# MANAGING THE SUPPLY CHAIN RISKS WITHIN THE CONSTRUCTION INDUSTRY OF AFRICA'S TOP THREE PERFORMING GDP NATIONS

**RESEARCH REPORT**


Submitted By

**Robert Hardham**

**1647136**

Supervisor

**Sabrina Chatur**


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**INDIVIDUAL DECLARATION WITH TASK SUBMITTED FOR ASSESSMENT**

I ***Robert Hardham*** student number ***1647136*** am registered for ***MECN7018A/ Research Report*** in the year 2021/2022

I herewith submit the following task:

***Managing The Supply Chain Risks Within the Construction Industry of Africa's Top Three Performing GDP Nations***

in partial fulfillment or full fulfillment of the requirements of the above course.

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## Abstract

The management of construction supply chain risks in Africa's top three performing GDP nations is vitally important in the mitigation of inefficient operations, schedule delays, and cost overruns during construction projects. The identification and implementation of mitigation operations, and processes, must be vastly researched and successfully implemented to mitigate construction wastes and inefficiencies. Given this, the supply chain risks, and the relevant impacts, need to be identified and investigated. Furthermore, the mitigation strategies and technologies are investigated in the attempt to mitigate or lessen the impact of the identified construction supply chain risks.

The study conducted research through a mixed methodology, followed by the collection and systematic review of published literature, before being coded into the identified key themes from the literature available. The frequency, severity and importance of the risk, and impacts, were determined using various indices. The results obtained showed that the impact of the construction supply chain risks were significant with regards to their cost and scheduling attributes. The risks and delays mainly stemmed from the lack of management, capable expertise, and financial restrictions. Furthermore, the correct implementation of mitigation strategies and technology could further reduce construction supply chain wastes and inefficiencies.

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## NOMENCLATURE

AR - Augmented Reality

BIM - Building Information Modelling

CRQ - Critical research question

ERP - Electronic Resource Planner

GDP - Gross Domestic Product

GIS - Geographical Information Systems

IoT- Internet of Things

MIS - Management Information Systems

PS - Project Specific

VR - Virtual Reality

# CHAPTER 1

# 1. INTRODUCTION

## 1.1 Background

The construction industry is vitally important to all industries around the world. The construction industry is a major contributor to all economies as it supports economic growth and is used as a tool to support economic objectives (Oyegoke & Al Kiyumi, 2017). However, the construction industry has been faced with criticisms of delays and budget overruns, leading to a negative effect on the industry. Furthermore, the response of the industry to coping with such risks is negative. Many project managers ignore the supply chain risks by considering other means of coping mechanisms such as contingencies in the project schedule. For a construction project to be regarded as successful, the project must be completed within the allocated time, cost and specification as detailed in the projects contract (Jalal & Shoar, 2017).

The supply chain risks in the construction industry are often interrelated due to the complexity of the construction supply chain. Construction projects often require numerous companies with processes that are interrelated, however occurring at different stages during the project and at different locations. Many construction projects require high levels of customisation, unique properties, and strict timelines. Given this, the identification of supply chain risks is often difficult due to the interrelated operations that occur during projects (Arantes & Ferreira, 2020).

The causes of supply chain risks in construction projects have varying impacts on the project successfulness. Supply chain risks may result in cost overruns, schedule delays and the incompletion of projects leading to the dissatisfaction of all parties involved (Panova & Hilletofth, 2018). Given this, the need to mitigate the effect of supply chains risks exists. The objective of risk mitigation is to reduce the potential impact of any possible risk or delay that might occur. Risks may be mitigated through effective management and thus, resulting in improved project performance (Wang, et al., 2018).

The subject of this research will be an investigation into the management of supply chain risks within the construction industry of Africa's top three performing gross domestic product (GDP) nations. The investigation will be conducted through analysing the risks of the construction supply chain, and the impact they have on the project. Furthermore, the mitigating factors that will lessen the effect of the construction supply chain risks will be determined. The data and information collected will be sourced from online databases which are readily available.

## 1.2 Problem Statement or Motivation

Large construction projects are used around the world to meet the housing, infrastructure, and economic needs of countries. Africa's top three preforming GDP nations, like other African countries, experience distinctive and in certain circumstances, similar risks with regards to the effective project execution and project management (Nkobane, 2013). It is not uncommon for construction projects, not only in Africa's top three performing GDP nations, to experience supply chain risks (Zidane & Anderson, 2018). Construction professionals and researchers have previously conducted research on the causes and effects of construction supply chain risks, however, these have yet to provide adequate results in mitigating the causes and effects of supply chain risks in the construction industry (Renault, et al., 2016). Given the recent advancements in technology and management practices in the industry, construction projects continue to suffer from supply chain risks through the late completion, budget overruns and poor-quality projects being completed (Jalal & Shoar, 2017). The integration of supply chains and information flows are difficult to integrate due to the nature of the construction supply chain (Zhao, et al., 2013). Thus, a need exists to analyse the construction industry to identify the supply chain risks, the impact the risks cause and the decisions that need to be taken in the responding to, and mitigating the risks, to allow construction projects to be more economical and sustainable in the future.

## 1.3 Research Question

The critical research question to be answered in this investigation is: "What is the impact of supply chain risks within the construction industry of Africa's top three performing GDP nations and how can these be mitigated?"

## 1.4 Objectives

The main objective of the study is to determine the impact of managing the supply chain risks within the construction industry in Africa's top performing GDP nations. This will be achieved through the following objectives:

1. Identify the supply chain risks in the construction industry that directly affects operations, costs, and scheduling delays.

2. Evaluate the impact of supply chain risks within the construction industry to determine its likelihood and potential impact.
3. Determine the mitigation factors that will lessen the effect of supply chain risks within the construction industry.

## 1.5 Summary of Research Method

The literature used to answer the critical research question was centered around qualitative and quantitative data, given this, the literature collected was analysed through a systematic and structured analysis process. Following the systematic analysis, coding of the collected literature into pre-defined themes will be conducted, thus constituting a thematic analysis. The themes are pre-determined based on the research objectives and answering the critical research question. The data collected was analysed to determine patterns and trends to answer the research objectives and critical research question. Furthermore, the impact of the supply chain risks and their impacts were determined through different indices calculations.

## 1.6 Delimitation

- The primary limitation on the research study was that only information from credible online public domains is utilised, from the years 2010 to present, to ensure the data collected is relevant to the modular construction industry today.
- Data was refined according to the construction industry and thus, other forms of projects were excluded from the research.
- Data was collected from online domains and thus, no data was collected through self-investigations.

## 1.7 Outline of Chapters

**Chapter 1:** This chapter aims to introduce the construction industry as well as outline the studies objectives, research method and limitations.
**Chapter 2:** This chapter aims to outline the existing themes related to the studies objectives and explore the risks, impacts, and mitigation measures for supply construction supply chain risks.
**Chapter 3:** This chapter aims to outline the research method to be undertaken in the study and explaining the steps taken thoroughly within the systematic literature review, thematic analysis and indices calculations.

**Chapter 4:** This chapter aims to present the findings of the thematic analysis and impacts of supply chain risks relating to the studies objectives.

**Chapter 5:** This chapter aims to discuss the results of the studies in terms of both literatures found locally and abroad as well as provide any limitations of the results obtained in the study.

**Chapter 6:** This chapter aims to answer the studies research question and address the objectives of the study. Furthermore, it will recommend areas in the studies topic where further investigation can be conducted.

# CHAPTER 2

## 2. LITERATURE REVIEW

A comprehensive review of literature was conducted with the aim of establishing an understanding of previous theoretical works and their contribution towards the understanding of the impact of managing the supply chain risks within the construction industry. The literature used was obtained from countries with similar GDPs to those of Africa's top performing GDP nations. According to (Statista, 2021), Africa's top 3 performing GDP nations are Nigeria, South Africa, and Egypt. In 2021, these countries had GDPs of $441.54, $418.02, and $402.84 billion respectably.

### 2.1 Construction industry supply chain risks and their impact

Construction projects are at the fate of uncertainty of time, and it becomes problematic to forecast the results of its implementation. The accuracy of the forecast of workflows determines how accurately the completion of the project is predicted. However, supply chain risks greatly affect the progress of the project and cause delays and cost overruns to activities downstream in the supply chain (Islam & Trigunarsyah, 2017). Delays can often be defined as the event or act that results in the extension of time required to complete outlined work in the contract (Marzouk & EL-Rasas, 2014). The main supply chain risks of construction projects are attributed to the client, consultant, contractor, material, equipment, labour, design, project specific and external factors (Wang, et al., 2018). Most construction projects fall behind schedule due to risk factors from the before mentioned categories. Despite the advanced technologies and thorough understanding of project management and engineering techniques, the issue of project risks, has yet to be resolved or mitigated. It is estimated that at least 81.5% of projects experience delays during the construction process (Zidane & Anderson, 2018). From the above 81.5% of projects, 76% of the projects experienced delays that were between 10-30% of the original contracted duration (Zidane & Anderson, 2018).

A construction risk is regarded as a situation where the contractor, client, consultant, or external factor is jointly or independently responsible for the risk in the project's completion, cost, and specification as speculated in the signed contract document (San Santoso & Soeng, 2016). Construction risks can be caused by a variety of excusable and non-excusable factors. Non-excusable risks are supplier or contractor related; thus, the implications of such risks fall directly on them. They are often not granted relief to these risks such as, an extension of time or compensation to make up lost time (Ismalia, et al., 2022). Excusable risks are unforeseeable delays that are beyond the contractor's control. They are events such as strikes, acts of God or changes of scope by the client and inadequate information in the plans and specifications (Islam & Trigunarsyah, 2017). Both excusable and non-excusable risks effect the management, completion time and budget of construction project (Oluwaseun & Kruger, 2017).

### 2.1.1 Client risks and impact

The client for any construction project plays a critical role in the continuity and progress of the project. (Arditi, et al., 2017) stated that between 30 and 60% of all construction risk are caused by the client. The client is responsible for inefficiencies, and not limited to, frequent change orders, changes in the scope of work, design changes, slow decision making, delayed payments and delays caused by having the wrong approvals in place. Changes to the project scope and change order delay construction schedules. Client initiated changes are the primary cause of project scope creep. Change orders and changes in the project's scope require meetings and consultations to be conducted. It further requires additional funds when necessary and alterations in the project's operations (Amoatey & Ankrah, 2017). The client, thus, is responsible for decisions that need to be made in the early stages of the project and providing the necessary decisions and specification in a timely and efficient manner (Islam & Trigunarsyah, 2017).

The client is responsible for processing and approving payments to the consultants and contractors employed on the project. Delays in the making of these payments often result in financial issues for the contractor and in turn, the subcontractors, and any trades downstream in the supply chain (Bajjou & Chafi, 2020). In many developing countries, some construction companies don't have sound financials. Given that many projects are characterized by payment periods that exceed 90 days, this has a negative impact on any progress occurring on the project due to construction works being suspended due to the lack of financing (Bajjou & Chafi, 2020).

### 2.1.2 Consultant risks and impact

The consultants appointed for a construction project are the sole agent responsible for the preparation and finalization of the projects design and specifications. Furthermore, they are responsible for the supervision of construction works on behalf of the client and given this, the oversee the constructability of the project, approve progress payments, and ensure the quality is within the standard acceptable (Islam & Trigunarsyah, 2017). Consultants are responsible for overseeing the projects costs and providing a detailed outline to the client to ensure they make a thoughtful decision on whether the project will be feasible or not. (Al-Hazim, et al., 2016), stated that up to 76% of construction projects had overestimated costs, whilst 24% of projects suffered from the underestimation of costs. Furthermore, the difference between the estimated costs and the actual costs of the construction project had large discrepancies, ranging from 101% to 600% over the estimated costs.

Consultants could be reasonable for project schedule and cost overruns due to the delays in approving major changes to the project scope, submitting incomplete and error ridden documents and specifications and delays in on-site inspections (Mukuka, et al., 2015). Furthermore, the experience of the consultant is evident to the project's success. Inadequate planning and due diligence from the consultant can result in project price fluctuations and cost overruns of up to 49% (Famiyeh, et al., 2017). Schedule and cost overruns commonly occur when the appointed consultants provide poor project and contract management assistance, communicate poorly with all parties involved and provide unrealistic project deadlines to the client (Wong & Vimonsatit, 2012).

### 2.1.3 Contractor risks and impact

In the construction industry, projects are attended to by various trades in the industry to construct the final product. Projects may have the main contractor, subcontractors, and other specialized trades. All trades involved in the project have vital timelines to ensure the project runs according to schedule (Islam & Trigunarsyah, 2017). Contractor delays arise from the difficulties in financing their subcontractors and specialized trades, conflicts in schedules amongst trades, ineffective planning, and management of the project schedule, underestimation of project complexity, poor communication, rework due to sub-standard quality, poor qualification of the contractor's technical staff and poor site management and supervision (Mukuka, et al., 2015). The lack of experienced management may cause project delays. Poor stakeholder experience greatly affects the project schedule performance. The lack of experience is largely due to the financial costs of achieving the necessary training (Durdyev & Hosseini, 2018). Thus, given the nature of on-site construction being labour intensive, shortage of labour and labour disputes cause unwanted uncertainty and delays. The experience and lack of labour stems down to create an issue where poor site management occurs. Given most work occurs on-site, the management of is of strategic importance. Site management is made up of various elements such as the material distribution, commitment of employees and the communication between all trades and parties involved (Famiyeh, et al., 2017). Communication and coordination among all parties in the project facilitate the accurate and timely commencement and completion of works. However, conflicts and disputes are detrimental to smooth operations and thus, often result in schedule and cost overruns. The inability to plan and organize site activities may result in all the delays mentioned previously. Given this, the competency of the site management in coordinating activities, resources and information is vital for the successful completion of any project (Durdyev & Hosseini, 2018).

The contractors experience in understanding the projects schedule is imperative to the success of the project. Unrealistic schedule acceptance often results in the client and consultant expecting the acceleration of workloads. This in turn increased the workload of labours. The increase workload often results in fatigue, stress, and discouragement from employees. The unrealistic schedule often leads to the extension of time being needed; however, this causes the quality of works to reduce, increasing the amount of rework required (Bajjou & Chafi, 2018).

Rework in construction projects accounts for up to 22% of schedule overruns and in turn, affects the projects costs. The rework may increase the project cost by up to 52% of initial project estimate (Bajjou & Chafi, 2020). Rework may also be a result of excessive sub-contracting by the contractor. Excessive subcontracting creates an environment where communication and coordination may break down between the parties involved. Rework may be required due to instructions not being made in a timely manner. Furthermore, planning and scheduling around many different trades in a construction project is difficult. (Bajjou & Chafi, 2020) states that more than half of the scheduled construction tasks are not performed within their time allocation. Improper planning may not take into consideration the availability of materials and workers needed, assurance of safety conditions and the provision of funds required to perform the task. The contractor is responsible for obtaining the necessary skills to successfully complete the project. Rework often occurs when unskilled staff are appointed leading to the acceptance of poor workmanship by the contractor’s team. This often results in defects, low productivity and errors occurring throughout the project (Islam & Trigunarsyah, 2017).

### 2.1.4 Material risk and impact

Delays due to material shortage often occur which greatly effect construction productivity. Material costs can contribute up to 65% of the total construction costs (Hasan, et al., 2018). The process of construction requires the transformation of a conceptual design into a physical structure which is impossible should there be a material shortage. The shortage of material results in schedule risks, potential cost overruns and the demotivation of workers to complete their specific task. The shortage of materials on the construction site may occur from, and not limited to, the inefficient material management, design changes, markets short supply, prolonged fabrication times, errors and poor-quality material being delivered, increased demand on-site, lack of distribution methods and delayed payments to the suppliers (Hasan, et al., 2018). The shortage of material in the market results in the rising costs of material. Given this, some contractors may postpone their purchases until the price falls allowing them to effectively procure their materials within their tendered allowance (Habibi & Kermanshachi, 2018). Furthermore, the procurement of materials for any construction project requires effective planning. The disproportion of the available storage space on site and material procurement is also a risk to the project schedule. Given this, the neglecting of the importance of the interdependency may result in material shortages, poor and unsafe site layouts, productivity losses and improper storage (Habibi & Kermanshachi, 2018).

### 2.1.5 Equipment risk and impact

Shortage or breakdowns of the correct construction equipment which is used for assisting work crews in lifting heavy items or providing a custom finish causes delays due to work not being able to be completed. Having the correct equipment on-site ensures that workflows are not interrupted and that high efficiency in operations is achievable. The failure to secure the correct equipment for a given project may result in at least 5% loss in productivity and working hours and has a high correlation with project finance and economic problems (Durdyev & Hosseini, 2018). The lack utilization of equipment may be caused by the lack of trained personal and inadequate maintenance and servicing processes (Mukuka, et al., 2015). Given that the equipment for construction projects is often quite expensive, many small to medium companies in developing nations don’t have the purchasing power to buy their own equipment. Given this, many companies rent the necessary equipment to carry out their required operations. Given this, companies look to buy cheaper secondhand equipment and oversee the maintenance required to operate the equipment at their optimum capacity. Furthermore, due to the overextension of machinery and the demand for the constant operation of machines, equipment often suffers from the lack of maintenance resulting in frequent equipment breakdowns. Furthermore, the spare parts required to fix the equipment may need to be sourced from abroad, resulting in idle time resulting in further delays and cost overruns (San Santoso & Soeng, 2016).

### 2.1.6 Design risk and impact

The design of any project is imperative in determining the project success. The complexity, accuracy, clarity, and completeness of the designs are all attributes that need to be achieved for delays not to occur. Typically, financial penalties are imposed due to the failure of achieving the projects schedule (Atout, 2016). Delays occur when designs have insufficient information and erroneous information (Akampurira & Windapo, 2019). The project design is a precursor for generating the full benefits of any construction project. In the early stages, the data and information required to design the project is often estimated and an allowance of errors or uncertainty is allowed for. Given this, the designs are generated with information based on data that is uncertain. Furthermore, the implications of design errors can affect the entire project delivery process due to the decisions effecting downstream processes (Wuni, et al., 2021). Common design risks are associated with a defective design, change in the projects scope or variation orders and the information gap between the contractors and subcontractors (Akampurira & Windapo, 2019).

The inaccurate designs constitute the largest factor in reworks required on site if the errors are not identified and mitigated during the design stage of the project (Wuni, et al., 2021). It is common that designs that are highly complex in nature, result in the most rework being required. Furthermore, rework can contribute up to 10% of the additional costs associated to the project (Hasan, et al., 2018). Given this, workers and contractors may feel disheartened by amount of rework required. This often results in frustration and discouragement, which translates to unsatisfactory performance and decreases productivity. Furthermore, the amount of rework required is often a result of poor workmanship or quality. This is attributed to poor instructions being given as a result of change orders and design errors (Hasan, et al., 2018).

### 2.1.7 External and project specific risks and impact

The characteristics of any construction project vary, as no one project is identical. Given this, a thorough investigation into the project's characteristics, based off experience is needed. Thus, the project specific conditions and external conditions are often viewed together. The geographic boundaries of the project need to be established (Wong & Vimonsatit, 2012). Given, these are poorly investigated, schedule and cost overruns may occur from the inaccurate site investigation, obsolete construction techniques, site clearance delays, evolving site conditions and project specific site constraints (Islam & Trigunarsyah, 2017). Furthermore, the effects of the ground conditions such as, soil type and water table level need to be established. The surrounding environment of the project needs to be established. This includes the impact of traffic on the surrounding area and the relationships with the neighbors in the area (Marzouk & El-Rasas, 2014). External factors relating to interference by governing bodies, political interference, bureaucracy by the governing bodies, delays in obtaining permits, regulatory changes and safety regulations are potential schedule and cost risks. Furthermore, evolving market conditions result in price fluctuations of material and running costs, these may result in the project running over budget and potential delays due to financial restrictions (Memon, et al., 2012). A major delay to on-site activities is a result of weather conditions, particularly to open-space sites. Despite weather conditions being an excusable delay, as they are beyond the control of the contractor, they cause major delays of downstream supply chains. The project schedule performance is affected by unforeseen weather conditions. A major implication could be attributed to the loss of work rhythm due to interruptions in work activities (San Santoso & Soeng, 2016).

Figure 1 below summarises the frequently encountered construction supply chain risks identified.

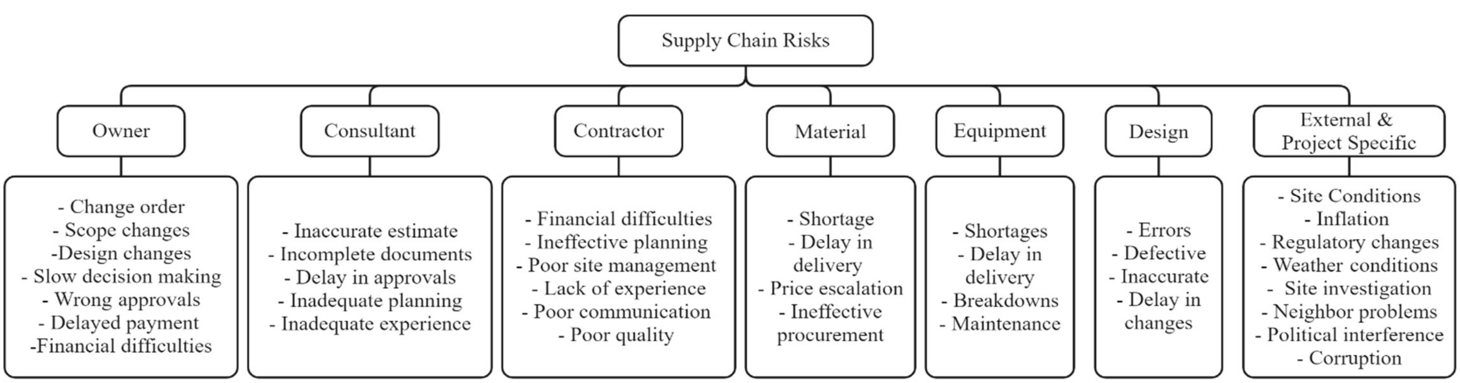


Figure 1: Frequently encountered supply chain risks.

## 2.2 Mitigation factors to lessen the impact of supply chain risk.

Construction projects around the world, contribute largely towards economic activities and is often used to stimulate economic growth post-recession. The industry contributes more than 10% of the world's economy. The construction industry is consistently evolving and complex in nature and has thus resulted in the operations needing effective and efficient management to ensure the projects are successful. Construction projects involve various types of risks such as contractual, technical, financial, and operational. Due to different trades and contractors being used on the same project, conflicting personalities and understandings make project management difficult. This is compounded due to the open space of projects and their vulnerability to changing weather conditions. Furthermore, poorly developed contracts, expertise, scheduling, and financial situations all give rise to construction risks. Given this, the risks and mitigation plans put in place, may not eradicate all the risks that may occur (Zhao, et al., 2013).

Risk mitigation frameworks require both theoretical and practical meanings. The risk mitigation process involves the identifying, analysing, and responding to the risks. The identification of risks in the early stages or before the commencement of the project help to develop a strategy that can effectively and efficiently mitigate or transfer the risk. The objective of risk mitigation is to reduce the potential impact of any possible risk or delay that might occur. Risks may be mitigated through effective management and thus, resulting in improved project performance (Wang , et al., 2010). Despite this, the construction industry is known for its lack of risk management and thus, results in many projects running over budget and overtime. Despite this, the construction industry is faced with many risks and delays such as poor quality, time overruns, cost overruns and construction waste. The cost overrun on a particular project affect's other projects going forward and thus, the infrastructure development of the nation. (Morena & Amoah, 2021).

The contractor and the client are tasked with the same goal, which is the successful completion of the construction project within the agreed timeline and budget. This is to ensure the client has value, from utilizing the final product, and the contractor ends their direct expenditure in the project as early as possible to begin a different project. Delays that occur during the construction period often result in the deferral in the completion date which brings about additional costs to the client and contractor. Given the extent of the delays, the projects may be costly and in instances be unsuccessful and thus, the need to implement risk mitigation practices exist (Morena & Amoah, 2021).

The party responsible for the delay must be identified for the delay to be mitigated in the future and for the impact of the delay be addressed accordingly. It is vital for the correct stakeholder to address the risk as the incorrect stakeholder may have insufficient, or no expertise with that particular risk at hand. This would result in the risk not being addressed accordingly and will further result in costs increases and further time delays. The main stakeholders responsible for delays are those of the main contractor, client, consultant, and the designer. Communication and planning between these parties is vital to ensure that delays don't occur and that should an unforeseeable delay occur, it is attended to in the correct and timely manner (Durdyev & Hosseini, 2019).

The risk management framework in Figure 2 below, taken from (Indruskevics, 2018), shows the process of identifying, evaluating and mitigating risks.

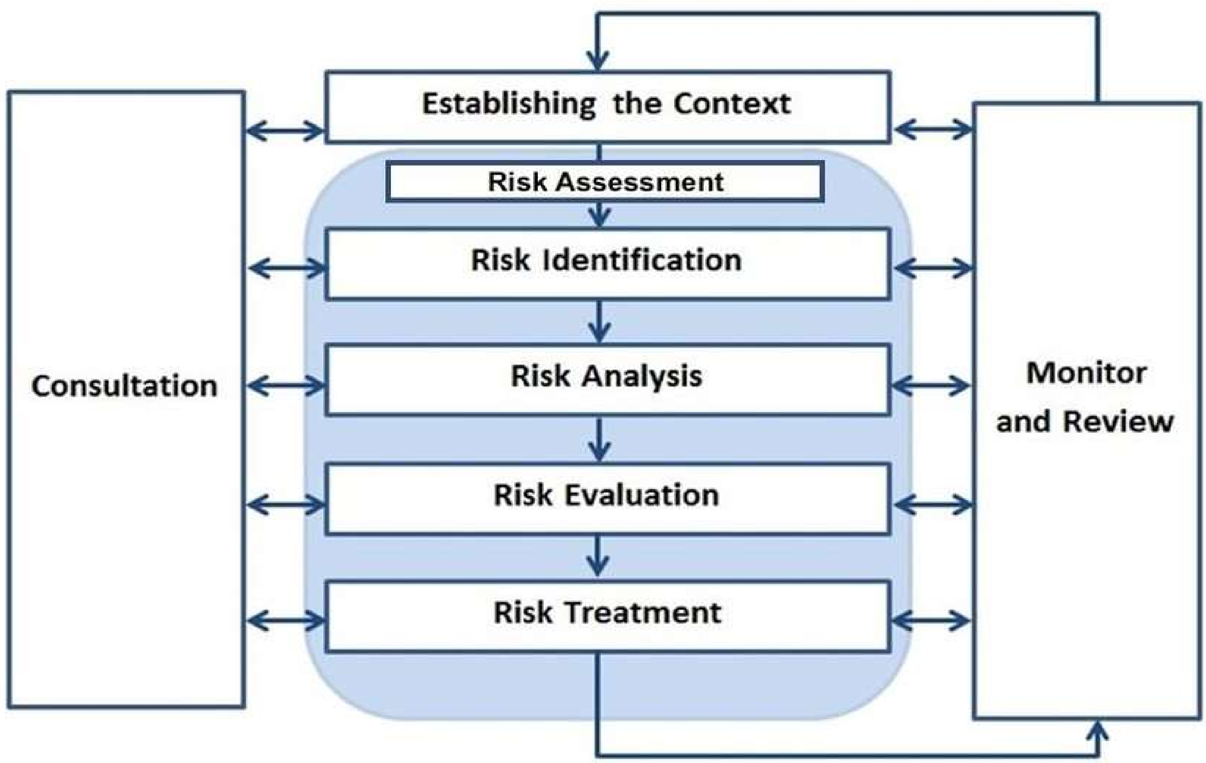


Figure 2: Risk Management Framework (Indruskevics, 2018).

### 2.2.1 Contract selection and bidding process

Many delays related to the poor planning and scheduling of any construction project are usually caused by the contract awarding and bidding process. The process usually involves the selection of a contractor with the lowest bid, thus, resulting in the least experience and inadequate skill. Given this, the adoption of a thorough bidding and contract awarding process must occur. Many clients have a lack of thorough understanding when it comes to engineering and project management skills. This results in the development of a sub-standard contract proposed inadequate and inexperienced contractors (Arantes & Ferreira, 2020). Furthermore, the contract needs to be developed with instruments that are capable of correctly managing the risks associate with the project. This includes, not limited to, including project specific conditions, time extension clause, adjustment clause, variation clause and claims (Morena & Amoah, 2021). Contractor claims, contractors' financial difficulties and changes in scope all need to be accommodated for in the contract. If not, disputes are often lengthy and in turn, costly to both parties involved. Given this, various steps should be taken to mitigate claims in the contract development. Claims made by the contractor can be mitigated by, not limited to, pre-contract negotiation, formulation of contract documents and review of the bid for technical viability (Prasad, et al., 2018). Mitigation of the contractor's financial position can be achieved by, not limited to, a detailed risk analysis, specify maximum contract deviation, thorough contractor selection and to adopt market-based escalation formulae (Hasan, et al., 2018). Lasty, the changes in scope can be mitigated by, not limited to, contract allowance for additional works, defined procedure for evaluation of new rates, written changes only and an outlined procedure for changes of scope (Hasan, et al., 2018).

### 2.2.2 Schedule development

The schedule should reflect a reasonable construction period allowing for the smooth implementation of the project, improved efficiency and ensure that the quality and economic benefits of the project are achieved (Morena & Amoah, 2021). This should be done with the application of the critical path method. Additionally, with the implementation of project specific procedures, the appointment of a planning engineer may be useful in managing the project schedule (Vacanas & Danezis, 2021). Furthermore, the client, contractor and consultants need to develop the schedule in conjunction, this is to ensure all their needs and requirements are met (Morena & Amoah, 2021). The schedule should be developed in a manner that is practical and achievable. Furthermore, the schedule should be reviewed by experienced experts to ensure no errors or omissions have been made (Mate & Hinge, 2015). The consultant's input into the schedule should be based off the project's objects and the planning of required resources. Furthermore, the contractor and consultant should ensure that they have the technical and managerial knowledge to ensure that the submitted schedule takes into consideration all the critical work activities, consideration for the general conditions of the contract to ensure no further risks affect the project schedule and cost (Atout, 2016).

Given the above, the mitigation of a changing schedule is vital. The schedule should be regarded as a document that is reliable and binding between all parties involved. It is imperative to mitigate confusion and misunderstandings from occurring throughout the project. Furthermore, the credibility of the schedule is vital to ensure that it is not regarded as guidance but rather as the contracted fixed deadline (Lindhard & Wandahl, 2014).

### 2.2.3 Pre-Project planning

Pre-project planning is vital for any construction project. Pre-project planning includes, not limited to, thorough project feasibility, contingency allocations, insurances, and financial options (Viswanathan, et al., 2020). Pre-project planning should engage all participants in the project to develop thorough preparation to address the projects probable risks and maximize the projects probability for success. For developing countries to meet the success criteria of any construction project, it is vital that the necessary contingencies, insurances, and feasibility study is conducted and put in place. Allocating adequate contingencies in the project planning can be used as to offset project risk, however if contingencies are too high, contractors may want to avoid the project. Albeit, if contingencies are too low, the project may carry significant financial risk for the contractor. An accurate estimation of project contingencies may result in overcoming project delays (Viswanathan, et al., 2020). Insurances are important in mitigating risks. By insuring construction projects, you can ensure or guarantee foreign investors a successful project. Furthermore, a thorough feasibility study outlining the projects financials can be portrayed as a guarantee to a workable and successful construction project, albeit it is done accurately, and no major unforeseen risks occur. Given the feasibility is backed by proper financial options. Risks relating to the projects funding should be analyzed and identified. Economic and financial risks can be identified by obtaining information from relevant authorities and information streams (Viswanathan, et al., 2020).

### 2.2.4 Client

The client's role in ensuring a successful construction project is vital as they are significant drivers in project delay factors. Economic uncertainties have been identified to affect the client's role in construction delays. Economic situations may delay decisions made as well as have material impacts on the projects financial position, change orders and payments. This in turn effects the execution of works according to the project schedule (Arantes & Ferreira, 2020). Given the slow decision making and constant change order of the client, this can be mitigated by the selection of experience contractors and consultants to assist the client where the specific item falls outside of their knowledge. Thorough preplanning should occur to identify and incorporate all the clients' requirements in the early stages of the project to avoid change orders and delays decision making. Given this, the client is responsible for ensuring that experienced contractors and consultants are appointed for the construction project, a suitable bid and contract award process is followed, and project risk management strategies are put in place (Arantes & Ferreira, 2020).

### 2.2.5 Contractor Selection

The selection of the contractor should be based on the most economically advantageous bid and the selection of the most developed plans and schedule for the specific project. This will ensure that projects plans are complete and free from omissions and errors (Arantes & Ferreira, 2020). (Viswanathan, et al., 2020) recommends that a three-stage approach is adopted in the selection of the contractors and sub-contractors employed for the project. Stage 1 would be to ensure that contractors are shortlisted based on their experience, formal relationship, workload, reputation, and financial position. Stage 2 would involve the negotiation based on the level of reliability, problem-solving ability, communication, quality awareness and knowledge of similar projects. Lastly, stage 3, the final selection of the contractor based on the proposed payment plan, quoted price and deployment of resources. Furthermore, the contractor is responsible for ensuring proper site management. The contractor's team should have competent mangers, reliable suppliers, reliable equipment, and good project management skills to mitigate risks related to project (Oshungade & Kruger, 2017). The appointment of consultants to the construction project with adequate skills should be achieved. The projects consultant should guide the client to assist in decision making and provide all parties with sufficient and details information to aid in performing their tasks. This is specifically important with regards to the projects plans and specifications (Zailani, et al., 2016).

The projects management teams are responsible for improving the project visibility and flexibility in moderating the effects of resource and communication issues. Project delays caused by poor communication and resource allocation can be mitigated through the constant communication of project information, strategic needs and collaboration between all parties involved in the project (Zailani, et al., 2016). The integration of activities and information flows within the project can be done though adoption technologies such as Building Information modeling (BIM) (Arantes & Ferreira, 2020).

