that both risk management and Earned Value Management (EVM) have a positive influence on project time (0.53) and cost (0.60). In this study, a questionnaire was crafted and distributed to experts in Iran's construction field. Geographically, participation rates were observed at 38.49% in East Azerbaijan, 31.65% in West Azerbaijan, and 26.86% in Tehran Province. The collected data underwent analysis utilizing SPSS and AMOS software packages. (Hussein & Moradinia, 2023)

2.3 Quality:

In the study by Banerjee Chattapadhyay et al., a risk prediction system was developed for construction megaprojects using a cross-analytical machine learning model. A comprehensive set of 63 risk factors related to cost, time, quality, and scope of the megaproject were identified, and primary data were collected from industry experts using a five-point Likert

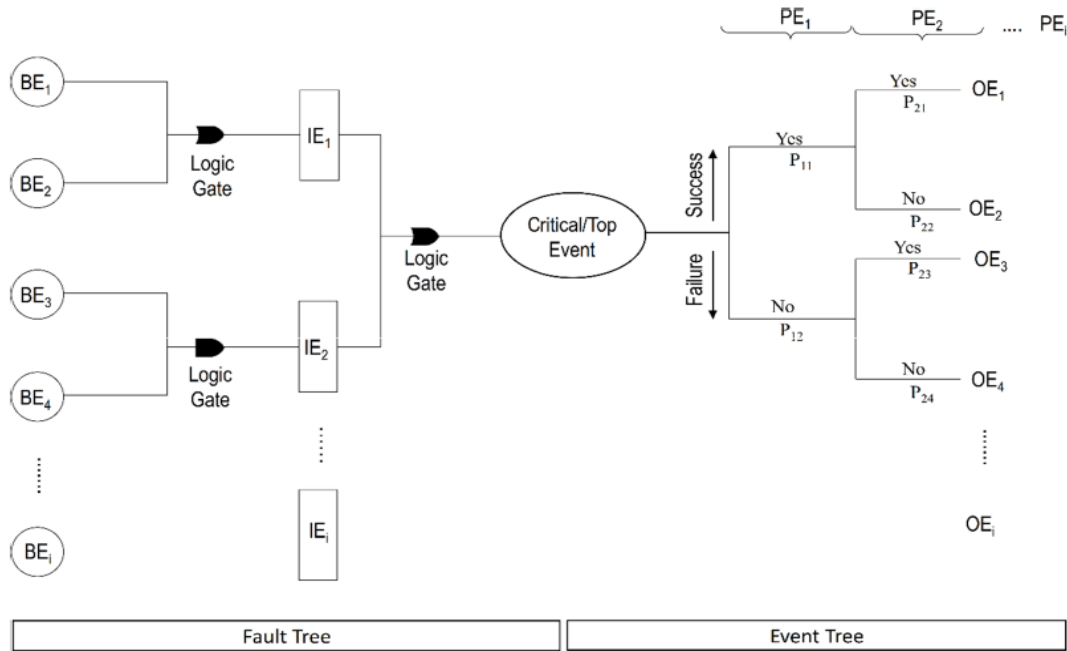
scale. Statistical processing of the obtained sample resulted in a significantly large feature set, which underwent K-means clustering to identify high-risk factors and associated sub-risk components. Descriptive analysis, coupled with techniques like the synthetic minority over-sampling technique (SMOTE) and the Wilcoxon rank-sum test, was employed to select the most pertinent features related to cost, time, quality, and scope. Subsequently, a genetic-algorithm-based K-means clustering algorithm (GA-K-means) was utilized, incorporating dual objective functions, to segment high-risk factors and associated sub-risk components. The proposed model effectively identified various high-risk factors and sub-risk factors, collectively influencing overall project performance.

3 Risk management tools used in the construction industry:

A variety of risk analysis techniques are utilized in tunnel engineering to identify, evaluate, and manage risks, each offering its own set of advantages. However, none of these methods address both the causes and consequences of risks concurrently. The bow-tie risk analysis technique combines cause and consequence models through fault trees and event trees, assisting project managers in formulating strategies for risk prevention and protection. Despite its success in other high-risk engineering sectors, the bow-tie risk analysis has not yet been adopted within the tunneling industry. This approach presents an opportunity to create a clear roadmap for pinpointing risks and implementing control measures, thereby serving as an effective risk management solution for complex TBM tunneling environments. This paper introduces an innovative risk analysis and management methodology based on bow-tie analysis for TBM tunneling projects facing challenging

Ground conditions, consisting of three main phases: risk identification, assessment, and mitigation. The systematic risk management technique can considerably reduce the root causes of risks, enhance their consequences, and offer recommendations rooted in tunnel engineering principles. (Zhang & Guan, 2018) (Challenges and Opportunities of Using Tunnel Boring Machines in Mining - ScienceDirect, n.d.)

Figure 2: Elements of a generic bow-tie (BE: Basic event, IE: Intermediate Event, PE: Pivotal Event,



Source: 111 (2021) 103865.

4 Comparing the current study with previous:

My study is distinguished from previous studies in that it examines the contribution of risk management in infrastructure construction projects, taking into account the factors of cost and time, and also the machine effect, using an analytical study of the risks of the Algerian Metro project for the National Cosider Company.(Project Management Institute, 2013)

Section 2: Conceptual Framework

1 Underground construction project management

1.1 Project Concept

1.1.1 Definition

During our daily routines, we tend to view a project as simply a task, however, the Guide to the Project Management Body of Knowledge (PMBOK) asserts that «a project is essentially a temporary endeavor undertaken to produce a distinctive product or service. This distinctiveness emerges from the unique characteristics of the final output. Hence, a project is primarily defined as an undertaking for temporary work with the objective of delivering an exceptional outcome ».

The International Organization for Standardization (ISO) defines a project as an endeavor that « is unique and temporary, with a defined beginning and end, aimed at achieving specific objectives within defined constraints such as time, cost, and quality ».

1.1.2 Characteristics and specify

Based on the provided sources, the characteristics and specificities of projects include:

- **Unique Objective:** Projects are oriented towards achieving a specific goal that distinguishes them from repetitive activities.
- **Limited Duration:** Projects have defined start and end points, making them temporary endeavors.
- **Autonomous Objectives:** Each project must have clearly defined objectives that address specific needs.
- **Uncertainty:** Projects inherently involve uncertainty due to their unique nature and external environmental factors that may be challenging to comprehend.

These characteristics highlight the distinct nature of projects, emphasizing their goal-oriented, time-bound, and uncertain aspects that set them apart from routine activities.

1.1.3 Project objectives:

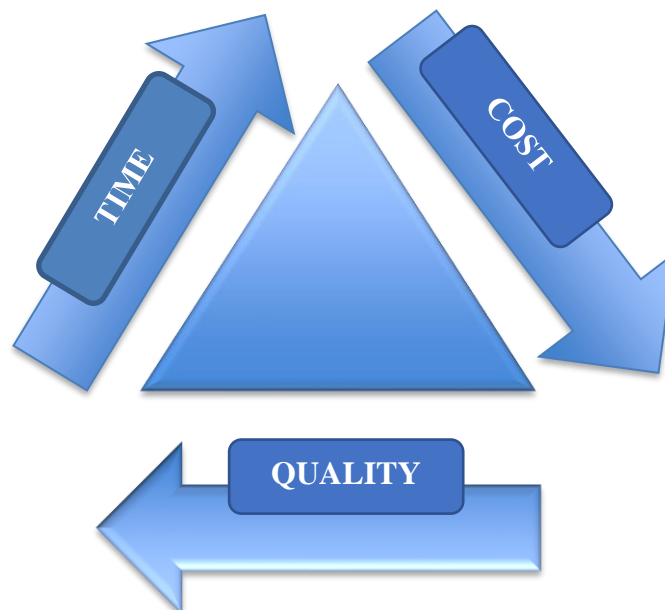
The success of the project means ensuring that the desired result is achieved and that progress is made towards the final result or deliverable by constantly checking that this

deliverable remains relevant in relation to the three basic Project criteria: quality, cost and time (CORBEL, 2012).

And according to (LIZARRAGA, 2005) within a project, we can identify three categories of objectives, their relative weights vary from one project to another:

- **Deadline objectives (time quality):** these are an important part of the expression of needs. In some cases, delays can render the successful technical completion of a project unimportant.
- **Economic objective (Cost quality):** is a financial transformation of the approach that the project leader undertakes to implement to achieve the technical performance and deadline objectives.
- **Technical performance objectives (quality):** linked to compliance with the functional specifications and technical characteristics of the product. These define the level of quality and are an important element in meeting the needs we seek to satisfy.

Figure 3: Project objectives (Time, Cost, and Quality)



Source: (LIZARRAGA, 2005)

1.1.4 Project life cycle:

Each business activity or process, regardless of the domain, has a clear beginning and end. In engineering, similar concepts are used to structure projects over time. The term "project life cycle" (PLC) serves as a management tool to enhance project performance. The scope and terminology of life cycles vary across industries and can include different phases depending on the sector (Smith et al., 2014). This variability makes it challenging to establish a universal scope and definition for a project life cycle. Smith et al. (Smith et al., 2014) found that the diverse PLC frameworks described in literature result from the variety of project types. For example, construction projects may follow an eight-phase PLC model, including pre-feasibility, feasibility, design, contract/procurement, implementation, commissioning, handover, and operation. In contrast, Pinto and Prescott (Pinto & Prescott, 1988) discuss a widely-used four-stage PLC, developed by Adams and Brandt, and King and Cleland, which includes conceptualization, planning, execution, and termination. Westland (Westland, 2007) similarly identifies initiation, planning, execution, and closure as the primary project stages.

Ward and Chapman propose another PLC model consisting of concept, planning, execution, and termination phases. In a subsequent publication, Chapman and Ward (2003) further divide each phase into additional stages and steps, facilitating easier and more accurate risk identification and enhancing risk management processes. Given the diversity of project types, the PLC requires customization and an individualized approach. Additional stages within each phase should be tailored to the specific project's scope and structure. Since every project is unique, a framework effective for one project may not be suitable for another. Therefore, the model proposed by Chapman and Ward (2003), as illustrated in Table 1, should be considered an example rather than a ready-made template.

Table 1: Phases, stages, and steps in the PLC

Phases	Stages	Steps
Conceptualization	Conceive The Product	Trigger event Concept capture Clarification of purpose Concept elaboration Concept evaluation
Planning	Design the product strategically	Development of performance criteria Design development Design evaluation

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	Plan The execution strategically	Basic activities and resources basic plan Development of targets and milestones Plan development plan evaluation
	Allocate Resources tactically	Basic design and activity-based plan detail Development of resource allocation criteria Allocation development Allocation evaluation
Execution	Execute Production	Co-ordinate and control Monitor progress Modification of targets and milestones Allocation modification Control evaluation
Termination	Deliver The product	Basic deliverable verification Deliverable modification of performance criteria Deliver evaluation
	Review The process	Basic review development Review evaluation

Source: (Chapman and Ward, 2003)

1.2 Project management concept:

1.2.1 Definition

Project management is defined as "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (Project Management Institute, 2017). This involves a series of processes, including initiating, planning, executing, monitoring and controlling, and closing, which are necessary for achieving project goals effectively and efficiently. (*PMBOK® Guide*, n.d.)

Another definition states that project management is "the art and science of coordinating people, equipment, materials, money, and schedules to complete a specified project on time and within approved cost" (Kerzner, 2013). This highlights the multidisciplinary nature of project management and the need for both technical and soft skills to manage various aspects of a project successfully. (Kerzner, 2009)

1.2.2 Project Management Golden Triangle:

The dynamic surrounding the project golden triangle is one of the oldest and most beneficial concepts for project success, although it has recently sparked controversy by giving

rise to a more restrictive model. Before approaching the new model of the project triptych, it is useful to understand the different elements of the classic triptych:

The first constraint of the project triptych is the scope of a project. The latter refers to the objectives, boundaries, and scope of work that must be carried out for the project to meet stakeholder expectations. It covers all products and services (in IT, for example) by detailing what will be done, but also what should not be included in the project. To avoid being surprised by scope creep, it is important to define and document the project's objectives and requirements. To help us, the PMBOK® (Project Management Body of Knowledge) includes six processes in scope management:

A. Delays:

When setting up a project, defining the time required to complete the tasks provided for in the specifications is one of the most important steps. To do this, you can use the WBS and PERT technique to help you.

B. Cost:

The cost of the golden triangle of the project includes the cost of the resources necessary to carry out the project tasks, but also the cost of materials, equipment, as well as all costs that go into carrying out the project from start to finish. Cost is also one of the constraints to the success of a project. Obviously, the budgets allocated to projects are increasingly tight. Therefore, to better define and manage your budget, it is advisable to base yourself on the PMBOK® recommendations.

C. Quality:

Quality is the final element of the golden triangle and refers to the degree to which the project meets the needs and expectations of the stakeholders. Quality management ensures that the project will satisfy the objectives for which it was undertaken. The PMBOK®

These processes ensure that the project's deliverables meet the required standards and specifications, thus ensuring stakeholder satisfaction. Effective quality management involves continuous improvement and adherence to established quality standards throughout the project lifecycle (PMI, 2021).

1.3 Underground construction project concept

1.3.1 Definition

Infrastructure construction projects are defined as complex undertakings that involve the creation of foundational services and facilities essential for economic development and societal well-being. These projects include the construction of transportation networks (such as roads, bridges, and railways), utility systems (including water supply, sewage, and electricity), and public facilities (like schools, hospitals, and parks) (Kiani Mavi et al., 2021)

Infrastructure construction projects refer to the organized efforts to design, build, and maintain the physical and organizational structures needed for the operation of a society or enterprise. This encompasses a broad range of activities, from the development of basic utilities and transport systems to the enhancement of public service buildings and communication networks, all aimed at supporting the economic and social activities of a region (*Evolution Des Risques : De La Gestion Du Risque Simple Au Management Des Risques. | Revue Du Contrôle, de La Comptabilité et de l'audit, n.d.*)

1.3.2 Characteristics

Unique Objective: Infrastructure projects are oriented towards specific goals, require the coordination of interdependent activities, have defined start and end points, and are unique in nature (Leila Mellal, 2009).

- **Specificity and Uniqueness:** Infrastructure assets are distinct from other types of investments due to their characteristics such as strong barriers to entry, stable cash flows, non-cyclical nature, low variable costs, and high leverage (Sell Side Handbook).
- **Financial Stability:** Infrastructure investments are known for stable and steady cash flows, non-cyclical behavior, low variable costs, and the ability to take on high leverage (Corporate Finance Institute).
- **Durability and Importance:** Infrastructure assets, like bridges, roads, highways, and energy systems, are crucial for a country's development, offering stable and predictable cash flows (Sell Side Handbook).
- **Risk Factors:** Infrastructure investments face risks related to leverage, environmental, social, and governance (ESG) factors, political influences, and different stages of project development (Sell Side Handbook).

- **Types of Infrastructure:** Infrastructure can be categorized into economic infrastructure (energy, transportation, communication) and social infrastructure (education, health, and housing) (GeeksforGeeks).
- **Importance of Infrastructure:** Infrastructure is essential for economic development, productivity improvement, job creation, investment stimulation, and overall quality of life enhancement (GeeksforGeeks).
- **Techno-Economic Dimensions:** Infrastructure sectors exhibit common patterns along dimensions like capital intensity, asset durability, regulation intensity, and environmental impacts, which influence sectoral transformation (Infrastructure Sector Characteristics)

2 Risk management

2.1 Risk concept

2.1.1 Definition

Table 2: Risk Definition

ISO 31000	the effect of uncertainty on objectives, whether positive Or negative.
(Larousse, 2002)	Possibility, probability of a fact, of an event considered as harm or damage
(Roger, 2011)	risk is a “random phenomenon corresponding to a situation where the future is only predictable with probabilities, as opposed to uncertainty which corresponds to a totally unpredictable future (escape from calculation) and to the certainty which allows a prediction, that is to say a forecast assigned a probability equal to 1 ^o .
Loosemore et al (2013)	According to Loosemore et al (2013), risk is a complex phenomenon that includes physical, financial, cultural and social dimensions and for most managers consider risk more on an unpredictable event that may occur in the future and the results can Affect profits and initial goals.

Source: Self-developed

In simple terms, risk can be defined as the probability of an event affecting the achievement of a goal. Certain risks may lead to positive outcomes, while others may result in negative effects. Consequently, the assessment of risk encompasses two essential elements: determining the probability of the event occurring and evaluating the magnitude of its potential impact.

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2.1.2 Risk and Uncertainty: A Clear Distinction:

Uncertainty and risk are often used interchangeably, but they have distinct meanings in the context of decision-making and risk management. The comparison is presented in the table below:

Table 3: Risk Vs Uncertainty

	Risk	Uncertainty
Definition	A specific type of uncertainty where we can assign probabilities to possible future outcomes. It involves a situation where we understand the potential outcomes and their likelihood.	A state of incomplete knowledge where the probability of future outcomes is unknown or unknowable. It encompasses situations where we lack sufficient information to predict the likelihood of different possibilities.
Characteristics	<ul style="list-style-type: none"> - Known probabilities: We can estimate the chance of each outcome occurring. - Quantifiable impact: The consequences of each outcome can be measured and assessed. - Potential for control: We can often take actions to mitigate or manage the risks. 	<ul style="list-style-type: none"> - Unknown probabilities: The chance of specific events occurring is unclear. - Multiple possibilities: There are several potential outcomes, and we cannot determine which is most likely. - Lack of control: We may have limited or no ability to influence the outcome.
Practical Implication	Can be managed through risk assessment, risk mitigation strategies, and risk transfer mechanisms.	Requires more flexible strategies, scenario planning, and preparedness for multiple outcomes.
Example	<p>Budget overruns: Actual costs can significantly exceed the initial budget due to unforeseen events, poor estimates or management issues.</p> <p>Schedule delays: Delays in the execution of the work can be caused by inclement weather, coordination problems or subcontractor failures.</p> <p>Quality issues: Construction defects, flaws or equipment failures can result in rectification costs and delays.</p>	<ul style="list-style-type: none"> - Unknown site conditions: The soil conditions, presence of groundwater or other underground obstacles can be difficult to anticipate accurately before the start of work. - Availability of resources: The supply of materials, equipment or skilled labor can be disrupted by shortages, delivery delays or cost fluctuations. - Regulatory changes: New regulations in the areas of urban planning, safety or the environment can be introduced during the project and require costly adaptations.

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Relationship:	- Risk is a subset of uncertainty. All risks are uncertain, but not all uncertainties are risks. Risks can be managed, while uncertainties are often addressed through adaptation and resilience.
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Source: (Project Risk Manager) (PM Study Circle).

2.2 Risk management concept:

2.2.1 Definition:

Risk management refers to the coordinated activities designed and implemented to manage risks and implement internal controls within an organization. (*The Orange Book – Management of Risk – Principles and Concepts*, n.d.)

Risk management is the process of identifying, assessing, and controlling risks to an organization's capital and earnings. It involves recognizing threats from various sources such as financial uncertainty, legal liabilities, strategic management errors, accidents, and natural disasters. The goal is to minimize negative events' impact while maximizing positive outcomes through a systematic approach that includes risk identification, analysis, assessment, and mitigation.

There are five primary strategies for addressing risks: avoidance, transfer, spreading, reduction, and sharing. These strategies aim to either eliminate, minimize, or distribute risks to ISO 31 000 protect the organization from potential losses or threats. Risk management also involves adhering to standards standard, which provides guidelines for effective risk management practices. (*What Is Risk Management / Risk Management / Marquette University*, n.d.)