### 2.2.6 Technologies used in mitigating construction supply chain risks

The industry 4.0 is a combination of concepts and technologies that blend the physical, digital, and biological functions together. The industry is broken down into various components that transform the interactions and relationships that occur throughout the supply chain being the suppliers, producers, and customers. The technology trends allow for more efficient and effective processes to occur within the industry (Schulzea & Dallasegaa, 2020).

Cloud computing and building information modelling (BIM) are used to evaluate and mitigate losses that occur due to inefficiencies. Cloud computing allows for the collaboration of all stakeholders involved in the project, without delay, thus, enabling smooth and speedy decisions being made, without disruptions disturbing the project progress. Furthermore, BIM is a collaborative and fundamental tool which allows the exchange of information between all stakeholders of the project at the various stages. BIM is used to reduce and eliminate wastes during the construction process (Eldeep, et al., 2021). These wastes may relate to design errors, sub-standard designs, change orders and poor communication. BIM allows parties to simulate the project through an accurate model. This allows for accurate decisions to be made without causing any clashes to the existing schedule and design. The use of BIM in the design phase allows for up to 50% time reduction throughout this stage (Eldeep, et al., 2021). Furthermore, clash detection and allows for design errors to be identified and mitigated before work construction work commences. The use of BIM in projects have resulted in cost reductions of up to 11% and schedule and time reductions of up to 25% (Eldeep, et al., 2021). It provides the platform where design, engineering, construction and operation information is shared throughout the life cycle of the project. BIM can be used to generate 4D simulations of the project in the design stages, this allows for the potential conflicts to be identified and analysed to ensure a solution is developed in the earliest stages of the project. Furthermore, it can allow improved building designs, shorter project duration and improved cost estimations through the collaboration and communication it offers between the client, contractor, architect, and engineers (Eldeep, et al., 2021).

Web portals, Real-time SCM, BIM and cloud computing can all be used to mitigate and deal with project management inefficiencies. This is because they all support the real time exchanging and communicating of information and data between all stakeholders involved in the project. Information and communication between suppliers, contractors and distributors is improved through web portals. This is due to improved communication and information sharing between stakeholders. The use of cloud computing, that uses the internet to share data from multiple locations, thus, reducing inadequate decisions resulting from incorrect and out-of-date information being used.  Furthermore, the projects progress and supply chain operations can be monitored through real-time data, provided by different stakeholders through the BIM platform (Schulzea & Dallasegaa, 2020).

Autonomous robotics can be used to complete tasks quicker and in a safer manner. Robots are more flexible, versatile, and therefore could reduce errors and construction time. The use of RFID tags allows for various recourses such as equipment and materials to communicate with one another. This allows for the continuous monitoring of material status and positioning throughout the supply chain. Given that the RFID system can be incorporated into the ERP system, waste reduction, quality and delivery response can be improved ( Li, et al., 2017).

Cloud computing, RFID, BIM, augmented reality (AR), virtual reality (VR) and geographical information systems (GIS) further reduce the inefficiencies of on-site activities. Cloud computing handles data locally at the various construction, fabrication and production sites and allows for the collaboration between stakeholders involved in the project. Furthermore, it allows for the immediate response in the event of errors occurring due to the ability to share data in real-time. BIM provides valuable information relating to the construction process as it tracks resources, thus, allowing for the improved efficiency and communication between the construction site, subcontractors, and suppliers. RFID tags can be used to track and trace any missing material or material that has been damaged throughout the supply chain. GIS can be utilised in determining whether there is a material layout conflict and the on-site rate of accessibility to materials. Furthermore, it can be linked to the BIM system to plan the layout of the site before material delivery is made. VR and AR bridge the gap between the physical and digital environments. The interaction and simulation of 3D models is done through VR, and it allows for the virtual training and development of skills for complicated tasks that need to be carried out on-site. AR allows for the on-site training of workers and the step-by-step guide for completing a certain task. This allows for improved automation and performance on-site (Schulzea & Dallasegaa, 2020).

## 2.3 Conclusion

The literature review explored the construction supply chain risks, the impact these risks had and the mitigation factors to lessen the effect of the supply chain risk. The various elements identified for the construction supply chain risks were the associated with the client, consultant, contractor, materials, equipment, design, and the project specific or external factors. The impact of the supply chain risks is predominantly cost and schedule overruns. However, it also included rework due to poor quality work, loss of productivity, reduced benefits, and disputed or legal action. The mitigation of supply chain risks highlighted the importance of the contract and bidding selection process, schedule development, pre-project planning, client involvement, contractor selection, and technologies available to the construction industry. The identified risks, impacts and mitigation factors analysed in the literature review will form the basis of the discussion later in the report. Given that the literature above has been analysed from countries with similar GDPs to that of Africa's top 3 GDP nations, it will form the basis of comparison where similarities and differences between the identified risks, impacts and mitigation factors are discussed. Furthermore, the analysed literature aids in developing the initial key themes and sub-themes to be included in the research design. Figure 3 below, outlines the structure of the sections discussed in the literature review as well as their key themes.

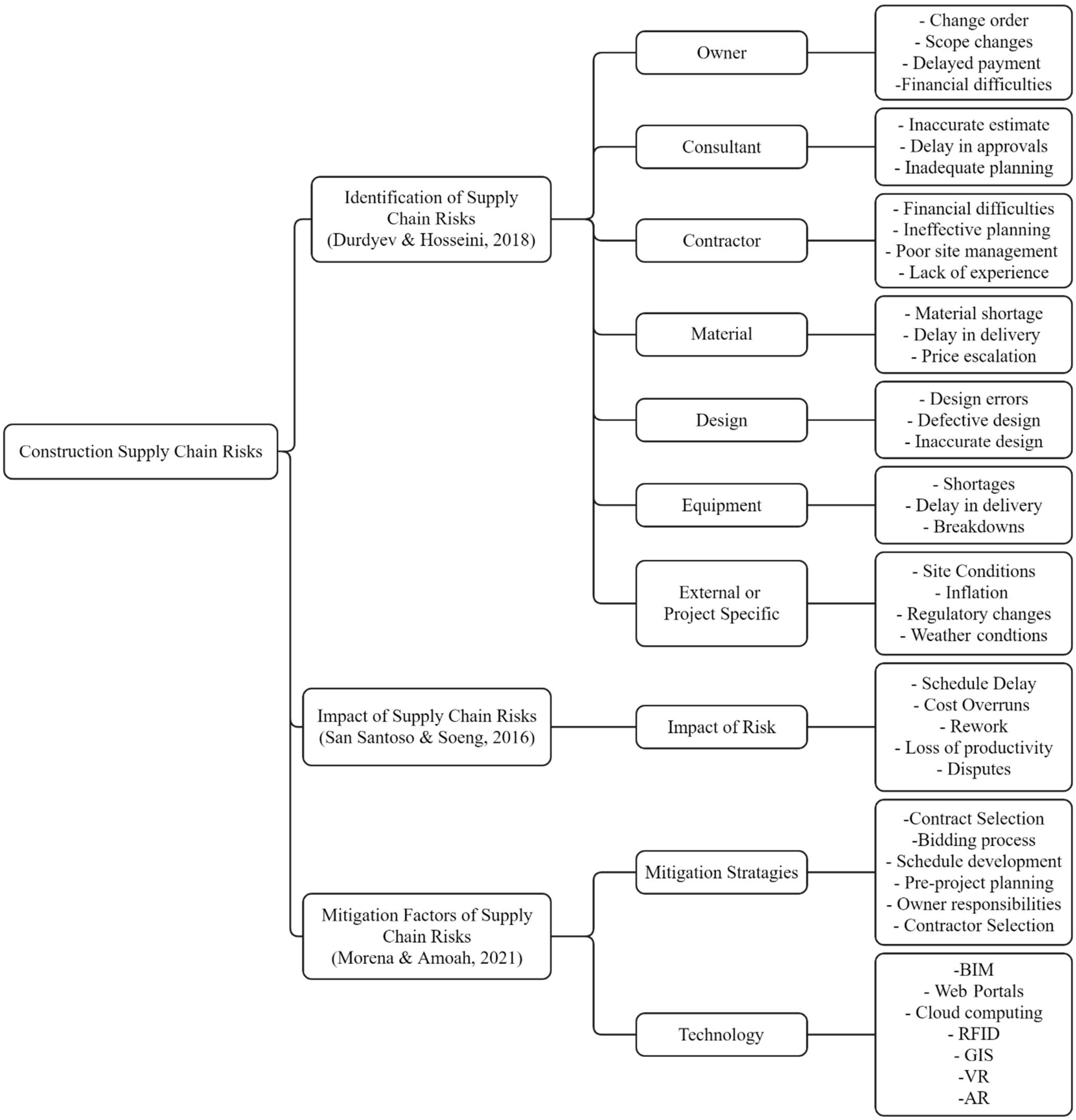


Figure 3: Structure of sections as discussed in the literature review (Hardham, 2022).

# CHAPTER 3

# 3. RESEARCH METHOD

## 3.1 Research Design

The literature used to answer the critical research question was centered around qualitative data, given this, the literature collected was analysed through a systematic and structured analysis process. The academic literature used in the study was gathered from online domains, such as google scholar and the electronic library at the University of the Witwatersrand. According to (Dewey & Drahota, 2016) A systematic review includes the identifying, evaluating and the synthesis of research to answer a clearly formulated question. Furthermore, (Ham-Baloyi & Jordan, 2015) states that a systematic review is one where a literature review is conducted in a manner that has a clearly formulated research question and uses a method that is systematic to identify, select and analyse literature that has been previously published from studies related to the topic at hand. The systematic approach creates a method where the selection of only the studies that meet the selection criteria is used. Thus, the rigorous set of criteria presented appraised the validity and reliability of literature used in the research project. Given the above definitions and information presented, the use of a systematic literature review allowed for the identification of meaningful relationships and patterns that the report's research question and objectives set out to achieve. The use of the systematic literature review allows for all types of qualitative data to be analysed such as interviews, focus groups, questionnaires, and qualitative surveys through reputable published journal articles. Journal articles typically undergo a rigorous screening process before being published. This allows for reliable information to sourced and analysed. Despite this, the method is limited to using only published literature that is available on public domains. However, the selected method used for the research analysis is capable of collecting and developing a thorough analysis of the academic literature.

The results found within the research design were derived through the three main themes which related to the study's objectives. The themes concerned were the supply chain risks in the construction industry, the impact of the supply chain risks and lastly, the mitigation factors that would lessen the effect of the supply chain risks within the construction industry.

Within the three main themes, sub-themes where developed based off current literature derived from the literature review. The main themes and sub-themes can be found in Figure 4 below:

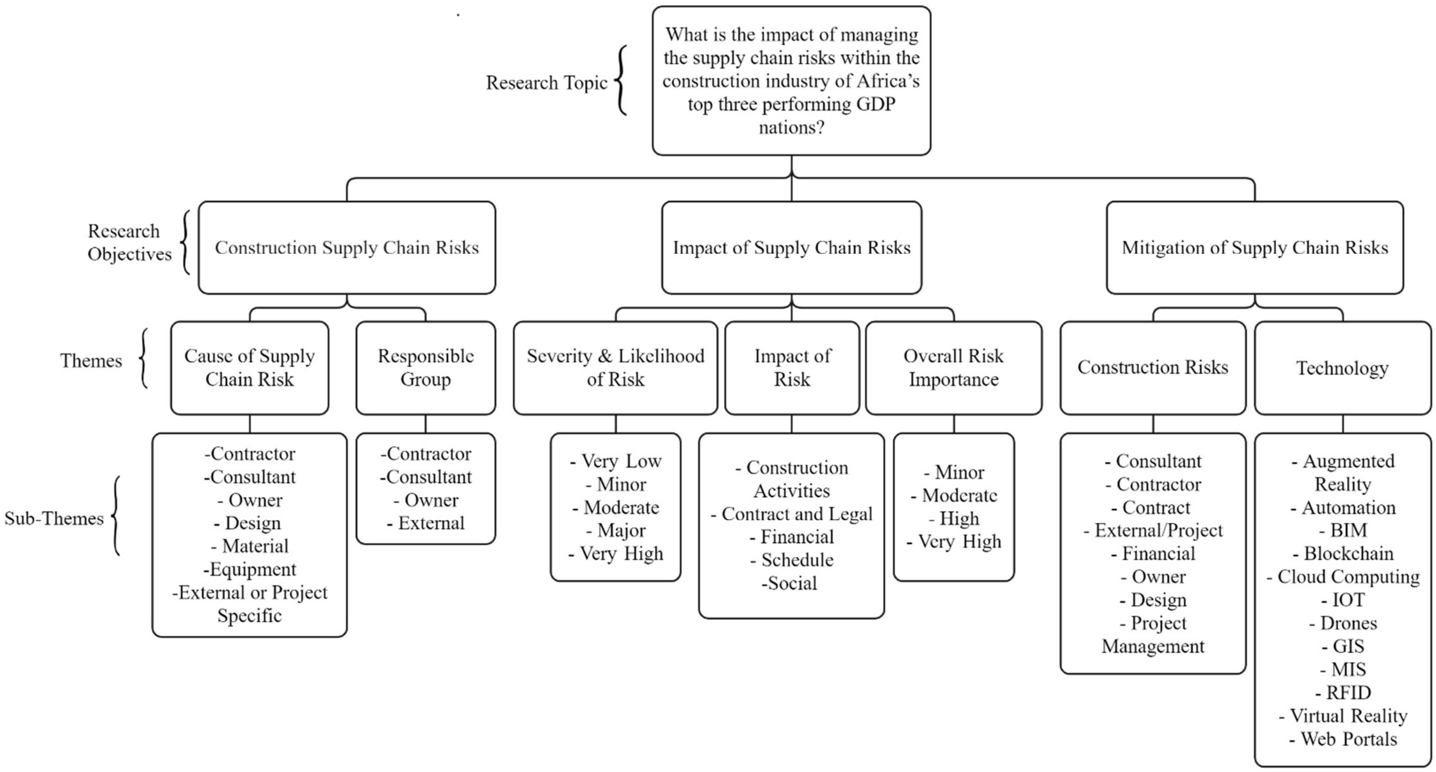


Figure 4: Breakdown of Themes and Sub-themes

## 3.2 Instrumentation

To conduct a thorough analysis of the data, a data extraction form is developed to outline the process to be followed as well as including the strict inclusion and exclusion criteria. The data extraction form can be found in Table 27 of Appendix A The form is used in aiding the reviewing and summarizing of literature and further allows for the review process to be tracked. The form was used to capture all the important data related to the research through the development of summaries taken from the literature journals. To ensure the study is conducted in a manner where quality work is produced, various considerations related to the validity of the study were taken. These considerations form the bases for the inclusion and exclusion criteria found in the data extraction form. Furthermore, the form allows for the identification of other pertinent information in other categories not in the field of direct concentration for the study. This information may be underlying sub-themes, not originally identified, that have direct implications on the theme being researched. Additional studies have been identified that can be reviewed. To ensure studies, which are relevant to the research topic, are included, the bibliographies are read and recorded and potential articles for inclusion are listed (Zaza, et al., 2000).

### 3.3 Data Collection and Analysis Procedure

The data was collected from online published literature. The use of journal articles was selected as these articles typically undergo a rigorous screening process, blind screening review, by independent experts who provide objective feedback and suggestions for the improvement of the report prior to publishing (Thyer, 2009). Given this, the selection of journal articles for the analysis, further adds to the validity of the report. The articles are readily available online, allowing for efficient and reliable information to be sourced from abroad countries. Furthermore, the information available in journals is often more up to date, as articles appear in print sooner than they would in books and other sources of data (Thyer, 2009). The published literature was taken from reputable online data bases being Taylor and Francis, ScienceDirect, ProQuest, ASCE Library, and Emerald Insights. Furthermore, the data collection process consisted of three main steps namely the Initial search, collection and sampling of data and the analysis. Table 1 below has been adapted from 'Data Collection Instrument and Procedure for Systematic Reviews in the Guide to Community Preventive Services' and illustrates the processes to be followed as well as the considerations taken for the data collection and analysis process.

Table 1: Processes and considerations followed for the data collection and analysis adapted from (Zaza, et al., 2000)

| **Data collection & Analysis Stages** | **Process and Considerations** |
|---|---|
| Initial Search | • Establishment of key phrases. Key phrases used: construction supply chain risks, construction delays, construction cost overrun, effect of construction delay, impact of construction risks, mitigation of construction risks, construction delay mitigation, construction supply chain management, construction technology.<br>• Determine themes and sub-themes from CRQ and objectives. Sub-themes used: Cause of supply chain risk, responsible group or party, severity of risk, likelihood of risk, overall risk importance, construction risk mitigation, technology.<br>• Determine limitations<br>o Date: 2010-present<br>o Publication stage: Final<br>o Language: English<br>o Source Type: Journal Article<br>o Location: Egypt, Nigeria, South Africa |

| | |
|---|---|
| Collection and Sampling of Data | • Filter literature according to popularity in the construction industry by removing articles that were not frequently cited.<br>• Filter literature according to relevance to the research reports objectives, ensuring adequate information is available to answer CRQ and objectives.<br>• Group data according to objective.<br>o Identify the supply chain risks in the construction industry.<br>o Evaluate the impact of the identified construction supply chain risks.<br>o Determine the response for mitigating the supply chain risks in the construction industry.<br>• Conduct title, abstract and text analysis.<br>• Identify duplications |
| Analysis of Data | • Thematic analysis. The thematic analysis process will involve the reading and coding of literature to identify patterns across the data.<br>• Summarize literature individually for NVivo coding<br>• Create nodes for specific themes<br>• Determine patterns in data |

### 3.3.1 Initial search

Given the CRQ and the objectives stipulated in Sections 1.3 & 1.4 respectively, a set of key phrases was established. The phrases were used to search academic literature, of different databases, on the electronic library, relating to the themes and sub-themes of the CRQ and objectives of the study. Table 2 below shows the initial key phrases used for the initial search of candidate sources:

Table 2: List of Each Researched Phrase Corresponding to the Objective.

| **Research Objective** | **Construction Supply Chain Risks** | **Impact of Supply Chain Risks** | **Mitigation of Supply Chain Risks** |
|---|---|---|---|
| **Researched Phrases** | "Construction supply chain risk" | "Construction delay effect" | "Construction risk mitigation" |
| | "Construction delay" | "Construction risk impact" | "Construction delay mitigation" |
| | "Construction Cost overrun" | | "Construction supply chain management" |
| | | | "Construction technology" |

Limitations were then added to the searches related to the study. The following limitations will be made:

- Date: 2010-present
- Publication stage: Final

- Language: English
- Source Type: Journal Article
- Location: Egypt, Nigeria, South Africa

### 3.3.2 Collection and sampling of data

The literature collected in Step 3.1 was analysed for any duplications. Any duplications in literature were removed from the population of data. Furthermore, the literature population was analysed according to their popularity in the construction industry. This was done by removing articles that were not frequently cited in previous studies. The data is grouped according to the objective upon which they are based.

The remaining literature underwent a title, abstract and full text analysis to determine whether the journals covered data in a similar manner. Should journals fall under the criteria above, they were eliminated from the population. Furthermore, journals that didn't contain adequate information for answering the CRQ were eliminated from the population.

### 3.3.3 Analysis and Processing of Data

The process taken to analyse the data is that of a thematic analysis. Given this, the approach taken was that of a deductive perspective as well as a semantic approach. The deductive approach entails the analysis of data where some of the themes and concepts are known through theory or previous knowledge. Furthermore, a semantic approach was taken to analyse the explicit content of the data in the literature selected for the research.

The academic literature is summarised individually to aid in the NVivo coding process. The coding process is the backbone for the project as it filters information into various categories such as the objective identification and experimental results. Within the NVivo software, various nodes were created that store data and information that align with a specific theme. These themes were set up to achieve the CRQ and objectives of the research report. To tabulate the data into a single theme, large amounts of qualitative data will need to be categorized. This process allows for patterns in similarities of data collected to be identified. The detailed breakdown of the main nodes and their respective sub nodes used within the NVivo coding process can found in Figures 13 to 25 in Appendix E. In Figure 5 below, a summary of the main nodes and sub nodes are shown.

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Equipment Related Risks | 55 | 137 | 12/8/2022 11:14 AM | RJ |
| Material Related Risks | 59 | 231 | 12/8/2022 11:13 AM | RJ |
| Design Related Risks | 60 | 287 | 12/8/2022 11:14 AM | RJ |
| Consultant Related Risks | 64 | 328 | 12/8/2022 11:13 AM | RJ |
| External or Project Specific Risks | 63 | 356 | 12/8/2022 11:14 AM | RJ |
| Contractor Related Risks | 66 | 473 | 12/8/2022 11:13 AM | RJ |
| Owner Related Risks | 66 | 477 | 12/8/2022 11:12 AM | RJ |
| Impact of Supply Chain Risks | 0 | 0 | 12/8/2022 10:56 AM | RJ |
| Social Impact | 11 | 25 | 12/13/2022 9:05 AM | RJ |
| Contract and Legal | 17 | 35 | 12/30/2022 4:53 PM | RJ |
| Construction Activities | 25 | 44 | 12/30/2022 5:01 PM | RJ |
| Financial Impact | 30 | 60 | 12/13/2022 9:06 AM | RJ |
| Scheudule and Project Duration | 31 | 70 | 12/13/2022 8:59 AM | RJ |
| Mitigation Factors | 0 | 0 | 12/8/2022 2:49 PM | RJ |
| Project Design | 2 | 4 | 12/20/2022 6:04 AM | RJ |
| External | 2 | 4 | 12/20/2022 9:49 AM | RJ |
| Financial Management | 12 | 18 | 12/15/2022 6:14 AM | RJ |
| Consultant | 13 | 27 | 12/15/2022 6:12 AM | RJ |
| Owner | 13 | 27 | 12/15/2022 6:12 AM | RJ |
| Contract | 17 | 46 | 12/15/2022 6:12 AM | RJ |
| Contractor | 17 | 53 | 12/15/2022 6:11 AM | RJ |
| Project Managment | 23 | 81 | 12/15/2022 6:14 AM | RJ |

Figure 5: Summary of the Nodes and Sub-nodes used in NVivo.

In line with the qualitative methodology used in the study, the results were obtained through the key findings in the thematic analysis. The literature analysed consisted of 90 published papers, which, conformed to the data extraction form developed. The form was established to outline the processes to be followed which included the strict inclusion and exclusion criteria. The results were distributed throughout the research objectives, namely the identification of construction supply chain risks, the impact of construction supply chain risks and the mitigation of construction supply chain risks.

The filtering of candidate sources was done following the data extraction form and the PRISMA process. (Matthew , et al., 2021). Due to the high number of initial articles found from the various databases, the screening process for duplications was conducted after the eligibility of articles. The initial searches yielded 22,955,830 candidate sources across the five different databases. The candidate sources were determined using the key phrases that were established to answer the research objectives. The first elimination stage considered the geographical location for which the journal articles study was based. Given the CRQ aims at determining the impact of supply chain risks in Africa’s top three GDP nations, the candidate sources underwent an abstract analysis for Egypt, Nigeria, and South Africa. This stage excluded 22,715,019 articles. The second elimination stage eliminated articles that fell outside the time period allowed for the study being 2010-present. This stage excluded a total of 40,004 articles. The third elimination stage excluded articles that weren’t journal or research articles. It further excluded articles that were not published in English. This stage excluded a total of 142,747 articles. The fourth elimination stage considered the articles relevance to the research study, construction industry and construction supply chain. This stage excluded 53,355 articles that weren’t relevant to the research. The fifth elimination stage excluded any sources that were duplicated across databases. The articles were all stored within Zotero. Within the Zotero software, a document merger is available. The document merger merges any duplicated articles. This stage eliminated a total of 3,202 articles. The final elimination stage excluded articles that weren’t frequently cited or popular. It further excluded articles that didn’t have adequate information to answer the CRQ. This stage eliminated a total of 1,317 articles. From the remaining 186 articles, 90 articles were selected for the final thematic analysis. The table showing the number of articles retrieved at the end of each elimination stage, per key phrase and database used, can be found in Table 46 in Appendix F. Furthermore, a table showing the database of articles selected for analysis can also be found in Table 47 of Appendix F. The PRISMA elimination process can be seen below in Figure 6.

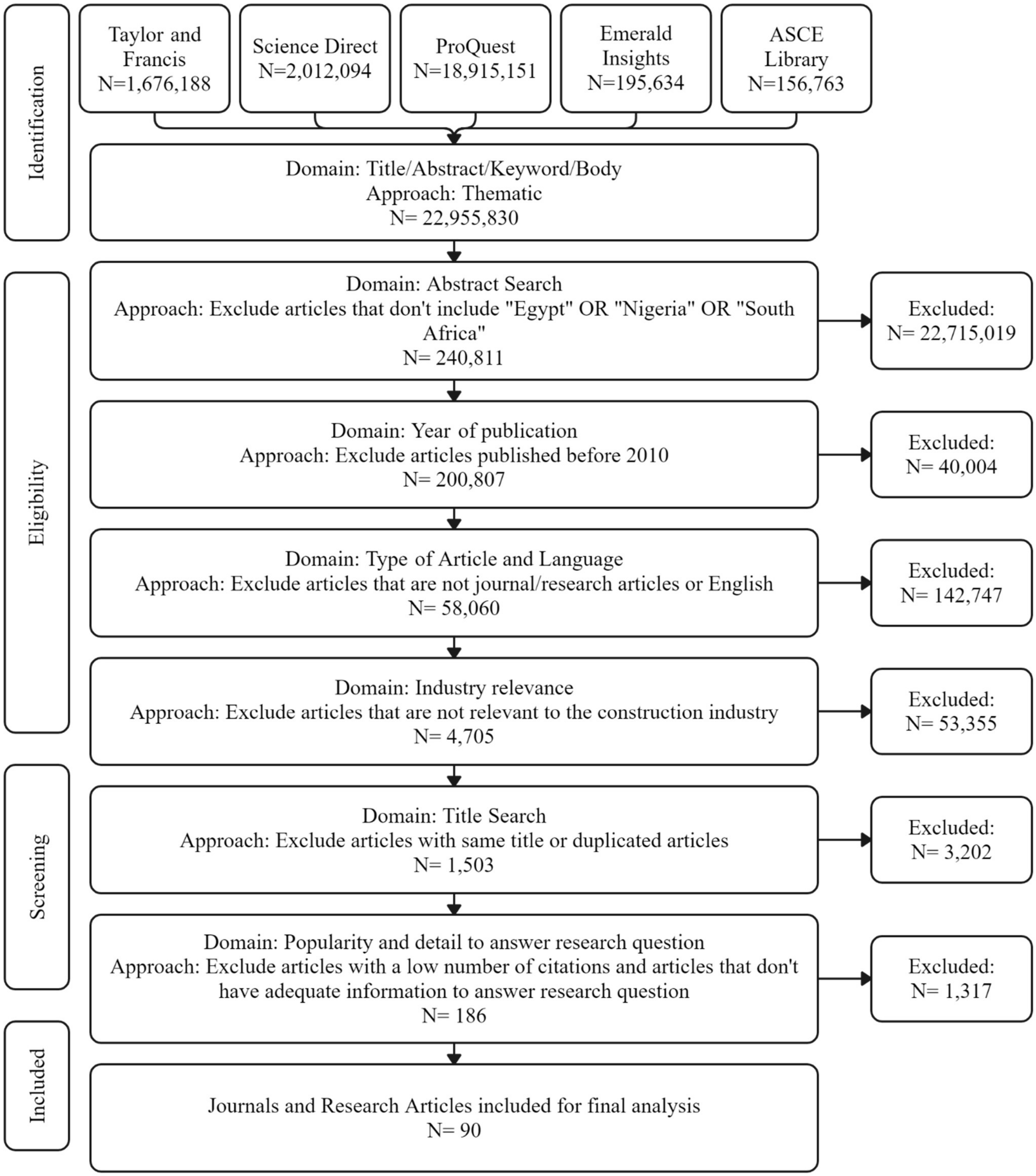


Figure 6: PRISMA process diagram for the elimination process.

The results were distributed throughout the research objectives, namely the identification of supply chain risks, the impact of supply chain risks, and the mitigation of supply chain risks in the construction industry. The content analysed generated the following findings: The approach to data collection that was most utilized was that of a critical literature review and questionnaire (33%), followed by that of systematic review (21%). The remainder of the methods used can be seen in Table 3.

Table 3: Data collection methods used in the published literature

| Data Collection Method | Number | Percentage |
|---|---|---|
| Critical Literature Review + Questionnaire | 30 | 33% |
| Systematic Review | 19 | 21% |
| Questionnaire | 15 | 17% |
| Critical Literature Review + Survey | 6 | 7% |
| Critical Literature Review + Interview | 5 | 6% |
| Case Study | 4 | 4% |
| Questionnaire and Interview | 4 | 4% |
| Survey | 3 | 3% |
| Critical Literature Review | 3 | 3% |
| Critical Literature Review + Questionnaire + Survey | 1 | 1% |

The articles used were sourced from reputable online databases. The database which was most utilized in the sourcing of published literature was Proquest (40%), followed by Science Direct (21%). The remainder of databases used can be seen in Table 4.

Table 4: Number of articles sourced from each database.

| Database | Number | Percentage |
|---|---|---|
| ProQuest | 36 | 40% |
| Science Direct | 19 | 21% |
| Emerald Insight | 15 | 17% |
| ASCE Library | 12 | 13% |
| Taylor and Francis | 8 | 9% |
| **Grand Total Selected** | **90** | **100%** |

The published literature was subjected to date of publication restrictions. The literature publication dates were required to fall within the date restrictions, being, 2010 to present. The time period was selected based on the number of articles available within the objectives of the study. From Figure

7 below, the most articles were published in the year 2020, having 17 articles followed by the years 2022 and 2021 both having 12. The number of articles published per year can be seen below in Figure 7.

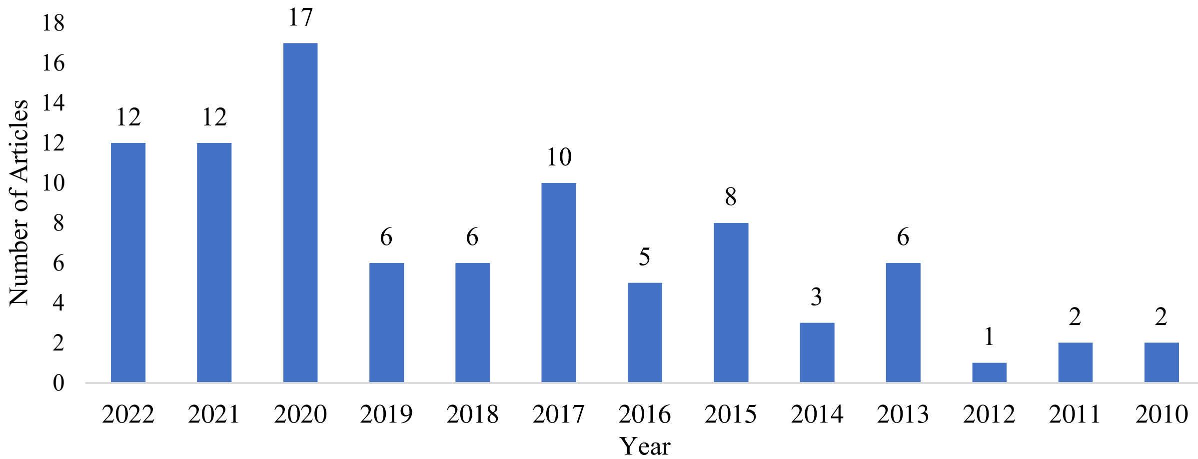


Figure 7: Number of articles published per year.

The data analysis that took place followed a multi-stage process. The initial stage was the analysis of the data according to the limitations of the study. This was done to ensure the data collected was relevant to the study. The second stage, qualitative data analysis, consisted of a textual narrative synthesis where specific extractions of the data were coded, grouped together in themes or their specific case node, which captured the context of the data. An extract of the codes made in Nvivo, for the contractor related risks, can be seen below in Figure 8. Figure 23, 24, and 25 in Appendix E further show the coding process followed.

<Files\\Mitigation\\Causes and mitigation strategies of delay in power construction projects. Gaps between owners and contractors in successful and unsuccessful projects> - § 7 references coded [0.60% Coverage]

Reference 1 - 0.03% Coverage
Poor cost management by the contractor

Reference 2 - 0.03% Coverage
Poor project planning and scheduling

Reference 3 - 0.02% Coverage
Contractor's poor site supervision

Reference 4 - 0.03% Coverage
Additional work attributable to mistakes

Reference 5 - 0.02% Coverage
Poor cost estimation

Reference 6 - 0.03% Coverage
Contractor's late payment to suppliers for works

Reference 7 - 0.03% Coverage
Late procurement order of material and equipment

<Files\\Supply Chain Risks\\Construction projects cost overrun. What does the literature tell us_> - § 12 references coded [2.87% Coverage]

Reference 1 - 0.30% Coverage
Technical incompetence, poor organizational structure, and lack of contractor's experience

Reference 2 - 0.12% Coverage
Poor project management. Incorrect preparation and planning by contractor.

Reference 3 - 0.12% Coverage
General poor preparation, planning and investigation of existing site conditions by contractors.

Reference 4 - 0.10% Coverage
Poor cost advice, inadequate contingency allowance or assessment of risks.

Reference 5 - 0.11% Coverage
Lack of cost planning, monitoring, and controlling during pre-and post-contract stages by the contractor.

Reference 6 - 0.18% Coverage
Contractor's poor site management and supervision skills.

Reference 7 - 0.11% Coverage
Cash flow and financial difficulties faced by contractor during construction stage.

Reference 8 - 0.09% Coverage
Mistakes during construction due to inadequate construction method.

Reference 9 - 0.06% Coverage
Delay payment to supplier /subcontractor.

Figure 8: Extract of the contractor related risks coded in Nvivo

Following the repetitive process of reading, contextualising, coding, grouping and node identification of all of the data, a collection of findings could be generated based off the themes, sub themes and ultimately the studies objectives. Table 5, below, shows the number of files used, or articles, and the number of codes made in identified sub-nodes. The number of codes refer to the number of codes made for the most frequently occurring elements in each theme and sub-theme.