2.2.2 Evaluation over time:

• Risks in the years (1970/1980)

The 1970s/1980s were witness to the rise of significant events that characterized this era, including the inception of technological innovations and the onset of global trade. Amidst these advancements, the era was plagued by speculative inclinations. The primary risk categories faced by companies during this period are as follows: The political stability of a country serves as the foundational element for ensuring physical stability. It goes without saying that civil wars, social unrest, injustice, vandalism, and political fragmentation hinder the smooth functioning and stability of organizations. (Sionneau Bernard, 1996)

Economic risks underwent significant transformation during this period, with all threats associated with business activity categorized into one encompassing domain, be it economic (competition, production processes, customers, etc.) or financial (interest rate risk, exchange risk, counterparty risk, etc.). The reason behind amalgamating this category within this specific period stems primarily from the events that defined this era, such as the evolution and dissolution of economic boundaries, which gave way to globalization. These occurrences culminated in amplified competition.

• **Emerging risks of a new era:**

In the last decade of the 20th century, there was a significant shift in the types of risks faced by groups. Risks that were important in the 1970s and 1980s, such as political, economic, and socio-cultural risks, became less important or completely disappeared in the late 1990s. Instead, some secondary risks from the previous decade became more significant. These included the increase in cybercrime, instances of harassment, terrorism, corporate insecurity, and declining employee health. (M'hamed RANNANE, 2019)

Sociocultural risks were predominantly linked to demographic shifts, income disparity, social mobility, changes in lifestyles, and attitudes towards leisure and work. Faced with this scenario, organizations are mandated to conduct in-depth analyses of their socio-cultural milieu to identify the varying needs of stakeholders and adopt the most apt production policies. (*Evolution Des Risques : De La Gestion Du Risque Simple Au Management Des Risques.* | *Revue Du Contrôle, de La Comptabilité et de l'audit*, n.d.)

2.2.3 Objectives

Early in a project, it is crucial to identify the risks that may arise from the design and construction processes. To ensure that all parties involved, including the owner, designers, insurers, and contractors, have a shared understanding, it is necessary for the owner to establish a construction risk policy.

The inclusion of a construction risk policy for the project may potentially signify a number of factors:

- The establishment of risk objectives is a crucial component within the realm of risk management.

- The implementation of a risk management strategy is of paramount importance in mitigating potential hazards and ensuring the overall safety and success of an organization.(Degn Eskesen et al., 2004)

2.2.4 Tools:

Most organizations use quality tools for various purposes related to controlling and assuring quality. Although a good number of quality tools are specific to certain domains, fields, and practices, some of the quality tools can be used across such domains. These quality tools are quite generic and can be applied to any condition.

There are seven basic quality tools used in organizations. These tools can provide a lot of information about problems in the organization, assisting in deriving solutions for the same.

The seven tools are: histogram, cause-effect diagram, Pareto diagram, correlation diagram, control chart, data stratification, and Brainstorming.(Liliana, 2016)

- **Ishikawa diagrams:**

In the 1960s, Kaoru Ishikawa popularized Ishikawa diagrams, as he innovated quality management processes at the Kawasaki shipyards. His contributions earned him recognition as one of the iconic figures in modern management. The diagram derives its name from its resemblance to the side view of a fish skeleton, hence being called a fishbone diagram.(Liliana, 2016)

The leader of the management team achieved significant and targeted improvements in quality by using his cause-and-effect diagram, also known as the "Ishikawa" or "fishbone" diagram.(Liliana, 2016)

This technique uses a diagram-based approach to think through all possible causes of a problem. This will help you analyze the situation thoroughly. There are four steps to using this tool:

1. Find the problem
2. Identify the key factors involved.
3. Find possible causes

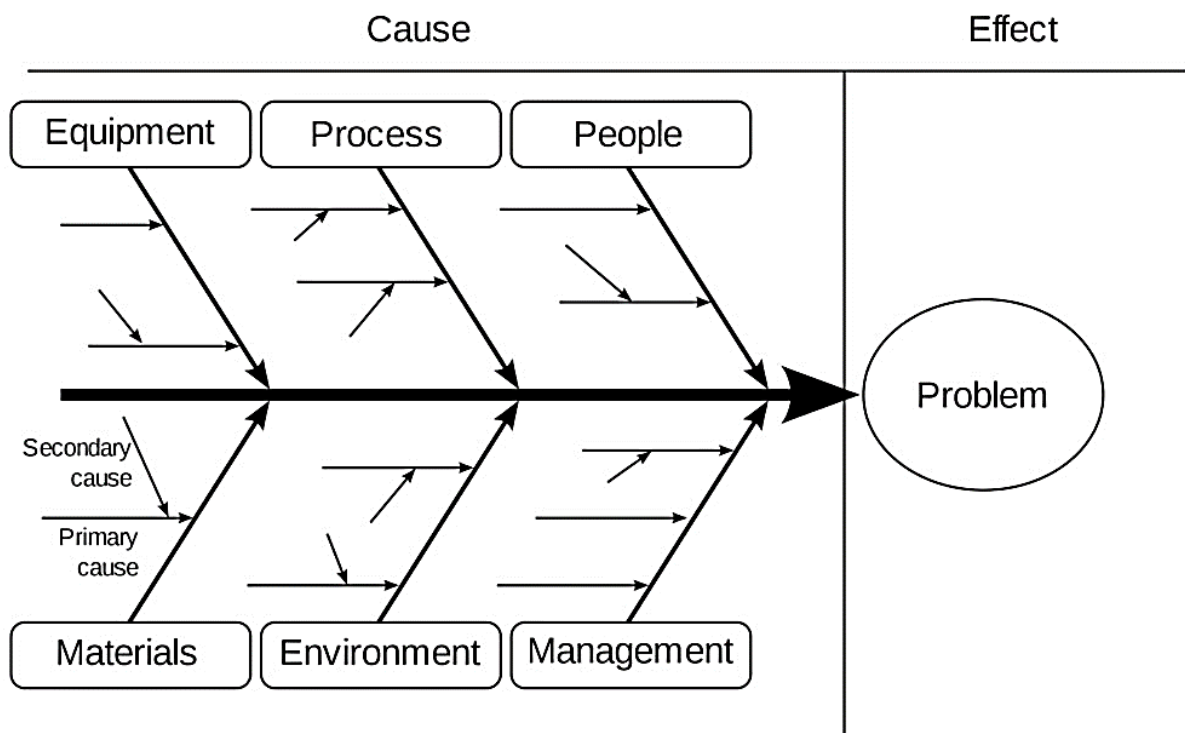
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4. Analyze your chart

Causes are often divided into major categories to identify these sources of variation. Categories typically include:

- People: anyone involved in the process;
- Method: How the process is implemented and specific requirements such as policies, procedures, rules, regulations and laws
- Machinery: All equipment, computers, tools, etc. needed to perform the job
- Materials: raw materials, parts, pens, paper, etc. used to produce the final product
- Measurement: Data generated during a process used to assess its quality
- Environment: The conditions under which a process occurs, such as place, time, temperature, and culture.

Figure 4: Ishikawa diagramme



Source: (What Is an Ishikawa Diagram, n.d.)

Bow Tie Analysis:

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Description: A visual tool that helps to understand the potential consequences of a hazard and the controls in place to mitigate those consequences. It features a hazard at the center, with the top branch representing potential consequences and the bottom branch outlining controls.

Benefits:

Offers a clear and visual representation of risk relationships.

Facilitates communication about risks to stakeholders.

Helps identify gaps in existing controls and areas where additional mitigation is needed.

Failure Mode and Effects Analysis (FMEA):

Description: A systematic approach for analyzing potential failure modes in a system (e.g., equipment, processes) and assessing their potential effects. It involves identifying potential causes of failure, the likelihood of those failures occurring, and the severity of their consequences.

Benefits:

- Allows for proactive identification of potential failure points.
- Helps to prioritize mitigation efforts based on the severity of potential consequences.
- Supports a focus on preventing failures rather than reacting to them.

Risk Reporting:

Description: Regular reporting of risk information to stakeholders. This includes risk assessments, summaries of the risk register, mitigation plans, risk dashboards, and trend analyses.

Benefits:

- Enhances transparency and accountability in risk management.
- Informs decision-making and resource allocation.
- Improves stakeholder trust and confidence.

According to previous studies, there are many risk management methods, so I have chosen the most famous ones and classified them in the following table:

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Table 4: Risk management Tools.

Risk management tool	Description	Benefits:
Risk Assessment Matrices	<p>These matrices visually prioritize risks based on their likelihood and impact. They typically use a grid with axes representing probability (low, medium, high) and impact (low, medium, high).</p>	<ul style="list-style-type: none"> - Clear visual representation of risk severity. - Easy prioritization for addressing high-risk items. - Helps focus efforts on the most critical risks.
Risk Register	<p>A comprehensive document that records and tracks identified risks, their likelihood, impact, owners, mitigation strategies, action items, and status updates.</p>	<ul style="list-style-type: none"> - Provides a centralized repository for risk information. - Promotes accountability by assigning risk owners. - Offers a structured approach to managing risk across the project lifecycle.
Hazard and Operability Studies (HAZOP)	<p>A structured process for systematically identifying potential hazards and operability problems in a construction project. It involves reviewing the design, procedures, and equipment to uncover potential risks and their causes.</p>	<ul style="list-style-type: none"> - Encourages a thorough examination of potential risks. - Helps to identify both known and unforeseen hazards. - Supports the development of comprehensive risk mitigation plans.
Risk Management Software	<p>Specialized software solutions that automate and streamline risk management processes. They can manage risk registers, perform risk assessments, generate reports, and provide data visualization tools.</p>	<ul style="list-style-type: none"> - Increases efficiency and accuracy in risk management. - Enables data-driven decision making. - Provides a centralized information platform for managing risk.
Risk Mapping	<p>A visual representation of risks, categorized by type, severity, and their interconnections. It helps to identify potential risk clusters and develop more effective mitigation strategies.</p>	<ul style="list-style-type: none"> - Provide a comprehensive overview of the risk profile. - Helps to understand how different risks might interact. - Enables a more strategic approach to risk mitigation.

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Risk Mitigation Plans	<p>Specific plans developed to reduce the likelihood or impact of identified risks. They include objectives, mitigation strategies (avoidance, mitigation, transfer, acceptance), action steps, timelines, and responsible parties.</p>	<ul style="list-style-type: none"> - Encourages a proactive approach to risk management. - Helps to minimize the potential for negative outcomes. - Provides a structured plan for addressing identified risks.
Risk Tolerance Statements	<p>Defines the level of risk the organization or project is willing to accept. It includes the overall risk appetite, specific risk tolerance limits, and the degree of risk aversion.</p>	<ul style="list-style-type: none"> - Provides a framework for decision-making and resource allocation. - Ensures consistency in risk management across projects and departments. - Improves communication and alignment with stakeholders.
Risk Control Self-Assessments	<p>Evaluations conducted by employees to assess the effectiveness of risk controls in their areas of responsibility. It involves reviewing existing controls, identifying potential weaknesses, and suggesting improvements.</p>	<ul style="list-style-type: none"> - Encourages ownership of risk management at all levels. - Helps to identify potential control gaps. - Encourages the development of a culture focused on ongoing enhancement within risk management practices.
Risk Simulation and Modeling	<p>Utilizes tools like Monte Carlo simulation, sensitivity analysis, and decision tree analysis to analyze the potential impact of different risks and evaluate the effectiveness of mitigation strategies.</p>	<ul style="list-style-type: none"> - Provides a quantitative understanding of risk and its potential consequences. - Helps to make more informed decisions about risk mitigation.

Source:(Gurtu & Johny, 2021) (*Exploring the Project Risk Management: Highlighting the Soft Side of Project Management* | IntechOpen, n.d.) (*The Best Risk Management Tools & Techniques for PM Pros*, n.d.)

2.2.5 Risk management process:

Supporting Principles

The individual designated as the accounting officer, along with their appointed lead for overseeing the organization's approach to risk management, must make certain that policies, procedures, and practices for identifying and assessing risks, as well as for treatment,

monitoring, and reporting, are adequately designed and systematically implemented. While risk management processes are typically portrayed as sequential, in reality, they are iterative.

A. Risk identification and assessment:

Risk identification endeavors should generate a comprehensive and unified perspective on risks, typically arranged according to taxonomies or risk categories. The goal is to grasp the organization's complete risk profile. A variety of methods can be employed by the organization to pinpoint particular risks that could potentially affect one or more objectives. Additionally, it's crucial to take into account the following factors, as well as the interplay between them:

- tangible and intangible sources of risk
- changes in the external and internal context
- Uncertainties and assumptions within options, strategies, plans, etc.
- indicators of emerging risks
- limitations of knowledge and reliability of information
- any potential biases and beliefs of those involved

It's crucial to identify risks irrespective of whether their origins are within the organization's direct influence. Even seemingly trivial risks, when combined with other events and circumstances, hold the potential to inflict considerable harm or offer significant opportunities.

In the realm of risk management, each identified risk, while inherently valuable, necessitates a form of measurement to ascertain its significance, thereby aiding decision-making processes. Devoid of a standardized benchmark for comparative analysis, the task of juxtaposing and amalgamating risks throughout the organization and its extended network becomes arduous. This prioritization imperative is underpinned by the practice of risk assessment, encompassing both rigorous risk analysis and meticulous risk evaluation methodologies.

The primary objective of risk analysis is to facilitate a comprehensive examination of the nature and magnitude of risk. This process of risk analysis necessitates the utilization of standardized risk criteria to promote uniform interpretation and application in determining the risk level. Such determination is predicated upon the assessment of both the probability of the risk occurrence and the potential ramifications ensuing from the event.

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The process of risk analysis may vary in terms of intricacy and depth, contingent upon several factors including the analysis's purpose, the accessibility and reliability of available evidence, and the allocated resources. Analysis methodologies may adopt qualitative, quantitative, or hybrid approaches, depending on the specific circumstances and intended application. It is imperative to acknowledge and address the constraints and influences inherent in the information and evidence bases employed, as well as the analysis techniques employed. These factors should be diligently identified, evaluated, and referenced in risk reports provided to decision-makers.

Furthermore, all critical analytical models within governmental contexts must be managed within a structured framework that ensures appropriately qualified personnel are entrusted with their development, utilization, and quality assurance.

Risk evaluation necessitates a comparison between the outcomes derived from the risk analysis and the organization's tolerance for risk, known as its risk appetite. This assessment aims to identify areas where additional measures are warranted. Possible courses of action may encompass the following:

- Avoiding the risk, if feasible, by deciding not to start or continue with the activity that gives rise to the risk.
- Taking or increasing the risk in order to pursue an opportunity.
- Retaining the risk by informed decision.
- Changing the likelihood, where possible.
- Changing the consequences, including planning contingency activities.
- Sharing the risk (e.g., through commercial contracts).

The results of risk evaluation must be documented, communicated, and verified at suitable hierarchical levels within the organization. These evaluations should undergo periodic review and adjustment to accommodate the evolving nature and magnitude of the risks encountered.

B. Risk treatment:

The process of choosing the optimal risk treatment option(s) requires a careful weighing of the potential advantages gained in advancing objective attainment against the associated costs,

efforts, or drawbacks of proposed interventions. The rationale behind the formulation of risk treatments and the implementation of internal controls extends beyond purely economic factors and should encompass the organization's full spectrum of responsibilities, commitments, and stakeholder perspectives.

In the process of selecting and formulating risk treatments, the organization must outline the implementation procedures for the chosen option(s), ensuring that all stakeholders comprehend the arrangements and enabling effective monitoring of their efficacy. This entails:

- The rationale for selection of the option(s), including the expected benefits to be gained.
- The proposed actions.
- those accountable and responsible for approving and implementing the option(s)
- The resources required, including contingencies.
- the key performance measures and control indicators, including early warning indicators
- the constraints
- When action(s) are expected to be undertaken and completed.
- The basis for routine reporting and monitoring.

If deemed suitable, the organization should establish and communicate contingency, containment, crisis, incident, and continuity management plans to bolster resilience and facilitate recovery in the event of risk materialization.

C. Risk monitoring:

Monitoring should be integral throughout the entire process, spanning before, during, and after the implementation of risk treatment measures. Continuous and ongoing monitoring is essential for comprehending shifts in the risk landscape and assessing the effectiveness of internal controls in providing reasonable assurance over risk management, thereby facilitating the achievement of organizational objectives at an acceptable level.

The outcomes of monitoring and review processes should be integrated into the broader spectrum of the organization's performance management, measurement, and reporting endeavors. The recording and reporting efforts aim to:

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- Transparently communicate risk management activities and outcomes across the organization.
- Provide information for decision-making.
- Improve risk management activities.
- Assist interaction with stakeholders, including those with responsibility and accountability for risk management activities.

The "three lines model" delineates an integrated approach to managing risks, designing and implementing internal controls, and furnishing assurance through ongoing, regular, periodic, and ad-hoc monitoring and review processes. When an organization has established and effectively operationalized the "three lines model," it should comprehend the contribution of each line toward the overarching assurance requirements and how these components can be seamlessly integrated and mutually reinforcing. It is imperative to ensure comprehensive coverage without redundant efforts. Particularly, the accounting officer and the board should receive impartial insights concerning the organization's primary risks and management's strategies for addressing them.

D. Risk reporting:

The board, with the assistance of the Audit and Risk Assurance Committee, ought to delineate the characteristics, origin, structure, and frequency of the information it deems necessary. Moreover, it must ensure transparency regarding the assumptions and models underpinning this information, enabling comprehension and, where warranted, interrogation. Key considerations for reporting encompass, among others, the following factors:

- Differing stakeholders and their specific information needs and requirements.
- Cost, frequency and timeliness of reporting.
- Method of reporting.
- Relevance of information to organizational objectives and decision-making.

The information provided should empower the board to evaluate the alignment of decisions with the organization's risk appetite in effectively attaining its objectives. It should facilitate assessments of the sufficiency and efficacy of internal controls, enabling determinations regarding the necessity for revisiting strategy and objectives, revising or implementing policies, reallocating resources, enhancing controls, and/or adjusting the risk appetite.

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Comprehensive reports or dashboards, characterized by clarity, informativeness, and utility, should facilitate the dissemination of key information pertaining to each principal risk. These reports aim to enhance visibility over risks by comparing outcomes against key performance and risk indicators, assessing alignment with risk appetite, evaluating the effectiveness of management actions, and synthesizing available assurance information. Incorporating both qualitative and quantitative data, where applicable, these reports should delineate trends and provide support for early warning indicators. To facilitate understanding and decision-making, information should be presented concisely, complemented by the use of graphics and visualization techniques.

Principal risks necessitate thorough scrutiny through "deep dive" reviews conducted by either the board or the Audit and Risk Assurance Committee. These reviews should involve the participation of individuals responsible for risk management, possessing the requisite expertise, convened at a frequency commensurate with the nature of the risk and reported performance.

Figure 5: Risk management framework



Source: The Orange Book Management of Risk – Principles and Concepts

2.2.6 The Benefits:

Enhanced Decision Making: Risk management facilitates informed decision-making by prioritizing risks based on impact and resource allocation¹.

Asset Protection: It helps protect financial resources, assets, intellectual property, and sensitive information from external threats, preserving their value and reducing liabilities. (Benefits of Risk Management |, n.d.)

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Improved Project Performance: Identifying project risks early on enhances project management by avoiding delays, cost overruns, resource wastage, and improving overall performance. (Benefits of Risk Management |, n.d.)

Compliance and Regulatory Adherence: Ensures adherence to government regulations, standards, and compliance requirements to avoid legal penalties, reputational damage, and operational disruptions. (Benefits of Risk Management |, n.d.)

Competitive Advantage: Organizations gain a competitive edge by managing risks effectively, differentiating themselves from competitors, building trust with stakeholders, fostering customer loyalty, and attracting investors. (Benefits of Risk Management |, n.d.)

Organizational Resilience: Contributes to organizational resilience by anticipating and preparing for potential risks, enabling faster recovery from unforeseen events and maintaining operations during difficult situations. (Benefits of Risk Management |, n.d.)

Stakeholder Confidence: Enhances transparency and communication among stakeholders by effectively communicating risks and response strategies, building trust among customers, investors, employees, and partners for long-term success. (Benefits of Risk Management |, n.d.).

Cost Reduction: Proactive risk mitigation minimizes financial losses, insurance premiums, legal expenses, operational disruptions leading to cost savings in the long run (Benefits of Risk Management |, n.d.).

Innovation and Growth Enablement: Provides a foundation for exploring opportunities, driving innovation, pursuing growth strategies by managing risks effectively in dynamic business environments. (Benefits of Risk Management |, n.d.).

Long-term Sustainability: Integrating risk management ensures long-term sustainability by protecting reputation, securing stakeholder trust, maintaining financial stability amidst market changes for continued success. (Benefits of Risk Management |, n.d.).

3 Risk management in the underground project Construction

3.1 Time Risks:

One of the challenges that any project can encounter is the risk of delays, which is a common issue in large-scale construction projects globally.

3.2 Cost Risks:

In construction projects, the issue of cost-effectiveness is prevalent, with a minority of projects being completed within the initially estimated budget. Based on current research, up to 90% of construction projects encounter cost overruns, exceeding estimates by anywhere from 5% to 200%. Cost management involves implementing processes to ensure that projects are finished within the approved budget, encompassing cost estimation, budget development, and cost control. The aim of this area is to enable projects to be completed within the authorized budgets. Poor cost performance issues are widespread in construction projects worldwide, often resulting in significant budget overruns.

3.3 Quality Risks:

Numerous factors play a significant role in influencing the performance of infrastructure projects in developing nations, with Algeria emerging as a notable case. The success of any construction project fundamentally depends on its quality, which should ideally meet the expectations of all stakeholders involved. Previous studies have shown that project failures are frequently attributable to performance issues and setbacks. In the Algerian context, numerous construction projects have encountered challenges in this area, prompting an empirical investigation into the impact of risk management on construction project performance.

Section 3: The ISO 31000 management system standard

1 Definition:

ISO 31000, initially published in 2009 and updated in 2018, is an international standard that provides comprehensive principles and guidelines for effective risk management. It presents a generic framework that can be applied to various types of risks, including financial, safety, and project risks, and is suitable for any organization. The standard establishes a common vocabulary and set of concepts for discussing risk management, offering guidelines that facilitate a critical review and enhancement of an organization's risk management processes. (14:00-17:00, n.d.)

2 The process:

According to the ISO 31000 standard involves the following key steps:

Communication and consultation:

Helps stakeholders understand the risks, decision-making principles, and reasons for necessary actions. Brings together different areas of expertise to consider multiple perspectives. Facilitates information sharing and monitoring of risks to support decision-making.

Establishing the context:

Defines the scope, parameters, and criteria for the risk management process. Considers the organization's objectives, resources, and internal/external factors that can be sources of risk.

Risk assessment:

Includes risk identification, analysis, and evaluation to understand the nature, sources, and level of risks.

Risk treatment:

Involves selecting and implementing options to modify risks, such as avoiding, accepting, reducing, or sharing the risks.

Monitoring and review:

Tracks the performance of risk management indicators and expected behaviors. Evaluates the effectiveness of the risk management process for continual improvement.

Recording and reporting:

Documents and communicates risk management activities and outcomes.

3 importance of ISO 31000 in risk management:

In the face of uncertainty and rapid change, every organization, regardless of its size or sector, is confronted with risks that can represent both a threat and an opportunity. ISO 31000 serves as a beacon:

- **Global understanding:** It promotes a common understanding of risks, their nature and how to manage them within an organization.
- **Strategic decision-making:** These guidelines help to integrate risk management into an organization's governance, strategy, planning, reporting processes, policies, values and culture.
- **Operational excellence:** Implementing ISO 31000 can lead to efficiency gains, as it helps organizations detect threats and opportunities at the right time, allocate resources wisely and build stakeholder confidence.
- **Proactive approach:** ISO 31000 goes beyond reactivity, enabling organizations to anticipate and address risks head-on, turning potential challenges into strategic advantages.
- **Stakeholder confidence:** A structured approach to risk management signals to stakeholders - from investors to customers - that the organization is well prepared to deal with uncertainties, building trust and credibility

4 Benefits

Standardized risk management principles, framework and processes
Guidelines for implementing risk management practices
Tools to contextualize risk management within any organization
Criteria for monitoring, reviewing and continuously improving risk management.
Basis for integrating risk management throughout the organization

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Table 5:ISO 31000 Risk Management Procedure.

Step	Description
1.Establishing the Context	Define External and Internal Context: Understand external factors (economic, social, political) and internal factors (organizational culture, structure, processes) influencing the organization's objectives. Define Risk Criteria: Establish criteria for evaluating risks considering organizational objectives, legal and regulatory constraints, and stakeholder expectations. Determine the Scope: Identify the areas, projects, or activities covered by the risk management process.
2. Risk Identification	Identify Risk Sources: Identify all possible sources of risks (internal and external) that could affect objective achievement. Identify Potential Events: Determine events that could trigger these risks. Identify Causes and Consequences: Analyze the root causes of risks and their potential consequences.
3. Risk Analysis	Evaluate Likelihood and Impact: Analyze the likelihood of the identified risks and their potential impact on organizational objectives. Evaluate Existing Controls: Assess existing control measures for managing the identified risks and determine their effectiveness.
4. Risk Evaluation	Prioritize Risks: Compare risk analysis results with the defined risk criteria to determine their significance and prioritize risks for treatment. Decide on Risk Responses: Determine risk response strategies: avoid, reduce, share, or accept the risk.
5. Risk Treatment	Develop Action Plans: Develop plans to treat priority risks, specifying actions, required resources, and timelines. Implement Risk Treatment Plans: Execute the planned actions to manage the risks.
6. Monitoring and Review	Monitor Risks and Controls: Ensure continuous monitoring of risks and the effectiveness of control measures. Review and Update Risks: Regularly review and update risk information and adapt treatment plans based on changes in context or objectives.
7. Communication and Consultation	Communicate with Stakeholders: Inform stakeholders about identified risks, treatment plans, and the status of risk management. Engage Stakeholders: Ensure stakeholder involvement in the risk management process to leverage their expertise and gain their support.

Source:(14:00-17:00, n.d.)

In construction project management, blending theoretical frameworks with practical risk management tools is crucial for navigating uncertainties and ensuring success. From traditional risk identification techniques to advanced machine learning models, each tool contributes to addressing construction risks and safeguarding project objectives. The synergy between theory and practice fosters resilience and sustainability, enabling firms to enhance outcomes and optimize resources. Ultimately, the integration of theoretical foundations guides informed decision-making, steering construction projects towards success in dynamic environments.

**Chapter II: ORGANIZATIONAL
CONTEXT AND METHODOLOGIC**

The organizational context and methodological framework lay the foundation for understanding and analyzing risk management practices within infrastructure projects, with a specific focus on the Algiers metro construction project undertaken by COSIDER Travaux Publics. Beginning with an exploration of COSIDER's rich history and its current organizational structure, this chapter provides insight into the company's evolution and its prominent position within the Algerian public works sector. Subsequently, the selection and description of the M28 project within the COSIDER TP portfolio offer a glimpse into the specific project under scrutiny, highlighting its significance and scope. Transitioning into the methodological framework, the chapter delves into the epistemological posture adopted, emphasizing the qualitative approach within a post-positivist framework for risk analysis. Moreover, it delineates the research rezoning undertaken to identify and analyze construction-related risks, followed by a detailed exposition of the data collection instruments employed, including documentary research, interviews, observations, and brainstorming sessions. This chapter sets the stage for a comprehensive examination of risk management practices within the Algiers metro construction project, offering a nuanced understanding of the organizational context and methodological underpinnings guiding the research endeavor.

Section 01: Organizational context

1 Presentation of the case study company: COSIDER PW

This part will provide an introduction to the hosting organization "COSIDER Public works" by presenting its profile and the company's organizational structure.

1.1 Company history:

COSIDER was created on January 1, 1979 as a semi-public company, in partnership with National Steel Company (S.N.S) and the Danish group CHRISTIANI et Nielsen. In 1982, S.N.S bought out the Danish partner's shares, thus becoming COSIDER's sole shareholder. In 1984, as part of the Algerian government's restructuring of state-owned companies, COSIDER was transformed into a national enterprise under the supervision of the Ministry of Heavy Industry. Following the implementation of economic laws and reforms, notably those concerning the autonomy of public enterprises in 1988, COSIDER was converted into a joint-stock company in October 1989. Over the years, COSIDER has seized a number of opportunities and expanded its scope of activity beyond the building and public works sector.

CHAPTER II: ORGANIZATIONAL CONTEXT AND METHODOLOGIC

Unlike its competitors in the local market, COSIDER has taken advantage of its stability and entrepreneurial spirit to diversify rapidly over the past decade. Thanks to continuous internal growth, COSIDER has become the largest Algerian group in the public works sector. Today, COSIDER Travaux Publics, one of the COSIDER Group's largest subsidiaries, is a joint-stock company with a share capital of DA4, 000,000,000. The COSIDER SPA Group, for its part, is structured as a group of companies holding the entire capital of ten (10) subsidiaries. It occupies a leading position in the Algerian public works sector, and ranks eleventh in Africa according to Jeune Afrique.

In 2006, the company obtained ISO 9001 Version 2000 certification, and is currently certified to ISO 9001 versions 2015, ISO 14001 versions 2015, and ISO 45001 versions 2018. COSIDER TP occupies a leading position in the public works sector, considered a key sector for the country's development. The company also emphasizes collaboration with domestic and foreign partners, forming consortia to ensure the success of its projects.

In 2013, the group posted sales of 87 billion dinars and employed over 28,500 people. COSIDER Travaux Publics has extensive experience in the construction of major public infrastructure works. The company has built up a considerable number of successful projects, making it the undisputed national leader in its field, a position it aims to maintain

1.2 The COSIDER context:

Table 6: Cosider context

Denomination	 Cosider Travaux public
Legal status	Public establishment (groupe COSIDER)
The head office	Cité Clément-ville - Mohammadia Algiers

Creation date	1995
Main activities	-Construction of roads, motorways, railways, airfield runways and engineering structures. -Special Works Division: -The construction of underground and maritime structures.
Contacts	(023) 75 11 42 tp@cosider-groupe.dz
Site	https://www.cosider-groupe.dz/fr/cosider-travaux-publics-contact

Source: internal document

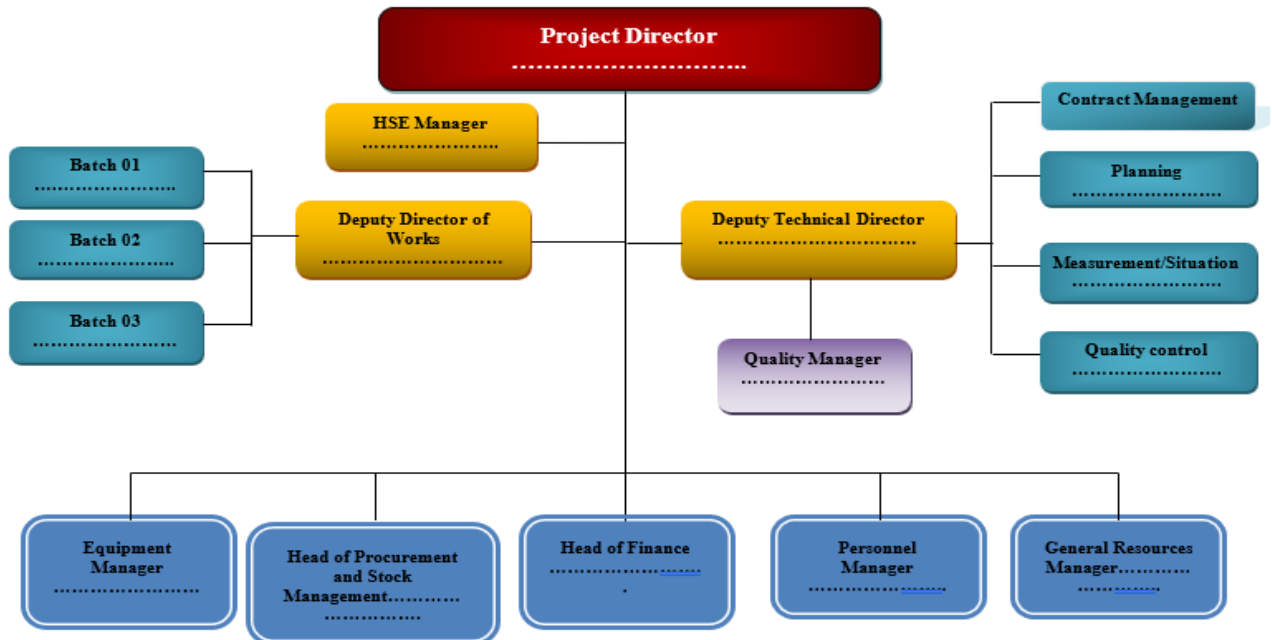
2 Site selection presentation: M28 Project COSIDER TP

Located at the four Chemins de university de Bab-Ezzouar, the M28 Project Management Office is part of the parent company "COSIDER TP" and is directly linked to the Special Works Division, as indicated in its organization chart. It is responsible for carrying out work on the extension of line 01 of the Algiers metro. The project is currently 87% complete (31 December 2022).

The project involves a 10 km extension of the Algiers metro line from EL HARRACH CENTRE to ALGIERS INTERNATIONAL AIRPORT (new terminal). It consists mainly of 9 stations and 10 ventilation shafts (see project description **Annex 01**).

2.1 The organizational Chart of the case study project M28:

Figure 6: Organisationnel Chart



Source: Internal document

2.2 Description of the M28 Metro construction:

The project involves extending the Algiers metro line from EL HARRACH CENTRE to ALGER AIR BAYDA INTERNATIONAL AIRPORT,

It is 9.569 km long and comprises 8 km of tunnels, 10 area extension structures and 09 stations. This extension will connect the east of the capital and serve the most populated quarters, the various university centers and the airport.

Figure 7: Ground plan



Source: Internal document

Excavation of the wall tunnel:

The tunnel will be dug using an earth pressure tunnel boring machine (TBM) specially built by CRE ZIRTH (China) to dig the tunnel for the extension. The TBM is adapted to the geological characteristics of the extension.

The tunnel will be built in two stages starting from the OUED SMAR station:

- **Oued SMAR Airport section with a tunnel length of 5680 m (including station crossings)**
- **Section from Oued SMAR to EL HARRACH CENTRE with a tunnel length of 3743 m (including station crossings).**

Stations:

- With a length of 9.5 km and 9 stations, this line will serve densely populated neighborhoods such as
- Beaulieu, Oued SMAR, Cite 5 juillet, Bab Ezzouar, Pôle Universitaire d'El Harrach, Centre des Affaires de Bab Ezzouar and Université Houari Boumediene.

- It will link the tramway to the Houari Boumediene University crossroads and offer multimodality at this station. The nine stations of this extension are

Hassan Badi station: Hacem Badi station is located in the Belfort district

In a topographically flat area, bounded to the east by the confluence of Rue Ahmed Alouane, to the west by “Rue des Frères Oudek” and to the south by Rue Slimane Hanafi. The dimensions of the end shafts are approximately 31.50 m and 36.00 m respectively, while the current width is approximately 20.90 m for each shaft. The average excavation depth of the shafts is approximately 40.20 m. With 02 accesses to the station.

University Centre station: Pile Universitario station

The intersection of the Boulevard de l'ALN with the N24 in the middle, by the École Nationale Supérieure d'Agronomie, the Ecole Nationale Supérieure N24, inaire and the École Polytechnique d'Architecture ET d'Urbanisme, the dimensions of the station are approximately 132.6 m long, with a running width of 23.38 m and a platform level at a depth of 38.0 m. With 03 entrances to access the station.

Beaulieu Station: Beaulieu Station is located in the Oued

SMAR, in a topographically flat area under the intersection of two roads, Avenue Ahmed Hamidouche and Boulevard Sidi Okba. The open-cast excavation areas will be approximately 120 m long, with a width varying between 7.9 m and 23.0 m, and a maximum depth of 29.2 m. In turn, the two underground galleries will be 50.0 m long and the diameter

Section 02: Methodological framework

1 Epistemological posture:

In the realm of risk analysis, a qualitative approach often involves conducting interviews to gather rich, contextual data. In a post-positivist framework, this approach would aim to understand the subjective perceptions and interpretations of risk held by individuals, while also acknowledging the existence of an objective reality that can be measured and observed to a certain extent. (*Testlify*, n.d.)

The interview process would be structured to collect data that can be analyzed in a systematic and rigorous manner, aligning with the post-positivist emphasis on empirical observation and verification. This would involve formulating hypotheses based on existing theories and using the interview data to either support or refute these hypotheses. (Parry et al., 2001)

Furthermore, the post-positivist approach would recognize that the researcher's perspective and biases can influence the interpretation of data. Therefore, efforts would be made to minimize these biases through reflexivity and the use of multiple coders to analyze the data, enhancing the validity and reliability of the findings. (IRJAH2-3371-6769-1-SM. Pdf, n.d.)

Overall, the qualitative interview approach to risk analysis, within a post-positivist framework, would seek to combine the depth of qualitative data with the rigor and systematic analysis associated with post-positivist methodologies. (IRJAH2-3371-6769-1-SM. Pdf, n.d.)

2 Research rezoning:

The qualitative approach allows us to identify and analyze risks related to the construction sector, especially infrastructure, by understanding the context and intricate details, in addition to applying new analysis methods, along with the challenges facing banks in this regard. Focusing on the experience of professionals in the field,

The qualitative approach enables us to understand the opinions of experts and explore their future visions in construction risk management, through conducting personal interviews or direct field observations.

3 The methodological approach adopted

The methodological approach adopted: In this academic research context, qualitative inquiry is employed as a fundamental tool for the deep analysis and understanding of risks within the construction sector. This approach aims to investigate the personal opinions and interpretations of the stakeholders involved in the industry, through personal interviews and field observations. In addition to the observation and brainstorming sessions that have been added, incorporating interviews into the data collection process further enriches qualitative inquiry. Interviews provide researchers with the opportunity for direct interaction with stakeholders, allowing for the exploration of their perspectives, experiences, and future visions regarding construction risk management. By integrating interviews with observation and

brainstorming sessions, researchers can gather comprehensive and diverse data, enhancing the depth and validity of qualitative analysis. (Parry et al., 2001)

4 Data collection instruments:

After defining our methodological approach, we will describe the data collection tools used.

4.1 Documentary research:

As part of our work, this tool allowed us to collect as much information as possible, from several sources of information, in particular: **consultation of works, articles, reports, regulations, standards and benchmarks, theses of research.**

4.2 Documents relating to the host organization:

We have consulted the company's documents within the limits of the company's internal regulations and confidentiality policy.

4.3 Interviews:

This qualitative research technique makes it possible to understand the subjects through the interpretation of the data collected during testimonies. Students can choose from:

Directive interview, Semi-structured interview. Non-directive interviews. (Claude, 2019)

4.4 Observations

During the internship period, time was spent on the various construction sites of the project, starting with a site visit on April 16th, which was repeated weekly, to directly observe the behaviors and processes related to risk management. These site visits were sometimes accompanied by the project's technical director, and at other times by the quality manager. Seeing how risk management procedures are applied daily by the operational teams Identifying the challenges and obstacles encountered in the practical implementation of these processes. Analyzing the interactions between the different stakeholders involved in risk management Recording good practices, as well as potential areas for improvement Careful notes were taken during the observations, supported by photographs and recordings when possible and relevant. This allowed for subsequent revisiting of the field data and in-depth analysis, in conjunction with the information gathered during the interviews.