Table 5: Number of files used, and number of codes made per theme.

| **Sub-Nodes** | **Relevant Articles** | **Number of Codes** |
|---|---|---|
| Cause of Supply Chain Risk | 49 | 3721 |
| Construction Risk Mitigation | 12 | 411 |
| Responsible Group | 22 | 405 |
| Impact of Risk | 27 | 289 |
| Technology | 12 | 141 |

The results are analysed according to their objectives within the study. Within the first objective, the causes of supply chain risks were identified per sub-theme. The impact of supply chains risks was broken up into the impact itself, severity, likelihood, and overall importance. The last objective was developed to determine the mitigation factors to lessen the impact of supply chain risks by identifying mitigation strategies and technologies.

### 3.3.4 Indices

The indices – frequency index, severity index and importance index were used to determine the frequency, severity, the importance of the construction industry supply chain risks and supply chain risk impacts. The formulas used for the calculations are stated in (Assaf & Al-Hejji, 2006) and is presented in the below sections. The degree of frequency and severity was determined by conducting a risk assessment on all the identified construction supply chain risks and their impact.

In the risk and impact assessment, found in Appendix G, the degree of frequency and degree of severity was ranked according to the description of each level of degree associated to the severity and risks and impacts. The degree of frequency was ranked on as scale from 1 being ‘rare’ to 5 being ‘very likely’. Furthermore, the degree of severity was ranked on a scale from 1 being ‘minor’ to 5 being ‘excessive’.

#### 3.3.4.1 Frequency Index (F.I)

The frequency index is depicted by Equation 1, as stated by (Assaf & Al-Hejji, 2006). The frequency index is used to rank the identified risks according to the frequency of their occurrence.

$$(\text{F.I})(\%) = a\left(\frac{n}{N}\right) \times \frac{100}{5} \tag{1}$$

Where, a implies the degree of frequency (ranges from 1 for rare to 5 for very likely), n is the number of codes in that section, N is the total number of codes.

#### 3.3.4.2 Severity Index (S.I)

The severity index is depicted by Equation 2, as stated by (Assaf & Al-Hejji, 2006). The severity index is used to rank the identified risks according to the severity of their occurrence.

$$(\text{S.I})(\%) = a\left(\frac{n}{N}\right) \times \frac{100}{5} \tag{2}$$

Where, a means the degree of severity (ranges from 1 for very low to 5 for very high), n is the number of codes in that section, N is the total number of codes

#### 3.3.4.3 Importance Index (IMP.I)

The important index is depicted by Equation 3. The important index of each identified construction supply chain risks is calculated as a product of the frequency index and severity index divided by 100.

$$(\text{IMP.I})(\%) = \left(\frac{[(F.I)(\%) \times (S.I)(\%)\,]}{100}\right) \tag{3}$$

Where, (F.I)(%) is the frequency index, and (S.I)(%) is the severity index.

### 3.4 Validity and Reliability

To ensure the validity of the research project, various protocols were carried out. The process highlighted in Section 3.3 is a comprehensive and thorough method, however, this does not exclude the chance of any bias being included in the research. Data used in Section 3.3 was selected through the collection and sampling of candidate sources that are of an acceptable repute and objectively based (Zaza, et al., 2000). Given this, the data collected would achieve an adequate consistency and validity. The use of clearly defined coding in Section 3.3, allowed the data to be clearly organized into themes and sub-themes to determine the patterns in a manner that provides an unbiased judgement in the research project (Gamage, 2019). This ensures that only data relevant to the research is portrayed in the research findings (Zaza, et al., 2000).

To ensure reliability of the research project, a clear definition and outline of the methodology was established. This was achieved by defining the research method and providing the required steps to be followed in the data collection, sampling, processing, and analysis process (Gamage, 2019). The presentation of clearly defined themes and sub-themes (Construction supply chain risks, impact of supply chain risks, mitigation of supply chain risks, cause of supply chain risks, technology, and the severity, likelihood, and importance of supply chain risks) are given, thus determining how the findings of the themes would be given in the thematic analysis. The exclusion and inclusion criteria of literature to be used is presented in Section 3.3. The PRISMA process was followed when conducting the sourcing, research, and analysis of relevant articles (Matthew , et al., 2021). Furthermore, the PRISMA and the exclusion and inclusion criteria process were repeated throughout the article selection process, allowing for consistency and repeatability of the research findings. This process was conducted to aid the internal consistency of the findings in the thematic analysis by ensuring the validity and reliability of the research project (Gamage, 2019).

## 3.5 Ethical Issues/Clearance

The data utilised in the research project is sourced from academic literature from various databases. The data is referenced and credited to align the data with ethical procedures. Ethical approval will still be needed in the form of a waiver that will be submitted to the schools Ethics Committee. Furthermore, ethical clearance was applied for in the August 2021 submission and was granted on the 3rd of September 2021. The ethics protocol number published was MIAEC 088/21.

# CHAPTER 4

# 4. ANALYSIS AND RESULTS

## 4.1 Introduction

This chapter gives a detailed breakdown of the analysed themes and sub-themes and presents the results from the data analysis. As discussed in Chapter 3, the construction industry supply chain risks and the responsible group were identified and presented in the identification of the supply chain risks section. The subsequent ranking of the risks according to the frequency, severity, and important indices for the client, consultant, contractor, material, equipment, design, and external or project specific risks was conducted. This was achieved after the data collection and Nvivo coding process was completed. The degree input for the frequency and severity of the risks and the impact of supply chain risks was established through the risk and impact assessments, found in Appendix G. Lastly, the mitigation factors to lessen the impact of the risks were identified and analysed according to the risks to which the mitigation factor is attempting to address.

## 4.2 Construction industry supply chain risks

Construction supply chain risks are activities or risks that cause delay, disruption to any activity, during or before the construction phase, that results in the disruption or increase in the project's completion time and costs (Oluwaseun & Kruger, 2017). The below section analyses the number of codes made in the Nvivo coding process to identify the construction supply chain risks and the subsequent responsible group. The risks are tabulated in Appendix B for each risk group. The table shows the risks identified which relate to that risk group, ranked according to the percentage of codes given to that risk during the coding process.

### 4.2.1 Client Construction Supply Chain Risks

The results for the identification of the client's related construction supply chain risks are presented in Table 28 of Appendix B. The client related risks were identified through the analysis of 52 different sources of published literature. From the literature analysed, 19 different client related supply chain risks were identified. The most frequently identified risk was that of change orders and scope changes by the client (16%), followed by that of financial difficulties and delayed payments (13%).

The client performs a significant role in determining whether the construction project will be successful or not. However, due to their lack of construction experience (3%), the decisions made throughout the project often result in schedule and cost overruns. Despite receiving a low percentage of codes, (Aljohani, 2017) states that the lack of experience is a critical factor effecting the projects performance. The lack of client experience often has knock on effects before and throughout the project. Poor pre-project planning (3%) leads to a poorly defined scope, unrealistic project duration (5%), and often require change orders and scope changes (16%), which was the most identified client related risk, through the construction phase. Likewise, (Gashahun, 2020), (Zidane & Anderson, 2018), and (Motlhatlhedi & Nel, 2019) all identified change orders and scope changes as the clients top cause of supply chain risks. Change orders and scope changes are caused by, not limited to, indecisiveness of the client, unrealistic designs, and financial difficulties.

Financial difficulties (13%), which ranked second for the client related supply chain risks, can be detrimental to the project's completion. Financial difficulties may result from economic situations, mismanagement, inflation, and unexpected costs throughout the construction phase. (Alade, et al., 2019), (Jacob & Sunjka, 2013), and (Amoah & Pretorius, 2019) all identified financial difficulties as a major concern for successfulness of the project. Furthermore, financial difficulties often result in delayed payments (13%). Delayed payments, also ranking second, result in milestone payments being missed, delay in material delivers and the non-payment of worker salaries. This is further reiterated by (Zidane & Anderson, 2018), stating that this often leads to loss of productivity onsite due to idle times.

The awarding the contract to the lowest bidder (4%) is often the case due to the client's lack of experience and cost saving opportunities. However, often this results in the inexperienced contractors being appointed. (Obianyo, et al., 2022) states that this often leads to errors and reworks being required. Should poorly contract management (5%) occur without developing clauses and tools to deal with such reworks and delays, claims (4%) and disputes (3%) may occur. Claims and disputes are also likely to occur due to poor communication (6%), and slow decision making (8%) between stakeholders in the project often leads to misunderstandings and the misrepresentation of facts. (Zidane & Anderson, 2018) and (Gashahun, 2020) both identified poor communication as a top critical factor causing supply chain risks. The least frequently occurring risk identified for the client was that of client death (0.13%).

### 4.2.2 Consultant Related Risks

The results for the identification of the consultants related construction supply chain risks are presented in Table 29 of Appendix B. The consultant related risks were identified through the analysis of 47 different sources of published literature. From the literature analysed, 9 different consultant supply chain risks were identified. The most frequently identified risk was that of poor planning and scheduling (23%), followed by that of an incorrect estimate (19%) and poor communication and coordination (12%).

Inadequate consultant experience ranked averagely with 11%. However, most of the consultant related supply chain risk are caused by their lack of experience. Poor managerial and supervisory skills are often the results of inadequate expertise by the consultant. (Enshassi, et al., 2010), identified the lack of consultant experience as a critical factor in causing supply chain risks. Poor planning and scheduling (23%) was the top ranked consultant risk. (Dlamini & Cumberlege, 2021) and (Gashahun, 2020) confirm this by stating that consultants often oversee factors such as weather, equipment idle time and material limitations, resulting in an incorrect estimate (19%) for the projects schedule and costs. The incorrect project estimate (19%), ranking second, is caused by technical errors in estimation, incompetence, and the lack of previous experience. (Baloyi & Bekker, 2011) reiterate the importance of an accurate and thorough estimate for any construction projects successful completion within the contracted period.

Poor communication and coordination (12%), ranking third, and the slow inspection of works (8%) often coincide. (Amoah & Pretorius, 2019) states that consultants are often found to not communicate sufficiently between each other in the implementation stages of the project, resulting in discrepancies in the estimates and designs. Change orders are often required once these design discrepancies are identified during the construction stage. Often the slow inspection of works (8%) by the consultant causes significant delays to the project momentum an operation. Lastly the use of incomplete documents (3%) reiterates the importance of communication and experience of the consultants to ensure all the documents are complete and thorough, avoiding delays on site.

### 4.2.3 Contractor Related Risks

The results for the identification of the contractors related construction supply chain risks are presented in Table 30 of Appendix B. The contractor related risks were identified through the analysis of 52 different sources of published literature. From the literature analysed, 16 different contractor related supply chain risks were identified. The most frequently identified risk was that of improper planning and coordination (13%), followed by that of the shortage of skills and labour (11%) and financial and cashflow difficulties (10%).

Financial and cash-flow difficulties (10%) for the contractor often contribute to project failures. Contractors sometimes don't allocate the funds paid from the client towards the projects resources often resulting in the shortage of resources needed. Furthermore, the lack of funds often results in delayed payments to workers and creates the low motivation for staff (2%). (Amoah & Pretorius, 2019) identified financial difficulties as a major impact on the project's success.

Inadequate contractor experience (9%), ranked fifth, has implications on many of the contractor related risks. The inexperience to resolve problems in an expeditious manner often results in the delay of works and poor labour productivity (5%). (Mukuka, et al., 2015) identified contractor inexperience as one of the top three significant causes of construction supply chain risks. The inexperience of the contractor often cascades down throughout their organisation. This leads to poor site management (10%) and project management (5%) as unskilled managers and labour (5%) are being deployed on the project. Furthermore, (Aljohani, 2017), and (Alade, et al., 2019) identified contractor inexperience as a major factor contribution to project delay.

The lack of contractor experience often leads to the improper planning and coordination (13%), as well as poor communication (6%). Planning in the construction industry is critical for its successful completion. (Gunduz & Al-Naimi, 2022) identified improper planning as the most important contractor related factor causing supply chain risk in construction projects. Many contractors, due to lack of experience, fail to provide practical building schedules which leads to an unachievable timeline expectation and thus, schedule delays occur. Poor communication between parties often results in the lack of planning and coordination between trades, allowing mistakes and errors (5%) to be made resulting in rework. (Obianyo, et al., 2022) reiterates the importance of the contractor experience in ensure effective planning and coordination is achieved throughout the project.

The shortage of labour and skills (11%), ranked second, may be because of the shortage of labour work permits and ineffective procurement of staff by the contractor. Both (Mukuka, et al., 2015) and (Zidane & Anderson, 2018) identified the shortage of labour and skills as a critical delay factor in construction projects. The least frequently occurring risks identified for the contractor were that of and inappropriate construction methods (2%).

### 4.2.4 Design Related Risks

The results for the identification of the design related construction supply chain risks are presented in Table 31 of Appendix B. The design related risks were identified through the analysis of 38 different sources of published literature. From the literature analysed, 8 different supply chain risks were identified. The most frequently identified risks were that of design changes and variation orders (20%), followed by that of incomplete designs (16%) and design errors (15%).

Design changes and variation orders (20%), ranked as most significant design risk, frequently occur in construction projects. Depending on the significance of the change, it may affect the project schedule and budget. (Oluyemi-Ayibiowu, et al., 2019) and (Herrera, et al., 2020) both identified design changes as a significant factor resulting in schedule and cost overruns. The use of incomplete designs (16%) ranked second. The incomplete design is characterised when there are inherent flaws and errors (15%) in the design drawings that have been submitted for construction to begin. (Gebrehiwet & Luo, 2017) found that incomplete designs and design errors often lead to significant schedule and cost implications. Furthermore, delays in performing changes (13%) due to design errors, are often responsible for lengthy schedule delays. The least frequently occurring risk identified for the projects design was that of changes in specification (3%).

### 4.2.5 Equipment Related Risks

The results for the identification of the equipment related construction supply chain risks are presented in Table 32 of Appendix B. The equipment related risks were identified through the analysis of 43 different sources of published literature. From the literature analysed, 9 different equipment related supply chain risks were established. The most frequently identified risk was equipment shortage (32%), followed by that of delay in equipment delivery (21%) and equipment price escalation (14%).

The shortage of equipment (32%), ranked first for equipment related risks. The shortage of equipment has a direct relationship with the contractor’s financial position. The unavailability of equipment in the required volume and quality, has significant impacts on the schedule and budget of the project. (Oluyemi-Ayibiowu, et al., 2019) found that the shortage of equipment was one of the top 10 overall risks of construction projects. The ineffective procurement (12%) of equipment results in the delay in equipment delivery (21%), due to late ordering or the unavailability of equipment from suppliers. (Gashahun, 2020) found that due to the delay in equipment delivery, and equipment breakdown (10%), resulted in the loss of worker productivity, and idle time occurs. This significant impacts on the projects schedule and operations. Furthermore, the financial position of the contractor determines whether the contractor can procure equipment for the project when equipment price escalation (14%) occurs. Equipment price escalation, ranked third, and is caused by supply and demand, variation in exchange rates and inflation. (Herrera, et al., 2020) found equipment price escalation as the second most reported factor causing supply chain risk impacts. The least frequently occurring risk identified for equipment was that of theft (0.43%), which is usually planned for mitigated as theft in developing countries has been significant throughout construction projects.

#### 4.2.6 External or Project Specific Risks

The results for the identification of the external or project specific related construction supply chain risks are presented in Table 33 of Appendix B. The external or project specific risks were identified through the analysis of 43 different sources of published literature. From the literature analysed, 18 different external or project related risks were identified. The most frequently identified risks were weather conditions and inflation (11%), followed by that of site conditions and location (10%).

The weather conditions (11%) on any project are a significant cause of schedule delay and cost overrun. Weather conditions can’t be mitigated, however, their impact on the project can. Weather conditions are found to impact labor productivity, especially temperature. Significant natural disasters may result in the project abandonment due to force majeure (4%) being enforced. (Zidane & Anderson, 2018) and (Carvalho, et al., 2021) found that weather conditions were a significant cause of construction delays. Furthermore, site conditions and location (10%), which ranked third, are greatly affected by weather conditions. The unstable site conditions may result in site accidents (2%) occurring. The inaccurate assessment of the site conditions could lead to unforeseen ground conditions (7%). (Dlamini & Cumberlege, 2021) and (Egwim, et al., 2021) found that, depending on what conditions were establish, unforeseen ground conditions, could potentially cause difficulty in planning and scheduling, thus, causing significant cost and schedule overruns to the project. As a result, the delay in site preparation (3%) may occur, this is due to ground specifications and engineering documents being amended. Given the location and site condition, traffic management (0.49%) may be difficult to coordinate, causing problems with the surrounding neighbors (2%).

Inflation (11%), ranked first for external or project specific risks, is a factor to the project that will always exist, however, it is often overlook by the project stakeholders. (Ejekwu, et al., 2022) found that inflation was the most severe causes of cost escalation and project overruns. Inflation and economic risks (9%) may result from political instability (6%). Irregular decisions by government and the changing of laws and regulations (7%), such as monetary and fiscal policies, can result in the overall escalation of the construction projects materials. (Jacob & Sunjka, 2013) found that political interference and inflation, significantly impacts the schedule as additional time is needed approvals for price fluctuations and contract revision. Corruption (7%) and political interference (6%) was identified by (Jacob & Sunjka, 2013) as being a significant risk in construction projects. Public sector projects often have political leaders who have vested interests in the project. This often results in irregular tenders and changes of scope being required. (Mahmud, et al., 2021) found that political interference and corruption were highly identified as causes of cost overruns.

### 4.2.7 Material Related Risks

The results for the identification of the material related construction supply chain risks are presented in Table 34 of Appendix B. The material related risks were identified through the analysis of 49 different sources of published literature. From the literature analysed, 10 different material related supply chain risks were identified. The most frequently identified risk was that of a shortage in materials (26%), followed by that of material price escalation (23%) and the delay in material delivery (17%).

The shortage of materials (26%), ranked first for material related risks, may be caused by the shortage of materials in the market or the financial difficulties faced by the contractor. The contractors lack of cash-flow, caused by poor financial management or delayed payments from the client results in the non-payment for materials. This is also due to suppliers not wanting to supply material on credit due to the substantial number defaulting contractors. (Egwim, et al., 2021) and (Mahmud, et al., 2021) found that the shortage of materials is an important factor that causes project delays.

Material price escalation (23%), ranked second, and can be attributed to the supply and demand in the market. Furthermore, the price escalation is associated with rising exchange rates and economic conditions in the country. (Saidu & Shakantu, 2017) and (Mahmud, et al., 2021) both stated that price escalation was one of the most severe causes of material related risks. Ineffective procurement (11%) often results in the delay material delivery (17%), which ranked third for material related risks. The delay in material delivery is also caused by unreliable suppliers (5%) and due to poor quality materials (10%) being available. The incorrect material delivered to site (1%), or material of the wrong specification, leads to schedule delays due to idle time waiting for the correct material to be delivered. (Carvalho, et al., 2021) found that unreliable suppliers and poor-quality materials are frequently occur material related risks. The least frequently occurring risk identified for materials was that of theft (1%).

### 4.2.8 Top Identified Construction Supply Chain Risks

The results for the identification of the top supply chain risks are shown below in Table 6. The table shows the top 20 risks identified relating to the following sub-themes or groups: client, consultant, contractor, material, equipment, design, and external or project specific related factors, ranked per the number of codes given to that risk, out of the total codes in the top identified risks. The top supply chain risks, analysed from 52 sources of published literature, were determined by taking the top twenty most frequently coded risks across all the above groups. The most frequently identified risk was related to the client and was that of change orders and scope changes (7.3%). The second most frequently identified risk was related to the contractor and was that of improper planning and coordination (6.7%). Lastly, the third most identified risks were related to the consultant and client. These risks were poor planning and scheduling (6.2%) as well as financial difficulties (6.2%) respectably. The remaining top risks identified for the various groups can be seen below in Table 6.

Table 6: Top identified supply chain risks and relevant responsible group.

| Construction Supply Chain Risks | Relevant Group Responsible | Percentage of Codes |
|---|---|---|
| Change Orders and Scope Changes | Client | 7.3% |
| Improper Planning & Coordination | Contractor | 6.7% |
| Poor Planning and Scheduling | Consultant | 6.2% |
| Financial Difficulties | Client | 6.2% |
| Delayed Payments | Client | 5.9% |
| Shortage of Skills or Labour | Contractor | 5.3% |
| Material Shortages | Material | 5.1% |
| Financial & Cash-flow Difficulties | Contractor | 5.0% |
| Incorrect Estimate | Consultant | 4.9% |
| Poor Site Management | Contractor | 4.8% |
| Design Changes | Design | 4.8% |
| Variation Orders | Design | 4.8% |
| Inadequate Contractor Experience | Contractor | 4.7% |
| Material Price Escalation | Material | 4.4% |
| Equipment Shortage | Equipment | 4.3% |
| Poor Contract Management | Client | 4.2% |
| Weather Conditions | External/Project Specific | 4.0% |
| Incomplete Designs | Design | 3.9% |
| Inflation | External/Project Specific | 3.8% |
| Slow Decision Making | Client | 3.8% |

Out of the top identified risks, based on the number of codes made, the relevant sub-themes can be analysed to determine which group is responsible for the most risks in the top identified supply chain risks. From Figure 9 below, the contractor and client are both responsible for 25% of the top identified risks, followed by that of the design which is responsible for 15%. The least responsible group is that of equipment risks with only 5% of the top identified risks. The remaining responsible groups can be seen below in Figure 9.

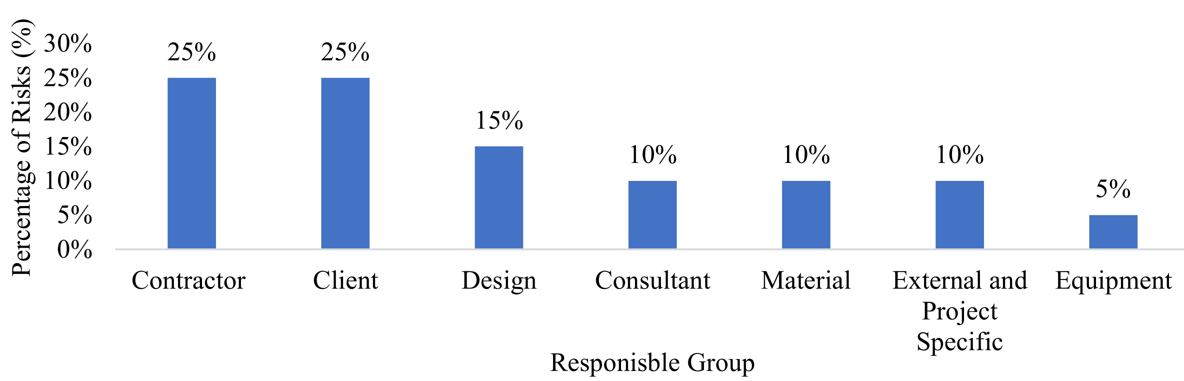


Figure 9: Responsible groups for the top identified risks

## 4.3 Impact of supply chain risks

The impact of the identified construction supply chain risks were determined using the risk and impact assessment which can be found in Table 48 of Appendix G. The subsequent frequency, severity, and importance of the risks was determined using indices. The frequency, severity and importance indices of the identified risks and their responsible group are presented in this section.

The subsequent frequency, severity, and importance indices for the identified supply chain risks, were colour coded to represent their respective frequency of occurrence, severity, and the overall importance of the risk. The following shows the criteria for which the frequency index was ranked.

| | |
|---|---|
| - Frequency Index 0 to 20%, risks that almost never occur | Likelihood is Rare |
| - Frequency Index 21 to 40%, risks that don't occur often | Likelihood is Unlikely |
| - Frequency Index 41 to 60%, risks that may occur | Likelihood is Possible |
| - Frequency Index 61 to 80%, risks that may occur often | Likelihood is Likely |
| - Frequency Index 81 to 100%, risks that are highly likely occur | Likelihood is Very Likely |

The severity of the supply chain risk impact was colour coded based on the below criteria:

| | |
|---|---|
| - Severity Index 0 to 20%, No impact on project | Very Low Severity |
| - Severity Index 21 to 40%, Minimal impact project | Minor Severity |
| - Severity Index 41 to 60%, Some impact on project | Moderate Severity |
| - Severity Index 61 to 80%, Significate impact on project | Major Severity |
| - Severity Index 81 to 100%, Excessive impact on project | Very High Severity |

The overall importance of the supply chain impact was colour coded based on the below criteria:

| | |
|---|---|
| - Importance Index: 0 to 20% | Negligible Overall Impact |
| - Importance Index: 21 to 40% | Minor Overall Impact |
| - Importance Index: 41 to 60% | Moderate Overall Impact |
| - Importance Index: 61 to 80% | High Overall Impact |
| - Importance Index: 81 to 100% | Very High Overall Impact |

The frequency, severity, and importance of the identified impacts are presented below sections.

### 4.3.1 Client related risk indices

The client related risks were analysed to determine which risks were the most frequent, severe the most important overall. From Table 7 below, both delayed payments and financial difficulties obtained scores of 100% for all the indices, ranking them the most important client related risks with a very high overall impact on the project. However, both awarding the project to the lowest bidder and change orders and scope changes ranked second with an overall importance of 80%, resulting in a high overall impact on the project. Despite the suspension of work and client death obtaining very high and major severities, the frequency of their occurrence meant that their overall importance was minor and negligible respectably. The analysis of the remaining risks can be found below in Table 7.

Table 7: Client related risk indices

| Risk Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Delayed Payments | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Financial Difficulties | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Awarding The Project to the Lowest Bidder | Very High | 100 | 1 | Likely | 80 | 2 | 80 | 2 |
| Change Orders and Scope Changes | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 2 |
| Unrealistic Project Duration | Major | 80 | 2 | Likely | 80 | 2 | 64 | 3 |
| Poor Pre-project Feasibility and Planning | Very High | 100 | 1 | Possible | 60 | 3 | 60 | 4 |
| Poor Communication | Major | 80 | 2 | Possible | 60 | 3 | 48 | 5 |
| Poor Contract Management | Major | 80 | 2 | Possible | 60 | 3 | 48 | 5 |
| Lack of Construction Experience | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 5 |
| Poor Project Management | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 5 |
| Slow Decision Making | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 5 |
| Claims | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Delay in Approving Documents | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Disputes | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Lack of Insurance & Contingencies | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Client Interference | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Suspension of Work | Major | 80 | 2 | Unlikely | 40 | 4 | 32 | 7 |
| Delay in Site Handover | Minor | 40 | 4 | Possible | 60 | 3 | 24 | 8 |
| Client Death | Very High | 100 | 1 | Rare | 20 | 5 | 20 | 9 |

### 4.3.2 Consultant related risk indices

The consultant related risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 8 below, multiple risks ranked first overall for the consultant. The incomplete estimate, poor planning and scheduling, and the slow inspection of works obtained both severity and frequency indices of 80%. Given this, they are both likely to occur whilst having major severity on the project. Their overall importance was 64%, having a high overall impact on the project. Despite the majority of the risks obtaining a major severity at 80%, due to the frequency of their occurrence, they obtained a moderate overall impact on project with their importance scoring 48%. Lastly, the least important risk related to the consultant is that of incomplete documents. Incomplete documents ranked fourth overall and obtained a severity of moderate, whilst its frequency scored unlikely. Given this, its overall importance is considered minor on the project. The remaining consultant related risks can be found below in Table 8.

Table 8: Consultant related risk indices

| **Risk Description** | **Severity** | **Severity Index (%)** | **S.I Rank** | **Likelihood** | **Frequency Index (%)** | **F.I Rank** | **Importance Index (%)** | **IMP.I Rank** |
|---|---|---|---|---|---|---|---|---|
| Incorrect Estimate | Major | 80 | 1 | Likely | 80 | 1 | 64 | 1 |
| Poor Planning and Scheduling | Major | 80 | 1 | Likely | 80 | 1 | 64 | 1 |
| Slow Inspection of Works | Major | 80 | 1 | Likely | 80 | 1 | 64 | 1 |
| Inadequate Consultant Experience | Major | 80 | 1 | Possible | 60 | 2 | 48 | 2 |
| Poor Communication & Coordination | Major | 80 | 1 | Possible | 60 | 2 | 48 | 2 |
| Poor Contract Management | Major | 80 | 1 | Possible | 60 | 2 | 48 | 2 |
| Poor Management | Major | 80 | 1 | Possible | 60 | 2 | 48 | 2 |
| Delay In Document Preparation & Submission | Moderate | 60 | 2 | Possible | 60 | 2 | 36 | 3 |
| Incomplete Documents | Moderate | 60 | 2 | Unlikely | 40 | 3 | 24 | 4 |

### 4.3.3 Contractor related risk indices

The contractor related risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 9 below, both inadequate contractor experience and poor site management obtained a score of 100% for all the indices, ranking them as the most important contractor related risks with a very high overall impact on the project. Poor project management ranked fourth overall with a moderate overall risk on the project, scoring 60% for its overall importance. However, its severity scored very high at 100%. Given this, its frequency scored 60% which suggests that it may possibly occur, however this is dependent on the expertise contacted to the project. The least important risk was that of low motivation which ranked seventh overall with minor in overall impact. The remaining contractor risks can be seen below in Table 9.

Table 9: Contractor related risk indices

| Risk Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Inadequate Contractor Experience | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Poor Site Management | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Financial & Cash-flow Difficulties | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 2 |
| Improper Planning & Coordination | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 2 |
| Shortage of Skills or Labour | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 2 |
| Poor Communication | Major | 80 | 2 | Likely | 80 | 2 | 64 | 3 |
| Poor Contract Management | Major | 80 | 2 | Likely | 80 | 2 | 64 | 3 |
| Poor Project Management | Very High | 100 | 1 | Possible | 60 | 3 | 60 | 4 |
| Poor Labour Productivity | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 5 |
| Subcontractor Issues | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 5 |
| Errors/Mistakes Leading to Rework | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Unskilled Management Team & Labour | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Inappropriate Construction Methods | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 7 |
| Insufficient Quality Control | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 7 |
| Labour Dispute or Strike | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 7 |
| Low Motivation | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 7 |

### 4.3.4 Design related risk indices

The design related risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 10 below, the design risk that is the most important is that of design changes. It ranked with a high overall impact on the project with an overall importance score of 80%. This is attributed to its very likely frequency of occurrence and major severity on the project. Variation orders scored a moderate severity whilst it is very likely to occur. Overall, it ranked second with an overall importance of moderate scoring 60%. Likewise, design errors and incomplete design ranked moderate overall whilst both obtaining major severities. Changes in specifications and structural variations both ranked fifth for their overall importance and impact being minor. The remaining design related risks can be seen below in Table 10.

Table 10: Design related risks indices

| Risk Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Design Changes | Major | 80 | 1 | Very Likely | 100 | 1 | 80 | 1 |
| Variation Orders | Moderate | 60 | 2 | Very Likely | 100 | 1 | 60 | 2 |
| Design Errors | Major | 80 | 1 | Possible | 60 | 2 | 48 | 3 |
| Incomplete Designs | Major | 80 | 1 | Possible | 60 | 2 | 48 | 3 |
| Delay in Changes | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 4 |
| Poor Communication | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 4 |
| Changes in Specification | Moderate | 60 | 3 | Unlikely | 40 | 3 | 24 | 5 |
| Structural Variations | Moderate | 60 | 3 | Unlikely | 40 | 3 | 24 | 5 |

### 4.3.5 Equipment related risk indices

The equipment related risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 11 below, equipment shortages were identified as the most important equipment related risk, with a high overall impact on the project. This was attributed to its severity being very high and scoring 100%, whilst its frequency was likely to occur and score 80%. The delay in equipment delivery scored 80% for both its severity and frequency, suggesting that it is likely to occur with major impacts on the project. Furthermore, it ranked second overall for its importance, scoring 64% overall, resulting in a high overall impact on the project. Theft and the wrong equipment being delivered ranked sixth overall scoring 12%. Given this, they would have negligible overall impact on the project, however, this is due to their frequency both being rare. The severity of both scored 60%, suggesting that they would have a moderate severity on the project deepening on situation that occurs. The remining equipment related risks can be seen below in Table 11.

Table 11: Equipment related risk indices

| Risk Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Equipment Shortage | Very High | 100 | 1 | Likely | 80 | 1 | 80 | 1 |
| Delay in Equipment Delivery | Major | 80 | 2 | Likely | 80 | 1 | 64 | 2 |
| Equipment Price Escalation | Major | 80 | 2 | Possible | 60 | 2 | 48 | 3 |
| Ineffective Procurement | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 4 |
| Equipment Breakdown | Moderate | 60 | 3 | Unlikely | 40 | 3 | 24 | 5 |
| Poor Equipment Operator Skills | Moderate | 60 | 3 | Unlikely | 40 | 3 | 24 | 5 |
| Poor Equipment Productivity | Moderate | 60 | 3 | Unlikely | 40 | 3 | 24 | 5 |
| Theft | Moderate | 60 | 3 | Rare | 20 | 4 | 12 | 6 |
| Wrong Equipment | Moderate | 60 | 3 | Rare | 20 | 4 | 12 | 6 |

### 4.3.6 External or Project specific related indices

The external or project specific risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 12 below, both weather conditions and inflation were identified as the most important risk overall, scoring 80% and having a high overall impact on the project. However, the frequency of weather conditions was very likely and ranked first with a score of 100%, whilst it ranked major for its severity scoring 80%. Contrary to that, inflation obtained a very high severity score of 100%, whilst its frequency of occurrence was likely scoring 80%. Corruption, force majeure, and site accidents all obtained very high severities scoring 100%, whilst their frequency of occurrence likely, unlikely and rare respectably.

Given the lower frequency of occurrences, corruption ranked third overall with a moderate overall impact on the project, force majeure ranked fifth overall with a minor overall impact on the project, whilst site accidents ranked seventh overall with a negligible overall impact on the project. The remaining external and project specific risks can be seen below in Table 12.