This combined approach of interviews and observations was essential to obtain a comprehensive understanding of the risk management issues in this complex infrastructure project.

4.5 Brainstorming:

Brainstorming is a technique for collecting information and solving problems, recognized in quality management, it is useful for generating a large number of ideas on a subject during a meeting, everyone will spontaneously offer their suggestions, and all ideas will be recorded without judgment. (Kumbhar Kalyan, 2018).

This brainstorming phase involved the research team, which was composed of the quality manager and two research assistants.

- **Participants:**

During this session, 7 key stakeholders were gathered, including engineers, quality department members, the procurement and planning manager, as well as the HSE manager.

- **Duration**

The brainstorming session lasted a total of 3 hours.

- **Outcomes:**

Through this collaborative approach, the team was able to identify the root causes of the primary risks impacting the project, thus providing an in-depth understanding of the challenges associated with risk management.

- **Results:**

Through this combined approach of interviews and observations, the research team was able to identify the root causes of the main risks affecting the project. This detailed information provided an in-depth understanding of the risk management challenges in this complex construction project.

Section 03: Data treatment and analysis

1 Conduct of interviews:

To examine how risk management processes are applied in infrastructure projects, we chose the Algiers metro construction project as our case study. In order to understand the risk management practices used by different professionals semi-structured interview were conducted, we interviewed all relevant stakeholders. The interviewees included 7 key personnel, such as the project implementation engineer, the project's topographer, the head of the quality management department and their assistant, the project cost control officer, the planning officer, and the HSE officer. Each semi-structured interview was conducted in French to ensure clear communication and avoid potential misunderstandings that could arise from an English interview. The interviews lasted approximately 40 minutes each. Recording the interviews was essential for accurately capturing information for this research and allowed us to revisit and analyze the respondents' comments in detail. We obtained consent from all participants to record the interviews.

The questions were designed to explore how risk management is applied in practical scenarios and to gauge the project actors' level of familiarity with this concept. This information was essential in order to ensure that representatives from each phase of the project were interviewed in order to capture a comprehensive view of the project's risks. Based on this information, all respondents were asked to, among other things, pinpoint the most significant risks in their respective stages of work and assess their impact on the project's golden triangle: time, cost, and quality, as well as the type of responses taken. The specific interview questions are provided in Appendix 1.

1.1 Collecting data:

Data was collected over a 26-day period between April 15, 2024 and May 11, 2024. First, interviews were conducted with various officials through which a set of risks threatening the project were identified. Internal documents and field observations were used by visiting the construction site

2 Data treatment and analysis:

When processing the results of the interview, I used the manual technique to streamline and enhance the entire process of qualitative interview data analysis, from transcription to

CHAPTER II: ORGANIZATIONAL CONTEXT AND METHODOLOGIC

theme identification to final insights. It makes the analysis more systematic, rigorous, and collaborative.

In conclusion, the organizational context and methodological framework elucidate the fundamental elements shaping the inquiry into risk management practices within the context of infrastructure projects, particularly the Algiers metro construction project undertaken by COSIDER Travaux Publics. By providing a comprehensive overview of COSIDER's history, organizational structure, and the specific project under study, this chapter establishes the backdrop against which risk management processes are examined and evaluated. Furthermore, the delineation of the methodological approach, characterized by a post-positivist qualitative stance, underscores the rigorous and systematic nature of the research endeavor. Through a combination of data collection instruments including interviews, observations, and brainstorming sessions, the chapter outlines a robust framework for gathering rich, contextual insights into risk management dynamics within the construction sector. As the study progresses, this foundational understanding of the organizational context and methodological framework will serve as a guiding compass, facilitating a nuanced exploration of risk management practices and their implications for project success and resilience.

CHAPTER III: RESULTS AND DISCUSSION

Section 1: Results

In this study, we delve into the comprehensive examination of project risk analysis, meticulously uncovering its nuanced results and implications. The project description sets the stage, elucidating the overarching goals, methodologies employed, and the context within which the project risk analysis was conducted. Subsequently, we navigate through the rich tapestry of interview outcomes, where real-world perspectives and experiences converge to offer depth and resonance to our analysis. By seamlessly weaving together the empirical insights gleaned from the project risk analysis with the firsthand accounts procured from interviews, we illuminate the multifaceted dimensions of our inquiry. This synthesis not only enriches our understanding of the subject matter but also fosters a holistic perspective that transcends isolated data points. Through this integrated approach, we aim to provide a comprehensive narrative that not only informs but also inspires further exploration and discourse in the field.

1 Establishment of the internal and the external context of the project:

Contribution to the strategic diagnosis of the environment of Cosider TP Analysis using SWOT

1.1 SWOT Analysis:

Here is an overview of the four focus areas that make up the acronym SWOT and how they apply to project management:

- **Strengths:** These are internal factors (factors you can control) that set your project or business up for success. Project strengths include any aspects of the project that make it likely to succeed. Some examples are detailed project requirements, an engaged customer, robust project management software, and experienced team members.
- **Weaknesses:** Weaknesses are internal factors that may make it difficult for you to succeed. For instance, if your team has never worked together before and several members are new and inexperienced. Other internal weaknesses could be overallocated resources, a lack of visibility into progress, disengaged stakeholders, or a lack of project funding.

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- **Opportunities:** Opportunities are factors that are outside of your control (external factors) that could help your project succeed. They could be current opportunities that exist now but have not yet been taken advantage of or future opportunities that you think may happen. If your primary material vendor suddenly offered a discount, it would be an opportunity to save your project money. If another project at your company finished early, it could free up resources you can then use to help your project succeed.
- **Threats:** These are external factors that could harm your project if they were to take place. As with opportunities, they can be current or future threats. The possibility of one of your vendors going out of business would be a threat. Other threats could be bad weather (such as a snowstorm causing employees to miss work), increased costs of supplies, materials, or contractors. (BlakSheep Creative, n.d.)

Table 7:SWOT Analysis

Forces	Weaknesses
<ul style="list-style-type: none"> ● Control and optimization of costs and deadlines. ● Notification of procedures and feedback in order to facilitate the work and the continuous incorporation and involvement of new staff. ● Reflection, innovation, the ability to adapt and the application of new execution methods, in particular the TOP-DOWN method and the TBM. ● Development of HSE instructions and procedures to control and minimize professional risks, general medicine medical consultations 24/7, nursing service (blood tests, stitches, injections, dressings, vaccinations, etc.). ● Development of contracts with authorized organizations for the management and collection of inert and household waste 	<ul style="list-style-type: none"> ● Lack of flexibility in current markets and contracts with customers. ● limited command of the language, which makes the ability to express oneself and write fairl demanding. ● loss of skills and qualified personnel. ● Recurrent breakdown due to misuse of equipment. ● use of low-capacity IT tools for certain technical profiles. ● Lack of training to meet the needs of project staff. ● Failure to achieve the objectives/targets set by our General Management (frequency rate, severity rate), Individual behaviors that contravenes current HSE standards and regulations.

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<p>(Extranet, Netcom, Naftal, public landfill, etc.)</p> <ul style="list-style-type: none"> ● Selective sorting of waste and their reuse for other purposes. 	<ul style="list-style-type: none"> ● Nuisance and inconvenience to certain interested parties (noise, dust, vibration, clutter,). ● critical economic situation and decline in the volume of public orders.
Opportunities	Threat
<ul style="list-style-type: none"> ● Facilitating the public authorities in granting licences and carrying out monitoring. ● The contribution of the M28 project to the successful transition from OHSAS 18001 to the new ISO-45001 standard. <p>Inter-company cooperation, local and foreign, with a high level of expertise.</p>	<ul style="list-style-type: none"> ● of some essential materials and products on the national market, such as steel, spare parts, etc.

Source: Internal document

2 Risk identification:

The initial step in Risk Management Planning (RMP) involves an informal process, adapting to the needs of Cosider Company and Project M28 team, relying on previous experiences of project employees extracted from interviews to identify potential risks for our future projects. Risk distribution is fundamental and can be determined by the company without there being a single ideal method; the aim is to identify potential risks for the project. Despite the challenge of completely eliminating risks, their identification facilitates taking preventive measures and enhancing control. Effective risk management includes addressing issues proactively and preparing for unexpected challenges. By dealing with potential threats, we not only reduce losses but also turn risks into opportunities, leading to numerous benefits. The goal of risk identification is to compile a list of potential risks to be managed within Cosider Company's project. Different techniques can be used, focusing on knowledge and benefit to the project team as the brainstorming sessions. The objective is to shed light on potential issues.

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Table 8: Risk identification and response from the interviews

The Processes	Risk ID	Risk
Laws and regulations	R1	Restrictive legislation (site safety, new regulations, laws, standards, taxes).
	R2	Lack of flexibility in current markets and contracts with customers
	R3	Pre-selection of unsuitable suppliers
	R4	Subjective evaluation of external providers
	R5	Non-compliance with contractual clause and inadequate call for tenders
	R6	Failure to meet delivery deadlines
	R7	Non-conforming product
	R8	Shortage of raw materials
	R9	Raw materials prices are rising and contract prices established in 2013 are depreciating Continued depreciation of the Algerian dinar Austerity plans since 2014 Difficult budgetary situation Finance law and halt to imports of several products (concrete blocks and others, etc.) Quality of local products
Technical design and planning	R10	Inherently limited technical expertise Limited pre-project study, Incomplete geotechnical survey.
	R11	The complex geological nature of the site (risk of collapse, landslides, subsidence, etc.) The proximity of the sites to red-listed buildings or high-rise buildings the almost immediate proximity to a disadvantaged population (risk of theft, physical aggression and trespassing)
	R12	Dynamic system strongly influenced by the environment (soil, meteorology, geology, hydrogeology, etc.)
	R13	The duration of the project, which increases the likelihood of events having a significant impact on performance dispersion (change in

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		standards, evolution of objectives, etc.), economic, political and social constraints, etc.
	R14	Human errors and may result from inappropriate decisions, insufficient.
	R15	Tracking of changes (deadlines, tasks, budget) absent or ineffective.
	R16	Contractual conflict with the owner and the contractor.
	R17	Incorrect assessment or estimate by the project owner during the feasibility phase (delayed approval of plans, failure to approve technically feasible plans).
	R18	Force majeure.
Material management	R19	The location of the project in a city with a very congested and narrow traffic network, poor quality and degradation of the roads.
	R20	Maintenance team unfamiliar with new technology (TBM).
	R21	Failure to properly use equipment.
	R22	Insufficient experience, lack of knowledge and/or
	R23	Skills.
	R24	Lack and restocking of spare parts.
	R25	Non-compliant equipment (no certificate of conformity, technical safety inspection).
HSE	R26	Poor expression or understanding of the need.
	R27	Inspections not carried out .
	R28	Failure to carry out awareness and induction sessions for new recruits.
	R29	Missed target (Severity & Frequency).
	R30	Failure to control risks on work at project level.
	R31	Failure to monitor the various non-conformities recorded.
	R32	Failure to transmit information on time.
	R33	Failure to achieve PM objectives.
	R34	Lack of staff following sick leave (covid 19).
Works	R35	Non-compliance with HSE regulations by external service providers (service provider, partner, subcontractors).

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	R36	Deviation of the TBM from its route Emergence of the TBM in groundwater the need for huge quantities of water for the TBM.
	R37	non-conformity poorly dealt with and unresolved stop points.
	R38	Appearance of competition, overlap of work with other companies, bureaucracy on the part of certain interested parties (Expropriation problems, issuing of permits, etc.) Political and socio-economic context in turmoil.
	R39	Penalties for non-compliance with regulations, -Delay in work completion -Material and human damage, -Company image.
HRM	R40	Unsatisfied recruitment requests.
	R41	Judiciable monitoring.
	R42	Conflicts/strikes Employee complaints
	R43	Escape of brains and skills.

Source: self-developed

2.1 Risk Identification Results

The risk identification process yielded a comprehensive list of 43 distinct risk events. These events were meticulously collected through a combination of interviews, observations, and brainstorming sessions facilitated by the quality team.

Distribution of Risk Events:

- **Operational Risk Events (9):** These risks pertain to potential disruptions or inefficiencies within the Laws and Regulations Processes. They encompass challenges related to compliance, legal constraints, and regulatory changes that may impact operations.
- **Technical, Design, and Planning Process (9):** Risks in this category revolve around technical complexities, design limitations, and planning uncertainties. They highlight potential setbacks in project execution stemming from inadequacies in technical expertise, design flaws, or insufficient planning.

- **Material Management Process (7):** These risks center on the management and procurement of materials essential for project implementation. They encompass issues such as supply chain disruptions, material shortages, quality control lapses, and cost overruns.
- **Works (8):** Risks within this domain concern the execution phase of the project. They encompass a wide range of operational challenges, including scheduling conflicts, resource allocation issues, equipment failures, and on-site safety hazards.
- **Human Resource Management:** Risks related to human resources management involve potential difficulties in recruiting, retaining, and effectively utilizing personnel. These risks include workforce shortages, skill gaps, labor disputes, and organizational culture conflicts.

The 43 risk events were meticulously gathered through a multifaceted approach. Interviews were conducted with key stakeholders to gather insights into potential risks and vulnerabilities. Observations were made during site visits and project meetings to identify operational challenges firsthand. Additionally, brainstorming sessions facilitated by the quality team provided a platform for collaborative risk assessment, allowing diverse perspectives to be incorporated into the risk identification process.

By delving into the specifics of each risk category and elucidating the methodology employed for risk identification, stakeholders gain a clearer understanding of potential challenges and the rigorous process undertaken to identify them.

2.2 Risk assessment:

Following a thorough review of the literature on risk management methods, multiple brainstorming sessions, and in-depth analysis of interviews with key stakeholders familiar with the project's risks, I have determined that the optimal approach for assessing the causes-effect of each identified risk is to amalgamate between the Fishbone method (see APPENDIX B) and the Bowtie method (see APPENDIX C).

Then I followed the Failure Mode and Results Analysis FAILURE MODE AND EFFECTS ANALYSIS FMEA (see APPENDIX D) and presented the results to the employees of the

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Quality Management Department to benefit from their experience of more than ten years in the field, and it was approved after some modifications and instructions.

And the utilizing of the 5 Whys questioning method, which serves to comprehensively identify the problem by iteratively asking "why" up to five times, facilitates obtaining sufficient information regarding all aspects of the problem. This method enables the precise determination of the root cause by thoroughly exploring deeper layers of causality.

Table 9:causes of risks

Risk	Cause
N	
R1	Non-compliance with applicable laws and standards.
R2	Failure to take into account the strengths and technical and economic advantages of the methods).
R3	Poorly defined criteria for pre-selecting suppliers Lack of periodic supplier file reviews, Lack of challenge between existing and new suppliers able to offer new solutions and pricing conditions,
R4	Loss of suppliers, subcontractors and partners, Poor quality of service from certain suppliers, subcontractors and partners, Lack of authorized service providers for recycling and taking care of DSD and other waste.
R5	Drafting of technical specifications so that only one supplier is selected Absence of certain important elements in the tender documents (supplier's response time to the request, address of the place where the offer is to be submitted) Failure to select suppliers offering the best quality/price ratio
R6	Indebtedness to certain suppliers. Delay in delivery due to means of transport (sea, rail, road). due to congestion at the port of transition. due to weather conditions long delivery times. Poor choice of suppliers. Supply was made to suppliers who did not respect.
R7	Product poorly received Poor understanding of specifications or expression of needs, Selection of suppliers offering poor quality
R8	- Exhaustion of existing safety stock before the next entry. Depletion of market stock.

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	<ul style="list-style-type: none"> - Insufficient stock management strategy. - Poor stock management. - Staff incompetence. - Inadequate distribution of tasks in the process.
R9	Country's economic crisis.
R10	Partial mastery.
R11	Geological nature of the soil.
R12	The trace of the project is located in a mountainous area, Natural constraints.
R13	Absence of clauses in the contract to deal with this type of risk.
R14	Lack of relevant management training, Pressure and workload, Communication problem with MOE.
R15	The company's specific organization
R16	Lack of communication and language problems with stakeholders, inherently limited technical expertise.
R17	Natural risk.
R18	Inherently limited technical expertise.
R19	Locating the project in the capital.
R20	Absence and lack of relevant training, Absence of clauses in purchase contracts on the technology owner's obligation to provide training and transfer know-how.
R21	Fault and lack of foresight in the long term, The Finance Act and the importation shutdown.
R22	Lack of relevant training.
R23	Lack of rigorous follow-up.
R24	Lack of rigorous follow-up.
R25	Unavailable on the national market (finance law) Lack of forward planning.
R26	Poor expression or understanding of the need.
R27	Lack of means to monitor and carry out HSE activities.
R28	Partial application of the procedure.
R29	Non-compliance with HSE regulations.
R30	<ul style="list-style-type: none"> - Lack of effective corrective action. - Partial application of the accident. - Incident investigation procedure.
R31	Partial application of the procedure.

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R32	Non-compliance with transmission deadlines Absence of input elements to complete monthly tracking.
R33	<ul style="list-style-type: none"> - Non-implementation of SST/AES actions. - Lack of resources. - Failure to allocate the necessary budget to OHS/HEA actions.
R34	<ul style="list-style-type: none"> - Staff vaccination. - Encourage staff to comply with barrier measures both inside and outside the company.
R35	Partial mastery of HSE.
R36	<ul style="list-style-type: none"> - Geological nature of the terrain. - System failure.
R37	Partial application of the procedure.
R38	<ul style="list-style-type: none"> - Non-compliance with contractual requirements. - Tough competition between companies.
R39	<ul style="list-style-type: none"> - Failure to comply with applicable regulations. - Failure to apply the emergency plan.
R40	Lack of some required positions in the job market Personnel list imposed by ANEM with inadequate skills Partial application of the Salary grid procedure.
R41	Partial application of the procedure.
R42	<ul style="list-style-type: none"> - Ineffective Governance Arrangements. - Personality Clashes and Disagreements. - Substandard Products and Services. - Substandard Products and Services.
R43	unmotivated human capital.

Source: Self-developed based on FMEA Analysis

In Appendix B and Appendix C, Fishbone analysis and Bowtie analysis, respectively, are conducted for each risk in each process.

3. The Impact on time cost and quality:

Table 10: Impact Scales of a Risk on Major Project Objectives

Defined Conditions for Impact Scales of a Risk on Major Project Objectives (Examples are shown for negative impacts only)					
Project Objective	Relative or numerical scales are shown				
	Very Low/.05	Low/.10	Moderate/.20	High/.40	Very high/.80
Cost	Insignificant	<10% cost increase	10-20% cost increase	20-40% cost increase	≥40% cost increase
Time	Project end item is effectively useless	<5% time increase	5-10% time increase	10-20% cost increase	≥20% Time increase
Quality	Project end item is effectively useless	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effective useless

Source: PMI (2004)

3.1 Risk probability and impact assessment:

The method of risk probability and impact assessment evaluates the likelihood of specific risks occurring and their potential impact on a project's objectives, including both positive effects for of

Risk impact assessment examines the potential impact on project objectives, such as time, cost, scope, or quality. Meanwhile, risk probability assessment evaluates the likelihood of each specific risk occurring. These assessments occur during interviews or meetings, where the level of probability for each risk and its impact on each objective are evaluated. Detailed explanations, including assumptions justifying the assigned levels, are recorded.

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The ratings for risk probabilities and impacts adhere to the definitions outlined in the risk management plan. Occasionally, risks with evidently low ratings of probability and impact may not be formally rated but are instead included on a watch-list for future monitoring.

2.3 Probability/impact risk rating matrix:

The probability and cost, quality, and time impacts, assessed previously, serve as the foundation for quantitative analysis and risk response, elaborated further in the paper. Consequently, the findings of this assessment are prioritized using various calculation methods outlined in the literature. The priority score is determined as the average of the probability and cost, quality, and time impacts. A range of priority scores, along with ratings and colors, is assigned to indicate the importance of each risk.

To establish priorities, the cost, quality, and time impacts are multiplied by the probability. The compiled results are presented in Table N, where this combination of factors reveals which risks hold low, moderate, or high priority. Regardless of the chosen calculation method, this amalgamation of data underscores the priority of previously identified risks, often denoted by corresponding colors or numerical systems, aiding in the assignment of appropriate risk responses.

For instance, threats with high cost, quality, and time impacts and likelihood are categorized as high-risk, potentially necessitating immediate responses. Conversely, threats with low priority scores can be monitored, with actions taken only when necessary.

Table 11:Probability and Impact Matrix.

0,80	0,080	0,240	0,400	0,560	0,720
0,40	0,040	0,120	0,200	0,280	0,360
0,20	0,020	0,060	0,100	0,140	0,180
0,10	0,010	0,030	0,050	0,070	0,090
0,05	0,005	0,015	0,025	0,035	0,045
IMPACT↑					
PROBABILITY→	0,1	0,3	0,5	0,7	0,9

Source: Probability and Impact Matrix (PMI, 2004)

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Table 12: Probability grid.

PROBABILITY	Very low	Low	Moderato	High	Very high
RISK A	0.1	0.3	0.5	0.7	0.9

Source: Probability and Impact Matrix (PMI, 2004)

Table 13: Evaluation results.

IDENTIFIED RISK	PROJECT	PROBABILITY	IMPACT	MATRIX
R1	Quality	0.5	0.05	0.025
	COST	0.5	0.1	0.05
	TIME	0.5	0.4	0.2
R2	QUALITY	8	0.4	0.2
	COST	0.7	0.4	0.2
	TIME	0.7	0.05	0.4
R3	QUALITY	0.5	0.05	0.035
	COST	0.5	0.2	0.14
	TIME	0.5	0.8	0.4
R4	QUALITY	0.7	0.4	0.2
	COST	0.7	0.1	0.05
	TIME	0.7	0.1	0.07
R5	QUALITY	0.1	0.05	0.035
	COST	0.1	0.05	0.035
	TIME	0.1	0.05	0.005
R6	QUALITY	0.9	0.1	0.01
	COST	0.9	0.4	0.04
	TIME	0.9	0.8	0.72
R7	QUALITY	0.5	0.8	0.72
	COST	0.5	0.2	0.18
	TIME	0.5	0.2	0.1

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R8	QUALITY	0.5	0.05	0.025
	COST	0.5	0.4	0.2
	TIME	0.5	0.8	0.4
R9	QUALITY	0.9	0.2	0.1
	COST	0.9	0.8	0.4
	TIME	0.9	0.1	0.09
R10	QUALITY	0.7	0.8	0.72
	COST	0.7	0.4	0.36
	TIME	0.7	0.2	0.14
R11	QUALITY	0.9	0.4	0.28
	COST	0.9	0.4	0.28
	TIME	0.9	0.4	0.36
R12	QUALITY	0.7	0.4	0.36
	COST	0.7	0.4	0.36
	TIME	0.7	0.4	0.28
R13	QUALITY	0.5	0.8	0.56
	COST	0.5	0.8	0.56
	TIME	0.5	0.8	0.4
R14	QUALITY	0.9	0.4	0.2
	COST	0.9	0.4	0.2
	TIME	0.9	0.2	0.18
R15	QUALITY	0.3	0.05	0.045
	COST	0.3	0.4	0.36
	TIME	0.3	0.8	0.24
R16	QUALITY	0.3	0.05	0.015
	COST	0.3	0.2	0.06
	TIME	0.3	0.2	0.06
R17	QUALITY	0.1	0.4	0.12
	COST	0.1	0.2	0.06
	TIME	0.1	0.1	0.01
R18	QUALITY	0.7	0.8	0.08

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	COST	0.7	0.8	0.08
	TIME	0.7	0.8	0.56
R19	QUALITY	0.1	0.8	0.56
	COST	0.1	0.8	0.56
	TIME	0.1	0.4	0.04
R20	QUALITY	0.9	0.8	0.08
	COST	0.9	0.4	0.04
	TIME	0.9	0.2	0.18
R21	QUALITY	0.9	0.8	0.72
	COST	0.9	0.4	0.36
	TIME	0.9	0.05	0.045
R22	QUALITY	0.7	0.8	0.72
	COST	0.7	0.05	0.045
	TIME	0.7	0.1	0.07
R23	QUALITY	0.7	0.2	0.14
	COST	0.7	0.4	0.28
	TIME	0.7	0.8	0.56
R24	TIME	0.7	0.8	0.56
	QUALITY	0.7	0.2	0.14
	COST	0.7	0.05	0.035
R25	TIME	0.7	0.4	0.28
	QUALITY	0.7	0.4	0.28
	COST	0.7	0.8	0.56
R26	TIME	0.9	0.2	0.14
	QUALITY	0.9	0.1	0.07
	COST	0.9	0.8	0.72
R27	TIME	0.7	0.1	0.09
	QUALITY	0.7	0.1	0.09
	COST	0.7	0.05	0.035
R28	TIME	0.7	0.1	0.07
	QUALITY	0.7	0.1	0.07

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	COST	0.7	0.1	0.07
R29	TIME	0.1	0.8	0.56
	QUALITY	0.1	0.8	0.56
	COST	0.1	0.8	0.08
R30	TIME	0.7	0.8	0.08
	QUALITY	0.7	0.8	0.08
	COST	0.7	0.8	0.56
R31	TIME	0.5	0.8	0.56
	QUALITY	0.5	0.4	0.28
	COST	0.5	0.4	0.2
R32	TIME	0.3	0.1	0.05
	QUALITY	0.3	0.4	0.2
	COST	0.3	0.8	0.24
R33	TIME	0.5	0.8	0.24
	QUALITY	0.5	0.8	0.24
	COST	0.5	0.8	0.4
R34	TIME	0.1	0.8	0.4
	QUALITY	0.1	0.8	0.4
	COST	0.1	0.8	0.08
R35	TIME	0.1	0.1	0.01
	QUALITY	0.1	0.1	0.01
	COST	0.1	0.05	0.005
R36	TIME	0.1	0.8	0.08
	QUALITY	0.1	0.8	0.08
	COST	0.1	0.8	0.08
R37	TIME	0.5	0.8	0.08
	QUALITY	0.5	0.4	0.04
	COST	0.5	0.2	0.1
R38	TIME	0.5	0.05	0.025
	QUALITY	0.5	0.05	0.025
	COST	0.5	0.05	0.025

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R39	TIME	0.3	0.05	0.025
	QUALITY	0.3	0.2	0.1
	COST	0.3	0.4	0.12
R40	TIME	0.1	0.2	0.06
	QUALITY	0.1	0.05	0.015
	COST	0.1	0.05	0.005
R41	QUALITY	0.1	0.05	0.005
	QUALITY	0.1	0.05	0.005
	COST	0.1	0.05	0.005
R42	TIME	0.1	0.05	0.005
	QUALITY	0.1	0.05	0.005
	COST	0.1	0.05	0.005
R43	TIME	0.1	0.05	0.005
	QUALITY	0.1	0.05	0.005
	COST	0.1	0.05	0.005
R44	TIME	0.1	0.05	0.005
	QUALITY	0.1	0.05	0.005
	COST	0.1	0.05	0.005

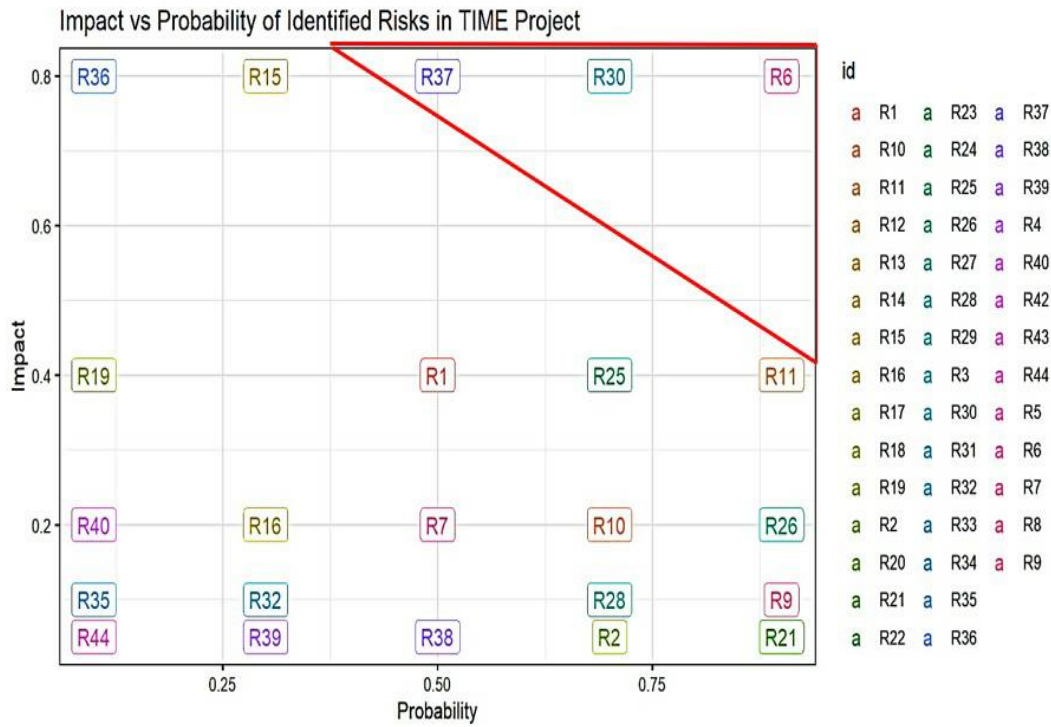
Source: Self-developed

Probability: This represents the likelihood of a risk occurring, usually on a scale from 0 to 1. For example, a probability of 0.5 means there is a 50% chance that the risk will occur.

Impact: This indicates the potential severity or consequence of the risk if it occurs, also on a scale from 0 to 1. For example, an impact of 0.1 signifies a low impact, while 0.8 signifies a high impact.

Matrix Value: This is the product of probability and impact, showing the overall risk score. It helps prioritize risks. For example, if a risk has a probability of 0.5 and an impact of 0.4, the matrix value is 0.2 (0.5 * 0.4)

Figure 8: Time matrix



Source: Self-developed

Regarding the risks identified in the interviews, some were more critical than others according to the assessment of the interviewees. In the Time case : Failure to meet delivery deadlines , Failure to control risks on work at project level and non-conformity poorly dealt with and unresolved stop points are were evaluated as high-risk problems that might occur and could cause delays in the schedule. Once they are under control, time delays can be prevented. This is one major benefit of conducting such a risk assessment; it indicates where to focus to keep the project running smoothly and maintain control.

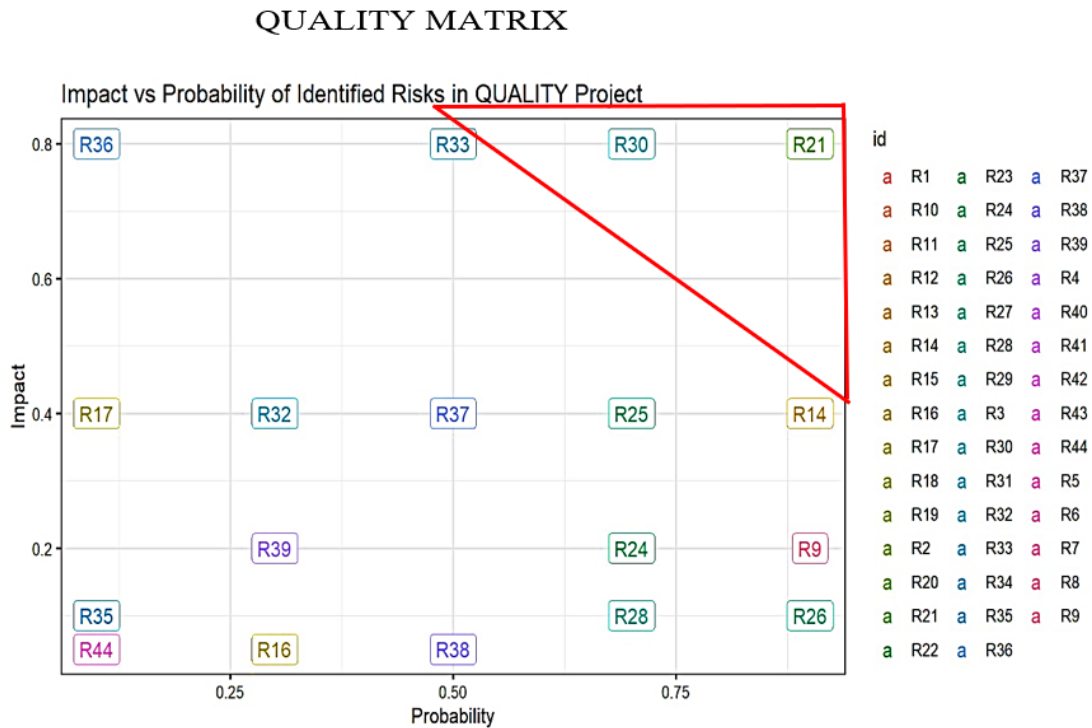
Figure 9: Cost matrix



Source: Self-developed

Critical risks affecting the cost aspect include improper equipment utilization, inadequate articulation or comprehension of project requirements, failure to manage risks at the project level, and inability to meet project management objectives. Neglecting these risks could lead to additional project costs.

Figure 10 : Quality matrix



Source: Self-developed

The risks that may challenge the project's quality include, for example, failure to properly use equipment. These mentioned risks are significant and can greatly impact the project. For instance, if equipment is not used correctly, it can negatively affect the quality, potentially leading to the project not being delivered to the client according to their requirements and expectations. Therefore, it is crucial to address these risks while they are still manageable to deliver what the client desires and meet the project objectives. This is why the three objectives - cost, time, and quality - have been examined and evaluated in this study. While there are many other risks that could arise in this project, due to limited research, only these risks in the matrices have been highlighted. The ideal scenario would involve evaluating all major and potential risks to facilitate the path to success for the project.

3 Risk treatment

After identifying the risks associated with the PW Metro M28 Algiers project, it's imperative to evaluate each risk thoroughly. This evaluation involves considering two key factors:

- A. Occurrence: This refers to how often the risk is likely to happen during the project. Assessing the occurrence helps gauge the likelihood of encountering the risk and allows for proactive measures to be implemented accordingly.
- B. Severity of Potential Damage: This aspect assesses the potential impact or harm that could result if the risk materializes. Understanding the severity allows project managers to prioritize risks based on their potential consequences and allocate resources effectively to mitigate them.

To quantify the criticality of each risk, we combine these two assessment criteria through multiplication. This method provides a comprehensive understanding of the overall impact and likelihood of each risk, enabling informed decision-making and risk management strategies throughout the project lifecycle.

$$\mathbf{RNP=SEVERITY \times OCCURRENCE}$$

The rating scales provided are as follows.

Table 14:Severity of risk values associated with an event.

Severity Levels	Quotation
Low	1
Medium	4
High	16
Very high	64

Source: evaluation grid used to consider TP

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Table 15:Severity values and definition of Occurrence of an event.

Cotation	Likelihood	Occurrence
8	Very High	From every day to once a month.
4	High	From once a month to once every 6 months.
2	Low	From once every 6 months to once a year.
1	Very Low	Less than once a year.

Source: evaluation grid for the Occurrence of occurrence used to consider TP

Risk mapping is a process to determine the probability of losses by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a threat of harm to property, people, livelihoods, and the environment on which they depend.

Risk mapping can be used to visualize and communicate specific risks an organization faces. A risk map helps companies identify and prioritize the risks associated with their business. It is often presented as a two-dimensional matrix, with likelihood of a risk occurring plotted on one axis and its potential impact on the other. Risks that fall in the high-likelihood and high-severity section are typically risks that demand attention.

Organizations can use risk maps to facilitate discussions and decision-making around risk management priorities and resource allocation. However, risk maps are not static and should be reviewed regularly as threats evolve and vulnerabilities change.

The UK government's "State-of-the-art in Risk Mapping" report provides a comprehensive overview of risk mapping approaches, including the definition of key terms like hazard, vulnerability and exposure. It also discusses the purpose and efficacy of risk mapping, as well as current best practices and future trends in the field.

Table 16:Risk Evaluation.

ID	Risk Evaluation		
	SEV	OCC	RPN
R1	1	8	8
R2	2	4	8
R3	16	2	32
R4	16	4	64
R5	4	4	16

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R6	64	2	128
R7	1	8	8
R8	16	2	32
R9	16	2	32
R10	4	8	32
R11	64	4	256
R12	16	4	64
R13	64	8	512
R14	4	1	4
R15	4	1	4
R16	4	1	4
R17	16	8	128
R18	64	1	64
R19	4	8	32
R20	64	8	512
R21	16	4	64
R22	1	4	4
R23	4	4	16
R24	2	4	8
R25	4	4	16
R26	1	4	4
R27	4	4	16
R28	4	4	16
R29	64	4	256
R30	8	16	128
R31	4	1	4
R32	4	1	4
R33	4	1	4
R34	4	1	4
R35	2	4	8
R36	4	64	256
R37	4	1	4

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R38	16	1	16
R39	64	1	64
R40	4	1	4
R41	4	1	4
R42	4	1	4
R43	2	4	8

Source: Self-developed based on FMEA Analysis

SEV (Severity): This column likely represents the severity of each risk, rated on a scale from 1 to 64. Higher numbers indicate risks that would have a more severe impact if they were to occur.

OCC (Occurrence): This column likely represents the likelihood or frequency of each risk occurring, rated on a scale from 1 to 16. Higher numbers indicate risks that are more likely to occur.

RPN (Risk Priority Number): This column represents the Risk Priority Number, which is calculated by multiplying the severity by the occurrence for each risk. The RPN helps prioritize risks for mitigation or management efforts. Higher RPN values indicate risks that are higher priority for mitigation.

For example, a risk with a severity of 16 and an occurrence of 4 would have an RPN of 64 (16 x 4 = 64), indicating that it is a higher priority risk compared to one with a lower RPN.

Table 17:RISK ASSESSMENT GRID.

c	R17 R1	R13 R10	R17 R30	R20 R13 R18
	R22 R26	R2 R4 R5 R23 R25 R27	R21	R29 R36 R11 R12
		R22 R26	R3 R8 R9 R35	R6
		R14 R15 R16 R31 R32 R33 R34 R35 R40 R41 R42 R43	R38	R39

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	Severity
--	-----------------

Source: Self-developed based on FMEA Analysis

The RPN was calculated for each combination and then prioritize them based on the RPN values.

Table 18:13Risks ordered by order of priority.

	High risk/to be controlled
	Medium risk/to be controlled
	Moderate/to Watch
	Minor/acceptable

Source: evaluation grid for the Occurrence of occurrence used to consider TP

Table 19:Risks ordered by order of priority.

Criticality type	Number of risks identified
Priority I	3
Priority II	7
Priority III	15
Priority VI	18

Source: Self-developed based on FMEA Analysis

Section 2: Risk Respond

1 Action /Means of control:

This table below(table 15) represents a comprehensive set of actions for assessing and managing risks within Cosider company, as part of my case of study. It outlines specific measures to address various risks, along with the individuals or teams responsible for each action and the frequency at which these actions should be taken. By implementing

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Table 20:Action of control.