Table 12: External or project specific related risk indices

| **Risk Description** | **Severity** | **Severity Index (%)** | **S.I Rank** | **Likelihood** | **Frequency Index (%)** | **F.I Rank** | **Importance Index (%)** | **IMP.I Rank** |
|---|---|---|---|---|---|---|---|---|
| Weather Conditions | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 1 |
| Inflation | Very High | 100 | 1 | Likely | 80 | 2 | 80 | 1 |
| Economic Risks | Major | 80 | 2 | Likely | 80 | 2 | 64 | 2 |
| Environment Concerns | Major | 80 | 2 | Likely | 80 | 2 | 64 | 2 |
| Law and Regulation Changes | Major | 80 | 2 | Likely | 80 | 2 | 64 | 2 |
| Site Conditions and Location | Major | 80 | 2 | Likely | 80 | 2 | 64 | 2 |
| Corruption | Very High | 100 | 1 | Likely | 60 | 3 | 60 | 3 |
| Political Instability | Major | 80 | 2 | Possible | 60 | 3 | 48 | 4 |
| Political Interference | Major | 80 | 2 | Possible | 60 | 3 | 48 | 4 |
| Unforeseen Ground Conditions | Major | 80 | 2 | Possible | 60 | 3 | 48 | 4 |
| Force Majeure | Very High | 100 | 1 | Unlikely | 40 | 4 | 40 | 5 |
| Delay in Approvals from Council | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 6 |
| Site Accident | Very High | 100 | 1 | Rare | 20 | 5 | 20 | 7 |
| Delay in site preparation | Minor | 40 | 4 | Unlikely | 40 | 4 | 16 | 8 |
| Arbitration | Major | 80 | 2 | Rare | 20 | 5 | 16 | 8 |
| Litigation | Moderate | 60 | 3 | Rare | 20 | 5 | 12 | 9 |
| Problem with Neighbours | Moderate | 60 | 3 | Rare | 20 | 5 | 12 | 9 |
| Traffic Management | Very Low | 20 | 5 | Rare | 20 | 5 | 4 | 10 |

### 4.3.7 Material related risk indices

The material related risks were analysed to determine which risks were the most frequently occurring, the most severe and which risks were the most important overall. From Table 13 below, both material price escalation and weather conditions and inflation were identified as the most important risk overall, scoring 80% overall and obtaining a high overall impact on the project. However, the frequency of material price escalation was very likely and ranked first with a score of 100%, whilst it ranked major for its severity scoring 80%. Contrary to that, material shortages obtained a very high severity score of 100%, whilst its frequency of occurrence was likely scoring 80%. Unreliable suppliers ranked sixth overall with negligible overall impact and an overall score of 16%. However, this is due to its frequency being rare, whilst it obtained major severity with a score of 80%. The remaining material related risks can be seen below in Table 13.

Table 13: Material related risk indices

| Risk Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Material Price Escalation | Major | 80 | 2 | Very Likely | 100 | 1 | 80 | 1 |
| Material Shortages | Very High | 100 | 1 | Likely | 80 | 1 | 80 | 1 |
| Delay in Material Delivery | Major | 80 | 2 | Likely | 80 | 2 | 64 | 2 |
| Poor Quality Materials | Moderate | 60 | 3 | Possible | 60 | 3 | 36 | 3 |
| Ineffective Procurement | Major | 80 | 2 | Unlikely | 40 | 4 | 32 | 4 |
| Incorrect Material Delivered | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 5 |
| Theft | Moderate | 60 | 3 | Unlikely | 40 | 4 | 24 | 5 |
| Poor Material Handling | Minor | 40 | 4 | Unlikely | 40 | 4 | 16 | 6 |
| Unreliable Suppliers | Major | 80 | 2 | Rare | 20 | 5 | 16 | 6 |
| Change in Material Specification | Moderate | 60 | 3 | Rare | 20 | 5 | 12 | 7 |

### 4.3.8 Top identified overall risks

The results from the importance index outlines the most important overall risks based on their severity and frequency of occurrence. Table 14 below outlines the Top 15 identified supply chain risks, ranked by their overall importance. Furthermore, these risks had an importance index of over 75%, falling in the very high overall risk category. The four risks that ranked 100% for importance were inadequate contractors experience, poor site management, delayed payments, and financial difficulties. The remaining top risks identified for the various groups can be seen below in Table 14.

Table 14: Top identified supply chain risks by overall importance

| Risk Group | Risk Description | Severity Index (%) | Frequency Index (%) | Importance Index (%) |
|---|---|---|---|---|
| Contractor | Inadequate Contractor Experience | 100 | 100 | 100 |
| Contractor | Poor Site Management | 100 | 100 | 100 |
| Client | Delayed Payments | 100 | 100 | 100 |
| Client | Financial Difficulties | 100 | 100 | 100 |
| Contractor | Financial & Cash-flow Difficulties | 80 | 100 | 80 |
| Contractor | Improper Planning & Coordination | 80 | 100 | 80 |
| Contractor | Shortage of Skills or Labour | 80 | 100 | 80 |
| Design | Design Changes | 80 | 100 | 80 |
| Equipment | Equipment Shortage | 80 | 100 | 80 |
| External/PS | Weather Conditions | 80 | 100 | 80 |
| External/PS | Inflation | 100 | 80 | 80 |
| Material | Material Price Escalation | 80 | 100 | 80 |
| Material | Material Shortages | 80 | 100 | 80 |
| Client | Change Orders and Scope Changes | 80 | 100 | 80 |
| Client | Awarding The Project to the Lowest Bidder | 100 | 80 | 80 |

Given the above table, Figure 10 below shows the fish bone diagram for the supply chain risks that ranked 80% or higher in the overall importance index analysis. This percentile identified 15 supply chain risks. These supply chain risks are the main contributors to the impacts of the supply chain risks as determined by the overall importance index.

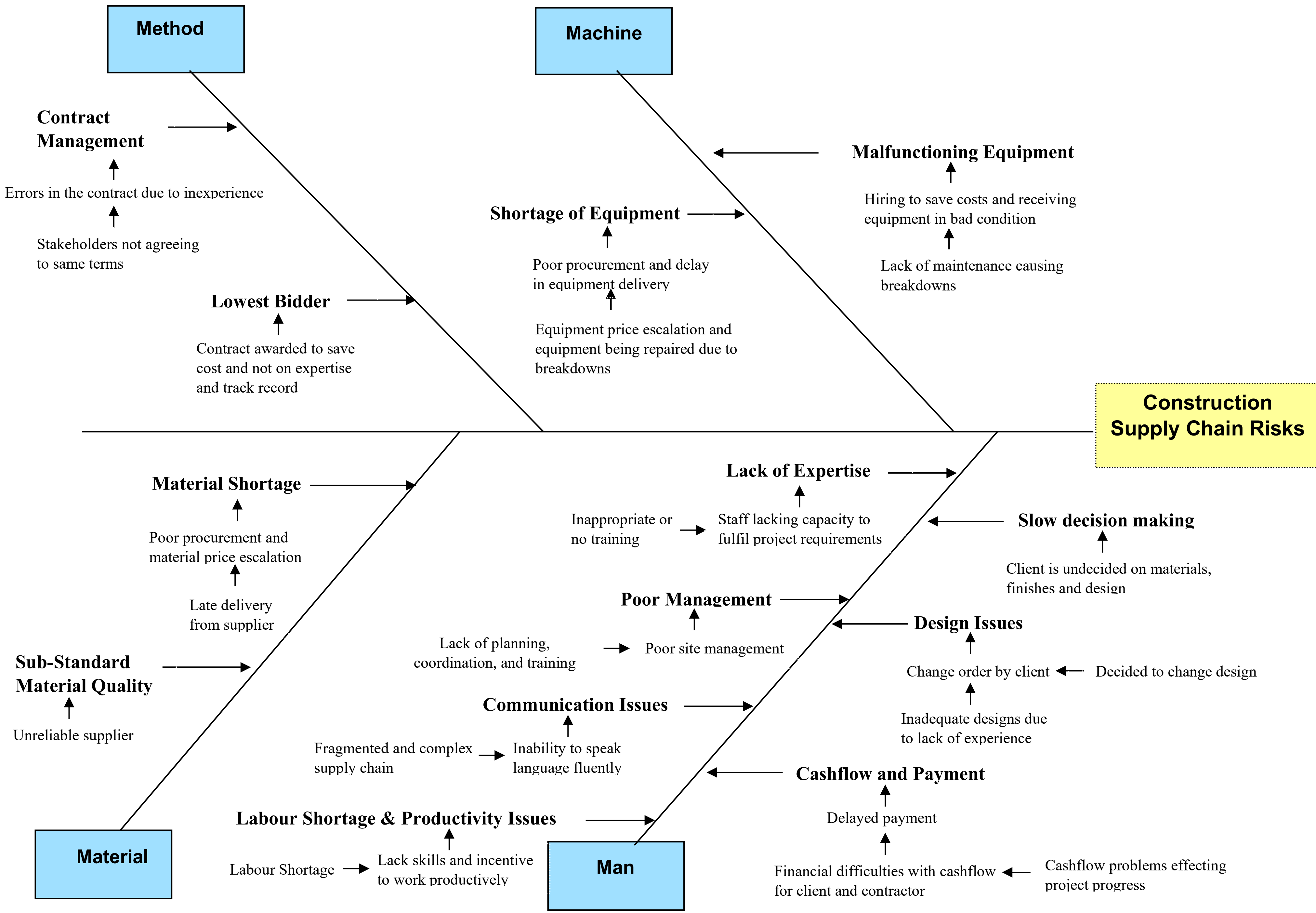


Figure 10: Fishbone diagram of risks that had an IMP.I of 80% or over.

### 4.3.9 Frequency of occurrence of risks by the responsible group

The frequency index analysis was used to rank the responsible group according to the frequency that their identified supply chain risks occur. The table ranks the responsible groups by the consultant, contractor, design, equipment, external or project specific, material, and client related. The mean is calculated by taking the average score of all likelihoods of the risks identified in that particular group. The results and ranking of the frequency index analysis for the responsible group are shown below in Table 15. The group responsible for the most frequent occurrence of risks is that of design, followed by that of the consultant. The group least responsible for the frequency in the occurrence of risks is that of material.

Table 15: Frequency index for the group responsible for the risk.

| Responsible Group | Mean | Frequency Index (%) | Rank |
|---|---|---|---|
| Contractor Related | 3.63 | 72.50 | 1 |
| Client Related | 3.42 | 68.40 | 2 |
| Design Related | 3.25 | 65.00 | 3 |
| Consultant Related | 3.22 | 64.44 | 4 |
| External or Project Specific | 2.72 | 54.44 | 5 |
| Material Related | 2.70 | 54.00 | 6 |
| Equipment Related | 2.56 | 51.12 | 7 |

### 4.3.10 Severity of risks by the responsible group

The severity index analysis was used to rank the responsible group according to the severity of their identified supply chain risks. The table ranks the responsible groups by the consultant, contractor, design, equipment, external or project specific, material, and client related. The mean is calculated by taking the average score of all severities of the identified risks in that particular group. The results and ranking of the severity index analysis for the responsible group are shown below in Table 16. The group responsible for the most severe occurrence of risks is that of the consultant, followed by that of the external or project specific. The group least responsible for the severity of risks is that of equipment.

Table 16: Severity Index for the group responsible for the risk

| Responsible Group | Mean | Severity Index (%) | Rank |
|---|---|---|---|
| Consultant Related | 3.78 | 75.60 | 1 |
| External or Project Specific | 3.78 | 75.56 | 2 |
| Client Related | 3.74 | 74.74 | 3 |
| Contractor Related | 3.69 | 73.75 | 4 |
| Material Related | 3.40 | 68.00 | 5 |
| Design Related | 3.38 | 67.50 | 6 |
| Equipment Related | 3.33 | 66.66 | 7 |

### 4.3.11 Importance of risks by the responsible party

The importance index analysis was used to rank the responsible group according to the overall importance of their identified supply chain risks. The table ranks the responsible groups by the consultant, contractor, design, equipment, external or project specific, material, and client related. The results and ranking of the analysis for the responsible group are shown below in Table 17. The group responsible for the most important risks is that of the contractor, followed by the client. The group least responsible for the most important risks is that of equipment.

Table 17: Importance Index for the group responsible for the risk.

| Responsible Group | Importance Index (%) | Rank |
|---|---|---|
| Contractor Related | 53.47 | 1 |
| Client Related | 51.12 | 2 |
| Consultant Related | 48.72 | 3 |
| Design Related | 43.88 | 4 |
| External or Project Specific | 41.13 | 5 |
| Material Related | 36.72 | 6 |
| Equipment Related | 34.08 | 7 |

Figure 11 below shows the group responsible for the identified risks with respect to the frequency index, severity index and the importance index. From the figure, it can be seen that the contractor has the highest frequency of risks, whilst the consultant has the most severe risks. The group with the most important risks is that of the contractor.

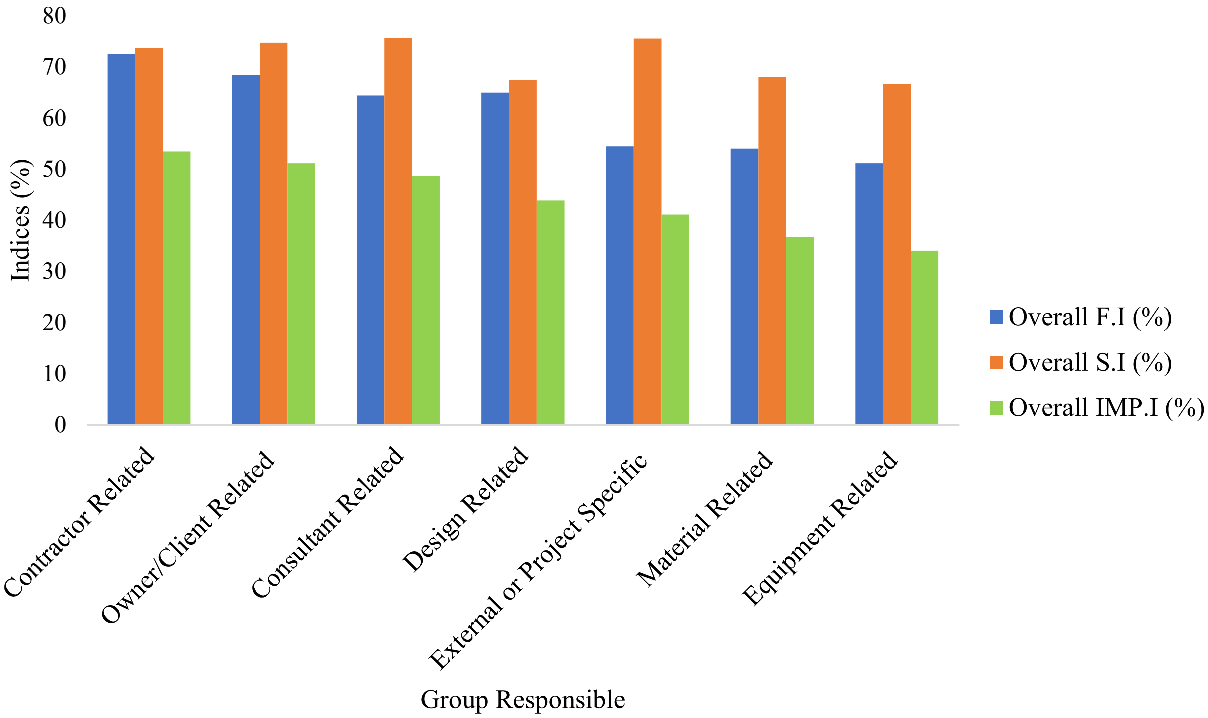


Figure 11: Group responsible for risks according to overall indices

## 4.4 Identified impact of supply chain risks

The impacts of the construction supply chain risks greatly affect the project performance and determine whether the project will be successful or not. The below section analyses the number of codes made in the Nvivo coding process to identify the impacts of construction supply chain risks and the subsequent responsible impact group. The impacts are shown per impact group, in their respective tables found in Appendix C. The tables show the impacts identified which relate to the to their impact group, ranked according to the percentage of codes given to that impact during the coding process.

### 4.4.1 Construction related impacts

The results for the identification of the construction related impacts caused by the supply chain risks are presented in Table 35 of the Appendix C. The construction related impacts of the supply chain risks were identified from 19 different sources of published literature. From the literature analysed, 4 different construction related impacts were identified. The most frequently identified impact was that of stress on the contractor (64%), followed by that of low-quality work (19%).

Stress on the contractor (64%) was the most identified construction related impact. It is likely to occur due to delay and disruptions throughout the construction process. The contractor may begin to lose confidence in the project when schedule delays being to occur, and cost begin to creep over budget. The lack of contractor experience to handle disruptions and delays that occur will further create stress on the contractor. (Oshungade & Kruger, 2017) found that the most significant impact caused from construction supply chain risks, was that of stress on the contractor. Low quality work (19%), ranked second, is likely to be caused by frequent change and variation orders. Contractors are likely to attended to these change and variation orders with minimal costs incurred for them, as to compensate for losses caused by the changes. Furthermore, Loss of productivity (9%) is often cause by change orders as normal operations are likely to pause whilst amendments are being made. Unskilled labour and rework may result in inferior workmanship leading to project quality issues. (Bello & Saka, 2017) found that low quality work was a significant impact caused by supply chain risks. Significant project delays and improper planning is likely to result in construction wastes (9%). Construction wastes occur when project resources are underutilised due to different supply chain risks occurring. (Olusengun & Michael, 2011) found that construction wastes ranked third overall when projects are abandoned.

### 4.4.2 Contract and Legal related impacts

The results for the identification of the contract and legal related impacts, caused by the construction supply chain risks are presented in Table 36 of the Appendix C. The contract and legal impacts of the supply chain risks were identified from 15 different sources of published literature. From the literature analysed, 5 different contract and legal impacts were identified. The most frequently identified was that of disputes (44%), followed by that of litigation (26%), and arbitration (24%).

Disputes (44%) was the most identified contract and legal related impact. Disputes often occur due to losses incurred by either stakeholder through schedule delays or by late payments for completed works. (Obodoh & Obodoh, 2016) identified disputes as one of the most significant impacts caused from project delays. Furthermore, construction schedule delays often create grievances among stakeholders. The aggrieved parties are likely to claim against the client to remedy damages that they incurred. Claims that are not resolved often lead to mediation (2%) between the parties. Subsequently, should the matter not be resolved through mediation, arbitration (24%) and litigation (26%) may ensue. Once the matter has been resolved, contract termination (4%) may occur. (Zailani, et al., 2016) stated that mediation, arbitration, and disputes were amongst the top 6 impacts caused by supply chain delays.

### 4.4.3 Financial related impacts

The results for the identification of the financial related impacts, caused by the construction supply chain risks are presented in Table 37 of the Appendix C. The financial impacts of the supply chain risks were identified from 27 different sources of published literature. From the literature analysed, 5 different financial impacts were identified. The most frequently identified impact was that of cost overruns (70%), followed by that of claims (26%) and reduced profits (13%).

The most frequently identified impact was that of cost overruns (70%). Cost overruns occur when the current project cost exceed the initial budget presented to the client in the tendering process. Delays often cause cost overruns in on-site construction projects. Changes in the project scope, inaccurate designs at the time of tendering, additional works, delays in costing variations and schedule delays all contribute to cost overruns. Cost overruns can be traced back to root causes such as poor management and planning that occur on the construction project. Furthermore, poor workmanship and quality of works completed often results in rework. Reworks are often costly and require schedules to be delays. (Gbahabo & Ajuwon, 2017), (Gebrehiwet & Luo, 2017) and (Morena & Amoah, 2021) all stated that cost overruns were either, the most or second most significant impact of supply chain risks. Given the severity of the delays that occur during the project, concern for responsible party increases, which can result in claims (26%) being made. Depending on the degree of cost overrun, reduced profits (13%), uneconomical projects (1%) and loss of investment (3%) to the project stakeholders may occurs. The financial position of the contractor and client is vital for the project's successful completion. Bankruptcy (4%) of either the client or contractor can have significant implications on the project's completion.

### 4.4.4 Schedule related impacts

The results for the identification of the schedule and time related impacts, caused by the construction supply chain risks are presented in Table 38 of the Appendix C. The schedule impacts of the supply chain risks were identified from 14 different sources of published literature. From the literature analysed, 4 different schedule impacts were identified. The most frequently identified impact was schedule delays (62%), followed by that of project abandonment (26%) and the extension of time (5%).

The most frequently identified impact was that of schedule delays (62%). Schedule delays often result in cost implications that must be accounted for. However, the cost implication depends on the severity of the schedule delay. (Tayade & Mahatme, 2020) and (Gbahabo & Ajuwon, 2017) found that schedule delays were one of the most significant effects that occur during construction projects. Schedule delays are often managed and planned for, however in some instances, project finances may be depleted which may result in project abandonment (26%). (Zailani, et al., 2016) found that schedule delays and project abandonment were amongst the top 6 overall effects caused by supply chain risks. Depending on the severity of the schedule delays, project acceleration (5%) may be called upon by the client or the contractor, depending on the penalties for late completion. The contractor may obtain an extension of time (5%), should they be able to prove that the schedule delays were beyond their reasonable control to mitigate.

### 4.4.5 Social related impacts

The results for the identification of the social related impacts, caused by the construction supply chain risks are presented in Table 39 of the Appendix C. The social impacts of the supply chain risks were identified from 7 different sources of published literature. From the literature analysed, 5 different social impacts were identified. The most frequently identified impact was worsening relationships (43%), followed by bad public relations (20%) and the loss of jobs and income (13%).

The most frequently identified impact was that worsening relationships (43%). Throughout the project different trades and sub-contractors are being used, conflicting personalities and understandings may cause conflicts, resulting in worsen relationships between stakeholders. Furthermore, cost overruns and schedule delays increase pressure of performance on the stakeholders. This may further increase tensions between stakeholders and result in disputes occurring. The impact that the project has on the surrounding area may cause bad public relations (20%) due to disruptions and grievances caused throughout the project’s duration. This coupled with non-completion, delayed completion, and cost overruns, the negative perception (13%) for construction projects arises. (Olusengun & Michael, 2011) identified negative perceptions as a significant effect cause people to be hesitant when considering construction projects. Construction projects in essence create more jobs, either directly or indirectly. When significant supply chain impacts affect the project, it jeopardises the potential for job creation. When projects are abandoned, there is a significant loss of jobs and income (13%).

### 4.5 Analysis of the supply chain impacts

The resultant impact caused by the construction supply chain risks were determined using the impact assessment which can be found in Table 49 of Appendix G. The subsequent frequency, severity, and importance of the impacts was determined using the indices. The resultant impacts from the supply chain risks were also identified during the Nvivo coding process. The frequency, severity and importance of the identified impacts and the responsible impact groups are determined in the section below.

The subsequent frequency, severity and importance indices were colour coded to represent their respective frequency of occurrence, severity, and the overall importance of their impact. The following shows the criteria for which the frequency index was ranked.

| | |
|---|---|
| - Frequency Index 0 to 20%, impacts that almost never occur | Likelihood is Rare |
| - Frequency Index 21 to 40%, impacts that don't occur often | Likelihood is Unlikely |
| - Frequency Index 41 to 60%, impacts that may occur | Likelihood is Possible |
| - Frequency Index 61 to 80%, impacts that may occur often | Likelihood is Likely |
| - Frequency Index 81 to 100%, impacts are highly likely to occur | Likelihood is Very Likely |

The severity of the supply chain risk impact was colour coded based on the below criteria:

| | |
|---|---|
| - Severity Index 0 to 20%, No impact on project | Very Low Severity |
| - Severity Index 21 to 40%, Minimal impact project | Minor Severity |
| - Severity Index 41 to 60%, Some impact on project | Moderate Severity |
| - Severity Index 61 to 80%, Significate impact on project | Major Severity |
| - Severity Index 81 to 100%, Excessive impact on project | Very High Severity |

The overall importance of the supply chain impact was colour coded based on the below criteria:

| | |
|---|---|
| - Importance Index: 0 to 20% | Negligible Overall Impact |
| - Importance Index: 21 to 40% | Minor Overall Impact |
| - Importance Index: 41 to 60% | Moderate Overall Impact |
| - Importance Index: 61 to 80% | High Overall Impact |
| - Importance Index: 81 to 100% | Very High Overall Impact |

The frequency, severity, and importance of the identified impacts are presented below sections.

### 4.5.1 Construction related impacts

The construction related impacts were analysed to determine which impacts were the most frequently occurring, the most severe and which impacts were the most important overall. From Table 18 below, stress on the contractor was identified as the most important construction related impact. It obtained a high overall impact on the project with an overall importance of 80%. This is attributed to its likely frequency of occurrence and very high severity on the project. Low quality work and the loss of productivity both ranked second overall, with an overall moderate importance, scoring 48%. This is attributed to the major severity score of 80%, whilst the likelihood of its occurrence was possible, with a score of 60%. The remaining construction related impact indices can be seen below in Table 18.

Table 18: Construction related impact indices

| Impact Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Stress on Contractor | Very High | 100 | 1 | Likely | 80 | 1 | 80 | 1 |
| Low Quality Work | Major | 80 | 2 | Possible | 60 | 2 | 48 | 2 |
| Lost Productivity | Major | 80 | 2 | Possible | 60 | 2 | 48 | 2 |
| Construction Waste | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 3 |

### 4.5.2 Contract and Legal impacts

The construction related impacts were analysed to determine which impacts were the most frequently occurring, the most severe and which impacts were the most important overall. From Table 19 below, contract termination was identified as the most important contract and legal impact. It obtained a minor overall impact on the project, scoring 40%. This attribute is largely due to its unlikely frequency of occurrence, scoring 40%, whilst obtaining a very high severity scoring of 100%. Litigation and arbitration both ranked negligible for their overall impacts, scoring 16%, despite their major severity, scoring 80%. The remaining contract and legal impact indices can be seen below in Table 19.

Table 19: Contract and legal impact indices

| Impact Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Contract Termination | Very High | 100 | 1 | Unlikely | 40 | 2 | 40 | 1 |
| Disputes | Moderate | 60 | 3 | Possible | 60 | 1 | 36 | 2 |
| Mediation | Moderate | 60 | 3 | Unlikely | 40 | 2 | 24 | 3 |
| Litigation | Major | 80 | 2 | Unlikely | 20 | 3 | 16 | 4 |
| Arbitration | Major | 80 | 3 | Unlikely | 20 | 3 | 16 | 4 |

### 4.5.3 Financial impacts

The financial related impacts were analysed to determine which impacts were the most frequently occurring, the most severe and which impacts were the most important overall. From Table 20 below, cost overrun was identified as the most important financial impact and obtained a score of 100% for all the indices, resulting in a very high overall impact on the project. The loss of investment ranked third overall with a minor overall impact on the project, scoring 32%, albeit obtaining a major severity on the project, scoring 80%. Despite bankruptcy obtaining a very high severity, the frequency of its occurrence meant that its overall impact om the project was negligible. The remaining financial impact indices can be seen below in Table 20.

Table 20: Financial impact indices

| Impact Description | Severity | Severity Index (%) | S.I Rank | Likelihood | Frequency Index (%) | F.I Rank | Importance Index (%) | IMP.I Rank |
|---|---|---|---|---|---|---|---|---|
| Cost Overrun | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Reduced Profits | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 2 |
| Uneconomical Projects | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 2 |
| Claims | Moderate | 60 | 3 | Possible | 60 | 2 | 36 | 2 |
| Loss of Investment | Major | 80 | 2 | Unlikely | 40 | 3 | 32 | 3 |
| Bankruptcy | Very High | 100 | 1 | Rare | 20 | 4 | 20 | 4 |

### 4.5.4 Schedule and Time impacts

The schedule and time impacts were analysed to determine which impacts were the most frequently occurring, the most severe and which impacts were the most important overall. From Table 21 below, schedule delay was identified as the most important schedule and time impact and obtained a score of 100% for all the indices, resulting in a very high overall impact on the project. The extension of time obtained a moderate overall impact, scoring 48%. This is attributed to the likely moderate severity, scoring 80%, despite the likely frequency of 80%. Both project acceleration and project abandonment obtained a minor overall importance, scoring 32%, despite project acceleration being likely occur, scoring 80%, and project abandonment being of major severity, scoring 80%. The schedule and time impact indices can be found in Table 21 below.

Table 21: Schedule and time impact indices

| **Impact Description** | **Severity** | **Severity Index (%)** | **S.I Rank** | **Likelihood** | **Frequency Index (%)** | **F.I Rank** | **Importance Index (%)** | **IMP.I Rank** |
|---|---|---|---|---|---|---|---|---|
| Schedule Delays | Very High | 100 | 1 | Very Likely | 100 | 1 | 100 | 1 |
| Extension of Time | Moderate | 60 | 3 | Likely | 80 | 2 | 48 | 2 |
| Project Acceleration | Minor | 40 | 4 | Likely | 80 | 2 | 32 | 3 |
| Project Abandonment | Major | 80 | 2 | Unlikely | 40 | 3 | 32 | 3 |

### 4.5.5 Social impacts

The social impacts were analysed to determine which impacts were the most frequently occurring, the most severe and which impacts were the most important overall. From Table 22 below, both bad public relations and loss of customer benefit obtained a minor overall impact, scoring 36% for their overall importance. Despite worsening relationships and loss of jobs and income obtaining a major severity, scoring 80%, their unlikely occurrence, scoring 40%, resulted in a minor overall impact, scoring 32%. Negative perceptions ranked last in overall importance. This is attributed to its moderate severity and its unlikely frequency of occurrence. Given this, it obtained a minor overall impact, scoring 24%). The social impact indices can be found in Table 22 below.

Table 22: Social Impact indices

| **Impact Description** | **Severity** | **Severity Index (%)** | **S.I Rank** | **Likelihood** | **Frequency Index (%)** | **F.I Rank** | **Importance Index (%)** | **IMP.I Rank** |
|---|---|---|---|---|---|---|---|---|
| Bad Public Relations | Moderate | 60 | 2 | Possible | 60 | 1 | 36 | 1 |
| Loss of Customer Benefit | Moderate | 60 | 2 | Possible | 60 | 1 | 36 | 1 |
| Worsening Relationships | Major | 80 | 1 | Unlikely | 40 | 2 | 32 | 2 |
| Loss of Jobs and Income | Major | 80 | 1 | Unlikely | 40 | 2 | 32 | 2 |
| Negative Perception | Moderate | 60 | 2 | Unlikely | 40 | 2 | 24 | 3 |

### 4.5.6 Top identified overall impacts

The results from the importance index outlines the most important overall impacts based on their severity and frequency of occurrence. Table 23 below outlines the impacts that obtained a moderate to very high overall impact on the project, ranked by their overall importance.

Furthermore, these risks had an importance index of over 41%. The two impacts that ranked 100% for importance were cost overruns and schedule delays. The remaining top impacts identified for the various groups can be seen below in Table 23.

Table 23: Top identified impacts

| **Impact Group** | **Impact Description** | **Severity Index (%)** | **Frequency Index (%)** | **Importance Index (%)** |
|---|---|---|---|---|
| Financial | Cost Overrun | 100 | 100 | 100 |
| Schedule & Time | Schedule Delays | 100 | 100 | 100 |
| Construction | Stress on Contractor | 100 | 80 | 80 |
| Construction | Low Quality Work | 80 | 60 | 48 |
| Construction | Lost Productivity | 80 | 60 | 48 |
| Schedule & Time | Extension of Time | 60 | 80 | 48 |

### 4.5.7 Frequency of occurrence of impacts by the impact group

The frequency index analysis was used to rank the impact group according to the frequency that their identified impacts occur. The table ranks the impact groups by the construction, contract and legal, financial, schedule and time, and social impacts. The mean is calculated by taking the average score of all likelihoods of the impacts identified in that group. The results and ranking of the frequency index analysis for the responsible impact group are shown below in Table 24. The impact group that has the most frequently occurring impacts is that of financial, followed by that of schedule and time. The group least responsible for the frequency in the occurrence of their impacts is that of contract and legal.

Table 24: Frequency index for the impact group

| **Impact Group** | **Mean** | **Overall F.I (%)** | **Rank** |
|---|---|---|---|
| Financial | 3.83 | 77 | 1 |
| Schedule & Time | 3.75 | 75 | 2 |
| Construction | 3.25 | 65 | 3 |
| Social | 2.40 | 48 | 4 |
| Contract & Legal | 1.80 | 36 | 5 |

### 4.5.8 Severity of the supply chain impact group

The severity index analysis was used to rank the impact group according to the severity of their identified supply chain impacts. The table ranks the impact groups by the construction, contract and legal, financial, schedule and time, and social impacts. The mean is calculated by taking the average score of all severities of the identified impacts in that group. The results and ranking of the severity index analysis for the impact group are shown below in Table 25. The impact group responsible for the most severe occurrence of impacts is that of construction, followed by that of financial. The impact group least responsible for the severity of the impacts is social.

Table 25: Severity Index for the impact group

| Responsible Group | Mean | Overall S.I (%) | Rank |
|---|---|---|---|
| Construction | 4.00 | 80.00 | 1 |
| Financial | 3.67 | 73.40 | 2 |
| Contract & Legal | 3.60 | 72.00 | 3 |
| Schedule & Time | 3.50 | 70.00 | 4 |
| Social | 3.40 | 68.00 | 5 |

### 4.5.9 Importance of impact groups

The importance index analysis was used to rank the impact group according to the overall importance of their identified supply chain impact. The table ranks the impact groups by the construction, contract and legal, financial, schedule and time, and social impacts. The results and ranking of the analysis for the impact group are shown below in Table 26. The impact group responsible for the most important impacts is that of financial, followed by schedule and time. The impact least important is that of contract and legal.

Table 26: Importance Index for the impact group

| Responsible Group | Overall IMP.I (%) | Rank |
|---|---|---|
| Financial | 56.22 | 1 |
| Schedule & Time | 52.50 | 2 |
| Construction | 52.00 | 3 |
| Social | 32.64 | 4 |
| Contract & Legal | 25.92 | 5 |

Figure 12 below shows the impact groups for the identified impacts with respect to the frequency index, severity index and the importance index. From the figure, the financial group has the highest frequency of impacts, whilst the construction group has the most severe risks. The impact group with the most important impacts is that of financial impacts.

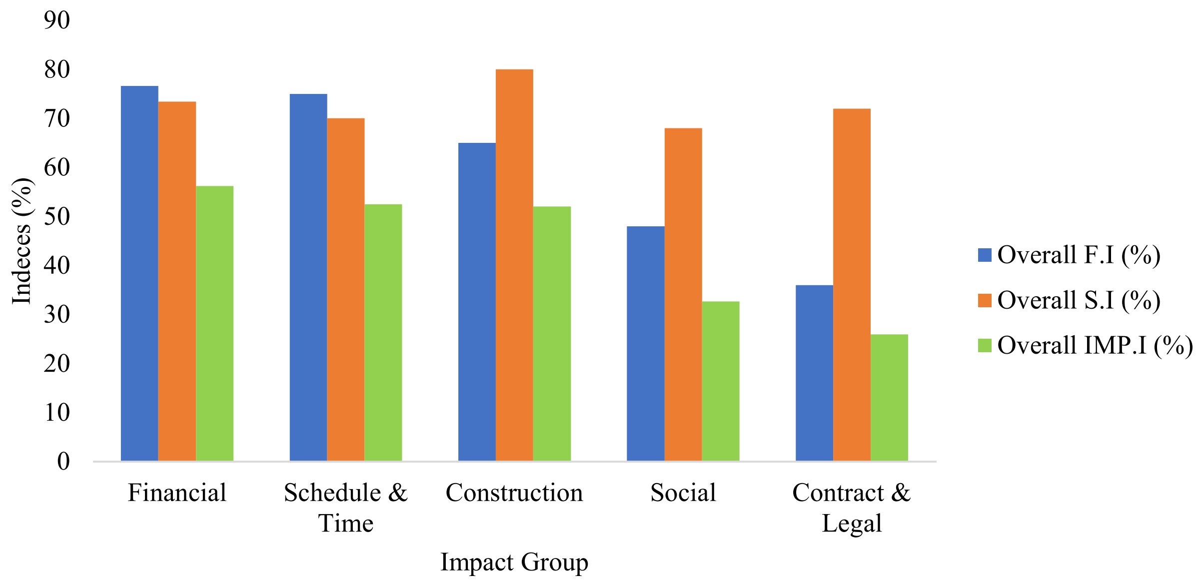


Figure 12: Impact group ranked by overall indices

### 4.6 Mitigation factors to lessen the impact of supply chain risks

The mitigation of construction supply chain risks and their associated impacts that occur throughout the construction process is critical in ensuring that the project meets the objectives and goals of all parties involved. Furthermore, it is vital in ensuring the performance, budget and schedule of the project remain within the agreed parameters, thus, ensuring the successful project delivery. The identification of mitigation strategies has been outlined according to the number of codes made during the Nvivo coding process. The mitigation factors are tabulated, per mitigation group, in Appendix D. The table shows the identified mitigation factors for their respective group, ranked as a percentage of the number of codes made per mitigation factor identified. The subsequent mitigation factors have been organised into the following groups: client, consultant, contractor, contract and financial, project management, and technology.

#### 4.6.1 Client mitigation factors

The results for the identification of the client mitigation factors are presented in Table 40 of Appendix D. The client mitigation factors were identified through the analysis of 8 different sources of published literature. From the literature analysed, 6 different client mitigation factors were identified. The most frequently identified mitigation factor was that of improved communication (47%), followed by that of reduced change orders (22%) and financial arrangements (19%).

Improved communication (47%) was the most identified client mitigation factor. The establishment of clear information channels and allowing open communication and feedback between all parties. (Awolesi, et al., 2015) and (Gunduz & Al-Naimi, 2022) identified improved communication through dedicated channels as one of the most significant mitigation factors for poor communication. During the pre-project planning, the client should establish all their requirements for the project. Clients should reframe from interfering (6%) in the project execution to reduce change orders (22%). Change orders can often result in schedule, cost overruns, and reduce the profits of the project. Any design changes can be mitigated further improved communication and coordination between stakeholders. Furthermore, the expedite decision making (16%) will also reduce the impacts of changes on the project. (Ekwuno & Nel, 2022) and (Mittal & Gorowara, 2020) both identified that the client should reframe form interfering and reduce change orders as mitigation factors for client related risks.

The client should ensure that adequate budgetary provision is available throughout the different milestones of the project by ensuring they have adequate financial arrangements (6%) in place. The client should ensure there is financial transparency and adequate funds available for reasonable project price inflation. They must ensure funds are readily available to pay payments to contractors when progress payments are submitted. (Ogbeide & Ehiorobo, 2022) found that financial arrangements were fundamental in ensuring the project's success and reduce schedule delays. The least identified mitigation factor was that of improved site handover (6%).

### 4.6.2 Consultant mitigation factors

The results for the identification of the consultant's mitigation factors are presented in Table 41 of Appendix D. The consultant's mitigation factors were identified through the analysis of 8 different sources of published literature. From the literature analysed, 6 different consultant mitigation factors were identified. The most frequently identified mitigation factor was that of improved communication (44%), followed by that of effectively managing changes (15%) and an accurate estimate (15%).

Improved communication (44%) was identified as the consultant's top mitigation factor. The consultant is often responsibly for guiding and directing the client in their design making process and bridging the gap between the client and the contractor. Given this, it is vital that the consultant provides the client with the necessary communication channels and tools to allow for effective and efficient communication between stakeholders. (Mittal & Gorowara, 2020) identified the need for effective communication between parties to mitigate change orders and errors occurring. Ensuring the consultant is experienced (9%) impacts what risks are by the consultant throughout the supply chain. Experience consultants provide complete and thorough designs (12%) which reduces the need for change orders. Furthermore, should there be changes to the project, efficiently managing changes (15%) reduces idle times and schedule delays. (Ogbeide & Ehiorobo, 2022) stated that the experience of the consultant to effectively manage changes would mitigate significant schedule delays.

Ensure the project has an accurate estimate (15%) is critical in ensuring the project is feasible and the necessary financial arrangement by the client can be obtained. This is particularly important in the initial cost estimate. (Ibironke, et al., 2013) identified the importance of an accurate estimate in ensuring the useful completion of the project and mitigating the surprise of unforeseen cost overruns. Computer aided programs are now available to assist with predicting cost overruns and ensuring accurate estimates. (Ahady, et al., 2017) identified the importance of an accurate estimate to mitigate cost overruns and schedule delays. The least identified mitigation factor was that of reference class forecasting (6%).

### 4.6.3 Contractor mitigation factors

The results for the identification of the contractor's mitigation factors are presented in Table 42 of Appendix D. The contractors' mitigation factors were identified through the analysis of 11 different sources of published literature. From the literature analysed, 11 different contractor mitigation factors were identified. The most frequently identified mitigation factor was that of the contractors past experience (20%), followed by that of improved communication and prequalification of the contractor, both with (18%).

Improved communication (18%) should be achieved by the open communication and feedback between all stakeholders of the project. Contractors can minimise control delays caused by resource coordination by effective communication and sharing knowledge of the business process with stakeholders. Furthermore, they should exchange information frequently and collaborate with stakeholders of the project. (Zailani, et al., 2016) identified the importance of communication in mitigating schedule delays on the project.

The prequalification of contractors (18%) based on their past experience (20%) is critical in mitigating contractor supply chain risks and their associated impacts. (Jacob & Sunjka, 2013) and (Banobi & Jung, 2019) both identified the importance of pre-qualifying contractors to ensure they have adequate past experience to successfully complete the project. Substantial past experience of the contractor will ensure improved site supervision and management (2%), effective material and plant management (8%), and experienced subcontractors and suppliers are employed for the project. The improved site management ensures proper coordination of project team members and that the procurement of material and plant is conducted with sufficient lead time to ensure not delays occur to the project due to the shortage of resources. (Ekwuno & Nel, 2022) identified the importance of ensuring that the shortages in resources are mitigated. The least identified mitigation factor was that of ensuring timely payment to the suppliers and subcontractors (1%).

### 4.6.4 Contract and financial mitigation factors

The results for the identification of the contract and financial mitigation factors are presented in Table 43 of Appendix D. The contact and financial mitigation factors were identified through the analysis of 10 different sources of published literature. The most frequently identified mitigation factor was that of the proper contract management and contract clauses (27%), followed by that of risk management (15%) and reasonable contract duration (11%).

The most frequently identified mitigation factor was that of the proper contract management and contract clauses (27%). (Tayade & Mahatme, 2020) identified the importance of the contract development, ensuring stakeholders remain accountable for their duties. The contract must contain the necessary clauses to deal with cost, schedule overruns, and handling disputes (2%). Furthermore, the identification of risks (11%) needs to occur during the planning stages and risk management (15%) should aim to mitigate the identified risks. The contract should outline the contract duration and associated penalties. A reasonable contract duration (11%) should be established between all stakeholders to avoid conflicts and the late completion of the project. (Banobi & Jung, 2019) found that a reasonable contract duration ensures all parties benefit from the successful completion of the project. Furthermore, a new contract awarding process (6%) should implemented ensuring experienced personal are appointed to the project.

The client and contractors financial arrangements (11%) should be outlined to provide comfort to the project stakeholders that sufficient funds have been allocated to the project. Furthermore, financial transparency (7%) and monitoring and controlling cost (9%) should be open to all stakeholders in an collaborate effort to ensure project costs are controlled and remain within budget. (Ahady, et al., 2017) identified the importance of financial arrangements and the monitoring and controlling of costs to mitigate cost overruns. The least identified mitigation factor was that of using public-private partnerships (1%).

### 4.6.5 Project management mitigation factors

The results for the identification of the project management mitigation factors are presented in Table 44 of Appendix D. The project management factors were identified through the analysis of 12 different sources of published literature. The most frequently identified mitigation factor was that of the thorough project planning (14%), followed by that of enhanced project management (13%) and improved information flows (11%).

Enhanced project management (13%) and constant project tracking (2%) ensures effective and efficient project management by appointing capable mangers to the project, in a bid to mitigate project schedule and cost overrun. This allows for improved supervision (4%) on site, ensuring the efficient coordination of staff and resource procurement. (Gbahabo & Ajuwon, 2017) found that enhanced project management was the most important mitigation factor of construction supply chain risks and impacts. Thorough project planning (14%), early engagement of stakeholders (2%) and project scheduling (4%) all emphasise the need to develop a structured and thorough project plan, detailing the requirements of all stakeholders and the structure of the project schedule and milestone dates. The use of up-to-date technology (6%) and the use of technology for planning and scheduling (7%) can be used to ensure that accurate and reasonable schedules for the project are developed. (Gunduz & Al-Naimi, 2022) identified the importance of using up to date technologies to track project schedule and costs to mitigate schedule and cost overrun.

Improved information flows (11%), development for collaborations (7%) appropriate development of communication channels (2%), relationship development (7%), and frequent project meetings (7%), all aim to mitigate inefficiencies in the construction supply chain by ensuring all parties are constantly informed of the plans or any changes that occur. (Arantes, et al., 2015) identified the importance of information flow for mitigating schedule delays. The least identified mitigation factor was that of mitigating corruption (1%).

### 4.6.6 Technology for mitigation supply chain risks

The results for the identification of technologies in the mitigation of supply chain risks are presented in Table 45 of Appendix D. The technologies were identified through the analysis of 12 different sources of published literature. The most frequently identified technology was that of BIM (37%), followed by that of cloud computing and IoT (25%) and RFID (11%).

BIM (37%), cloud computing and IoT (25%), web portals (1%) and blockchain (5%) can improve the overall construction management due to its integrated nature. They create a collaborative and transparent construction process allowing for efficient communication and information flows across functional teams. They aim at reducing cost and schedule overruns. Both (Shemov, et al., 2020) and (Onungwa, et al., 2017) identified either one of the before mentioned technologies as a major tool for the improvement of project management and efficiency.

MIS (3%) is used to integrate different technologies allowing for the effective exchange of information between platforms. AR (5%) and VR (5%) aid in product and process visualisation. The simulation of the real-life project can be achieved using VR. Problems and bottlenecks can be found and resolved virtually and implemented on site AR can be used overlay simulations to the real-world view. This can be used to assist with complex installations on-site. (Shemov, et al., 2020) identified these technologies as significant additions to project efficiency. Drones (3%) can also be used to inspect projects when conditions don’t allow for easy inspection. (Adepoju & Aigbavboa, 2020) stated that drones can significantly reduce inspection times of projects. RFID provides real-time information about the whereabouts of a materials, thus allowing for effective and efficient planning of operation on-site.

## 4.7 Conclusion

The aim of the analysis was to identify the various construction supply chain risks, their impact on the project and the mitigation strategies to lessen their impact. The construction supply chain risks were identified through the systematic review of literature and the Nvivo coding process. The identified risks were then presented according to the risk group being the client, consultant, contractor, material, equipment, design, and external or project specific risks. The top identified risks for all the responsible groups were that of change orders and scope changes by the client, improper planning and coordination by the contractor, and poor planning and scheduling by the consultant. The group most responsible for causing supply chain risks was that of contractor followed by the client. The frequency, severity, and importance of the risks were determined. This was achieved using the risk assessment as well as the frequency, severity, and importance indices. The most important risks were that of inadequate contractor experience, poor site management by the contractor, delayed payments, and financial difficulties by the client.

The construction supply chain impacts were identified through the systematic review of literature and the Nvivo coding process. The identified impacts were then presented according to their impact group being construction, financial, contract and legal, schedule and time, and social. The top identified impacts for all the responsible groups were that cost overrun, schedule delays, and stress on the contractor. Furthermore, the impact group most responsible for the impacts was that of financial, followed by that of schedule and time. Lastly, the mitigation strategies and technologies used to lessen the impact of supply chain risks and impacts were identified through the coding process and presented.

# CHAPTER 5

# 5. DISCUSSION

This section discussed the findings of the research with regards to the research objectives. The objectives of the study were to identify the construction supply chain risks, their impacts, and the mitigation factors to lessen the impact of the risks. Literature revealed that construction supply chain risks are a frequent phenomenon and occurs during and before nearly all construction projects. The impact of these supply chain risks may be detrimental to the projects, schedule, costs, and operations. Therefore, the identification of risks and their impact is a prerequisite to mitigate and lessen the impact of these risks on the construction project. Comparisons are made to the findings of the literature review and the limitations of the results are presented.

## 5.1 Construction supply chain risks

Within this section, the construction industries supply chain risks that affect the costs, schedule, and operations are investigated. The supply chain risks are discussed per risk group and the overall most important supply chain risks identified.

### 5.1.1 Client related risks

The findings within Section 4.2.1, using the percentage of codes made, suggest that the most frequently identified client risks were those of change orders and scope changes, financial difficulties, delayed payments, poor contract management, and slow decision making by the client. The least identified client related risks where those of client death, lack of insurance and contingencies, and poor supervision of work.

Likewise, Section 4.3.1 was used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 7 suggests that most frequently occurring risks by the client are those of delayed payments, financial difficulties, and change orders and scope changes. The most severe client related risks are those of awarding the project to the lowest bidder, delayed payments, financial difficulties, client death, and poor pre-project feasibility and planning. The most important risks are those of delayed payments, financial difficulties, change orders and scope changes, and awarding the project to the lowest bidder. The least important client related factors are those of client death, site handover and the lack of insurances and contingencies. Given this, both Section 4.2.1 and 4.3.1.3 suggest that the most important client related supply chain risks are those of delayed payments, financial difficulties, and change orders and scope changes.

Project finance is a major contributor towards the construction project risks and impacts. Delayed payments and financial difficulties go hand in hand. Often when the client is experiencing financial risks, they experience cash flow problems which result in the late payment of the necessary stakeholders. The financial risks that often occur are due to cash-flow issues, local and international market conditions, inflation, and financial resources available. Project finance is often a problem when large-scale construction projects are undertaken. In developing countries and in particular Africa's top three GDP nations, contractors and clients are often inadequately financed and irregular tenders cause major project implementation and completion consequences. Many large-scale projects, in these GDP nations, are financed by the government. This creates an environment for late progress payments due to the bureaucratic process and many layers of approval that needs to be completed (San Santoso & Soeng, 2016). (Famiyeh, et al., 2017) found that financial difficulties were also significant causes of project delay in Ghana, Malaysia, Zambia, and Jordan. In smaller and medium sized projects, cash-flow is important for paying subcontractors and suppliers. Delays, in progress payments influence the project schedule and performance. Delay in payments and non-payment may result in disputes, claims, arbitration, and potential litigation due to contractors wanting to minimise their financial losses.

Change orders and the change of scope are very likely to occur and often have major impacts on the project. Given this, their overall importance is very high and the appropriate mitigation factors should be put in place. (Hasan, et al., 2018) found that change orders and scope changes, ranked highly for their impact on project delay, in Indonesia, Malaysia, Canada, Iran, Oman, Qatar, and Kuwait. During the design stages of the project, the slow decision making, and requirements wanted by the client, often result in in the scope of work not being fully finalised. The slow decision making by the client ranked likely to occur with moderate impacts on the project. Furthermore, during this stage the clients' requirements are likely to change frequently. This results in ongoing changes during the design stage. Furthermore, due to the limited funds and timeline allowed for the design stage, change orders are likely to occur during the construction of the project. The frequent changes during both the design and construction stages are also due to the client lacking in construction experience. The lack of construction experience for the client ranked likely for their occurrence and moderate for their severity on the project. Overall, the lack of client experience ranked as moderate, however, this is dependent on the extent of changes being request. Many change orders and scope changes during the construction phase result in the temporary pause of works. As a result, schedule delays may occur. Extensive delays may result in contractual conflicts especially in terms of the completion time of the project. In many developing countries, like Africa's top three GDP nations, large construction projects are usually government projects (Gashahun, 2020). These projects are usually rushed through without proper scope definition. Furthermore, irregular bidding processes and possible corruption mean designs are rushed and, in some instances, projects are started without the scope being defined. The original scope is therefore changed during the construction process which results in change orders occurring.

Contractual risks and awarding construction projects to the lowest bidder are not uncommon in the construction industry. (Enshassi, et al., 2010) stated that the awarding of the contract to the lowest bidder frequently occurs in Gaza, whilst (San Santoso & Soeng, 2016) found that it frequently occurs in Cambodia. The lowest bid price is often the criterion by clients and lenders to which the construction projects are awarded, this is due to large financial resources being required for constriction works. Often this leads to less experienced and capable contractors being appointed. Consequently, project management, planning, and coordination are often poorly executed. This results in schedule delays and cost overruns, which often occur due to low productivity, mistakes, rework, and extended construction durations. Often clients set out an unrealistic contract that is littered with discrepancies and ambiguous requirements. The client wants the project to be completed faster due to the cost savings associated with earlier completion, these often lead to unrealistic timelines with significant penalty ramifications.

### 5.1.2 Consultant and Design related supply chain risks

The findings for the consultant and design related supply chain risks will be discussed in one Section due to many sources of literature, discussing them under one umbrella term, being either the design team or the projects consultants. The findings within Section 4.2.2, using the number of codes made, suggested the most frequently identified consultant risks were those of poor management and planning, incorrect estimate, and poor communication and coordination. The least identified consultant related risks where those of incomplete documents and the delay in document preparation and submission. Furthermore, from Section 4.2.4, the highest coded design risk was that of design changes, variation orders, and incomplete designs. The least identified risks were those of changes in specification.

Likewise, Section 4.3.2 and 4.3.4 were used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 8 suggests that most frequently occurring, and most severe risks caused by the consultant are those of the incorrect estimate, poor planning and scheduling, and the slow inspection of works. Whilst the overall importance suggests that the most important risks are those of the incorrect estimate, poor planning and scheduling, and slow inspection of works. Table 10 presents the most frequently occurring design risks as design changes, variation orders, and design errors. The most severe design related risks are design changes, design errors, and incomplete designs. The most important design risks are those of design changes and variation orders. Given this, both Section 4.2.2 and 4.3.2 suggest that the most important consultant risks are those of the incorrect estimate, poor planning and scheduling, and slow inspection of works. (Habibi & Kermanshachi, 2018) and (Atout, 2016) found that the same most important consultant risks identified, affected projects in the Gulf region, Hong Kong, and Palestine. Section 4.2.4 and 4.3.4 both suggest that the most important design risks are those of design changes and variation orders. (Hasan, et al., 2018) found that frequent design changes occurred in Malaysia, Indonesia, Iran, UK, Hong Kong and the Gaza strip, whilst, (Famiyeh, et al., 2017) , (San Santoso & Soeng, 2016), and found that variation orders frequently occurred in Kuwait , Ghana, Gaza Strip, Hong Kong, UK, Cambodia, and Hong Kong.

The most important consultant risks are directly linked to the consultant's experience. Inadequate consultant experienced ranked moderately in the overall importance. This was however due to the low frequency of occurrence. It can be seen in Table 8, that the severity ranked as major resulting in significant impacts on the construction project. However, due to its frequency being possible, the overall risk on the project is moderate. The lack of communication between consultants during the design and implementation phases of the project. The lack of communication between the engineers and design team may lead to discrepancies between the architectural drawings and the structural drawings. These discrepancies are likely to be found on-site. This leads to delays as the contractors are required to wait until the plans are amended before commencing with operations. Incorrect estimates may result from the consultant using data that is outdated or from projects with lesser complexity than that of the project being estimated. The lack of experience of the estimator and honest mistakes may also result in incorrect estimates. Furthermore, the process of estimating the projects costs and quantities is a complex exercise. It involves the collecting, retrieving, and manipulating of large amounts of different data. This process allows for errors to occur due to the volume of data being integrated into the estimate. However, technologies are now available to assist with the process in the attempt to mitigate these errors. The project estimate is vital in ensuring the correct finances are in place for the successful completion of the project. Incorrect estimates may result in project abandonment, uneconomical projects, and cost overruns.

Design risks affect the schedule performance and budget of any construction project. Given the nature construction projects, designs are highly customisable and unique from one project to another. The client has freedom of design which becomes problematic should their financial standing not be understood correctly. Significant changes in project designs can occur up until the superstructure is at about 40% completion (Wuni, et al., 2021). This creates risks for the contractor, as they must plan for the changes and often halt work to change elements of the building. The degree of changes depends on whether the client issues a change order, variation order or simply changes a couple elements in the design. Vast change orders and variation orders constitute changes to large aspects of the project design. Design changes can greatly affect the costs associated with the project. The design changes may lead to reworks, additional payments, and additional works not quantified in the original budget. Given that extensive changes may occur, the project costs may increase exponentially where the possibility of non-completion due to ill finances becomes apparent. Furthermore, the design changes should be handled by experienced designers who need to ensure that the changes are possible with the current designs, and that the new loads are calculated, otherwise the potential for inaccurate and defective design arises.

### 5.1.3 Contractor Related Risks.

The findings within Section 4.2.3, using the number of codes made, suggested that the most frequently identified contractor risks were those improper planning and coordination, shortage of skills and labour, and financial and cash flow difficulties. The least identified contractor related risks where those of low motivation, inappropriate construction methods, and insufficient quality control.

Likewise, Section 4.3.3 was used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 9 suggests that most frequently occurring risks by the contractor are those of inadequate contractor experience, poor site management, financial and cash flow difficulties, improper planning, and the shortage of skills and labour. The most severe contractor related risks are those of inadequate contractor experience, poor project management and poor site management. The overall most important risks are those of inadequate contractor experience, poor site management, financial and cash flow difficulties, improper planning and the shortage of skills and labour. The least important client related factors are those of low motivation, labour strike, insufficient quality control. Given this, both Section 4.2.3 and 4.3.3 confirm the most important contractor related risks are those of inadequate contractor experience, poor site management, financial and cash flow difficulties, improper planning and the shortage of skills and labour.

The expertise employed to complete a construction project have direct influences on the project's performance. (Al-Hazim, et al., 2016) and (Islam & Trigunarsyah, 2017) stated that Jordan, Malaysia, Ghana, Tanzania, and Zambia experienced issues with inexperienced contractors. The training and education in the construction industry lacks in developing countries such as Africa's top three performing GDP nations. There are a limited number of institutions and courses offered in the industry. The intake of students is further burdened by the financial implications required to attend. Furthermore, this also leads to the shortage of skilled labour that are required for construction projects. The perceived image of the industry and the potential of other lucrative career options hinders enrolment as people look elsewhere for lucrative career options. Developed countries such as the UAE and Qatar, experience labour shortages due to the extensive construction works occurring simultaneously throughout the country (Durdyev & Hosseini, 2019). Tenders are often sent to contractors who have limited experience which creates numerous risks such as schedule delays and incomplete projects. The implications of such result in extensive cost overruns and can be attributed to the lack of expertise and management capabilities. Poor site management is a direct result of professionals who lack experience and qualifications. (San Santoso & Soeng, 2016) and (Hasan, et al., 2018) found that poor site management occurred in the Gaza strip and the UAE. Given most of the construction activities occur on-site, the management of these activities is vitally important. Improved site management allows for the completion of the project within the time and cost specification agreed to in the contract. Furthermore, it reflects the capability and competence of the appointed contractor to coordinate, direct information between the stakeholders and plan effectively to ensure the successful implementation of on-site activities. The planning of construction activities includes an operational plan that outlines the goals, milestones and considerations taken for potential obstacles throughout the project's lifetime. Delays in the project's goals and milestones, depending on their float time and severity of the delay, effect the performance of the project. Under performance results in schedule delays which are not excusable as they are planned milestones and thus, in the control of the appointed contractor. Given this, the causes of poor planning are the lack of expertise and accelerated project schedules. The accelerated schedules are results of client interference and delays in the project works. This often results in poor labour attitude due to physical fatigue and increased worker expectations. Thus, it is vital to appoint contractors who have the competence and expertise to plan and manage the project effectively to ensure project milestones, timelines and performance standards are met without schedule delays and cost overruns.

The financing and cash flow of the appointed contractor is vital in the implementation of a successful project within the outlined time. Contractors may face financing issues during the project as the payment for works completed occur after the section of work is completed. Thus, contractors should have sufficient funds available for the project before accepting the project. Contractors should ensure they have effective project financing methods in place to ensure they can pay suppliers, subcontractors, and staff when required. The delayed payment of staff, subcontractors and suppliers may result in the delay of resources and works being completed. This further delays the project's completion time, resulting in financial penalties being implemented.

### 5.1.4 Equipment related risks

The findings within Section 4.2.5, using the number of codes made, suggest that the most frequently identified equipment risks were those of equipment shortages, delays in equipment delivery, and equipment price escalation. The least identified equipment related risks where those of theft, poor equipment operator skills and the wrong equipment being used.

Likewise, Section 4.3.5 was used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 11 suggests that the most frequent and severe equipment risks are those of equipment shortages, delays in equipment delivery, and equipment price escalation. The most important equipment related risk was that of equipment shortage, followed by the delay in equipment delivery and equipment price escalation, which ranked second and third respectably. Given this, both Section 4.2.5 and 4.3.5 confirm the most important contractor related risks are those of equipment shortages, delays in equipment delivery, and equipment price escalation.

Equipment shortages and breakdowns often occur in construction projects in developing countries such as Africa's top three performing GDP nations. Developed countries have the financial means and technological advancements to equip themselves with the best equipment required for the construction project. However, (Hasan, et al., 2018) found that equipment shortages occur in the USA, UK, Uganda, UAE and New Zealand, suggesting that it isn't an isolated occurrence. In developing countries with poorly developed and import reliant economies, shortages in equipment often occur. Machinery and equipment are used on-site to assist workforce in moving and completing on-site activities. Thus, the shortage of equipment can result in 5-15% loss in productivity (Durdyev & Hosseini, 2019). The shortage of machinery and equipment are results of not only a shortage in the market but the lack of skilled operators, maintenance, and breakdown issues. In developing nations, machinery and equipment is often expensive and thus, construction companies often hire the equipment they need. Given this, delays in the delivery of equipment to site may occur. This is due to the possible unavailability of the equipment or having to wait for the necessary mode of transportation to deliver the equipment to site. This results in the low productivity and idle times for teams onsite that require the equipment to carry out their desired works. Furthermore, it is found that the importance of maintenance is neglected compared to developed nations. Poor maintenance results in frequent equipment breakdowns which affect the schedule performance and costs of the project going forward. Escalation in prices occur when the demand for the equipment exceeds the available supply in the market. Subsequently, the cost of construction will increase which may lead to cost overruns, should the consultant not factor the escalation into their original estimate. Furthermore, in Africa's top three GDP nations, political instability and strikes impact the availability of resources through their impact on the country's economic position. This results in the increase price of equipment in the market leading to potential cost overruns and delays for equipment should the funds not be available to accommodate the increased prices.

### 5.1.5 External or project specific delays.

The findings within Section 4.2.6, using the number of codes made, suggested that the most frequently identified external or project specific risks were those off weather conditions, inflation, and site conditions and location. The least identified external or project specific related risk was that of traffic management.

Likewise, Section 4.3.6 was used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 12 suggests that most frequently occurring external, or project specific risks, which are all ranked likely to occur, are those of weather conditions, inflation, economic risks, law and regulation changes, site conditions and location, and corruption. The most severe external or project specific related risks were those of corruption, force majeure, inflation, and site accidents which all have very high severity impacts. The most important overall external or project specific related risks are those of weather conditions and inflation which both have an overall very high risk on the project. Given this, both Section 4.2.6 and 4.3.6 confirm the most important external or project specific risks are those of weather conditions and inflation.

External and project specific causes are usually beyond the control of stakeholders. These causes can be influenced by the location and political situations occurring in the area. Given that on-site construction is an open-space activity, weather, and climate conditions, particularly severe or unpredictable conditions, cause project delays and potential cost implications due them being out of the control of the contractor. (Zidane & Anderson, 2018) found that weather conditions significantly affected projects in, not limited to, Burkina Faso, Ghana, Hong Kong, Indonesia, Kenya, and Lebanon. Despite their direct impact on schedule and costs, unpredictable weather conditions may result in lowered project performance that is not easy to quantify or predict. Given this, the interruption of works may result in lower project performance due to the stop, start nature of works.

Inflation occurs throughout all construction projects. However, excessive fluctuations in market prices often occur due to local, national, and global market fluctuations. Furthermore, the fluctuations may occur from political situations and unpredicted regulation changes. (Habibi & Kermanshachi, 2018) found that inflation was a significant factor for cost overruns in countries around the world. These fluctuations result in the increase cost of labour, equipment, and the necessary material required for the project. Thus, because of the increased costs, the clients financial position for the project may be affected. Excessive increases in construction costs may result in projects being abandoned and the unsuccessful completion due to the excessive cost overruns and the lack of financials to successfully complete the project.

### 5.1.6 Material related risks

The findings within Section 4.2.7, using the number of codes made, suggested that the most frequently identified material risks were those of material shortages, material price escalation and the delay of materials to site. The least identified material related risks where those of theft and the incorrect material being delivered.

Likewise, Section 4.3.7 was used to determine the likelihood, severity, and the importance of the supply chain risks identified. Table 13 suggests that most frequently occurring material risks were those of material price escalation and material shortages. The most severe material related risks were those of the delay in material delivery, ineffective procurement, material price escalation, material shortages, and unreliable suppliers. The most important overall material related risks are those of material price escalation and material shortages. Given this, both Section 4.2.7 and 4.3.7 confirm the most important material related risks are those of material price escalation and material shortages. (Durdyev & Hosseini, 2019) found that material price inflation and shortages occur in Saudi Arabia, Qatar, Sweden, UAE and the USA.

Material price escalation and material shortages are very likely to occur, whilst both have major impacts on the project. Furthermore, both risks obtained a very high overall risk. To ensure on-site construction occurs according to the projects schedule, the prompt delivery and supply of materials is vital. The unavailability of materials as of when they are needed, results in decreased project performance due to the disruption and the interference in labour momentum. Steady cash-flow is required to ensure the financial means of procuring materials are available when needed. The main causes of material shortages are from design changes, late delivery, late procurement, poor resource planning and management and changes in material specification. Material quality varies between suppliers, furthermore, suppliers may change quarries, and this may impact in the quality of materials being delivered. Sub-standard materials that do not comply with the regulations and specifications may cause disturbances to construction works. Works may be halted until the correct materials are delivered and within the specifications set out in the contract. Delays to the projects schedule result in cost overrun and dissatisfaction from the client. Furthermore, it is highly likely that escalation and fluctuations in the material price occur throughout the project. Escalation in prices occur when the demand for the material exceeds the available supply in the market. Subsequently, the cost of construction will increase which may lead to cost overruns, should the consultant not factor the escalation into their original estimate. Furthermore, in Africa's top three GDP nations, political instability and strikes impact the availability of resources through their impact on the country's economic position. This results in the increase price of material in the market leading to potential cost overruns and delays for materials should the funds not be available to accommodate the increased prices.

### 5.1.7 Top identified causes of supply chain risks

Section 4.3.8 presents the overall most important construction supply chain risks. These risks were discussed in detail within the group they relate to. Furthermore, Figure 10 shows the fishbone diagram of the most important supply chain risks.

### 5.1.8 Group responsible for supply chain risks

The group responsible for the supply chain risk must be identified for the risk to be mitigated in the future and for the impact of the risk to be addressed accordingly. It is vital for the correct stakeholder to address the risk as the incorrect stakeholder may have insufficient, or no expertise with that particular risk at hand. This would result in the risk not being addressed accordingly and result in further risks and their associated impacts occurring. The findings in Sections, 4.3.9 to 4.3.11, which analyse the frequency, severity, and importance of the responsible groups respectably, suggest that the group responsible for the most frequent and severe risks, are not always the group responsible for the most important risks.

In Section 4.3.9, the frequency of occurrence for the group causes was determined. Table 15 shows that the most frequently responsible group is that of the contractor, followed by that of the client, and the design, which ranked second and third overall. Whilst the least frequent responsible group was that of equipment related risks. Table 16 shows that the group responsible for the most severe risks was that of the consultant, followed by that of the external or project specific factors. The least severe group was that of the equipment related factors. Table 17 shows that the group responsible for the most important risks was that of the contractor, followed by that of the client which ranked second overall. The least important group was that of the equipment related risks.

Figure 11 shows the group responsible for the overall frequency of occurrence, severity, and importance. Despite the contractor not having the most severe risks and ranking fourth, the highest ranked frequency for their risks occurring was responsible for the group ranking first in the overall importance. The consultant group ranked the highest overall for the severity of their risks, however, the frequency of their risks occurring ranked fourth. Given this, their overall importance was ranked third. The external or project specific group had the second highest severity of risks. However, due to their frequency of occurrence, ranking third last, it ranked fifth for its overall importance. The equipment group ranked last in both frequency and severity, given this, it was ranked as the least important group responsible for the supply chain risks.