IDEN TIFIE D RISK	Action /Means of control	The Risk Owner (s)	Deadlines/Fre quency
R1	Compliance with current regulations, regulatory watch, awareness-raising and collaboration with interested parties, with follow-up and processing of recorded complaints,	project management Team	Each complaint/complaint
R2	Anticipate, define and give value to the choice of methods (creation of a communication unit dedicated exclusively to promoting the strong points and technical and economic advantages of the methods),	project management Team	Each month
R3	Establish a strategic monitoring process through which the project listens proactively to its socio-economic and political environment in order to open windows of opportunity and reduce the risks linked to uncertainty.	project management Team	Each month
R4	Measurement of supplier performance through comparative analysis, Determination and rating of pre-selection criteria, Use of a pre-selection grid and transfer of criteria, Allocation of status and ranking of selected suppliers Establishment of a panel of approved suppliers for each type of	process pilot	Each month
R5	Include at least one new supplier to allow access to new technologies and to evaluate the market from time to time. Measure the performance of suppliers, by carrying out a comparative analysis between them. Determine and rate pre-selection criteria,	process pilot	Each month

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R6	Avoiding the use of technical specifications so that only one supplier is selected, Gathering information Objective recruitment of buyers	the General Manager and Head of the Finance process and department	On each payment date
R7	Respect payment deadlines Diversify sources of supply for each raw material Favor the closest suppliers. Look for at least two nearest sources of supply for each raw material.	Purchasing manager Stock manager and a competent person	Each delivery
R8	Expression of needs well established Selection of suppliers offering good quality, Receipt of products must be done by a competent person non-conforming product must be isolated to prevent its use.	Purchasing manager Stock manager and a competent person	Each delivery
R9	Update inventory management strategy to avoid stock-outs. Manage raw material inventories properly. Specialized training for storekeepers to manage the store properly. All departments must accurately determine monthly raw material consumption and trends.	Purchasing manager Stock manager and a competent person	Monthly
R10	Reinforce and intensify coordination meetings with MOE, Review preliminary design in sensitive areas	Technical responsible,	Yearly

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		works responsible	
R11	Rigorous follow-up and monitoring Simulation tests on the various major risks, involving the relevant stakeholders	Technical responsible, works responsible	Monthly
R12	Standardize procedures, techniques and working documents, Rigorous monitoring, carry out simulation tests on the various major risks, involving the parties concerned,	the General Manager and Head of the Finance process and department	Monthly
R13	Ensure a relevant training plan for everyone involved in the process,	all those involved in the project	Monthly
R14	Strengthen and intensify coordination meetings with customers and stakeholders	technical supervisor	Monthly
R15	Carry out simulation tests on the various major risks, with the integration of the various project stakeholders	Purchasing manager Stock manager and a competent person	Monthly
R16	A procedure for tracking changes, Designation of a competent person to manage and track changes,	the heads of department concerned	Monthly

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R17	Carry out simulation tests on the various major risks, with the integration of the various project stakeholders	The heads of department concerned.	Monthly
R18	A procedure for tracking changes, Designation of a competent person to manage and track changes,	The heads of department concerned.	Monthly
R19	Review and include a clause in the contract on the obligation of technology suppliers in terms of training and follow-up, Ensure a relevant training plan for everyone involved in the process	the heads of department concerned	Monthly
R20	A detailed traffic plan for the various worksites, Driver awareness of road risks and compliance with traffic regulations.	Stock manager	Monthly
R21	A detailed traffic plan for the various worksites, Driver awareness of road risks and compliance with traffic regulations.	the heads of department concerned	Monthly
R22	Ensure a relevant training plan for everyone involved in the process.	The heads of department concerned.	Monthly
R23	Detailed forecast planning, set up an interactive dashboard, Competent inventory management, Increase storage capacity	The heads of department concerned.	Daily
R24	Rigorous follow-up, Designation of a competent person for follow-up.	The heads of department concerned.	Monthly
R25	Reliable provisional schedules, Develop partnership relations with suppliers.	general resources responsible	Daily

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R26	Coordination between the various project players Raising staff awareness	general resources responsible	Daily
R27	Ensure the presence of an HSE officer at both sites, with daily visits by the engineers and HSE manager.	HSE Responsible	Daily
R28	"Establishment of an awareness program with daily briefings according to the work schedule.	Project Management	Daily
R29 R30	Analysis of workplace accident statistics CPHSU and management meeting OHS management programme Staff training, information and awareness HSE instructions and procedures.	Project Management	daily/ weekly/ half-yearly/ yearly
R31	Removal of reservations by taking corrective action in accordance with procedure.	HSE Responsible	Each audit
R32	THE communication	QUALITY MANAGER	Monthly
R33	Joint workplace visits, meetings and HSE inspections.	Project Management	Yearly
R34	Staff vaccination Encourage staff to comply with barrier measures both inside and outside the company.	HSE responsible	Yearly
R35	Make external service providers aware of HSE regulations and standards Make external service providers aware of HSE best practices.	HSE responsible	Yearly
R36	Coordination between the various parties involved in driving the TBM Drawing up a contract with SEAAL for the recovery of purified water.	HSE responsible	Yearly

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R37	Internal management and works meetings and with the design office Lifting of reservations and non-conformities .	Project Management	Yearly
R38	Compliance with contract clauses (deadlines, quality, HSE) Reinforce and intensify coordination meetings with different stakeholders.	Works Department	Yearly
R39	Implement regular compliance audits, enhance project management practices, conduct thorough risk assessments, improve communication, invest in technology and infrastructure, manage reputation, foster a culture of continuous improvement, and ensure legal compliance.	Project management	Yearly
R40	Preparation of a database See the possibility of COSIDER projects in the final phase for mutations.	HR Manager	Yearly
R41	Preparation of a database See the possibility of COSIDER projects in the final phase for mutations.	HR Manager	Yearly
R42	Awareness-raising and communication Installation of worksite secretaries at all sites.	HR Manager	Yearly
R43	Motivation and skills retention - Implementation of forward-looking employment and skills management.	HR Manager	Yearly

Source: Self-developed

The risk management action plan presented demonstrates a comprehensive and multifaceted approach to addressing the identified risks. After reviewing the detailed plan, key comments to share:

1. **Comprehensive Approach:** The plan covers a wide range of risks and outlines a diverse set of actions to address them. This comprehensive approach is commendable as it demonstrates a thorough risk assessment and a commitment to proactive mitigation.
2. **Stakeholder Involvement:** The plan emphasizes the importance of collaboration, coordination, and engagement with various stakeholders, including regulatory bodies,

suppliers, customers, and project team members. This collaborative approach can help build buy-in, enhance information sharing, and improve the effectiveness of the risk management efforts.

3. **Continuous Monitoring and Improvement:** The plan includes actions related to ongoing monitoring, such as regulatory watch, supplier performance measurement, and strategic environmental scanning. This reflects a recognition of the dynamic nature of risks and the need for continuous adaptation and improvement.
4. **Training and Competency Development:** The plan prioritizes training and competency development for various roles, from storekeepers to project team members. This focus on building internal capabilities is crucial for ensuring effective implementation and sustainable risk management practices.
5. **Proactive Measures:** Several actions, such as anticipating and defining the choice of methods, introducing new suppliers, and diversifying supply sources, demonstrate a proactive approach to risk management. This forward-looking mindset can help the project anticipate and adapt to emerging risks.
6. **Operational-level Details:** The plan provides a good level of detail in terms of specific actions, responsible parties, and deadlines. This granularity can facilitate clear accountability and effective execution of the risk management strategies.
7. **Potential Areas for Improvement:** While the plan is comprehensive, it could be further strengthened by incorporating more quantitative risk assessment techniques, such as risk scoring or Monte Carlo simulations, to prioritize and allocate resources more effectively. Additionally, the inclusion of contingency planning and escalation procedures could enhance the project's overall resilience.

Overall, the action plan presents a well-structured and multifaceted approach to risk management, reflecting a good understanding of the project's risk landscape and a commitment to proactive risk mitigation. Continuous monitoring, stakeholder engagement, and a focus on building internal capabilities are the key strengths of this plan.(Mustaro & Rossi, 2013)

Section 3: Discussion

To demonstrate the practical application of the RMP, it is useful to break the process down into its main components: identification, assessment, and response.

How Are Risks and Risk Management Perceived in Infrastructure Project?

1 Identification phase:

Among respondents, the most frequently used techniques to identify potential risks were past experience and discussions. This aligns with Lyons and Skitmore's (Lyons & Skitmore, 2004) research, which identified brainstorming and a case-based approach as the most popular risk identification tools. Notably, no specific time was allocated for risk management in the project, and respondents reported addressing potential risks as they emerged. This indicates that the project team did not engage in a structured risk identification process as recommended in the literature. They believed their time was better spent working on the project rather than proactively searching for problems. Risks were identified to some extent through experience, and a checklist of risks common to construction projects could be useful for future projects.

Additionally, interviews revealed that discussion was the most common method of risk identification. This method, along with brainstorming and leveraging past experience, was employed during the project's kick-off meeting, where participants identified potential threats. Although risk management practices were not formally used in the investigated project, these meetings allowed stakeholders to discuss and identify potential issues, aligning with Westland's (Paravina et al., 2006) theory that involving all stakeholders in risk planning ensures comprehensive risk identification. The timing of these meetings, held at the beginning of the planning phase, also supports Lyons and Skitmore's (Lyons & Skitmore, 2004) findings that risk management is most prevalent during the planning and execution phases.

Furthermore, the interviews highlighted a distinction between individual and group risk management practices. Individuals and their organizations typically relied on checklists and manuals, while groups preferred discussions to identify risks and issues. This finding is partly supported by (*Risk Management in Construction Project Networks*, n.d.) Who identified meetings and group discussions as effective ways of identifying and managing risks? The risk identification methods and tools that are commonly used in the construction industry were not utilized

2 Assessment phase:

One of the reasons for not using organized methods according to the respondents was the limited budget. One interviewee explained that most large infrastructure projects have a significant budget but the budget goes to construction materials, tools and personnel. The

culture of the Algerian industry plays a crucial role when it comes to project management. The technical project manager said that the company spends more time in the implementation phase than in planning, which is a negative point when it comes to overall project management and risk management; this prevents major changes or the implementation of new solutions. Furthermore, a general lack of knowledge in the area of resource management can result from limited resources such as time or money. This statement is consistent with the previously cited research by Lyons and Skidmore (Lyons & Skitmore, 2004) which suggests that lack of time is a factor that prevents organizations from implementing risk management. Furthermore, the industry is not willing to change. Only some companies are willing to implement ERM in their operations if only a tangible result will be awarded.

3 Response:

In theory, four common actions are recommended for addressing potential risks: avoidance, reduction, sharing, and acceptance. However, interviews revealed that the respondents had limited knowledge of these response strategies. Only a few participants mentioned responses that could be interpreted as risk transfer, thereby mitigating the issue. The primary tools used were discussions and checklists, indicating a lack of comprehensive knowledge in this area.

Moreover, in the case study where risks were identified by participants, mitigation emerged as the most frequently chosen action. Many respondents believed that all risks are manageable, making risk reduction the preferred strategy. This aligns with the findings of Lyons and Skitmore (2004), who also identified risk reduction as the most commonly chosen response to risks.

How Project Risk Management Impact the Golden Triangle?

Project risk management plays a crucial role in the Golden Triangle framework, which encompasses the interdependent relationship between scope, time, and cost in project management. Here's how project risk management impacts each aspect of the Golden Triangle: **Time:** Effective risk management can prevent delays in project timelines. By identifying risks that could lead to schedule slippages and implementing strategies to mitigate these risks, project managers can better adhere to project schedules. For instance, if a risk related to inclement

weather affecting construction activities is identified, project teams can adjust the project schedule accordingly or implement measures to minimize the impact of weather-related delays.

Cost: Project risk management directly impacts project costs by identifying potential cost overruns and implementing measures to mitigate them. By addressing risks that could lead to budget overruns early on, project teams can better manage project finances and ensure that the project is completed within budget constraints. For example, if a risk related to fluctuations in material prices is identified, project teams can explore options such as hedging or sourcing materials from alternative suppliers to mitigate the impact on project costs.

Quality: Quality: Effective risk management ensures that project quality standards are maintained throughout the project lifecycle. By identifying risks that could compromise the quality of deliverables and implementing appropriate mitigation strategies, project teams can uphold quality standards and meet stakeholder expectations. For example, if a risk related to the availability of skilled labor is identified, project teams can proactively address this by investing in training programs or sourcing qualified personnel to maintain the desired level of quality. Additionally, by addressing quality-related risks early on, project teams can avoid rework and costly defects, ultimately enhancing the overall quality of the project deliverables. Thus, integrating risk management practices into project planning and execution contributes to achieving and sustaining high-quality project outcomes.

4 Conclusion :

In examining risk management practices within infrastructure projects, particularly the Algiers metro construction project by COSIDER Travaux Publics, key insights emerge. The identification phase relied heavily on past experience and discussions, indicating a need for a more structured approach. While formal risk management processes were lacking, stakeholder engagement during project kick-off meetings was observed. However, limited resources and industry culture hindered organized risk assessment. Respondents showed a gap in knowledge of response strategies, highlighting a need for education and training. Project risk management's impact on the Golden Triangle framework emphasized its critical role in safeguarding project success. Despite challenges, integrating robust risk management processes into project planning and execution is crucial for mitigating uncertainties and enhancing resilience.

GENERAL CONCLUSION

GENERAL CONCLUSION

The study delves into the perceptions and practices of risk management within the construction industry, with a particular focus on the Algiers metro construction project undertaken by COSIDER Travaux Publics. Despite the ubiquitous presence of risk in construction endeavors, the understanding and formal application of risk management processes often fall short of theoretical ideals. Through semi-structured interviews and on-site observations, the study uncovers insights into how risks are perceived, managed, and the willingness of industry professionals to embrace structured risk management processes (RMP). The findings suggest a gap between theoretical concepts and practical application, with an emphasis on the need for profitability and simplicity in risk management practices. Additionally, the study identifies key suggestions for enhancing risk management within construction projects, along with acknowledging inherent limitations and proposing avenues for future research and extension.

1 Main obtained results:

- Risk is considered a negative concept, although in theory it can have two dimensions.
- Construction industry professionals use techniques described in RM literature, but they are not aware of them. Risk is managed every day in industry, but it is not structured in the way described in the literature. As other researchers have also confirmed, although the concept of risk management is becoming increasingly popular in the construction sector, the understanding of RM and RMP is close to zero.
- Respondents are willing to start using RMP, but it must be profitable for the organization.
- By applying simple methods, potential risks can be easily identified. Additionally, it provides the opportunity to determine which of the identified risks have the greatest impact on time, cost and quality. These risks should be eliminated or reduced through appropriate measures. The most common measures taken were risk reduction, the study found. Furthermore, it has been demonstrated that the results of probability and impact methods may vary from project to project because each project and its scope are unique.

2 Suggestions:

1. **Establish Formal Risk Management Processes:** Create structured procedures for identifying, assessing, and responding to risks.

GENERAL CONCLUSION

2. **Invest in Training:** Provide comprehensive training to project teams to enhance their understanding of risk management.
3. **Allocate Adequate Resources:** Ensure that sufficient time and budget are allocated for effective risk management activities.
4. **Promote Risk Awareness:** Foster a culture where everyone is encouraged to actively identify and communicate risks.
5. **Utilize Technology:** Explore the use of specialized software to streamline risk management processes.
6. **Continuous Improvement:** Regularly review past projects to identify areas for improvement in risk management practices.
7. **By implementing these steps, Cosider Company can strengthen its risk management practices and improve project outcomes.**

3 Limits:

Despite rigorous efforts to ensure the comprehensiveness and accuracy of this research, several limitations should be acknowledged:

1. **Limited Geographical Scope:** The study focused exclusively on the Algiers metro construction project. While this project serves as a relevant case study, the findings cannot be generalized to all infrastructure projects without further analysis.
2. **Subjectivity of Perceptions:** The semi-structured interviews relied on the subjective perceptions and experiences of the participants. While this approach is essential for understanding risk management practices, it is recognized that it can be influenced by individual biases.
3. **Limited Observation Period:** On-site observations, though insightful, were conducted over a relatively short period. A longitudinal study would allow for a more comprehensive analysis of the evolution of risk management practices throughout the project.
4. **Partial Consideration of Contextual Factors:** Although efforts were made to understand the organizational and regulatory context, other elements such as political, social, or cultural aspects could only be partially integrated into the analysis.
5. **Language Barrier:** The language of the study was not the working language of the company, necessitating numerous translations of research documents, which could have led to misinterpretations.

6. **Time Constraints:** The internship period was not sufficient for a comprehensive study of all strategic risks, limiting the scope of the analysis.

4 Possible extensions of the research:

1. **Comparative Analysis:** Conduct a comparative study to analyze how different industries manage risks and explore the transferability of risk management practices from one sector to another.
2. **Longitudinal Study:** Conduct a longitudinal study to track the evolution of risk management practices within the construction industry over time, identifying trends and changes in attitudes and approaches.
3. **Case Studies:** Conduct in-depth case studies of specific construction projects to analyze the practical application of risk management techniques, identifying success factors and challenges encountered.
4. **Cultural Impact:** Investigate the cultural factors influencing risk management practices within construction companies, exploring how organizational culture affects risk perception and management strategies.
5. **Stakeholder Perspectives:** Explore the perspectives of various stakeholders involved in construction projects, including contractors, subcontractors, clients, and regulatory authorities, to gain insights into their roles in risk management and potential areas for collaboration and improvement.
6. **Integration of Sustainability:** Investigate the integration of sustainability considerations into risk management practices within the construction industry, examining how environmental, social, and governance (ESG) factors impact risk assessment and mitigation strategies.
7. **Advanced Risk Assessment Techniques:** Explore the use of advanced risk assessment techniques, such as probabilistic risk assessment (PRA) or Monte Carlo simulation, to enhance the accuracy and reliability of risk analysis in construction projects.
8. **Emerging Technologies:** Investigate the potential impact of emerging technologies, such as Building Information Modeling (BIM), drones, and artificial intelligence (AI), on risk management practices within the construction industry, identifying opportunities for innovation and efficiency gains.

By pursuing these extensions, researchers can deepen their understanding of risk management in the construction industry and identify new avenues for improving practices and outcomes.