As discussed above, the contractor carries the most construction risk, which occurs for most of the project's duration. This period of time is extensively longer than that of the other parties involved such as the consultant and client. However, the client can change designs, delay payments and ultimately, this determines their own risk impact on the project, as they are actively participating in the project throughout its lifespan. The contractor has the most responsibility regarding the planning, management and coordinating and thus, needs to be experienced to fulfil these responsibilities effectively. Many of the contractor causes of risks can be mitigated through proper planning and control of construction works. Despite this, the client has the ability to make the planning and management of the contractor more difficult. Extensive changes to designs, material specifications and slow decision-making can cause schedule delays and cost overruns which may be beyond the control of the contractor to mitigate. Furthermore, the consultants are once again at the peril of the client. Given the consultants experienced, they may be capable of accommodating the clients' requirements, quickly and efficiently before on-site delays occur. However, this may not be possible depending on the clients demands. Given this, many of the risks can be mitigated and in the event of external, material or equipment risks, planned and managed effectively. However, the responsible group must be accountable for their risks and have the capabilities to effectively deal with and manage the associated risks.

### 5.2 Identified impacts resulting from supply chain risks

Supply chain risks that occur during and before any construction project all result in certain impacts affecting the project. However, the impacts of these risks differ in frequency, severity, and importance. The impact of the risk refers to the influence or consequence that the risk has on the project's completion within the outlined budget, time, and specification. The impacts of the supply chain risks are devastating to the project's performance. When the risks are not mitigated and addressed meritoriously, the consequences are referred to as impact or the effects of the project's risks.

The impacts of the different supply chain risks were determined through the coding process and are outlined in Section 4.4. From the number of codes made, the most identified impact was that of cost overruns, followed by that of schedule delays and stress on the contractor. The least identified impacts were those of loss of investment, uneconomical projects, and mediation.

Section 4.5 analysed the severity, frequency, and overall importance of the impacts, resulting from the various supply chain risks occurring. The findings in sections 4.5.1 to 4.5.5 suggest that the most frequently occurring impacts are those of cost overrun, schedule delays, stress on the contractor, extension of time, and project acceleration due to delays. The least frequently occurring impacts was that of bankruptcy, arbitration, and litigation. The findings also suggest that the most severe impacts of supply chain risks were that of cost overruns, schedule delays, contract termination, bankruptcy, and stress on the contractor. The least severe impact was that of project acceleration. Lastly, the most important impacts caused by supply chain risks were cost overruns and schedule delays, followed by that of stress on the contractor. This aligns with the number of codes made for the respectable impacts during the coding process results in Section 4.4. However, the least important risks were those of mediation, litigation, arbitration, bankruptcy, and negative perception, which differs from the results found in Section 4.4.

The most important impacts were those of cost overruns and schedule delays. (Elhusseiny, et al., 2021) further identified cost overruns and schedule delays as the most important impacts caused by construction supply chain risks. Both impacts ranked first in their frequency of occurrence and in severity. Given this, they were categorised as very likely to occur and very high in severity causing excessive impacts on the construction project. Schedule overruns often result in cost implications that must be accounted for. However, the cost implication depends on the severity of the schedule delay. Schedule delays are often managed and planned for, however in some instances, project finances may be depleted resulting in the non-completion and abandonment of the construction project. Furthermore, in developing countries, at least 70% of construction projects have schedule delays (Rachid, et al., 2018). These delays vary from 10 to 30% of the original contract duration and can sometimes account for 50% of the cost overrun (Rachid, et al., 2018). Delays often cause cost overruns in construction projects. Changes in the project scope, inaccurate designs at the time of tendering, additional works, delays in costing variations and schedule delays all contribute to cost overruns. Cost overruns can be traced back to root causes such as poor management, communication and planning that occur on the construction project. Furthermore, poor workmanship and quality of works completed often results in rework. Rework of poorly completed works augments the execution of remedy by 2 to 25 % of the original contractual assigned charge (Yousry Akal & Metwally El-Kholy, 2021). Furthermore, the reworks required additional time to complete, thus, the need for rework may extend the project schedule by up to 4.1% of the original contracted time (Yousry Akal & Metwally El-Kholy, 2021). Many of the identified supply chain risk impacts the schedule of the project. Given this, projects may require the acceleration of works or potentially the extension of time. Both impacts affect the project schedule and have their associated cost implications. Project acceleration and the extension of time ranked likely to occur, whilst their respective severities were categorised as minor and moderate respectably, resulting in minimal or some impact on the project.

All the impacts resulting from supply chain risks cause stress on the contractor as they are largely responsible for ensuring that the supply chain risks are adequality mitigated, thus, having minimal impact on the projects schedule, cost, and operations. Contractor stress was ranked likely, very high and very high for its frequency, severity, and importance respectably. Given this, contractor stress often occurs with excessive impacts on the project resulting in an overall very high impact on the project.

Throughout the project different trades and sub-contractors are being used, conflicting personalities and understandings may cause conflicts, resulting in worsen relationships between stakeholders. Subsequently, disputes are often called upon. The claims and dispute are often results of losses that occurred due to cost and schedule overruns. The responsible group must be identified, the extent of the impacts must be determined, and what renumeration must be awarded. Furthermore, when disputes aren't resolved between stakeholders, arbitration usually occurs. This further delays the project and has additional costs for the engagement of arbitrators. The last resort for resolving disputes is usually litigation. This is the most time consuming and costly remedy and is often avoided at all means. However, the results of the proceedings may result in the termination of the contract, which ranked very high in its severity, often resulting in excessive impacts on the project. Mediation, arbitration, and litigation all ranked low in their overall importance. However, this is due to their low frequency of occurrence. The severity of their impact's ranges from moderate to major and are thus, are largely impactful on the project's success.

### 5.2.1 Impact group responsible for the supply chain risk impacts

Sections 4.5.7 to 4.5.9 analysed the frequency, severity, and importance of the impact group responsible for the impacts of supply chain risks. Determining which group is responsible for the most important impacts, allows the stakeholders to ensure that adequate planning and mitigation measures are put in place to minimise and mitigated their potential impacts, thus, ensuring the project is successful and completed efficiently and effectively with the projects budget, schedule, and specifications.

In Section 4.5.7, the frequency of occurrence for the group impacts was determined. Table 24 shows that the most frequently responsible impact group was the financial group, followed by that of schedule and time which ranked second. The least frequently responsible impact group was that of the contract and legal. Section 4.5.8 outlines the severity of the responsible impact group. Table 25 shows that the most severe impacts on the project emanated from the construction group, followed by that of financial impact group which ranked second. The impact group least responsible for severe project impacts is that of the social group. Section 4.5.9 outlines the overall importance of the impact group responsible for causing impacts to the project. Table 26 shows that the most important impact group is financial, followed by of schedule and time which ranked second. The least important impact group responsible for the projects impacts is that of the contract and legal.

Figure 12 shows the impact group responsible for the overall frequency of occurrence, severity, and importance. The financial group ranked first overall for its frequency of occurrence and overall importance, despite ranking second in their groups impact severity. However, the severity of the financial impacts is largely related to the severity of the remaining groups impacts. It is highly likely that cost overruns occur on any given project, whilst it is possible for reduced profits and uneconomical projects to occur. However, the severity of the impacts of the financial group, greatly depend on the extent of the impacts caused by the construction and schedule groups. Given that the schedule and construction groups ranked second and third overall for their frequency, their associated supply chain risks need to be mitigated as their occurrence results in cost overruns occurring. Many of the supply chain risks, not limited to, improper planning, poor site management, errors, rework, and material and equipment shortages, may all result in schedule delays and construction rework. This is evident in the severity of the construction group impacts, ranking first overall. Thus, depending on their severity, it largely impacts the projects financials. Thus, the importance of managing the supply chain risks and mitigating their impacts on the schedule, will greatly reduce the frequency of financial impacts occurring, ensuring the project is successful and completed within budget. The contract and legal group ranked last in the overall importance. This was due to the frequency of occurrence ranking last overall. Furthermore, the frequency of occurrence was significantly lower than that of financial, schedule, and construction. However, the severity of the group's impact ranked third overall suggesting that their impacts will severely impact the projects successful implementation. Thus, the contract and legal impacts need to be managed and planned efficiently ensuring that their impact on the project is minimised as their severity on the project is significant despite the impacts rarely occurring.

## 5.3 Mitigation supply chain risks

The mitigation of supply chain risks within the construction industry is relatively difficult due to the evolving and complex nature. This is due to various activities occurring on-site and off-site simultaneously with on-site activities occurring with constantly changing site and weather conditions. Given this, operations require effective and efficient management to ensure the projects are successful. Risk mitigation frameworks require both theoretical and practical meanings. The risk mitigation process involves the identifying, analysing, and responding to the risks. The identification of risks in the early stages or before the commencement of the project help to develop a strategy that can effectively and efficiently mitigate or transfer the risk. The objective of risk mitigation is to reduce the potential impact of any possible risk or delay that might occur. The below section discusses the risk mitigation strategies identified in the report.

### 5.3.1 Mitigation strategies to lessen the impact of supply chain risks

The findings within Section 4.6 suggest that there is a demand for the change in construction management processes. The aim of the change is to mitigate the supply chain risks and inefficiencies that are currently present. The mitigation of these factors is imperative for construction of a high-quality projects that drive value towards the client or customer. The suggest that the mitigation of supply chain risks can be achieved through the thorough planning, contract development, awarding process, communication, effective management, financial arrangements, and technology.

One of the major risks in the construction industry is that of improper planning. Given this, thorough planning for the project needs to occur before and during the construction phase, beginning in the inception phase of the project. The early engagement of all stakeholders in the pre-project planning phase is crucial. All stakeholders need to communicate their requirements and any special conditions that they may require during the project. By doing such in the pre-project planning, contingencies and plans can be developed to accommodate the requirements and conditions, ensuring they don't affect the projects budget and schedule once construction commences.

The development of the construction contract needs to be thorough and include all the necessary clauses to address the frequently occurring and most severe supply chain risks. All the stakeholders involved need to establish a fair and reasonable contact period. Unrealistic contract periods often result in excessive stress on the contractor and poor-quality. This is due to work being rushed to finish the project within the specified time allocated. The contract needs to incorporate the necessary instruments to manage and mitigate the risks of the construction project. These instruments need to deal with issues such as, not limited to, the extension of time, change orders, delayed payments, dispute resolution procedures, penalties, adjustment clauses, project specific conditions, and claims. The inclusion of the following procedures: pre-contract negotiation, formulation of contract documents, and reviewing the bid for technical viability allow for the mitigation of claims throughout the project. Inflation and escalation of the project resources was a major supply chain risk discussed earlier. The adoption of a market-based escalation formulae to accommodate such fluctuations in the price of resources will further mitigate claims between the parties. The high volume of change orders and scope changes can be mitigated by the inclusion of clauses that outline the allowance of change orders, the new rate of work under change orders, procedures that need to be followed, and ensuring all change orders are made in writing. Furthermore, the client should ensure that the necessary financial arrangements are in place to ensure that there will be no delayed payments to contractors. Funds secured for the project should be adequate to accommodate cost escalation at a reasonable percentage of the original tendered amount.

The efficient communication is vital for the project's success, stakeholders should establish clear information and communication channels and provide adequate and advanced communication channels and tools to facilitate the coordination among the members of the construction project. Early collaborations between the client, design team and project consultant can be optimised by improving communications through the real-time integration of decisions across all the interfaces in the supply chain through BIM and cloud computing. Given the resources available in BIM, clash detection can be used to identify potential problems before they occur on-site, mitigating the risk of delays and costly corrections. Furthermore, collaboration and information sharing between stakeholders in the supply chain is vital for its implementation and to avoid idle times and the loss of productivity. MIS can be used as a platform that allows for the integration and collaboration of stakeholders on a single platform. This ensures information is not lost and all the stakeholders understand their role in providing adequate information.

The development of a thorough and effective schedule should reflect a reasonable construction period allowing for the smooth implementation of the project operations and promote project performance and efficiency. Furthermore, it should ensure that the economic benefits and value to the client are achieved. The critical path method can be used to establish the projects schedule. The method can be adapted to suit the project and account for any project specific requirements. The development of the schedule should be done collectively between the stakeholders, ensuring that all parties requirements and conditions are met. It is recommended that the project schedule is over seen by an experienced professional to ensure there are no errors, omissions, and that the project schedule is practical, and the goals and milestone are achievable. The schedule needs to consider the critical work activities and ensure the schedule aligns with the provisions set out in the contract. The schedule once complete, should be set in stone and regarded as reliable and binding between all parties involved.

The selection of the appropriate contractor determines whether the project is successful or not. Clients often select the contractor that has submitted the lowest bid, despite not having the necessary expertise and skills to carry out the project. Given this, the awarding of the contract should be based on a bidding and award process that considers the contractors experience and ability to carry out the project. The owners lack of engineering and construction knowledge allows them to be easily persuaded by contractors and consultants, to accept bids based on conversations and promises made by those involved. However, the selection of the contractor should be based on the most economically advantageous bid and the selection of the most developed plans and schedule for the specific project. This will ensure that projects plans are complete and free from omissions and errors. The contractors and subcontractors should be prequalified for the project. They should be shortlisted based off their experience, reputation, and formal relationship they have established throughout the construction industry. The shortlisted contractors would then enter a negotiation period with the client. The client will need to establish the level competence and expertise the contractor possesses. This may be conducted based on, not limited to, their past experience on similar projects, problem solving ability, level of reliability, and ensuring they have the capable communication skills. The client must then establish the payment plan options, quoted price and the deployment of resources before the selection of the contractor is finalised. Consultants with adequate experience and qualifications should also be appointed. The projects consultant should guide the client to assist in decision making and provide all parties with sufficient and detailed information to aid in performing their tasks. This is specifically important with regards to the projects design and requirements.

The contractor and their team are responsible for ensuring proper site management. The contractor’s team should have the necessary project management skills, competence, and reliability to ensure that they can be trusted with mitigating any supply chain risks that may occur. The projects management team are responsible for improving the project visibility and flexibility in moderating the effects of resource and communication issues. Furthermore, the contractor should enhance their relationships with suppliers by developing long term relationships with them through multiple projects. This will mitigate the risk of delayed deliveries of the resources required for the project. Project delays caused by poor communication, poor project management and resource allocation can be mitigated through the constant communication and daily project meetings, these meeting can also be used to improve worker motivation, worker communication and promote the utilisation of group problem solving. These management strategies and tools all align with the construction supply chain management and enhance the activities and processes of the stakeholders and workers involved in the construction project.

Section 4.6.6 outlines the technologies available for supply chain risk management. The implementation of technologies in mitigating supply chain risks may reduce the project duration and result in cost reductions. The use of BIM in projects have resulted in cost reductions of up to 11% and schedule and time reductions of up to 25%. (Onungwa, et al., 2017). Other technologies such as web portals, real-time supply chain management, BIM and cloud computing will all assist in planning and controlling the construction supply chain. These technologies provide the platform for communicating and the exchange of real-time data. Web portals and cloud computing can be used to integrate stakeholders for improved communication and the reduction in slow deciosn making. BIM is utilised to monitor progress and performance of the project by analysing the real-time data made available by the other project stakeholders.

The use of VR and AR can be adopted in the training and guidance of workers, as well as during complicated installation processes. Furthermore, the adoption of RFID technology allows for the trackability and transparency in the supply chain. It enables the tracking of labour, materials, and equipment throughout the project duration. The integration of the RFID system into BIM or an established ERP allow for the real-time transfer of information and data which promotes the improved monitoring, control, and management of onsite activities. This results in tighter supply chain control and improved project performance.

The use of cloud computing can be used to monitor, in real-time, the location data, information and material and tool status required during the project such as equipment delivery. Furthermore, BIM can be utilised to improve communications between all stakeholders by monitoring and providing updates on the necessary resource availability and statuses. BIM and cloud computing integrated with GIS and RFID allows for an accurate and transparent monitoring of activities and resources throughout the supply chain, whilst updating all stakeholders with the relevant data and information needed to perform their necessary works effectively and efficiently.

## 5.4 Limitations of Study

The limitations of the study are: Firstly, the sample size was relatively small with 90 articles being systematically analysed. This may affect the results generalisability. Despite this, the generalization is useful in the progression of construction supply chain risk management as it is sometimes useful to oversee this such that the generalised results can be tailored towards a specific projects risk. Secondly, the qualitative analysis was conducted throughout the report, given this, it would have been beneficial to incorporate the perceptions of industry professionals who have experience in the construction industry. Given this, the future research should include a qualitative assessment with industry relevant interviews and questionnaires which will in turn validate the outcomes of the research. Thirdly, publications on the topics have indeed increased in number, however, the relative publications are still low on any one developing country.

# CHAPTER 6

# 6. CONCLUSIONS AND FURTHER RECOMMENDATIONS

## 6.1 Conclusion

The aim of the research was to determine the impact of managing the supply chain risks within the construction industry of Africa's top three performing GDP nations. The research aimed to expose the results through the primary research objectives, namely through the identification of construction supply chain risks, evaluating the impact of the supply chain risks in the construction and lastly determining the mitigation factors that would lessen the impact of the supply chain risks within the construction industry. The study conducted research through a mixed methodology. The collection and systematic review of published literature was conducted before being coded into the identified key themes from the literature available. The themes were developed based on the literature found regarding the supply chain risks and their impacts forming the basis of the thematic analysis. Subsequently, the importance of the risks and their impacts was determined using various indices. In large, the result obtained showed that the impact of managing the construction supply chain risks were significant with regards to their cost and scheduling attributes.

Within the first objective, the construction supply chain risks were identified as well as their relevant group responsible for them occurring. The main supply chain risks were due to the lack of expertise, design risks, financial constraints, market conditions, and resource shortages. These risks stemmed from the lack of expertise being appointed to manage, plan, design, and coordinate construction projects. The financial restrictions on available funds, cash-flow and making on time payments results in construction works being temporarily suspended. The prevailing market conditions impact the price of the resources necessary for the successful implementation of the construction project. The shortage of materials, equipment and necessary labour creates idle time which results in delays and lowered project performance. Furthermore, it was identified that the contractor and client were the most responsible group for causing the supply chain risks.

The second objective investigated the impact of the identified supply chain risks. The subsequent investigation found that the supply chain risks had cascading effects on the project. These effects were related to the project's direct costs, scheduling, and operations. It was found that the financial impacts were the most important in the successful completion of the project, followed by that of the projects schedule and duration.

The last objective investigated the mitigating factors to lessen the impact of construction supply chain risks. The investigation found that the construction supply chin risks need to be mitigated though the correct contract formation, appropriate appointment of expertise and project planning. The early involvement of the client in the decision-making process allows for their requirements to be met and thus, reduces that number of change orders made. The integration of both mitigation strategies and available technology, allows for the supply chain risks, impacts, and inefficiencies to be minimised and mitigated. Thus, improving the projects performance and creating enhanced value towards the client or project customer.

Therefore, the research contributed to the in-depth understanding of the identification and manging of supply chain risks through technology and mitigation strategies. This required the in-depth analysis of supply chain risks, responsible groups, the associated impacts, the mitigation strategies, and technology available. The analysis was conducted in the aim of mitigating construction supply chain risks and their associated impacts in Africa's top three performing GDP nations. Furthermore, the supply chain risks, and their associated impacts can be mitigated and thus, the implementation of mitigation strategies and technologies are vital for reducing effects of the impacts within the construction supply chain of Africa's top three performing nations.

## 6.2 Recommendations

This research report is a good starting point to understand the construction supply chain risks, the associated impacts, and the mitigation strategies and technology available to mitigate the overall impacts of these risks within the construction industry. However, future research can be conducted to further understand: Firstly, the implementation of barriers and difficulties associated with implementation of the mitigation strategies and technologies into the construction industry must be evaluated. Given this, investigation should be conducted into how the supply chain flexibility could be increased through the onsite operations and increasing the supply chain reaction in the attempt to meet the increasing levels of variability of the activities that occur throughout the construction project. Secondly, the investigation into how value is created throughout the construction supply chain. This would analyse the suppliers, contractors, and the manufacturers to determine whether they are cable of accommodating enhanced project benefits to the stakeholders involved. Thirdly, the development of a comprehensive framework for categorising the supply chain risk causes with the aim of exploring their relationships between the defined categories of risk causes and the explanatory for the risks occurring. Lastly, an economic analysis can be conducted and an examination of the critical risks impact on the project objectives when the adoption of modular integrated construction is used.

## REFERENCES


A. Olanrewaju, A. & J. Anavhe, P., 2014. Perceived claim sources in the Nigerian construction industry. *Built Environment Project and Asset Management,* July, Volume 4, p. 281–295.

A. Osman, M. M., H. Issa, U. & Zakaria Eraqi, A. M., 2020. Identifying the Risk Impact on Cost and Time of the Egyptian Non-Residential Buildings Projects. *International Journal of Scientific Research in Science, Engineering and Technology,* January.p. 01–12.

Abd El-Karim, M. S. B. A., Mosa El Nawawy, O. A. & Abdel-Alim, A. M., 2017. Identification and assessment of risk factors affecting construction projects. *HBRC Journal,* August, Volume 13, p. 202–216.

Abdullah, M. S., Alaloul, W. S., Liew, M. S. & Mohammed, B. S., 2018. Delays and Cost Overruns Causes During Construction of Palm Oil Refinery Projects. *MATEC Web of Conferences,* Volume 203, p. 02004.

Adepoju, O. O. & Aigbavboa, C. O., 2020. Implementation of Construction 4.0 in Nigeria: Evaluating the Opportunities and Threats on the Workforce. *Academic Journal of Interdisciplinary Studies,* September, Volume 9, p. 254.

Ahady, S., Gupta, S. & Malik, R. K., 2017. A critical review of the causes of cost overrun in construction industries in developing countries. *International Research Journal of Engineering and Technology,* Volume 4.

Akal, A. A. & El-Kholy, A. M., 2021. Exploring the critical frequent factors of rework and assigning strategies to mitigate their occurrence in the Egyptian construction projects. *Journal of King Saud University - Engineering Sciences,* October.p. S1018363921001410.

Akampurira, E. & Windapo, A., 2019. Key quality attributes of design documentation: South African perspective. *Journal of Engineering, Design and Technology,* 17(2).

Akinradewo, O., Aigbavboa, C. & Akinradewo, O., 2019. Revisiting Causative Factors of Project Cost Overrun in Building Construction Projects in Nigeria. *IOP Conference Series: Materials Science and Engineering,* November, Volume 640, p. 012002.

Alade, K. T., Lawal, A. F., Omonori, A. A. & Olowokere, E. N., 2019. Causes And Effects Of Delays In Construction Projects In Akure, Ondo State, Nigeria. *Journal of Management and Technology.*

Al-Hazim, N., Salem, Z. A. & Ahmad, H., 2016. Delay and Cost Overrun in Infrastructure Projects in Jordan. *7th International Conference on Engineering, Project, and Production Management,* Volume 182, pp. 18-24.

Aljohani, A., 2017. Construction Projects Cost Overrun: What Does the Literature Tell Us?. *International Journal of Innovation, Management and Technology,* p. 137–143.

Amoah, C. & Pretorius, L., 2019. Evaluation of the impact of risk management on project performance in small construction firms in South Africa: the case study of construction systems. *Acta Structilia.*

Amoatey, C. T. & Ankrah, A. N. O., 2017. Exploring critical road project delay factors in Ghana. *Journal of Facilities Management,* 15(2), pp. 110-127.

Ansah, R. H. & Sorooshian, S., 2017. Effect of lean tools to control external environment risks of construction projects. *Sustainable Cities and Society.*

Arantes, A., da Silva, P. F. & Ferreira, L. M. D. F., 2015. Delays in construction projects - Causes and impacts. *Civil and Environmental Research,* Volume 5.

Arantes, A. & Ferreira, L. M. D., 2020. Underlying causes and mitigation measures of delays in construction projects, An empirical study. *Journal of Financial Management of Property and Construction.*

Arditi, D., Nayak, S. & Damci, A., 2017. Effect of organizational culture on delay in construction. *International Journal of Project Management,* Volume 35, pp. 136-147.

Assaf, S. A. & Al-Hejji, S., 2006. Causes of delay in large construction projects. *International Journal of Project Management,* Volume 24, pp. 349-357.

Atout, M. M., 2016. Delays Caused by Project Consultants and Designers in Construction Projects. *International Journal of Structural and Civil Engineering Research,* 5(2), pp. 102-107.

Awolesi, J. A. B., Fabi, J. K. & Akinseinde, O. A., 2015. Assessment of Contractors' Mitigating Measures for Cost Overrun of Building Projects in South-Western Nigeria. *Journal of Sustainable Development,* November, Volume 8, p. 139.

Aziz, R. F., 2013. Factors causing cost variation for constructing wastewater projects in Egypt. *Alexandria Engineering Journal,* March, Volume 52, p. 51–66.

Aziz, R. F. & Abdel-Hakam, A. A., 2016. Exploring delay causes of road construction projects in Egypt. *Alexandria Engineering Journal,* June, Volume 55, p. 1515–1539.

Bajjou, M. S. & Chafi, A., 2018. Lean construction implementation in the Moroccan construction industry. *Journal of Engineering, Design and Technology.*

Bajjou, M. S. & Chafi, A., 2020. Empirical study of schedule delay in Moroccan construction projects. *International Journal of Construction Management,* 20(7), pp. 783-800.

Baloyi, L. & Bekker, M., 2011. Causes of construction cost and time overruns: The 2010 FIFA World Cup stadia in South Africa. *Acta Structilia,* Volume 18.

Banobi, E. T. & Jung, W., 2019. Causes and Mitigation Strategies of Delay in Power Construction Projects: Gaps between Owners and Contractors in Successful and Unsuccessful Projects. *Sustainability,* October, Volume 11, p. 5973.

Bello, A. M. & Saka, A. B., 2017. Impact of variation on project delivery in Oyo state, Nigeria. *World Scientific News,* Volume 86, p. 265–282.

Bendi, D. et al., 2021. An Off-site construction Readiness Maturity Model for the Indian Construction Sector. *Construction Innovation.*

Bertram, N. et al., 2019. Modular Construction: From porjects to products. *McKinsey & Company.*

Bikitsha, L. & Amoah, C., 2022. Assessment of challenges and risk factors influencing the operation of emerging contractors in the Gauteng Province, South Africa. *International Journal of Construction Management,* August, Volume 22, p. 2027–2036.

Carvalho, A. B., Maués, L. M. F., Moreira, F. d. S. & Reis, C. J. L., 2021. Study on the factors of delay in construction works. *Ambiente Construído,* September, Volume 21, p. 27–46.

Chai, S., Liu, M., Zhang, Z. & Li, S., 2021. Study on Risk Identification and Key Risks of Prefabricated Building Supply Chain Based on Grounded Theory. *Web of confrences.*

Dallasega, P., 2018. Industry 4.0 Fostering Construction Supply Chain Management: Lessons Learned From Engineer-to-Order Suppliers. *IEE xplore,* 46(3), pp. 49-55.

Dallasega, P., 2018. Industry 4.0 Fostering Construction Supply Chain Management: Lessons Learned From Engineer-to-Order Suppliers. *IEEE Engineering Management Review,* September, Volume 46, p. 49–55.

Dallasega, P. & Rauch, E., 2017. Sustainable Construction Supply Chains through Synchronized Production Planning and Control in Engineer-to-Order Enterprises. *Sustainability,* Volume 10.

Dewey, A. & Drahota, A., 2016. *Charels Sturt University.* [Online]
[Accessed 28 June 2021].

Dlamini, M. & Cumberlege, R., 2021. The impact of cost overruns and delays in the construction business. *IOP Conference Series: Earth and Environmental Science,* February, Volume 654, p. 012029.

Durdyev, S. & Hosseini, M. R., 2018. Causes of delays on construction projects: a comprehensive list. *Emerald Insights.*

Durdyev, S. & Hosseini, M. R., 2019. Causes of delays on construction projects: a comprehensive list. *International Journal of Managing Projects in Business.*

Egwim, C. N. et al., 2021. Extraction of underlying factors causing construction projects delay in Nigeria. *Journal of Engineering, Design and Technology,* September.

Ejekwu, T. B., Ekweani, C. P. & Oha, E. J., 2022. Evaluation of the Effects and Risks of Cost Estimation on Project Costs and Claims: A Study in Imo State, Nigeria. *International journal of environemnt, engineering and eductaion,* Volume 4.

Ekanayak, E., Shen, G. Q., Kumaraswamy, M. & Owusu, E. K., 2021. Critical supply chain vulnerabilities affecting supply chain resilience of industrialized construction in Hong Kong. *Engineering, Construction and Architectural Management.*

Ekwuno, A. O. & Nel, H., 2022. Analyzing The Project Delay Causes In The South African Construction Industry. *International Journal of Engineering Applied Sciences and Technology,* Volume 7, p. 15–73.

Eldeep, A. M., Farag, M. A. & El-hafez, L. A., 2021. Using BIM as a lean management tool in construction processes – A case study. *Ain Shams Engineering Journal.*

Elhusseiny, H., Nosair, I. & Ezeldin, A. S., 2021. Systematic processing framework for analyzing the factors of construction projects' delays in Egypt. *Ain Shams Engineering Journal,* Volume 12, pp. 1501-1511.

Elinwa, A. U. & Joshua, M., 2010. Time-Overrun Factors in Nigerian Construction Industry. *Journal of Construction Engineering and Management,* October, Volume 127, p. 419–425.

Enshassi, A., Kumaraswamy, M. & Al-Najjar, J., 2010. Significant Factors Causing Time and Cost Overruns in Construction Projects in the Gaza Strip: Contractors' Perspective. *International Journal of Construction Management,* January, Volume 10, p. 35–60.

Famiyeh, S., Amoatey, C. T. & Adaku, E., 2017. Major causes of construction time and cost overruns. *Journal of Engineering, Design and Technology,* 15(2), pp. 181-198.

Ferdous, W. et al., 2019. New advancements, challenges and opportunities of multi-storey modular buildings – A state-of-the-art review. *Engineering Structures,* Volume 183, pp. 883-893.

Fergany, M., El-Nawawy, O. & Badawy, M., 2020. Estimation of the Overall risk in Residential Building in Egypt. *International Journal of Scientific & Engineering Research,* Volume 11.

Gamage, S., 2019. Thematic Analysis of Interview Data in the Context of Managment Controls Research. *SAGE research methods datasets.*

Gashahun, A. D., 2020. Causes and Effects of Delay on African Construction Projects: A State of the Art Review. *Civil and Environmental Research,* May.

Gbahabo, P. T. & Ajuwon, O. S., 2017. Effects Of Infrastructure Project Cost Overruns And Schedule Delays In Sub-Saharan Africa. *Acta Structilia.*

Gebrehiwet, T. & Luo, H., 2017. Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study. *Procedia Engineering,* Volume 196, p. 366–374.

González, P., González, V., Molenaar, K. & Orozco, F., 2014. Analysis of Causes of Delay and Tim ePerformance in Construction Projects. *American Society of Civil Engineers..*

Goodier, C. & Gibb, A., 2019. Future opportunities for offsite in the UK. *Construction Management and Economics.*

Gosling, J. et al., 2016. Defining and Categorizing Modules in Building. *American Society of Civil Engineers.*

Gouda Mohamed, A., Helmy Ammar, M. & Nabawy, M., 2022. Risks assessment using structural equation modeling: mega housing projects construction in Egypt. *International Journal of Construction Management,* June.p. 1–12.

Gunduz, M. & Al-Naimi, N. H., 2022. Construction projects delay mitigation using integrated balanced scorecard and quality function deployment. *Engineering, Construction and Architectural Management,* May, Volume 29, p. 2073–2105.

Habibi, M. & Kermanshachi, S., 2018. Phase-based analysis of key cost and schedule performance causes and preventive strategies. *Engineering, Construction and Architectural Management,* 25(8), pp. 1009-1033.

Ham-Baloyi, W. t. & Jordan, P., 2015. Systematic review as a research method in post-graduate nursing education. *Health SA,* Volume 21.

Hasan, A., Baroudi, B., Elmualim, A. & Rameezdeen, R., 2018. Factors affecting construction productivity: a 30 year systematic review. *Engineering, Construction and Architectural Management,* 25(7), pp. 916-937.

Herrera, R. F., Sánchez, O., Castañeda, K. & Porras, H., 2020. Cost Overrun Causative Factors in Road Infrastructure Projects: A Frequency and Importance Analysis. *Applied Sciences,* August, Volume 10, p. 5506.

Hwang, B.-G., Zhao, X. & Ng, S., 2013. Identifying the critical factors affecting schedule performance of public housing projects. *Habitat International.*

Ibironke, o. T., Oladinrin, T. O., Adeniyi, O. & Eboreime1, I. V., 2013. Analysis of Non-Excusable Delay Factors Influencing Contractors' Performance in Lagos State, Nigeria. *Journal of Construction in Developing Countries,* Volume 18, p. 53–72.

Indruskevics, R., 2018. *Robotic Process Automation Risk Analysis in Circle K Business Centre,* s.l.: Riga Business School.

Islam, M. S. & Trigunarsyah, B., 2017. *Construction Delays in Developing Countries: A Review.* 7 ed. s.l.:Journal of Construction Engineering and Project Management.

Islam, M. S. & Trigunarsyah, B., 2017. Construction Delays in Developing Countries: A Review. *Journal of Construction Engineering and Project Management,* March.7(1).

Ismaila, U., Jung, W. & Park, C. Y., 2022. Delay Causes and Types in Nigerian Power Construction Projects. *Energies,* January, Volume 15, p. 814.

Ismalia, U., Jung, W. & Park, C. Y., 2022. Delay Causes and Types in Nigerian Power Construction Projects. *Energies,* Volume 15.

Jacob, U. & Sunjka, B. P., 2013. *Significant Causes And Effects Of Project Delays In The Niger Delta Region, Nigeria.* s.l., s.n.

Jalal, M. P. & Shoar, S., 2017. A hybrid SD-DEMATEL approach to develop a delay model for construction projects. *Engineering, Construction and Architectural Management,* 24(4), pp. 629-651.

Jeong, J.-S. & Jung, E.-Y., 2017. Construction Delays in Developing Countries: A Review. *Journal of Construction Engineering and Project Management,* March, Volume 7, p. 1–12.

Kadry, M., Osman, H. & Georgy, M., 2017. Causes of Construction Delays in Countries with High Geopolitical Risks. *Journal of Construction Engineering and Management,* February, Volume 143, p. 04016095.

Khabisi, L., 2013. Causes and Effects of Cost overruns in public sector construction projects in south africa. *Jounral of Construction in devloping countries.*

Khodeir, L. M. & El Ghandour, A., 2019. Examining the role of value management in controlling cost overrun [application on residential construction projects in Egypt]. *Ain Shams Engineering Journal,* September, Volume 10, p. 471–479.

Kikwasi, G., 2013. Causes and Effects of Delays and Disruptions in Construction Projects in Tanzania. *Australasian Journal of Construction Economics and Building,* 1(2).

Li, C. Z. et al., 2021. A blockchain- and IoT-based smart product-service system for the sustainability of prefabricated housing construction. *Journal of Cleaner Production,* March, Volume 286, p. 125391.

Lindhard, S. & Wandahl, S., 2014. Exploration of the reasons for delays in construction. *International Journal of construction managment,* 14(1), pp. 47-57.

Mahamid, I. & Dmaidi, N., 2013. Risks Leading to Cost Overrun in Building Construction from Consultants' Perspective. *Organization, Technology & Management in Construction: An International Journal,* December, Volume 5, p. 860–873.

Mahmud, A. T., Ogunlana, S. O. & Hong, W. T., 2021. Key driving factors of cost overrun in highway infrastructure projects in Nigeria: a context-based perspective. *Journal of Engineering, Design and Technology,* November, Volume 19, p. 1530–1555.

Marzouk, M. M. & El-Rasas, T. I., 2014. Analyzing delay causes in Egyptian construction projects. *Journal of Advanced Research.*

Marzouk, M. M. & EL-Rasas, T. I., 2014. Analyzing delay causes in Egyptian construction projects. pp. 49-55.

Mate, R. M. & Hinge, G. A., 2015. Delay Mitigation in the Construction Industry. *International Journal of Engineering Research & Technology,* 4(6), pp. 172-176.

Matodzi, E., 2015. South African construction industry's perception of mitigation measures for addressing avoidable delay factors. *Acta Structilia.*

Matthew , J. P. et al., 2021. *The PRISMA 2020 statement: an updated guideline for reporting systematic reviews.* s.l., s.n.

Memon, A. H., Rahamn, I. A. & Aziz, A. A. A., 2012. THE CAUSE FACTORS OF LARGE PROJECT'S COST OVERRUN: A SURVEY IN THE SOUTHERN PART OF PENINSULAR MALAYSIA. *International Journal of Real Estate Studies,* Volume 7.

Mittal, S. & Gorowara, N., 2020. Identifying and Mitigating delay factors in Engineering, Procurement and Construction Phases. *PalArch's Journal of Archaeology of Egypt,* Volume 17.

Mohamed, K. L., 2017. Efficient Risk Management: Cause And Effect Analysis Of Key Risks Of Complex Construction Projects In Egypt. *Journal of Engineering Sciences,* Volume 45, p. 773–790.

Mohammed, K. A. & Isah, A. D., 2012. Causes Of Delay In Nigeria Construction Industry. *INTERDISCIPLINARY JOURNAL OF CONTEMPORARY RESEARCH IN BUSINESS,* Volume 4.

Morena, M. & Amoah, C., 2021. Assessment of the mitigating measures for cost overruns in the South African construction industry. *IOP Conference Series: Earth and Environmental Science.*

Motlhatlhedi, I. G. & Nel, H., 2019. Investigation of Project Delay in Construction Projects in the South African Rail Industry. *Industrial Engineering and Operations Management.*

Mukuka, M., Aigbavboa, C. & Thwala, W., 2015. Effects of construction projects schedule overruns: A case of the Gauteng Province, South Africa. *Procedia Manufacturing.*

Mukuka, M., Aigbavboa, C. & Thwala, W., 2015. Understanding Construction Projects' Schedule Overruns in South Africa. *International Conference on Construction and Real Estate Management,* 9 September.

Mulalo, R., Ibrahimu, K. & Nwobodo-Anyadiegwu, E., 2018. Project Cost Overrun in the South African Construction Sector: A case study of Johannesburg Metropolis. *Industrial Engineering and Operations Management,* Volume 12.

Nabawy, M., Ofori, G., Morcos, M. & Egbu, C., 2021. Risk identification framework in construction of Egyptian mega housing projects. *Ain Shams Engineering Journal,* June, Volume 12, p. 2047–2056.

Nkobane, M. A., 2013. Causes of delay and cost overruns in engineering, procurement and Construction Management prjects in South Africa. *University of Johannesburg.*

Obianyo, J. I., Okey, O. E. & Alaneme, G. U., 2022. Assessment of cost overrun factors in construction projects in Nigeria using fuzzy logic. *Innovative Infrastructure Solutions,* October, Volume 7, p. 304.

Obodoh, D. A. & Obodoh, C., 2016. Causes and Effects of Construction Project Delays in Nigerian Construction Industry. *International Journal of Innovative Science, Engineering & Technology,* Volume 3.

Ogbeide, F. N. & Ehiorobo, J. O., 2022. Prioritizing Delay Mitigation Strategies for Road Projects in Nigeria. *American Journal of Sciences and Engineering Research,* Volume 5.

Okafor, C. C., Sydney Ani, U. & Ugwu, O., 2022. Critical solutions to the lapses of supply chain management in Nigeria's construction industry. *International Journal of Building Pathology and Adaptation,* April.

Oke, A. E. & Arowoiya, V. A., 2022. Critical barriers to augmented reality technology adoption in developing countries: a case study of Nigeria. *Journal of Engineering, Design and Technology,* August, Volume 20, p. 1320–1333.

Oke, A. E. et al., 2021. Exploring the benefits of cloud computing for sustainable construction in Nigeria. *Journal of Engineering, Design and Technology,* August.

Oke, A. et al., 2021. Assessment of Cloud Computing Success Factors for Sustainable Construction Industry: The Case of Nigeria. *Buildings,* January, Volume 11, p. 36.

Olaniyi, A., Bosede, A. & Olusola, O., 2015. Supply Chain Management Practices in Construction Procurement: Perceptions of Professional Quantity Surveyors in Ondo State, Nigeria. *PM World Journal,* Volume 6.

Olawale, Y. A. & Sun, M., 2010. Cost and time control of construction projects: inhibiting factors and mitigating measures in practice. *Construction Management and Economics,* May, Volume 28, p. 509–526.

Olusengun, A. E. & Michael, A. O., 2011. Abandonment of Construction Projects in Nigeria: Causes and Effects. *Journal of Emerging Trends in Economics and Management Sciences,* Volume 2, p. 142–145.

Oluwaseun, O. & Kruger, D., 2017. Comparative study of causes and effects of project delays and disruptions in construction projects in the South African construction industry. *Journal of Construction Engineering and Project Management,* pp. 13-25.

Oluyemi-Ayibiowu, B. D., Aiyewalehinmi, O. E. & Omolayo, O. J., 2019. Most Critical Factors Responsible For Cost Overruns In Nigeria Building Construction Industry. *Journal of Multidisciplinary Engineering Science Studies,* Volume 5.

Onungwa, I. O., Uduma-Olugu, N. & Igwe, J. M., 2017. *Building Information Modelling As A Construction Management Tool In Nigeria.* Alicante, s.n., p. 25–33.

Oshungade, O. O. & Kruger, D., 2017. A COMPARATIVE STUDY OF CAUSES AND EFFECTS OF PROJECT DELAYS AND DISRUPTIONS IN CONSTRUCTION PROJECTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY. *Journal of Construction Engineering and Project Management.*

Osunsanmi, T., Aigbavboa, C. & Oke, A., 2018. Construction 4.0: The Future of the Construction Industry in South Africa. *World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering,* Volume 12.

Othman, A. A. E. & Alamoudy, F. O., 2021. Optimising building performance through integrating risk management and building information modelling during the design process. *Journal of Engineering, Design and Technology,* November, Volume 19, p. 1233–1267.

Oyegoke, A. S. & Al Kiyumi, N., 2017. The causes, impacts and mitigations of delay in megaprojects in the Sultanate of Oman. *Journal of Financial Management of Property and Construction,* 22(3), pp. 296-302.

Panova, Y. & Hilletofth, P., 2018. Managing supply chain risks and delays in construction project. *ndustrial Management & Data systems,* 118(7), pp. 1413-1431.

Prasad, K. V., Vasugi, V. & Bhat, N. S., 2018. Critical causes of time overrun in Indian construction projects and mitigation measures. *nternational Journal of Construction Education and Research.*

Rachid, Z., Toufik, B. & Mohammed, B., 2018. Causes of schedule delays in construction projects in Algeria. *International Journal of Construction Management.*

Rashed, E. F. & Shaqour, E. N., 2014. Factors Causing Cost Overrun In Administrative Construction Projects Of Egypt. *Journal of Engineering Sciences,* Volume 6, p. 199–215.

Rashed, I. A., Sanad, A. M. & Alhazimi, M., 2015. Risk Analysis for Construction Contractors in Egypt and Yemen. *Journal of Engineering and Computer Sciences,* Volume 8, p. 109–122.

Renault, B., Agumba, J. & Ansary, N., 2016. *An Appraisal of Critical Risk Factors in Construction Projects in South Africa: Perspective of Contractors.* Zambia, s.n.

Saidu, I. & Shakantu, W., 2017. An investigation into cost overruns for ongoing building projects in Abuja, Nigeria. *Acta Structilia,* June.Volume 24.

San Santoso, D. & Soeng, S., 2016. Analyzing Delays of Road Construction Projects in Cambodia: Causes and Effects. *Asce Journals.*

San Santoso, D. & Soeng, S., 2016. Analyzing Delays of Road Construction Projects in Cambodia: Causes and Effects. *Journal of Management in Engineering.*

San Santoso, D. & Soeng, S., 2016. Analyzing Delays of Road Construction Projects in Cambodia: Causes and Effects. *Journal of Management in Engineering.*

Schulzea, F. & Dallasegaa, P., 2020. Industry 4.0 Concepts and Lean Methods Mitigating Traditional Losses in Engineer-to-Order Manufacturing with Subsequent Assembly On-Site: A Framework. *Procedia Manufacturing.*

Segerstedt, A. & Olofsson, T., 2010. Supply chains in the construction industry. *Supply Chain Management: An International Journal.*

Shaqour, E. N., 2022. The role of implementing BIM applications in enhancing project management knowledge areas in Egypt. *Ain Shams Engineering Journal,* January, Volume 13, p. 101509.

Shemov, G., Garcia de Soto, B. & Alkhzaimi, H., 2020. Blockchain applied to the construction supply chain: A case study with threat model. *Frontiers of Engineering Management,* December, Volume 7, p. 564–577.

Statista, 2021. *Statista.* [Online]
Available at: https://www.statista.com/statistics/1120999/gdp-of-african-countries-by-country/
[Accessed 20 December 2022].

Su, Y., Lucko, G. & Thompson, R. C., 2016. EVALUATING PERFORMANCE OF CRITICAL CHAIN PROJECT MANAGEMENT TO MITIGATE DELAYS BASED ON DIFFERENT SCHEDULE NETWORK COMPLEXITIES. *Proceedings of the 2016 Winter Simulation Conference,* pp. 3314-3324.

Tayade, A. & Mahatme, P. S., 2020. Delay in Construction its Causes and Mitigation: A review. *International Research Journal of Engineering and Technology,* Volume 7.

Thyer, B. A., 2009. The Importance of Journal Articles. *Preparing Research Articles,* pp. 1-12.

Tshidavhu, F. & Khatleli, N., 2020. An assessment of the causes of schedule and cost overruns in South African megaprojects: A case of the critical energy sector projects of Medupi and Kusile. *Acta Structilia,* June, Volume 27, p. 119–143.

Ugulu, R. A., Arewa, A. & Allen, S., 2019. Project-specific constraints influencing productivity of tradespeople in the Nigerian construction industry. *Built Environment Project and Asset Management,* October, Volume 10, p. 94–109.

Unegbu, H. C. O., Yawas, D. S. & Dan-asabe, B., 2022. An investigation of the relationship between project performance measures and project management practices of construction projects for the construction industry in Nigeria. *Journal of King Saud University - Engineering Sciences,* May, Volume 34, p. 240–249.

Vacanas, Y. & Danezis, C., 2021. Determination of Effective Delay-Avoidance Practices in Construction Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction ,* 13(1).

Viswanathan, S. K., Tripath, K. K. & Jha, K. N., 2020. Influence of risk mitigation measures on international construction project success criteria – a survey of Indian experiences. *Construction Management and Economics,* 38(3), pp. 207-222.

Wang , S. Q., Dulaimi , M. F. & M., 2010. Risk management framework for construction projects in developing countries. *Construction Management and Economics.*

Wang, T.-K., Ford, D. N., Chong, H.-Y. & Zhang, W., 2018. Causes of delays in the construction phase of Chinese building projects. *Engineering, Construction and Architectural Management,* 25(11), pp. 1534-1551.

Wong, K. & Vimonsatit, V., 2012. A study of the factors affecting construction time in western Australia. *Academic journals,* 7(40), pp. 3390-3398.

Wuni, I. Y., Shen, G. Q. & Antwi-Afari, M. F., 2021. Exploring the design risk factors for modular integrated construction projects. *Construction Innovation.*

Wuni, I. Y., Shen, G. Q. & Hwang, B.-G., 2020. Risks of modular integrated construction: A review and future. *Frontiers of Engineering Management.*

Yousry Akal, A. & Metwally El-Kholy, A., 2021. Exploring the critical frequent factors of rework and assigning strategies to mitigate their occurrence in the Egyptian construction projects. *Journal of King Saud University - Engineering Sciences,* October.p. S1018363921001410.

Yousry Akal, A. & Metwally El-Kholy, A., 2021. Exploring the critical frequent factors of rework and assigning strategies to mitigate their occurrence in the Egyptian construction projects. *Journal of King Saud University - Engineering Sciences,* October.p. S1018363921001410.

Zailani, S. et al., 2016. The moderating effect of project risk mitigation strategies on the relationship between delay factors and construction project performance. *Journal of Science and Technology Policy Management,* 7(3), pp. 346-368.

Zaza, S. et al., 2000. Data Collection Instrument and Procedure for Systematic Reviews in the Guide to Community Preventive Services. *American Journal of Preventive Medicine,* Volume 18.

Zhao, X., Hwang, B.-G. & Phng, W., 2013. Construction Project Risk Management in Singapore: Resources, Effectiveness, Impact, and Understanding. *Korean Society of Civil Engineers.*

Zhong, S., Elhegazy, H. & Elzarka, H., 2022. Key factors affecting the decision-making process for buildings projects in Egypt. *Ain Shams Engineering Journal,* May, Volume 13, p. 101597.

Zidane, Y. J.-T. & Anderson, B., 2018. The top 10 universal delay factors in construction projects. *International Journal of Managing projects in business,* 11(3), pp. 650-672.

# APPENDICES

## Appendix A

Table 27: Data Extraction Form adapted from (Zaza, et al., 2000)

| FACTORS | ASSESMENT | COMMENTS |
|---|---|---|
| **PARTICIPENTS** | | |
| 1. Does the literature apply to the construction industry and is it relevant to the supply chain risks. | Yes No<br>Exclude | |
| 2. Does the literature relate to the sub-themes? | Yes No<br>Exclude | Sub themes: cause of supply chain risk, responsible group or party, severity of risk, likelihood of risk, overall risk importance, construction risk mitigation, technology. |
| 3. Does the literature satisfy the limitations of the research? | Yes No<br>Exclude | -Date: 2010-present<br>-Publication stage: final<br>-Language: English<br>-Source Type: Journal<br>- Location: Egypt, Nigeria, South Africa |
| **COLLECTION AND SAMPLING** | | |
| 1. Is the literature duplicated? | Yes No<br>Exclude | |
| 2. Do the literature cover data in a similar manner? | Yes No<br>Exclude | Filtered through the title, abstract and full text analyses. |
| 3. Does the literature have sufficient information to answer the CRQ and objectives and is it frequently cited? | Yes No<br>Exclude | Main body skim reading. |
| **ANALYSIS OF DATA** | | |
| 1. Summarizing data individually for coding. | | |
| 2. Create nodes related to the themes and sub-themes to store related data together. | | |
| 3. Determine and analyse patterns form the coding of the literature. | | |

## Appendix B

Table 28: Client related supply chain risks

| Client Related Risks | Number of Codes | Percentage of Codes |
|---|---|---|
| Change Orders and Scope Changes | 126 | 16% |
| Financial Difficulties | 107 | 13% |
| Delayed Payments | 101 | 13% |
| Poor Contract Management | 72 | 9% |
| Slow Decision Making | 65 | 8% |
| Poor Communication | 51 | 6% |
| Unrealistic Project Duration | 40 | 5% |
| Poor Project Management | 38 | 5% |
| Claims | 31 | 4% |
| Awarding The Project to the Lowest Bidder | 29 | 4% |
| Lack of Construction Experience | 22 | 3% |
| Poor Pre-project Feasibility and Planning | 22 | 3% |
| Disputes | 21 | 3% |
| Delay in Approving Documents | 20 | 3% |
| Delay in Site Handover | 17 | 2% |
| Client Interference | 17 | 2% |
| Suspension of Work | 10 | 1% |
| Lack of Insurance & Contingencies | 8 | 1% |
| Client Death | 1 | 0.13% |

Table 29: Consultant related supply chain risks

| Consultant Related Risks | Number of Codes | Percentage of Codes |
|---|---|---|
| Poor Planning and Scheduling | 107 | 23% |
| Incorrect Estimate | 85 | 19% |
| Poor Communication & Coordination | 54 | 12% |
| Poor Contract Management | 52 | 11% |
| Inadequate Consultant Experience | 48 | 11% |
| Poor Management | 46 | 10% |
| Slow Inspection of Works | 38 | 8% |
| Delay In Document Preparation & Submission | 15 | 3% |
| Incomplete Documents | 12 | 3% |

Table 30: Contractor related supply chain risks

| **Contractor Related Risks** | **Number of Codes** | **Percentage of Codes** |
|---|---:|---:|
| Improper Planning & Coordination | 115 | 13% |
| Shortage of Skills or Labour | 92 | 11% |
| Financial & Cash-flow Difficulties | 86 | 10% |
| Poor Site Management | 83 | 10% |
| Inadequate Contractor Experience | 81 | 9% |
| Poor Communication | 53 | 6% |
| Subcontractor Issues | 51 | 6% |
| Poor Labour Productivity | 46 | 5% |
| Poor Contract Management | 45 | 5% |
| Unskilled Management Team & Labour | 44 | 5% |
| Poor Project Management | 41 | 5% |
| Errors/Mistakes Leading to Rework | 40 | 5% |
| Labour Dispute or Strike | 28 | 3% |
| Insufficient Quality Control | 27 | 3% |
| Inappropriate Construction Methods | 20 | 2% |
| Low Motivation | 19 | 2% |

Table 31: Design related supply chain risks

| **Design Related Risks** | **Number of Codes** | **Percentage of Codes** |
|---|---:|---:|
| Design Changes | 83 | 20% |
| Variation Orders | 82 | 20% |
| Incomplete Designs | 67 | 16% |
| Design Errors | 61 | 15% |
| Delay in Changes | 55 | 13% |
| Structural Variations | 31 | 8% |
| Poor Communication | 20 | 5% |
| Changes in Specification | 13 | 3% |

Table 32: Equipment related supply chain risks

| Equipment Related Risks | Number of Codes | Percentage of Codes |
|---|---|---|
| Equipment Shortage | 74 | 32% |
| Delay in Equipment Delivery | 49 | 21% |
| Equipment Price Escalation | 32 | 14% |
| Ineffective Procurement | 27 | 12% |
| Equipment Breakdown | 23 | 10% |
| Poor Equipment Productivity | 15 | 6% |
| Wrong Equipment | 8 | 3% |
| Poor Equipment Operator Skills | 5 | 2% |
| Theft | 1 | 0.43% |

Table 33: External or Project specific related risks

| External or Project Specific Risks | Number of Codes | Percentage of Codes |
|---|---|---|
| Weather Conditions | 69 | 11% |
| Inflation | 66 | 11% |
| Site Conditions and Location | 61 | 10% |
| Economic Risks | 57 | 9% |
| Environment Concerns | 46 | 8% |
| Law and Regulation Changes | 45 | 7% |
| Unforeseen Ground Conditions | 45 | 7% |
| Corruption | 40 | 7% |
| Political Interference | 37 | 6% |
| Political Instability | 34 | 6% |
| Delay in Approvals from Council | 26 | 4% |
| Force Majeure | 22 | 4% |
| Delay in site preparation | 16 | 3% |
| Site Accident | 13 | 2% |
| Problem with Neighbours | 12 | 2% |
| Arbitration | 11 | 2% |
| Litigation | 9 | 1% |
| Traffic Management | 3 | 0.49% |

Table 34: Material related supply chain risks

| **Material Related Risks** | **Number of Codes** | **Percentage of Codes** |
|---|---:|---:|
| Material Shortages | 88 | 26% |
| Material Price Escalation | 76 | 23% |
| Delay in Material Delivery | 58 | 17% |
| Ineffective Procurement | 38 | 11% |
| Poor Quality Materials | 33 | 10% |
| Unreliable Suppliers | 16 | 5% |
| Change in Material Specification | 15 | 4% |
| Poor Material Handling | 8 | 2% |
| Incorrect Material Delivered | 3 | 1% |
| Theft | 2 | 1% |

## Appendix C

Table 35: Construction related impacts

| Construction Impacts | Number of Codes | Percentage of codes |
|---|---:|---:|
| Stress on Contractor | 30 | 64% |
| Low Quality Work | 9 | 19% |
| Construction Waste | 4 | 9% |
| Lost Productivity | 4 | 9% |

Table 36: Contract and Legal related impacts

| Contract & Legal Impacts | Number of Codes | Percentage of codes |
|---|---:|---:|
| Disputes | 24 | 44% |
| Litigation | 14 | 26% |
| Arbitration | 13 | 24% |
| Contract Termination | 2 | 4% |
| Mediation | 1 | 2% |

Table 37: Financial related impacts

| Financial Impacts | Number of Codes | Percentage of codes |
|---|---:|---:|
| Cost Overrun | 55 | 70% |
| Claims | 10 | 13% |
| Reduced Profits | 8 | 10% |
| Bankruptcy | 3 | 4% |
| Loss of Investment | 2 | 3% |
| Uneconomical Projects | 1 | 1% |

Table 38: Schedule related Impacts

| Schedule & Time Impacts | Number of Codes | Percentage of codes |
|---|---:|---:|
| Schedule Delays | 49 | 62% |
| Project Abandonment | 22 | 28% |
| Extension of Time | 4 | 5% |
| Project Acceleration | 4 | 5% |

Table 39: Social related impacts

| **Impact of Risks** | **Number of Codes** | **Percentage of codes** |
|---|---:|---:|
| Worsening Relationships | 13 | 43% |
| Bad Public Relations | 6 | 20% |
| Loss of Jobs and Income | 4 | 13% |
| Negative Perception | 4 | 13% |
| Loss of Customer Benefit | 3 | 10% |

## Appendix D

Table 40: Client mitigation factors

| Client Mitigation Factors | Number of Codes | Percentage of Codes |
|---|---|---|
| Improved Communication | 15 | 47% |
| Reduced Change Orders | 7 | 22% |
| Financial Arrangements for Payments | 6 | 19% |
| Expedited Decision Making | 5 | 16% |
| Reframe from Interfering | 2 | 6% |
| Improved Site Handover | 2 | 6% |

Table 41: Consultant mitigation factors

| Consultant Mitigation Factors | Number of codes | Percentage of Codes |
|---|---|---|
| Improved Communication | 15 | 44% |
| Effectively Managing Changes | 5 | 15% |
| Accurate Estimate | 5 | 15% |
| Complete and Thorough Design | 4 | 12% |
| Experienced Consultant | 3 | 9% |
| Reference Class Forecasting | 2 | 6% |

Table 42: Contractor mitigation factors

| Contractor Mitigation Factors | Number of Codes | Percentage of Codes |
|---|---|---|
| Past Experience | 17 | 20% |
| Improved Communication | 15 | 18% |
| Prequalification of Contractors | 15 | 18% |
| Effective Material and Plant management | 7 | 8% |
| Experienced Subcontractors and Suppliers | 7 | 8% |
| Incentives for Staff and Labour | 7 | 8% |
| Appropriate Construction Techniques | 6 | 7% |
| Training for Personal and Labour | 5 | 6% |
| Improved Site Supervision and Management | 2 | 2% |
| Conflict Mitigation | 1 | 1% |
| Timely payment to suppliers & subcontractors | 1 | 1% |

Table 43: Contract and Financial mitigation factors

| Contract and Financial Mitigation Factors | Number of Codes | Percentage of Codes |
|---|---:|---:|
| Contract Management & Clauses | 22 | 27% |
| Risk Management | 12 | 15% |
| Reasonable Contract Duration | 9 | 11% |
| Thorough Risk Identification and Allocation | 9 | 11% |
| Financial Arrangements | 9 | 11% |
| Monitoring and Controlling Project Costs | 7 | 9% |
| Financial Transparency | 6 | 7% |
| New Contract Awarding Process | 5 | 6% |
| Handling Disputes | 2 | 2% |
| Use of Public-Private Partnerships | 1 | 1% |

Table 44: Project Management Mitigation Factors

| Project Management Mitigation Factors | Number of Codes | Percentage of Codes |
|---|---:|---:|
| Thorough Project Planning | 25 | 14% |
| Enhanced Project Management | 23 | 13% |
| Improved Information Flows | 19 | 11% |
| Development for Collaborations | 13 | 7% |
| Relationship Development | 13 | 7% |
| Frequent Project Meetings | 12 | 7% |
| Risk and Contingency Planning | 12 | 7% |
| Technology for Project Planning and Scheduling | 12 | 7% |
| Up to Date Technology | 11 | 6% |
| Improved Supervision | 8 | 4% |
| Project Scheduling | 8 | 4% |
| Technology & Computer Aided Estimating | 6 | 3% |
| Appropriate Development of Communication | 4 | 2% |
| Constant Project Tracking | 4 | 2% |
| Early engagement of Key Stakeholders | 4 | 2% |
| Community Involvement | 4 | 2% |
| Mitigate Corruption | 1 | 1% |

Table 45: Technologies for mitigation

| **Technology** | **Number of Codes** | **Percentage of Codes** |
|---|---:|---:|
| BIM | 52 | 37% |
| Cloud Computing & IoT | 35 | 25% |
| RFID | 16 | 11% |
| Augmented Reality | 7 | 5% |
| Blockchain | 7 | 5% |
| Virtual Reality | 7 | 5% |
| Autonomous Robots | 5 | 4% |
| Drones | 4 | 3% |
| Management Information Systems | 4 | 3% |
| Graphical information Systems | 2 | 1% |
| Web Portals | 2 | 1% |

## Appendix E

Figure 13: Nvivo codes for consultant related

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Consultant Related Risks | 64 | 328 | 12/8/2022 11:13 AM | RJ |
| Poor Planning and Scheduling | 47 | 107 | 12/8/2022 11:25 AM | RJ |
| Poor Contract Management | 30 | 52 | 12/8/2022 11:28 AM | RJ |
| Incomplete Documents | 12 | 12 | 12/8/2022 12:59 PM | RJ |
| Poor Communication | 34 | 54 | 12/8/2022 1:07 PM | RJ |
| Delay in Document Submission | 12 | 15 | 12/8/2022 1:44 PM | RJ |
| Inadequeate Consultant Experience | 30 | 48 | 12/8/2022 2:39 PM | RJ |
| Slow Inspection of Works | 25 | 38 | 12/8/2022 3:42 PM | RJ |
| Incorrect Estimate | 39 | 85 | 12/8/2022 4:56 PM | RJ |
| Poor Management | 28 | 46 | 12/11/2022 9:44 AM | RJ |

Figure 14: Nvivo codes for contractor related risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Contractor Related Risks | 66 | 473 | 12/8/2022 11:13 AM | RJ |
| Imporpper Planning | 52 | 115 | 12/8/2022 1:40 PM | RJ |
| Shortage of Skills or Labour | 47 | 92 | 12/8/2022 11:22 AM | RJ |
| Financial Difficulties | 45 | 86 | 12/8/2022 11:21 AM | RJ |
| Poor Site Management | 44 | 83 | 12/8/2022 11:20 AM | RJ |
| Inadequate Contractor Experience | 48 | 81 | 12/8/2022 11:21 AM | RJ |
| Poor Communication | 35 | 53 | 12/8/2022 2:26 PM | RJ |
| Subcontractor Issues | 31 | 51 | 12/8/2022 12:53 PM | RJ |
| Poor Labour Productivity | 31 | 46 | 12/8/2022 11:22 AM | RJ |
| Poor Contract Management | 26 | 45 | 12/8/2022 2:29 PM | RJ |
| Unskilled Labour | 34 | 44 | 12/8/2022 1:12 PM | RJ |
| Poor Project Management | 29 | 41 | 12/11/2022 9:44 AM | RJ |
| Errors leading to Rework | 30 | 40 | 12/8/2022 2:40 PM | RJ |
| Labour Dispute or Strike | 20 | 28 | 12/8/2022 1:07 PM | RJ |
| Quality control | 20 | 27 | 12/10/2022 12:11 PM | RJ |
| Innapropriate construction method | 15 | 20 | 12/10/2022 5:37 PM | RJ |
| Low Motivation | 12 | 19 | 12/10/2022 5:34 PM | RJ |

Figure 15: Nvivo codes for design related risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Design Related Risks | 60 | 287 | 12/8/2022 11:14 AM | RJ |
| Incomplete Designs | 37 | 67 | 12/8/2022 11:20 AM | RJ |
| Delay in Changes | 29 | 55 | 12/8/2022 12:51 PM | RJ |
| Changes in Specification | 9 | 13 | 12/8/2022 12:57 PM | RJ |
| Structural Variations | 18 | 31 | 12/8/2022 1:09 PM | RJ |
| Design Errors | 38 | 61 | 12/8/2022 1:47 PM | RJ |
| Poor Communication | 16 | 20 | 12/8/2022 1:47 PM | RJ |
| Variation Orders | 31 | 82 | 12/11/2022 9:39 AM | RJ |
| Design Changes | 38 | 83 | 12/11/2022 9:41 AM | RJ |

Figure 16: Nvivo codes for equipment related risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Equipment Related Risks | 55 | 137 | 12/8/2022 11:14 AM | RJ |
| Equipment Shortage | 43 | 74 | 12/8/2022 11:22 AM | RJ |
| Equipment Breakdown | 15 | 23 | 12/8/2022 1:04 PM | RJ |
| Poor Equipment Productivity | 13 | 15 | 12/8/2022 2:32 PM | RJ |
| Poor Equipment Operator skills | 4 | 5 | 12/8/2022 2:32 PM | RJ |
| Wrong Equipment | 7 | 8 | 12/8/2022 3:58 PM | RJ |
| Ineffective Procurement | 15 | 27 | 12/8/2022 5:48 PM | RJ |
| Equipment Escalation | 20 | 32 | 12/8/2022 6:19 PM | RJ |
| Theft | 1 | 1 | 12/11/2022 12:44 PM | RJ |

Figure 17: Nvivo codes for material related risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Material Related Risks | 59 | 231 | 12/8/2022 11:13 AM | RJ |
| Material Shortages | 49 | 88 | 12/8/2022 11:11 AM | RJ |
| Delay in material Delivery | 33 | 58 | 12/8/2022 12:52 PM | RJ |
| Ineffective Procurement | 24 | 38 | 12/8/2022 1:11 PM | RJ |
| Change in Material Specification | 12 | 15 | 12/8/2022 2:32 PM | RJ |
| Material Price Escalation | 34 | 76 | 12/8/2022 2:33 PM | RJ |
| Poor Material Handling | 7 | 8 | 12/8/2022 3:45 PM | RJ |
| Incorrect Material Delivered | 3 | 3 | 12/8/2022 3:56 PM | RJ |
| Poor Quality Materials | 23 | 33 | 12/10/2022 5:32 PM | RJ |
| Unreliable Suppliers | 11 | 16 | 12/10/2022 5:59 PM | RJ |
| Theft | 2 | 2 | 12/11/2022 12:44 PM | RJ |

Figure 18: Nvivo codes for external or project specific risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| External or Project Specific Risks | 63 | 356 | 12/8/2022 11:14 AM | RJ |
| Economic Risks | 33 | 57 | 12/8/2022 12:52 PM | RJ |
| Inflation | 36 | 66 | 12/8/2022 12:52 PM | RJ |
| Political Instability | 25 | 34 | 12/8/2022 12:52 PM | RJ |
| Weather Condtions | 43 | 69 | 12/8/2022 12:56 PM | RJ |
| Site Conditions and Location | 39 | 61 | 12/8/2022 12:56 PM | RJ |
| Delay in Approvals | 21 | 26 | 12/8/2022 12:56 PM | RJ |
| Force Majeure | 17 | 22 | 12/8/2022 12:56 PM | RJ |
| Law and Regulation Chnages | 30 | 45 | 12/8/2022 12:59 PM | RJ |
| Unforseen Ground Conditions | 26 | 45 | 12/8/2022 1:01 PM | RJ |
| Political Interfernace | 29 | 37 | 12/8/2022 1:11 PM | RJ |
| Site Accident | 12 | 13 | 12/8/2022 1:12 PM | RJ |
| Corruption | 22 | 40 | 12/8/2022 5:41 PM | RJ |
| Litigation | 5 | 9 | 12/8/2022 8:16 PM | RJ |
| Problem with neighbors | 10 | 12 | 12/10/2022 5:42 PM | RJ |
| Environment Concerns | 22 | 46 | 12/11/2022 12:57 PM | RJ |
| Traffic Management | 3 | 3 | 12/11/2022 12:57 PM | RJ |
| Delay in site preparation | 13 | 16 | 12/8/2022 2:34 PM | RJ |