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APPENDIX

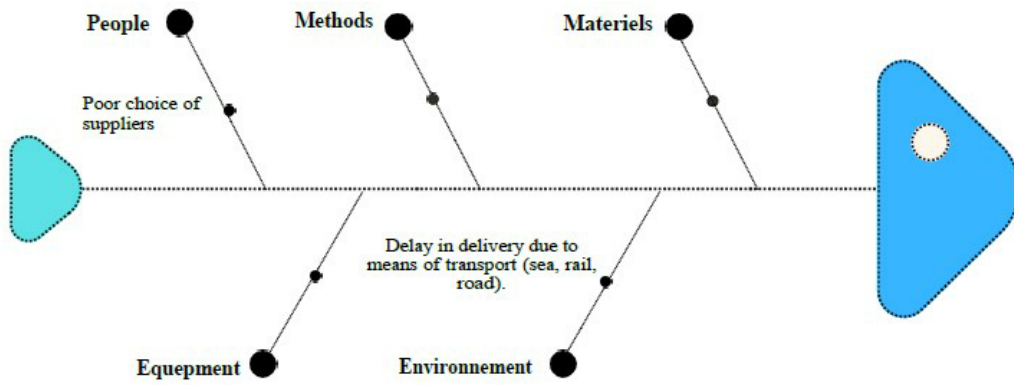
APPENDIX A: THE INTERVIEW GUIDE

	<p>Interview Guide</p>	
<p>Theme: Risk Management in Infrastructure Projects - Case Study: Cosider Company ((Algiers Metro)</p>		
<p>Interview Date : The simple :</p>		<p>Position held :</p>
<p>Objectifs : I am a Master's student in Entrepreneurship and Project Management at the National Higher School of Management -Kolea- , Thank you for agreeing to participate in this interview. The purpose of this interview is to explore the role of risk management in infrastructure projects, specifically focusing on the Algiers Metro project undertaken by Cosider Company. Your insights are invaluable to our research.</p>		
<p>General information:</p> <ol style="list-style-type: none"> 1. Can you please provide a brief overview of you and your role and responsibilities in the Algiers Metro project? <p>Information on the Algires Metro project: Could you tell us about the Algires Mtro project and its objectives?</p> <p>Overview of the main risks :</p> <ol style="list-style-type: none"> 1. Could you discuss potential risks that you are aware of and have encountered in this project? 2. Can you provide examples of how risk management practices have influenced the project's schedule and deadlines or cost overruns or quality-related ? 3. How often can we find them? 4. How does the utilization of tunnel boring machines (TBMs) contribute to the overall risk management framework of the construction project?" 5. . Are there any best practices or strategies that you believe contributed to the effective management of risks in this project? 6. Are there any aspects of risk management that you believe could have been improved or implemented differently in the Algiers Metro project? 7. Do you have any comments or suggestions? 		

APPENDIX B: FISHBONE DIAGRAM

Laws and regulations

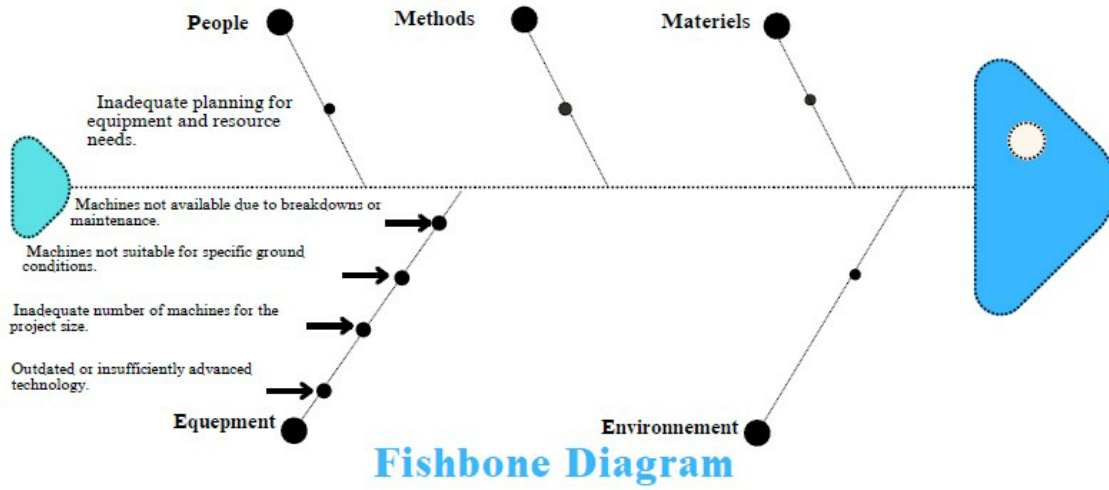
Failure to meet delivery deadlines



Fishbone Diagram

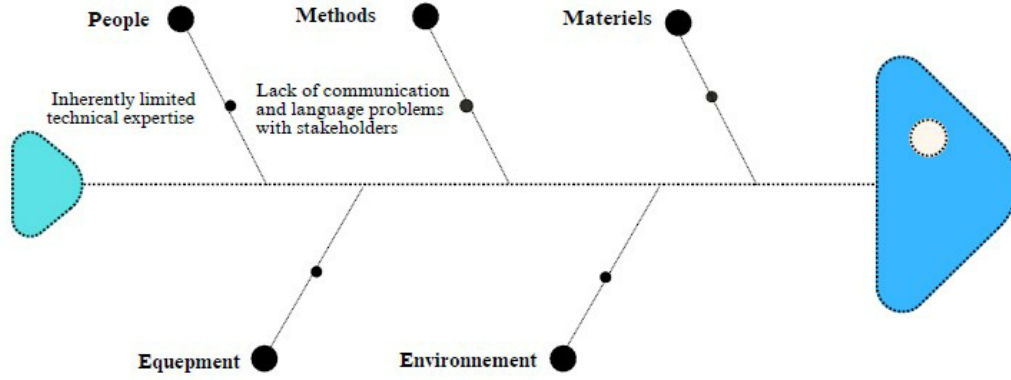
Material management

Lack of equipment and resources



Technical, design and planning

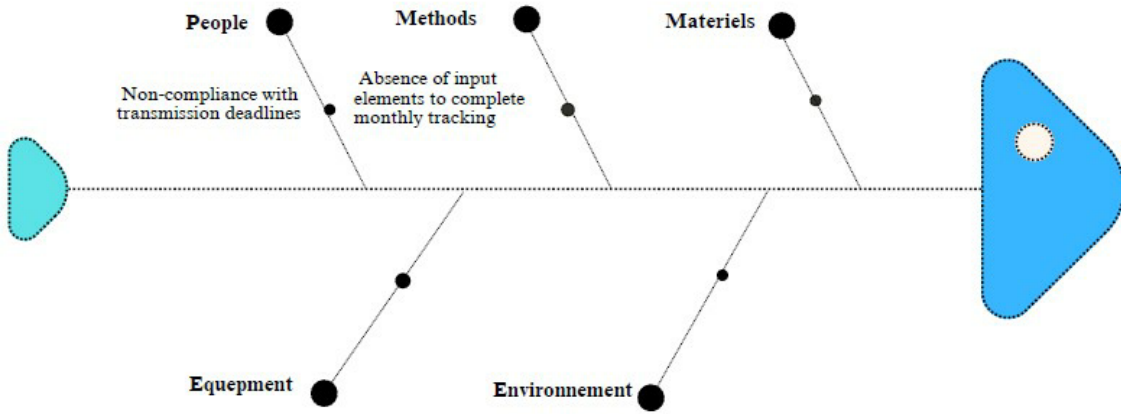
Contractual conflict with the owner and the contractor



Fishbone Diagram

Health, Safety and Environment

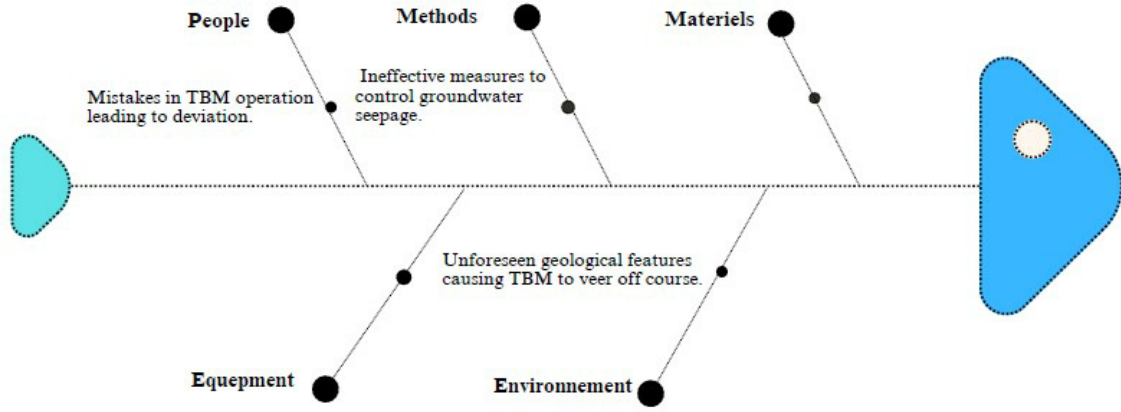
Failure to transmit information on time



Fishbone Diagram

Works

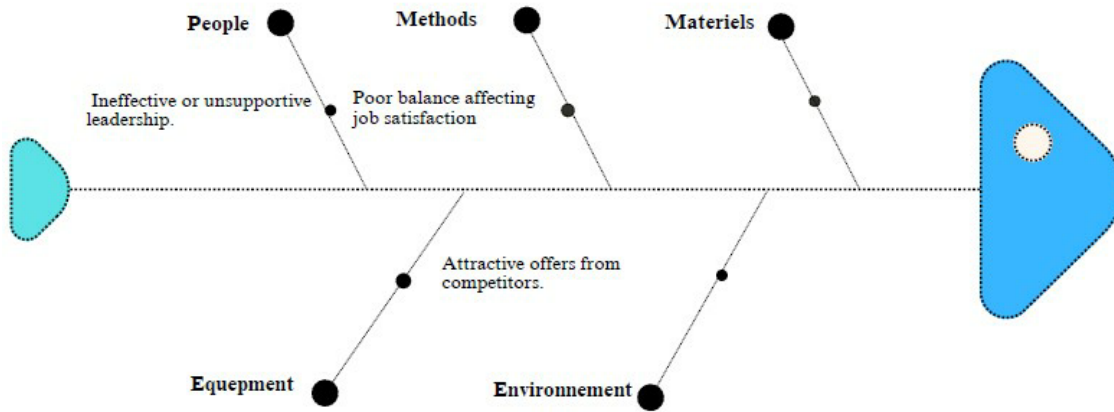
Failure to transmit information on time



Fishbone Diagram

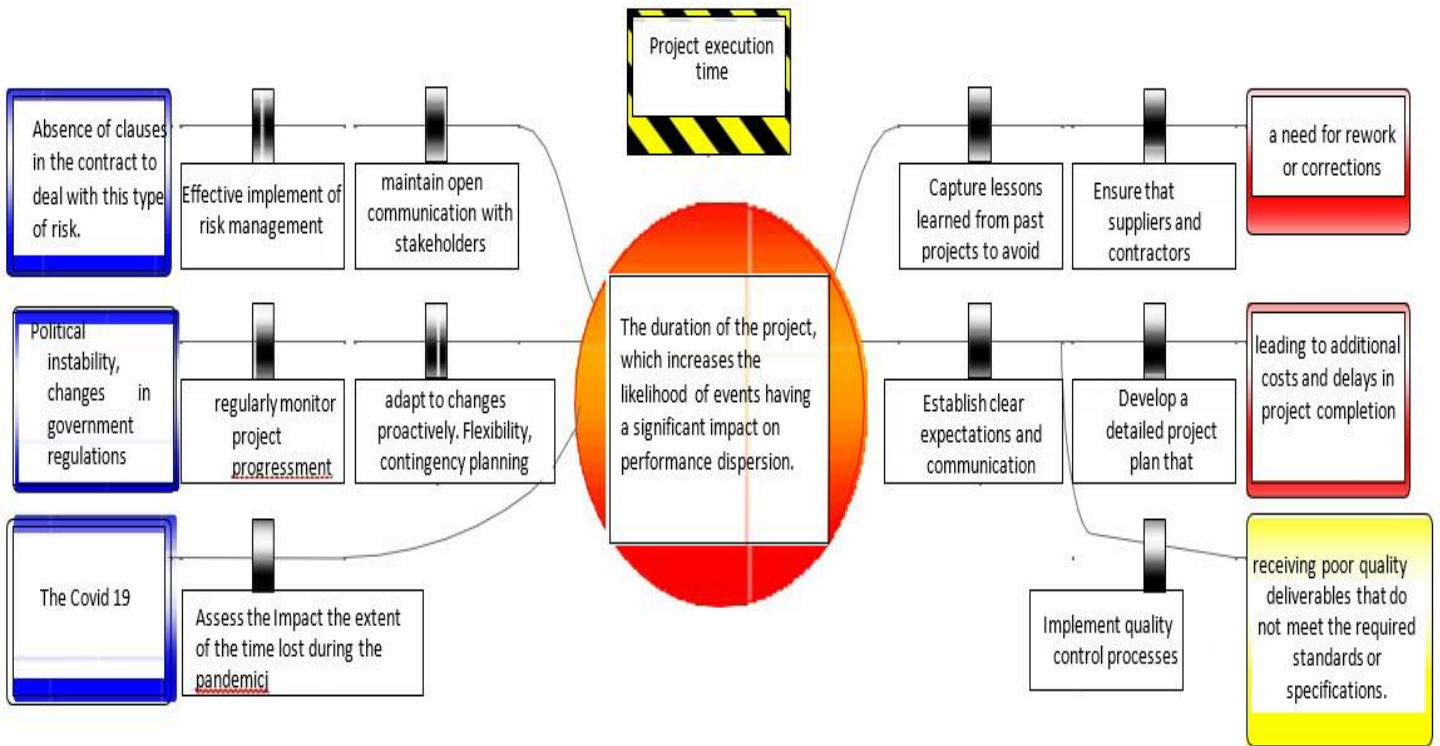
Human Resource Management

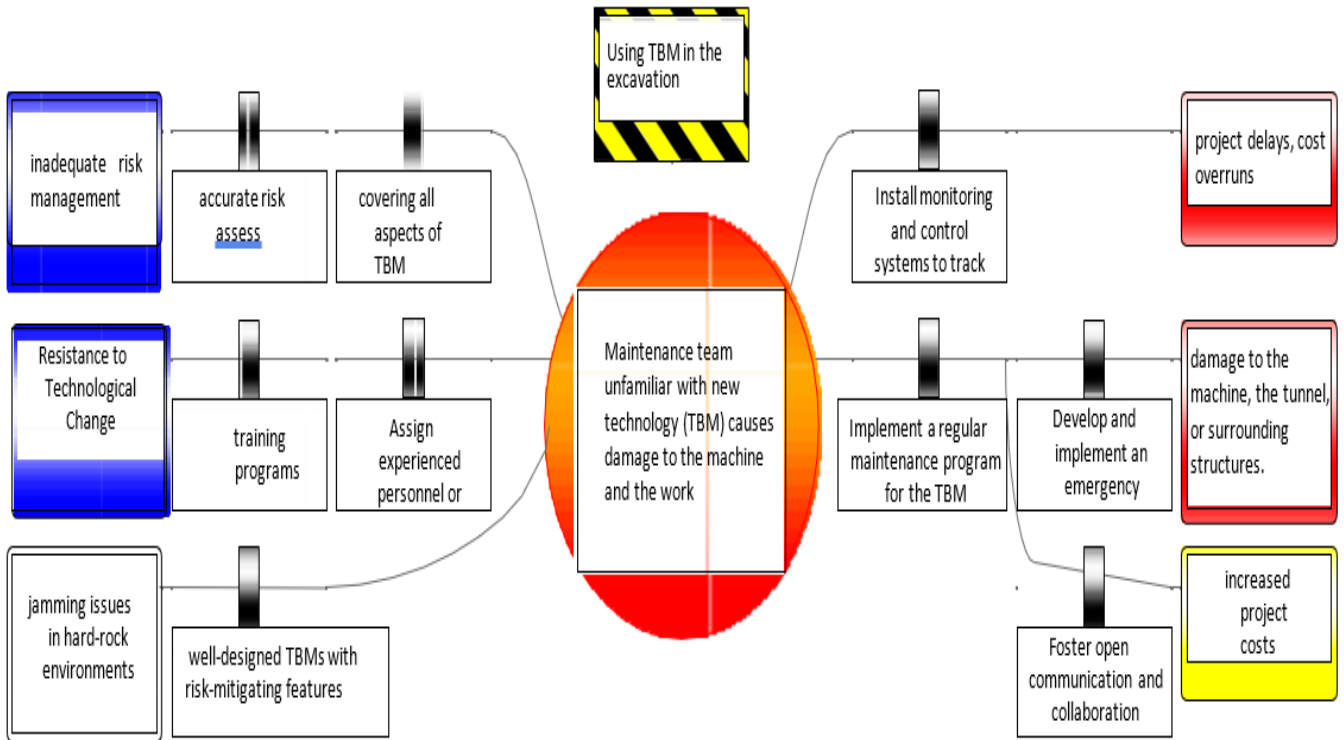
Escape of brains and skills



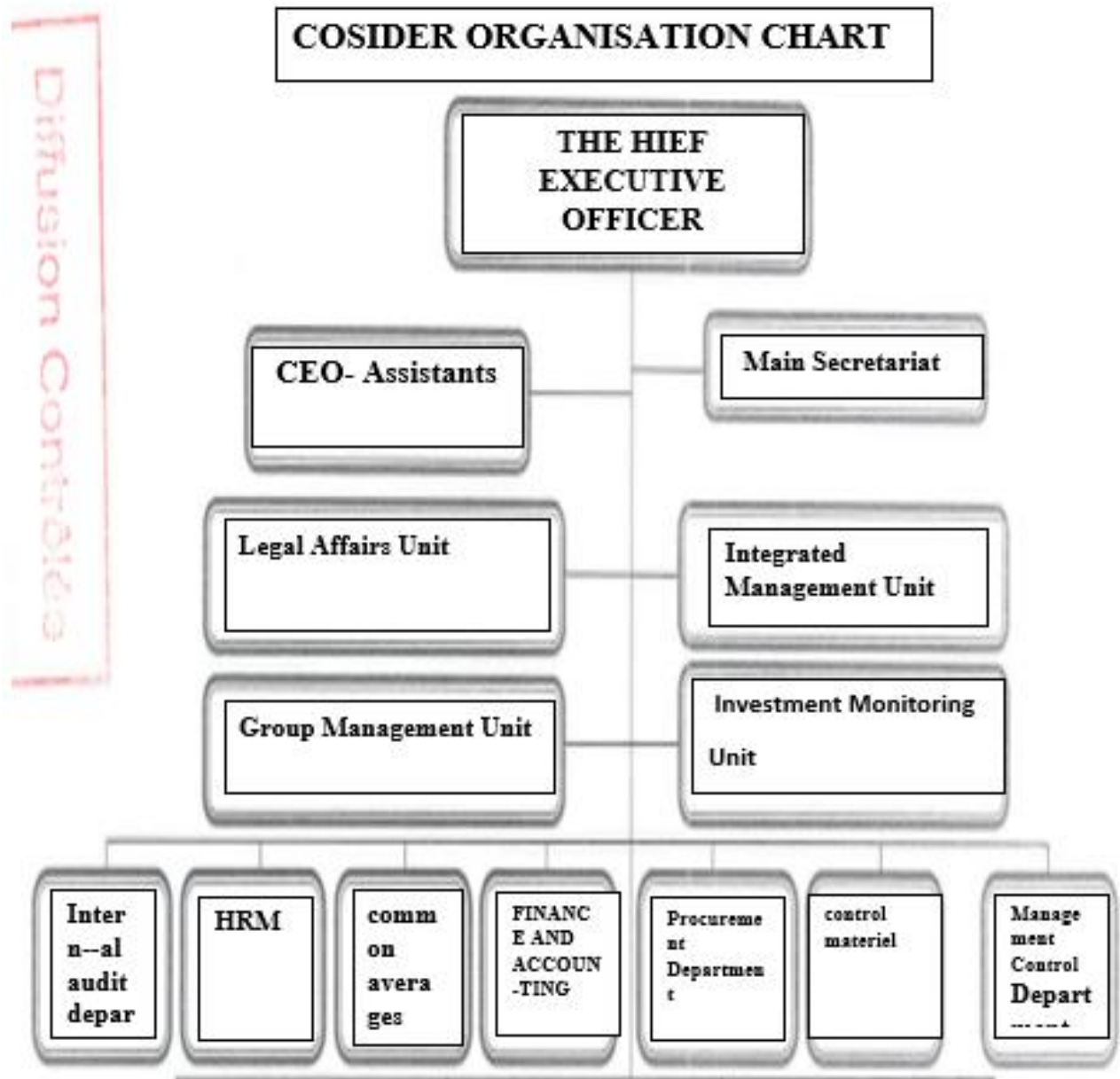
Fishbone Diagram

APPENDIX C: THE BOWTIE DIAGRAM

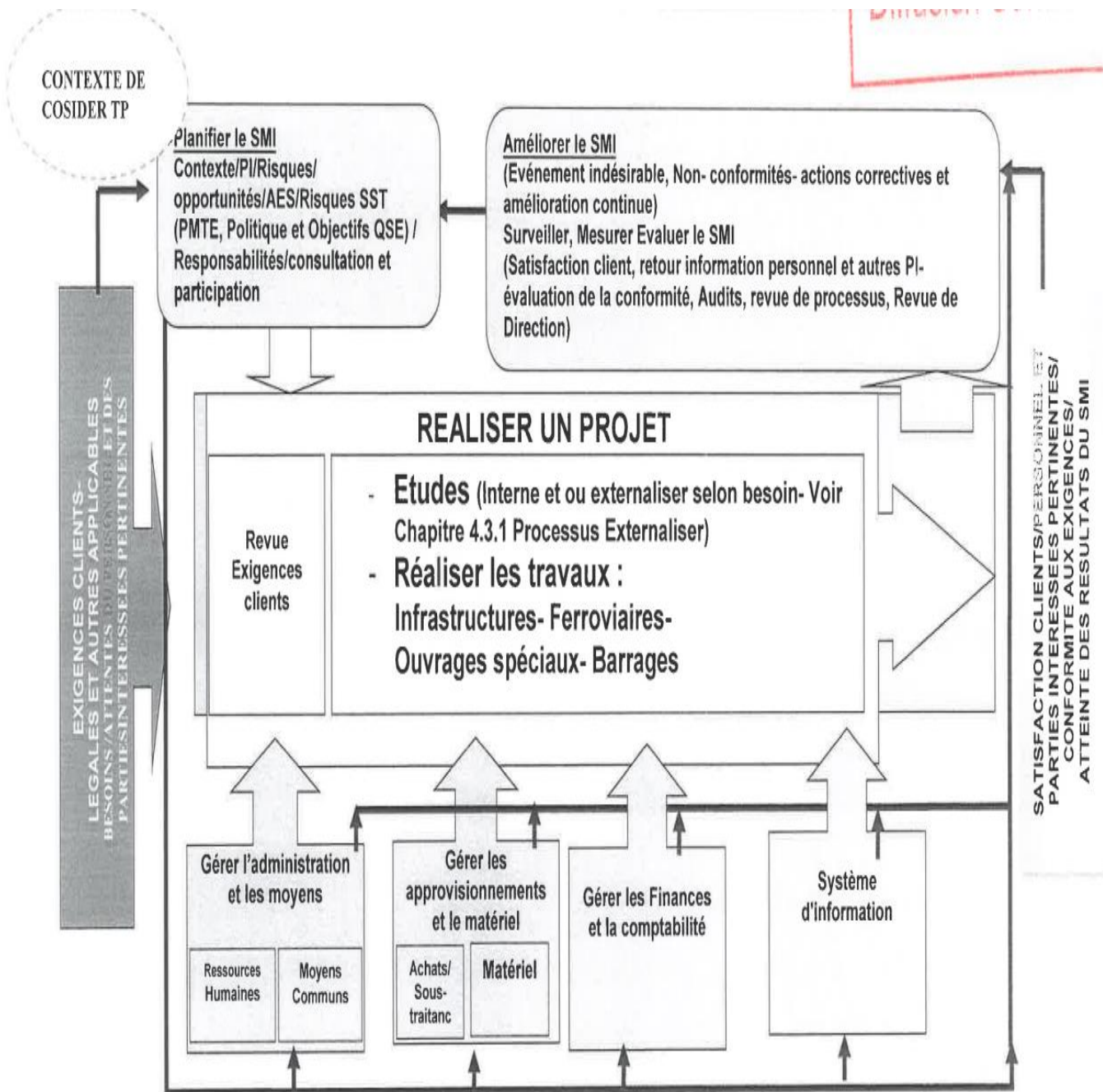




APPENDIX E: M28 Project Diagram Chart



APPENDIXE: CosiderTPDiagramchart



APPENDIX

APPENDIX F: FMEA Analysis



Table of Risk Assessment

Version R0

Date Last Updates: 28 Mars 2024

The Process Type	Risk ID	Risks	Cause (s)	Impact	The Risk Owner (s)	Risk Evaluation			Action/Mean of control	Deadlines /Frequency	Indicators	Advanceme
						SE	VO	CRPN				
	R1	Restrictive legislation (site safety, new regulations, laws, standards, taxes).	Non-compliance with applicable laws and standards.	I-1	project management Team	1	8	8	Compliance with current regulations, regulatory watch, awareness-raising and collaboration with interested parties, with follow-up and processing of recorded complaints	Each complain t/complain t	Number of complaints	0%
	R2	Lack of flexibility in current markets and contracts with customers	Failure to take into account the strengths and technical and economic advantages of the methods).	I-1	project management Team	2	4	8	Anticipate, define and give value to the choice of methods (creation of a communication unit dedicated exclusively to promoting the strong points and technical and			
	R3	Politicization of projects in terms of deadlines	pricing conditions,	I-1 I-2	project management Team	16	2	32	Establish a strategic monitoring process through which the project listens proactively to its socio-economic and political environment in order to open windows of opportunity and reduce the risks linked to uncertainty.			

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Laws and regulations	R4	Pre-screening of unsuitable suppliers	Poor definition of supplier pre-selection criteria, Absence of a periodic review of supplier files, Absence of challenge between existing and new suppliers who can provide new solutions and pricing conditions, Lack of knowledge of key suppliers, Choice of incomparable suppliers collusion with	I-1	process pilot	4	4	16	Measurement of supplier performance through comparative analysis, Determination and rating of pre-selection criteria, Use of a pre-selection grid and transfer of criteria, Allocation of status and ranking of selected suppliers Establishment of a panel of approved suppliers for each type of	each month	Supplier service rate Supplier panel Number of supplier complaints. Provider performance New suppliers Provider turnover
			Setting the price in relation to the previously established price without reference to the market price	I-1 I-2 I-3		16	4	64	Include at least one new supplier to allow access to new technologies and to evaluate the market from time to time. Measure the performance of suppliers, by carrying out a comparative analysis between them. Determine and rate pre-selection criteria,		
90%											

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Laws	R5	Non-compliance with contractual clause and inadequate call for tenders	Drafting of technical specifications so that only one supplier is selected Absence of certain important elements in the tender	I-1 I-2 I-3		4	4	16	Avoiding the use of technical specifications so that only one supplier is selected, Gathering information Objective recruitment of buyers			
	R6	Failure to meet delivery deadlines	Indebtedness to certain suppliers. Delay in delivery due to means of transport (sea, rail, road). due to congestion at the port of transition. due to	I-1 I-2 I-3	the General Manager and Head of the Finance process and department	64	2	128	Respect payment deadlines Diversify sources of supply for each raw material Favour the closest suppliers. Look for at least two nearest sources of supply for each raw material	On each payment date	On-time delivery	70%
	R7	Non-conforming product	Product poorly received Poor understanding of specifications or expression of needs, Selection of suppliers offering poor quality	I-1 I-3	Purchasing manager Stock manager and a competent person	1	8	8	Expression of needs well established Selection of suppliers offering good quality. Receipt of products must be done by a competent person Non-conforming product must be isolated to prevent its use.	Each delivery	Number of downgraded products / Number of products Cost of non-compliant products / Total cost of products	65%
	R8	Shortage of raw materials	Exhaustion of existing safety stock before the next entry. Depletion of market stock. Insufficient stock management strategy. Poor stock management. Staff incompetence. Inadequate distribution	I-1 I-2 I-3		16	2	32	Update inventory management strategy to avoid stock-outs. Manage raw material inventories properly. Specialized training for storekeepers to manage the store properly. All departments must accurately determine monthly raw material consumption and trends.			

APPENDIX

Law	R5	Non-compliance with contractual clause and inadequate call for tenders	Drafting of technical specifications so that only one supplier is selected Absence of certain important elements in the tender documents (supplier's response time to the indebtedness to certain suppliers.	I-1 I-2 I-3		4	4	16	Avoiding the use of technical specifications so that only one supplier is selected, Gathering information Objective recruitment of buyers			
	R6	Failure to meet delivery deadlines	Delay in delivery due to means of transport (sea, rail, road), due to congestion at the port of transition, due to weather conditions Long delivery times	I-1 I-2 I-3	the General Manager and Head of the Finance process and department	64	2	128	Respect payment deadlines Diversify sources of supply for each raw material Favour the closest suppliers. Look for at least two nearest sources of supply for each raw material.	On each payment date	On-time delivery	70%
	R7	Non-conforming product	Product poorly received Poor understanding of specifications or expression of needs, Selection of suppliers offering poor quality	I-1 I-3	Purchasing manager Stock manager and a competent person	1	8	8	Expression of needs well established Selection of suppliers offering good quality, Receipt of products must be done by a competent person Non-conforming product must be isolated to prevent its use.	Each delivery	Number of downgraded products / Number of products Cost of non-compliant products / Total cost of products	65%
	R8	Shortage of raw materials	Exhaustion of existing safety stock before the next entry. Depletion of market stock. Insufficient stock management strategy. Poor stock management. Staff incompetence. Inadequate distribution of tasks in the process.	I-1 I-2 I-3		16	2	32	Update inventory management strategy to avoid stock-outs. Manage raw material inventories properly. Specialized training for storekeepers to manage the store properly. All departments must accurately determine monthly raw material consumption and trends.			

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R9	Raw materials prices are rising and contract prices established in 2013 are depreciating Continued depreciation of the Algerian dinar Austerity plans since 2014 Difficult budgetary situation Finance law and halt to imports of several	Country's economic crisis	I-1	Gestionnaire de stock	16	2	32	Update inventory management strategy to avoid stock-outs. Manage raw material inventories properly. Specialized training for storekeepers to manage the store properly. All departments must accurately determine monthly raw material consumption and trends.	Each day	Coefficient or Inventory turnover rate (total demand / average inventory) Rate of requirement coverage; (average inventory / average demand)	65%
			I-2								
R10	Inherently limited technical expertise Limited pre-project study, Incomplete geotechnical survey	Partial mastery	I-3	Technical responsible, works responsible	4	8	32	Reinforce and intensify coordination meetings with MOE, Review preliminary design in sensitive areas			0%
R11	The complex geological nature of the site (risk of collapse, landslides, subsidence, etc.) The proximity of the sites to red-listed buildings or high-rise buildings The almost immediate proximity to a disadvantaged population (risk of theft, physical aggression and trespassing)	Geological nature of the soil	I-1	Technical responsible, works responsible	64	4	32	Rigorous follow-up and monitoring Simulation tests on the various major risks, involving the relevant stakeholders			0%
			I-2								
			I-3								

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ical, design and planning	R12	Dynamic system strongly influenced by the environment (soil, meteorology, geology, hydrogeology, etc.)	The trace of the project is located in a mountainous area, Natural constraints	I-1	Raising staff and stakeholder awareness	16	4	64	Standardize procedures, techniques and working documents, Rigorous monitoring, Carry out simulation tests on the various major risks, involving the parties concerned,				70%
				I-2									
				I-3									
	R13	The duration of the project, which increases the likelihood of events having a significant impact on performance	Absence of clauses in the contract to deal with this type of risk,	I-1	all those involved in the project	64	8	512					
	I-2												
	I-3												
	R14	Human errors and may result from inappropriate decisions, insufficient	Lack of relevant management training, Pressure and workload, Communication problem with MOE	I-1	technical supervisor	4	1	4	Ensure a relevant training plan for everyone involved in the process,				65%
	I-2												
	I-3												

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Techn	R15	Tracking of changes (deadlines, tasks, budget) absent or ineffective	The company's specific organization	I-1	the heads of department concerned	4	1	4	Strengthen and intensify coordination meetings with customers and stakeholders			90%
				I-2								
				I-3								
	R16	Contractual conflict with the owner and the contractor	Lack of communication and language problems with stakeholders , Inherently limited technical expertise	I-1	the heads of department concerned	4	1	4	Strengthen and intensify coordination meetings with colaborators Write letters and make requests on behalf of the customer			90%
				I-2								
				I-3								
	R17	Incorrect assessment of estimate by the project owner during the feasibility phase (delayed approval of plans, failure to approve technically feasible plans)	Natural risk	I-1	the heads of department concerned	16	8	128	Carry out simulation tests on the various major risks, with the integration of the various project stakeholders			90%
				I-2								
				I-3								
	R18	Force majeure	Inherently limited technical expertise	I-1	the heads of department concerned	64	1	64	A procedure for tracking changes, Designation of a competent person to manage and track changes,			90%
				I-2								
				I-3								

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Operational management	R19	The location of the project in a city with a very congested and narrow traffic network, poor quality and degradation of the roads.	Locating the project in the capital	I-3		4	8	32	Review and include a clause in the contract on the obligation of technology suppliers in terms of training and follow-up. Ensure a relevant training plan for everyone involved in the process			85%
	R20	Maintenance team unfamiliar with new technology (TBM)	Absence et manque de formation pertinente, Absence des clauses dans les contrats d'achat sur l'obligation de propriétaire de la technologie sur le volet formation et transfert du savoir faire	I-1 I-2 I-3		64	8	512	A detailed traffic plan for the various worksites, Driver awareness of road risks and compliance with traffic regulations.			85%
	R21	Failure to properly use equipment	Fault and lack of foresight in the long term, The Finance Act and the importation shutdown	I-2 I-3		16	4	64	A detailed traffic plan for the various worksites, Driver awareness of road risks and compliance with traffic regulations.			100%
	R22	Insufficient experience, lack of knowledge and/or skills	Lack of relevant training	I-2 I-3		1	4	4	Ensure a relevant training plan for everyone involved in the process,	Monthly	Nombre de formation par mois	In progress

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Mater	R23	Lack and restocking of spare parts	Lack of rigorous follow-up	I-3	The department heads concerned	4	4	16	Detailed forecast planning, Set up an interactive dashboard, Competent inventory management, Increase storage capacity	Daily	Number of stock-outs per month	In progress
	R24	Non-compliant equipment (no certificate of conformity, technical safety inspection)	Lack of rigorous follow-up	I-1			2	4	8	Rigorous follow-up, Designation of a competent person for follow-up,	Monthly	zero reclamation et non-conformite
				I-2								
				I-3								
	R25	Lack of equipment and resources	Unavailable on the national market (finance law) Lack of forward planning	I-1	general resources responsible	4	4	16	Reliable provisional schedules, Develop partnership relations with suppliers	Monthly	Satisfaction with equipment and materials	In progress
				I-2								
				I-3								
	R26	Poor expression or understanding of the need	Poor expression or understanding of the need	I-1		1	4	4	Coordination between the various project players Raising staff awareness	Daily	Offer or prospect success rate	In progress
	I-2											
	I-3											
	R27	Inspections not carried out	Lack of means to monitor and carry out HSE activities	I-3	HSE	4	4	16	Ensure the presence of an HSE officer at both sites, with daily visits by the engineers and HSE manager.	Daily		
		Failure to carry out	Partial application of the						Establishment of an awareness program with daily briefings according to the work			80%

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HSE	R28	Failure to carry out awareness and induction sessions for new recruits	Partial application of the procedure	I-2		4	4	16	Establishment of an awareness program with daily briefings according to the work schedule	Daily		85%
	R29	Missed target (Severity & Frequency)	Non-compliance with HSE regulations	I-1 I-2 I-3	Project Management	64	4	88	Analyse des statistiques des accidents de travail CPHSU et réunion de management Programme de management SST Formations, informations et sensibilisations du personnel Instructions et procédures HSE	daily/ weekly/ half-yearly/ yearly	zero accidents and incidents	80%
	R30	Failure to control risks on work at project level	Lack of effective corrective action / Partial application of the accident/incident investigation procedure	I-1 I-2 I-3		8	16	128				
	R31	Failure to monitor the various non-conformities recorded	Partial application of the procedure	I-1 I-2 I-3		HSE	4	1				
	R32	Failure to transmit information on time	Non-compliance with transmission deadlines Absence of input elements to complete monthly tracking	I-1 I-2 I-3	QUALITY MANAGER	4	1	4	la communication	Monthly	Zero complaints	In progress
	R33	Failure to achieve PM objectives	Non-implementation of SST/MS actions Lack of resources Failure to allocate the necessary	I-1 I-2 I-3	Project Management	4	1	4	Joint workplace visits, meetings and HSE inspections	Yearly	Actions to be taken/ Actions to be planned	In progress

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	R33	Failure to achieve PM objectives	Non-implementation of SSTAES actions	I-1	Project Management	4	1	4	Joint workplace visits, meetings and HSE inspections	Yearly	Actions to be taken/ Actions to be planned	In progress
			Lack of resources	I-2								
			Failure to allocate the necessary budget to DHS/HEA	I-3								
	R34	Lack of staff following sick leave (covid 19)	Staff vaccination Encourage staff to comply with barrier measures both inside and outside the company.	I-1		4	1	4				
				I-2								
				I-3								
	R35	Non-compliance with HSE regulations by external service providers (service provider, partner,	Partial mastery of HSE	I-1		2	4	8	Make external service providers aware of HSE regulations and standards Make external service providers aware of HSE best practices	Project Director / HSE Manager	Continuous	0%
				I-2								
				I-3								
R36	Deviation of the TBM from its route Emergence of the TBM in groundwater The need for huge quantities of water for the TRM	Geological nature of the terrain System failure	I-1		4	64	##	Coordination between the various parties involved in driving the TBM Drawing up a contract with SEAAL for the recovery of purified water				
			I-2									
			I-3									

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Works	R37	non-conformity poorly dealt with and unresolved stop points	Partial application of the procedure	I-1	HSE	4	1	4	Internal management and works meetings and with the design office Lifting of reservations and non-conformities	No. of stop points registered/ No. of stop points surveyed
				I-2						
				I-3						
				100%						
R38	Appearance of competition, overlap of work with other companies, bureaucracy on the part of certain interested parties (Expropriation problems, issuing of permits, etc.) Political and socio-economic context in	Non-compliance with contractual requirements Tough competition between companies	Works Department	I-1	16	1	16	Compliance with contract clauses (deadlines, quality, HSE) Reinforce and intensify coordination meetings with different stakeholders,		
				I-2						
				I-3						

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HRM	R39	Penalties for non-compliance with regulations, -Delay in work completion -Material and human damage, -Company image.	Failure to comply with applicable regulations,	I-2	Project management	64	1	64	implement regular compliance audits, enhance project management practices, conduct thorough risk assessments, improve communication, invest in technology and infrastructure, manage reputation, foster a culture of continuous improvement, and ensure legal compliance.		
			-Failure to apply the								
	R40	Unsatisfied recruitment requests	Lack of some required positions in the job market Personnel list imposed by ANEM with inadequate skills Partial application of the Salary	I-1 I-2 I-3	HR Manager	4	1	4	Preparation of a database See the possibility of COSIDER projects in the final phase for mutations	Request satisfaction rate	In progress
	R41	Judicial monitoring	Partial application of the procedure	I-1 I-2 I-3		4	1	4			In progress
	R42	Conflicts/strikes Employee complaints	Partial application of the procedure	I-1 I-2 I-3		4	1	4	Awareness-raising and communication Installation of worksite secretaries at all sites	Employee satisfaction	In progress
R43	escape of brains and skills		I-1 I-2 I-3	2		4	8	"Motivation and skills retention - implementation of forward-looking employment and skills management".	Employee satisfaction	In progress	

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