Figure 19: Nvivo codes for client related risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Owner Related Risks | 66 | 477 | 12/8/2022 11:12 AM | RJ |
| Change Orders and Scope Changes | 52 | 126 | 12/8/2022 11:23 AM | RJ |
| Financial Difficulties | 52 | 107 | 12/8/2022 11:21 AM | RJ |
| Delayed Payment to Contractor | 51 | 101 | 12/8/2022 11:24 AM | RJ |
| Poor Contract Management | 35 | 72 | 12/8/2022 11:09 AM | RJ |
| Slow Decision Making | 35 | 65 | 12/8/2022 12:53 PM | RJ |
| Poor Communication | 36 | 51 | 12/8/2022 3:35 PM | RJ |
| Unrealistic project duration | 29 | 40 | 12/8/2022 2:44 PM | RJ |
| Poor Project Management | 25 | 38 | 12/11/2022 9:44 AM | RJ |
| Claims | 18 | 31 | 12/11/2022 9:34 AM | RJ |
| Lowest Bidder | 20 | 29 | 12/8/2022 2:38 PM | RJ |
| Poor Pre-project feasabiity and planning | 16 | 22 | 12/10/2022 12:03 PM | RJ |
| Lack of Construction Experience | 17 | 22 | 12/10/2022 5:39 PM | RJ |
| Disputes | 16 | 21 | 12/10/2022 12:35 PM | RJ |
| Delay in Approving Documets | 14 | 20 | 12/8/2022 2:38 PM | RJ |
| Owner Interferance | 14 | 17 | 12/8/2022 2:39 PM | RJ |
| Delay in site handover | 10 | 17 | 12/8/2022 3:52 PM | RJ |
| Suspension of Work | 10 | 10 | 12/8/2022 2:37 PM | RJ |
| Lack of Insurance & Contingencies | 6 | 8 | 12/10/2022 11:38 AM | RJ |
| Owner Death | 1 | 1 | 12/21/2022 6:26 AM | RJ |

Figure 20: Nvivo codes for responsible Party

| | | | | | | |
|---|---|---|---|---|---|---|
| Responisble Party | 0 | 0 | 1/17/2022 | RJH | 1/17/2022 2:25 PM | RJH |
| External | 32 | 107 | 1/17/2022 | RJH | 1/4/2023 1:54 PM | RJH |
| Consultant | 45 | 159 | 1/17/2022 | RJH | 1/4/2023 1:54 PM | RJH |
| Owner or Client | 45 | 295 | 1/17/2022 | RJH | 1/4/2023 1:54 PM | RJH |
| Contractor | 47 | 379 | 1/17/2022 | RJH | 1/4/2023 1:54 PM | RJH |

Figure 21: Nvivo codes for impacts of supply chain risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Impact of Supply Chain Risks | 0 | 0 | 12/8/2022 10:56 AM | RJ |
| Scheudule and Project Duration | 31 | 70 | 12/13/2022 8:59 AM | RJ |
| Schedule Delays | 25 | 49 | 12/13/2022 9:07 AM | RJ |
| Project Abondonment | 14 | 22 | 12/10/2022 7:20 PM | RJ |
| Extension of time | 4 | 4 | 12/13/2022 8:59 AM | RJ |
| Project Accelaration | 4 | 4 | 12/15/2022 6:09 AM | RJ |
| Financial Impact | 30 | 60 | 12/13/2022 9:06 AM | RJ |
| Cost Overrun | 27 | 55 | 12/13/2022 8:59 AM | RJ |
| Reduced Profits | 6 | 8 | 12/13/2022 8:59 AM | RJ |
| Bankrupcy | 3 | 3 | 12/14/2022 10:24 AM | RJ |
| Loss of Investment | 1 | 2 | 12/21/2022 6:29 AM | RJ |
| Uneconomical Projects | 1 | 1 | 12/14/2022 10:20 AM | RJ |
| Construction Activities | 25 | 44 | 12/30/2022 5:01 PM | RJ |
| Stress on Contractor | 19 | 30 | 12/14/2022 10:24 AM | RJ |
| Low Quality Work | 7 | 9 | 12/14/2022 10:25 AM | RJ |
| Construction Waste | 3 | 4 | 12/14/2022 10:19 AM | RJ |
| Lost Productivity | 4 | 4 | 12/15/2022 6:09 AM | RJ |
| Contract and Legal | 17 | 35 | 12/30/2022 4:53 PM | RJ |
| Disputes | 15 | 24 | 12/14/2022 6:05 AM | RJ |
| Litigation | 11 | 14 | 12/14/2022 6:05 AM | RJ |
| Arbitration | 9 | 13 | 12/20/2022 6:20 AM | RJ |
| Claims | 6 | 10 | 12/14/2022 10:26 AM | RJ |
| Contract Termination | 2 | 2 | 12/21/2022 6:32 AM | RJ |
| Mediation | 1 | 1 | 12/14/2022 10:24 AM | RJ |
| Social Impact | 11 | 25 | 12/13/2022 9:05 AM | RJ |
| Worsening Relationships | 7 | 13 | 12/14/2022 10:24 AM | RJ |
| Bad Public Relations | 4 | 6 | 12/13/2022 8:59 AM | RJ |
| Negative Perception | 3 | 4 | 12/14/2022 6:06 AM | RJ |
| Loss of Jobs and Income | 3 | 4 | 12/14/2022 6:06 AM | RJ |
| Loss of customer benifit | 2 | 3 | 12/14/2022 10:24 AM | RJ |

Figure 22: Nvivo codes for mitigating the effects of supply chain risks

| Name | Files | References | Created on | Created by |
|---|---|---|---|---|
| Construction Supply Chain Risks | 0 | 0 | 12/8/2022 10:39 AM | RJ |
| Impact of Supply Chain Risks | 0 | 0 | 12/8/2022 10:56 AM | RJ |
| Mitigation Factors | 0 | 0 | 12/8/2022 2:49 PM | RJ |
| Technology | 17 | 84 | 12/15/2022 9:25 AM | RJ |
| BIM | 12 | 52 | 12/15/2022 9:26 AM | RJ |
| Cloud Computing & IoT | 9 | 35 | 12/15/2022 9:26 AM | RJ |
| RFID | 5 | 16 | 12/15/2022 9:27 AM | RJ |
| Augmented Reality | 5 | 7 | 12/15/2022 9:25 AM | RJ |
| Blockchain | 2 | 7 | 12/15/2022 9:26 AM | RJ |
| Virtual Reality | 5 | 7 | 12/15/2022 9:27 AM | RJ |
| Autonomous Robots | 3 | 5 | 12/15/2022 9:26 AM | RJ |
| Management Information Systems | 3 | 4 | 12/15/2022 9:27 AM | RJ |
| Drones | 1 | 4 | 12/15/2022 11:14 AM | RJ |
| Graphical information Systems | 2 | 2 | 12/15/2022 9:26 AM | RJ |
| Web Portals | 2 | 2 | 12/15/2022 9:27 AM | RJ |
| Artificial Intelligence | 0 | 0 | 12/15/2022 9:25 AM | RJ |
| Project Managment | 23 | 81 | 12/15/2022 6:14 AM | RJ |
| Project Planning | 12 | 25 | 12/20/2022 6:04 AM | RJ |
| Enhanced Project Management | 11 | 23 | 12/14/2022 6:07 AM | RJ |
| Improved information flows | 9 | 19 | 12/20/2022 5:52 AM | RJ |
| Relationhship Deveopment | 5 | 13 | 12/20/2022 5:50 AM | RJ |
| Development for Collaborations | 9 | 13 | 12/20/2022 5:55 AM | RJ |
| Risk and Contingency Planning | 7 | 12 | 12/14/2022 6:09 AM | RJ |
| Frequent Project Meetings | 7 | 12 | 12/20/2022 6:06 AM | RJ |
| Up to Date Technology | 5 | 11 | 12/20/2022 6:08 AM | RJ |
| Project Scheudling | 5 | 8 | 12/20/2022 6:28 AM | RJ |
| Improved Supervision | 4 | 8 | 12/20/2022 6:29 AM | RJ |
| Constant Project Tracking | 4 | 4 | 12/14/2022 10:27 AM | RJ |
| Appropriate Delpoyment of communication | 2 | 4 | 12/15/2022 6:18 AM | RJ |
| Early engaement of key stakeholders | 3 | 4 | 12/20/2022 5:51 AM | RJ |
| Contractor | 17 | 53 | 12/15/2022 6:11 AM | RJ |
| Pastt Experience | 11 | 17 | 12/20/2022 6:11 AM | RJ |
| Prequalification of Contractors | 10 | 15 | 12/14/2022 6:09 AM | RJ |
| Poor Communication | 8 | 15 | 12/15/2022 6:18 AM | RJ |
| Experienced Subcontractors and Suppiers | 5 | 7 | 12/20/2022 6:06 AM | RJ |
| Effective Material and Plant management | 4 | 7 | 12/20/2022 6:47 AM | RJ |
| Incentive's for labour | 5 | 7 | 12/20/2022 6:48 AM | RJ |
| Appropriate construction techiques | 3 | 6 | 12/20/2022 6:07 AM | RJ |
| Training for Personal and Labour | 5 | 5 | 12/20/2022 6:55 AM | RJ |
| Improved site supervison and Management | 2 | 2 | 12/20/2022 6:59 AM | RJ |
| Rework | 1 | 1 | 12/15/2022 6:19 AM | RJ |
| Conflicts | 1 | 1 | 12/15/2022 6:19 AM | RJ |
| Ensure timely payment to suppliers and subcont | 1 | 1 | 12/20/2022 6:47 AM | RJ |

| | | | | |
|---|---|---|---|---|
| Contract | 17 | 46 | 12/15/2022 6:12 AM | RJ |
| Contract Managment & Clauses | 10 | 22 | 12/15/2022 6:10 AM | RJ |
| Thourough Risk Identification and Allocation | 6 | 9 | 12/20/2022 5:42 AM | RJ |
| Reasnable Contract Duration | 5 | 9 | 12/20/2022 6:05 AM | RJ |
| New Contract Awarding Process | 3 | 5 | 12/21/2022 11:05 AM | RJ |
| Handling Disputes | 2 | 2 | 12/15/2022 6:13 AM | RJ |
| Use of Public-Private Partnerships | 1 | 1 | 12/14/2022 6:10 AM | RJ |
| Consultant | 13 | 27 | 12/15/2022 6:12 AM | RJ |
| Improved Communication | 8 | 15 | 12/15/2022 6:18 AM | RJ |
| Effectively manage changes | 4 | 5 | 12/20/2022 6:24 AM | RJ |
| Experienced consultant | 2 | 3 | 12/20/2022 3:48 PM | RJ |
| Reference Class Forecasting | 2 | 2 | 12/14/2022 6:08 AM | RJ |
| Owner | 13 | 27 | 12/15/2022 6:12 AM | RJ |
| Imporved Communication | 8 | 15 | 12/15/2022 6:18 AM | RJ |
| Delayed Payments | 5 | 6 | 12/15/2022 6:11 AM | RJ |
| Expedited desicion making | 3 | 5 | 12/15/2022 6:17 AM | RJ |
| Delay in Site Handover | 2 | 2 | 12/15/2022 6:17 AM | RJ |
| Change Orders | 2 | 2 | 12/15/2022 6:17 AM | RJ |
| Reframe from Interfeing | 2 | 2 | 12/20/2022 6:22 AM | RJ |
| Financial Management | 12 | 18 | 12/15/2022 6:14 AM | RJ |
| Financial Arrangements | 6 | 9 | 12/20/2022 6:31 AM | RJ |
| Monitoring and Controlling Project Costs | 7 | 7 | 12/14/2022 10:27 AM | RJ |
| Financial Transparancy | 5 | 6 | 12/20/2022 5:51 AM | RJ |
| Project Design | 2 | 4 | 12/20/2022 6:04 AM | RJ |
| Complete and thorough design | 2 | 4 | 12/20/2022 9:45 AM | RJ |
| External | 2 | 4 | 12/20/2022 9:49 AM | RJ |
| Community Involvement | 2 | 4 | 12/20/2022 9:49 AM | RJ |
| Mitigate Corruption | 1 | 1 | 12/21/2022 10:58 AM | RJ |

Figure 23: Design risks coded in Nvivo example

<Files\\Mitigation\\Causes and mitigation strategies of delay in power construction projects. Gaps between owners and contractors in successful and unsuccessful projects> - § 1 reference coded [0.17% Coverage]

Reference 1 - 0.17% Coverage

Design changes during construction Inappropriate data collection.
Mistakes and delays in design documents. Failure in planning and design risk
Poor resource estimation and allocation

<Files\\Mitigation\\Cost and time control of construction projects inhibiting factors and mitigating measures in practice> - § 3 references coded [0.59% Coverage]

Reference 1 - 0.29% Coverage

Nigeria and found out that the most important variables causing construction delays and cost overruns are poor contract management, financing, and payment of completed works, changes in site conditions, shortage of materials, imported materials and plant items, design changes, subcontractors and nominated suppliers.

Reference 2 - 0.01% Coverage

Design changes

Reference 3 - 0.29% Coverage

Lack of detailed design specification leads to the contractor pricing the risk but also looking for every loophole in the specification document to increase cost, reduce specification, etc.
There is a lack of clear distinction between design change and design development. As a result, project partners often argue whether a design change is a change or a development where there would not be the need for additional cost and time compensation.

<Files\\Supply Chain Risks\\Assessment of cost overrun factors in construction projects in Nigeria using fuzzy logic> - § 5 references coded [1.21% Coverage]

Reference 1 - 0.54% Coverage

Orders for design variations and changes.
During the planning stage, the scope of work is usually not finalized, and it is frequently subject to change depending on the interests of the parties involved. Due to the uniqueness of the project, the limited timeline and the funds set aside during the planning stage, changes in scope and design are likely to occur [24]. Sunjka and Jacob [20] identify design variation and change orders as causing a temporary pause in the project, which can add to the project's delay. According to Memon et al. [25], project cost is primarily affected by inadequate and delayed design.

Reference 2 - 0.03% Coverage

Figure 24: Design risks coded in Nvivo example continued

Design variation from client/consultant

Reference 3 - 0.04% Coverage

Failures in design and inadequate project planning

Reference 4 - 0.09% Coverage

Delay in providing approvals for variations from consultants, Incomplete drawings and details provided by consultants.

<Files\\Mitigation\\Significant causes and effects of project delays in the Niger delta region, Nigeria> - § 2 references coded [0.67% Coverage]

Reference 1 - 0.28% Coverage

Change in specifications and scope which were not considered originally or changes of design to address some omissions that were vital to project functionality. Alterations may require temporary stoppages that delay overall project completion.

Reference 2 - 0.39% Coverage

Improper design stalls project execution because of the time it takes for such design to be reviewed, amended and accepted for construction works. When errors are observed in the design, works are temporary suspended until such errors are removed. This is predominant in organisations where selection processes of vendors are compromised.

<Files\\Supply Chain Risks\\South African construction industry's perception of mitigation measures for addressing avoidable delay factors> - § 3 references coded [0.03% Coverage]

Reference 1 - 0.01% Coverage

Design Changes

Reference 2 - 0.01% Coverage

Poor communication and misunderstandings in design works

Reference 3 - 0.01% Coverage

Poor design by consultants

Reference 4 - 0.01% Coverage

Delays in design work

Reference 3 - 0.01% Coverage

Figure 25: Coding example

*2.2 Causes of cost overrun*

Over the years, the inability of many highway infrastructure projects to be delivered within the contractual budgets has inspired many researchers to enquire about the various factors responsible for the underperformance in different countries. This is because of sensitivity in the culture, practices and institutional structures of various countries (Johnson and Babu, 2018). For instance, Mansfield *et al.* (1994) explored the causes of cost overrun in Nigerian highway projects from the perspective of key industry stakeholders i.e. client, consultant and contractors using a questionnaire survey. The study found that the major causes of cost overrun were attributed to finance and payment for completed works by the client, inaccurate estimates or forecasts, poor contract management and fluctuation in prices of materials as unanimously agreed by the stakeholders. Similarly, Omoregie and Radford (2006) conducted an experimental survey on the causes and effects of delay and cost escalation in infrastructure projects in Nigeria based on the data and findings of the study of Mansfield *et al.* (1994). The study identified the major causes of cost overruns as price fluctuation, financing and payment of completed works, poor contract management, delay and unsuitable ground conditions, inaccurate estimates, design changes, fraudulent practices and kickbacks and shortage of materials. Amadi and Higham (2017), who found with a high level of significance, the impact of inadequate geotechnical investigation has on the cost performance of highway projects, revealed that adverse ground conditions are the primary triggers of high cost overrun experienced in highway projects in the Niger Delta region of Nigeria. Leo-Olagbaye and Odeyinka (2018) conducted a study on the risk factors that impact the financial performance of highway projects in Osun state, Nigeria. Using a sample size of 115 experienced professionals involved in about 34 highway projects, the study found changes in scope, defective design, changes in the initial design, delay in the availability of design information and adverse weather conditions to be the most significant risk factors. Anigbogu *et al.* (2019) examined the causes of cost overrun using questionnaire responses complemented by analysis of project documents and interviews to affirm the significance of the factors from key stakeholders involved in highway infrastructure development in the Federal Capital Territory, Nigeria. Analysis of the questionnaire survey data, project documents and interviews showed that inflation, fluctuation of prices, exchange rate, government-related issues like changes in policies, variation, delays in payment to contractors, design changes, corruption and unforeseen ground conditions were the key contributory causes.

Kaliba *et al.* (2009) investigated the major causes and effects of cost escalation and schedule delays in road construction projects in Zambia between 2006 and 2007. The findings of the study revealed that reasons for cost overrun are unfavourable weather, change in scope of projects, environmental issues, schedule delays, civil unrest, pressure from the government at the local level, technical difficulties and inflation.

# Appendix F

Table 46: Number of articles retrieved at the end of each elimination stage, per key phrase and database.

| Database | Searching string and searching terms | No of Articles | Date | Type of Article | Relevance to Industry |
|---|---|---|---|---|---|
| **Taylor & Francis** | "Construction Supply Chain " and "risk" | 48,383 | | | |
| | "Construction Supply Chain " and "risk" and "Egypt OR Nigeria OR South Africa" | 790 | 460 | 446 | 26 |
| | "Construction" and "delay" | 195,575 | | | |
| | "Construction" and "delay" and "Egypt OR Nigeria OR South Africa" | 2,420 | 1,381 | 1,322 | 57 |
| | "Construction" and "Cost overrun" | 6,544 | | | |
| | "Construction" and "Cost overrun" and "Egypt OR Nigeria OR South Africa" | 121 | 67 | 66 | 9 |
| | "Construction Delay" and "effect" | 174,722 | | | |
| | "Construction Delay" and "effect" and "Egypt OR Nigeria OR South Africa" | 2,229 | 1,250 | 1,196 | 53 |
| | "Construction risk" and "Impact" | 356,024 | | | |
| | "Construction risk" and "Impact" and "Egypt OR Nigeria OR South Africa" | 5,894 | 3,927 | 3,755 | 135 |
| | "Construction risk" and "Mitigation" | 80,108 | | | |
| | "Construction risk" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 15,819 | 11,217 | 9,920 | 891 |
| | "Construction delay" and "Mitigation" | 25,570 | | | |
| | "Construction delay" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 5,243 | 3,241 | 2,730 | 295 |
| | "Construction supply chain " and "Management" | 67,166 | | | |
| | "Construction supply chain " and "Management" and "Egypt OR Nigeria OR South Africa" | 1,119 | 653 | 633 | 36 |
| | "Construction" and "Technology" | 722,096 | | | |
| | "Construction" and "Technology" and "Egypt OR Nigeria OR South Africa" | 7,082 | 4,539 | 4,350 | 180 |
| **Science Direct** | "Construction Supply Chain " and "risks" | 63,451 | | | |
| | "Construction Supply Chain " and "risks" and "Egypt OR Nigeria OR South Africa" | 610 | 525 | 384 | 35 |
| | "Construction" and "delay" | 277,496 | | | |
| | "Construction" and "delay" and "Egypt OR Nigeria OR South Africa" | 1,377 | 908 | 735 | 132 |
| | "Construction" and "Cost overrun" | 5,998 | | | |
| | "Construction" and "Cost overrun" and "Egypt OR Nigeria OR South Africa" | 102 | 73 | 65 | 37 |
| | "Construction Delay" and "effect" | 210,230 | | | |
| | "Construction Delay" and "effect" and "Egypt OR Nigeria OR South Africa" | 973 | 657 | 523 | 106 |

| | | | | | |
|---|---|---|---|---|---|
| | "Construction risk" and "Impact" | 299,703 | | | |
| | "Construction risk" and "Impact" and "Egypt OR Nigeria OR South Africa" | 2,966 | 2,346 | 1,938 | 226 |
| | "Construction risk" and "Mitigation" | 104,459 | | | |
| | "Construction risk" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 1,200 | 1,072 | 869 | 116 |
| | "Construction delay" and "Mitigation" | 44,392 | | | |
| | "Construction delay" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 366 | 302 | 232 | 51 |
| | "Construction supply chain " and "Management" | 72,675 | | | |
| | "Construction supply chain " and "Management" and "Egypt OR Nigeria OR South Africa" | 687 | 567 | 434 | 48 |
| | "Construction" and "Technology" | 933,690 | | | |
| | "Construction" and "Technology" and "Egypt OR Nigeria OR South Africa" | 4,500 | 3,217 | 2,629 | 481 |
| **Emerald Insights** | "Construction Supply Chain " and "risks" | 16,005 | | | |
| | "Construction Supply Chain " and "risks" and "Egypt OR Nigeria OR South Africa" | 316 | 297 | 200 | 14 |
| | "Construction" and "delay" | 19,067 | | | |
| | "Construction" and "delay" and "Egypt OR Nigeria OR South Africa" | 462 | 416 | 283 | 19 |
| | "Construction" and "Cost overrun" | 1,814 | | | |
| | "Construction" and "Cost overrun" and "Egypt OR Nigeria OR South Africa" | 646 | 588 | 418 | 29 |
| | "Construction Delay" and "effect" | 1,587 | | | |
| | "Construction Delay" and "effect" and "Egypt OR Nigeria OR South Africa" | 369 | 333 | 249 | 17 |
| | "Construction risk" and "Impact" | 52,342 | | | |
| | "Construction risk" and "Impact" and "Egypt OR Nigeria OR South Africa" | 1,124 | 1,013 | 710 | 48 |
| | "Construction risk" and "Mitigation" | 5,567 | | | |
| | "Construction risk" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 709 | 677 | 467 | 32 |
| | "Construction delay" and "Mitigation" | 2,054 | | | |
| | "Construction delay" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 70 | 66 | 49 | 3 |
| | "Construction supply chain " and "Management" | 20,566 | | | |
| | "Construction supply chain " and "Management" and "Egypt OR Nigeria OR South Africa" | 395 | 360 | 256 | 17 |
| | "Construction" and "Technology" | 76,632 | | | |
| | "Construction" and "Technology" and "Egypt OR Nigeria OR South Africa" | 1,359 | 1,186 | 890 | 61 |
| **ProQuest** | "Construction Supply Chain " and "risks" | 1,244,481 | | | |
| | "Construction Supply Chain " and "risks" and "Egypt OR Nigeria OR South Africa" | 16,288 | 14,331 | 1,106 | 86 |
| | "Construction" and "delay" | 2,540,350 | | | |
| | "Construction" and "delay" and "Egypt OR Nigeria OR South Africa" | 17,755 | 14,865 | 1,617 | 154 |
| | "Construction" and "Cost overrun" | 215,396 | | | |
| | "Construction" and "Cost overrun" and "Egypt OR Nigeria OR South Africa" | 2,055 | 1,702 | 268 | 126 |

| | | | | | |
|---|---|---|---|---|---|
| | "Construction Delay" and "effect" | 1,316,609 | | | |
| | "Construction Delay" and "effect" and "Egypt OR Nigeria OR South Africa" | 14,682 | 12,082 | 1,369 | 131 |
| | "Construction risk" and "Impact" | 3,309,991 | | | |
| | "Construction risk" and "Impact" and "Egypt OR Nigeria OR South Africa" | 33,631 | 29,217 | 5,988 | 172 |
| | "Construction risk" and "Mitigation" | 369,254 | | | |
| | "Construction risk" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 4,792 | 4,504 | 974 | 41 |
| | "Construction delay" and "Mitigation" | 174,714 | | | |
| | "Construction delay" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 2,265 | 2,108 | 211 | 23 |
| | "Construction supply chain " and "Management" | 1,445,378 | | | |
| | "Construction supply chain " and "Management" and "Egypt OR Nigeria OR South Africa" | 20,410 | 18,515 | 1,359 | 119 |
| | "Construction" and "Technology" | 8,298,978 | | | |
| | "Construction" and "Technology" and "Egypt OR Nigeria OR South Africa" | 64,397 | 58,682 | 7,758 | 332 |
| **ASCE Library** | "Construction Supply Chain " and "risks" | 3,008 | | | |
| | "Construction Supply Chain " and "risks" and "Egypt OR Nigeria OR South Africa" | 215 | 148 | 72 | 30 |
| | "Construction" and "delay" | 22,051 | | | |
| | "Construction" and "delay" and "Egypt OR Nigeria OR South Africa" | 753 | 381 | 189 | 36 |
| | "Construction" and "Cost overrun" | 2,802 | | | |
| | "Construction" and "Cost overrun" and "Egypt OR Nigeria OR South Africa" | 165 | 126 | 67 | 22 |
| | "Construction Delay" and "effect" | 19,502 | | | |
| | "Construction Delay" and "effect" and "Egypt OR Nigeria OR South Africa" | 697 | 355 | 185 | 42 |
| | "Construction risk" and "Impact" | 24,447 | | | |
| | "Construction risk" and "Impact" and "Egypt OR Nigeria OR South Africa" | 919 | 642 | 314 | 69 |
| | "Construction risk" and "Mitigation" | 11,255 | | | |
| | "Construction risk" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 480 | 367 | 179 | 44 |
| | "Construction delay" and "Mitigation" | 5,135 | | | |
| | "Construction delay" and "Mitigation" and "Egypt OR Nigeria OR South Africa" | 224 | 167 | 78 | 22 |
| | "Construction supply chain " and "Management" | 5,190 | | | |
| | "Construction supply chain " and "Management" and "Egypt OR Nigeria OR South Africa" | 291 | 175 | 84 | 20 |
| | "Construction" and "Technology" | 63,373 | | | |
| | "Construction" and "Technology" and "Egypt OR Nigeria OR South Africa" | 1,844 | 1,102 | 493 | 82 |

Table 47: Database of articles selected for the final analysis

| Title | Authors | Journal | Year | Database | Country |
|---|---|---|---|---|---|
| A blockchain- and IoT-based smart product-service system for the sustainability of prefabricated housing construction | Clyde Zhengdao Li, Zhe Chen, Fan Xue , Xiang T.R. Kong, Bing Xiao, Xulu Lai, Yiyu Zhao | Journal of Cleaner Production | 2020 | Science Direct | South Africa |
| A critical review of the causes of cost overrun in construction industries in developing countries | Shambalid Ahady, Sakshi Gupta, R.K.Malik | International Research Journal of Engineering and Technology | 2017 | ProQuest | Egypt |
| Abandonment of Construction Projects in Nigeria: Causes and Effects | Ayodele Elijah Olusegun, Alabi Olumuyiwa Michael | Journal of Emerging Trends in Economics and Management Sciences | 2011 | ProQuest | Nigeria |
| An Appraisal of Critical Risk Factors in Construction Projects in South Africa: Perspective of Contractors | Berenger Renault, Justus Agumba, Nazeem Ansary | Renewable Energy and Sustainable Development | 2016 | ProQuest | South Africa |
| An assessment of the causes of schedule and cost overruns in South African megaprojects: A case of the critical energy sector projects of Medupi and Kusile | Fhumulani Tshidavhu, Nthatisi Khatleli | Acta Structilia | 2020 | ProQuest | South Africa |
| An investigation into cost overruns for ongoing building projects in Abuja, Nigeria | Ibrahim Saidu, Winston Shakantu | Acta Structilia | 2017 | ProQuest | Nigeria |
| An investigation of the relationship between project performance measures and project management practices of construction projects for the construction industry in Nigeria | H.C.O. Unegbu, D.S. Yawas, B. Dan-asabe | Journal of King Saud University – Engineering Sciences | 2020 | Science Direct | Nigeria |
| Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study | Tsegay Gebrehiweta, Hanbin Luob | Creative Construction | 2017 | Science Direct | Nigeria |
| Analysis of Non-Excusable Delay Factors Influencing Contractors' Performance in Lagos State, Nigeria | Olajide Timothy Ibironke, Timo Olugbenga Oladinrin, Onaopepo Adeniyi, Idowu Victor Eboreime | Journal of Construction in Developing Countries | 2013 | ProQuest | Nigeria |
| Analyzing delay causes in Egyptian construction projects | Mohamed M. Marzouk, Tarek I. El-Rasas | Journal of Advanced Research | 2013 | Science Direct | Egypt |
| Analyzing The Project Delay Causes In The South African Construction Industry | Anthony Obododike Ekwuno, Dr. H. Nel | nternational Journal of Engineering Applied Sciences and Technology | 2022 | ProQuest | South Africa |
| Assessment of challenges and risk factors influencing the operation of emerging contractors in the Gauteng Province, South Africa | Linda Bikitsha & Christopher Amoah | International Journal of Construction Management | 2022 | Taylor and Francis | South Africa |
| Assessment of Cloud Computing Success Factors for Sustainable Construction Industry: The Case of Nigeria | Ayodeji Emmanuel Oke, Ahmed Farouk Kineber, Ibraheem Albukhari, Idris Othman, Chukwuma Kingsley | Sustainability | 2021 | Science Direct | Nigeria |
| Assessment of Contractors' Mitigating Measures for Cost Overrun of Building Projects in South-Western Nigeria | Jacob A. B. Awolesi, Jonathan K. Fabi, Olubola A. Akinseinde | Journal of Sustainable Development | 2015 | ProQuest | Nigeria |
| Assessment of the mitigating measures for cost overruns in the South African construction industry | M Morena, C Amoah | Earth and Environmental Science | 2021 | ProQuest | South Africa |
| Assessment of cost overrun factors in construction projects in Nigeria using fuzzy logic | Jude Iloabuchi Obianyo, Okey Enangha Okey, George Uwadiegwu Alaneme | Journal of Engineering, Design and Technology | 2022 | Science Direct | Nigeria |
| Blockchain applied to the construction supply chain: A case study with threat model | Gjorgji Shemov, Borja Garcia de Soto, Hoda Alkhzaimi | Fronteiers of engineeering Management | 2020 | Science Direct | South Africa |

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|---|---|---|---|---|---|
| Building Information Modelling As A Construction Management Tool In Nigeria | Ihuoma Onyinyechi Onungwa, Nnezi Uduma-Olugu, Joseph M. Igwe | Transactions on the Built Environment | 2017 | ProQuest | Nigeria |
| Causes and Effects of Construction Project Delays in Nigerian Construction Industry | Obodoh D. AP, Chikasi Obodoh | International Journal of Innovative Science, Engineering & Technology | 2016 | ProQuest | Nigeria |
| Causes and Effects of Cost Overruns in Public Sector Construction Projects in South Africa | Lisebo Jerminah Khabisi | Acta Structilia | 2013 | ProQuest | South Africa |
| Causes and Effects of Delay on African Construction Projects: A State of the Art Review | Abebe Demisew Gashahun | Civil and Environmental Research | 2020 | ProQuest | Egypt |
| Causes And Effects Of Delays In Construction Projects In Akure, Ondo State, Nigeria | Alade, K.T, A. F. Lawal, A. A. Omonori, E. N. Olowokere | Journal of Management and Technology | 2016 | ProQuest | Nigeria |
| Causes and Mitigation Strategies of Delay in Power Construction Projects: Gaps between Owners and Contractors in Successful and Unsuccessful Projects | Edwin Thomas Banobi, Wooyong Jung | Sustainability | 2019 | ProQuest | Egypt |
| Causes of construction cost and time overruns: The 2010 FIFA World Cup stadia in South Africa | Lucius Baloyi & Michiel Bekker | Acta Structilia | 2011 | ProQuest | South Africa |
| Causes of Construction Delays in Countries with High Geopolitical Risks | Mohamed Kadry, Hesham Osman, Maged Georgy | American Society of Civil Engineers | 2017 | ASCE Library | Egypt |
| Causes Of Delay In Nigeria Construction Industry | Kasimu Alhaji Mohammed, Abubakar Danladi Isah | Interdisciplinary Journal Of Contemporary Research In Business | 2012 | ProQuest | Nigeria |
| Construction 4.0: The Future of the Construction Industry in South Africa | Temidayo. O. Osunsanmi, Clinton Aigbavboa, Ayodeji Oke | International Journal of Civil and Environmental Engineering | 2018 | ASCE Library | South Africa |
| Construction Delays in Developing Countries: A Review | Muhammad Saiful Islam, Bambang Trigunarsyah | KICEM Journal of Construction Engineering and Project Management | 2017 | ASCE Library | Egypt |
| Construction Projects Cost Overrun: What Does the Literature Tell Us? | Abdulelah Aljohani, Dominic Ahiaga-Dagbui, David Moore | International Journal of Innovation, Management and Technology | 2017 | ProQuest | Nigeria |
| Construction projects delay mitigation using integrated balanced scorecard and quality function deployment | Murat Gunduz, Nasser H. Al-Naimi | Engineering, Construction and Architectural Management | 2021 | Emerald Insight | South Africa |
| Cost and time control of construction projects: inhibiting factors and mitigating measures in practice | Yakubu Adisa Olawale & Ming Sun | Construction Management and Economics | 2010 | Taylor and Francis | Egypt |
| Cost Overrun Causative Factors in Road Infrastructure Projects: A Frequency and Importance Analysis | Rodrigo F. Herrera, Omar Sánchez, Karen Castañeda, Hernán Porras | Applied Science | 2020 | ProQuest | Nigeria |
| Critical barriers to augmented reality technology adoption in developing countries: a case study of Nigeria | Ayodeji Emmanuel Oke, Victor Adetunji Arowoiya | Journal of Engineering, Design and Technology | 2022 | Emerald Insight | Nigeria |
| Critical solutions to the lapses of supply chain management in Nigeria's construction industry | Chigozie Collins Okafor, Ugochukwu Sydney Ani, Onuegbu Ugwu | International Journal of Building Pathology and Adaptation | 2022 | Emerald Insight | Nigeria |
| Delay Causes and Types in Nigerian Power Construction Projects | Usman Ismaila, Wooyong Jung, Chan Young Park | Energies | 2022 | ProQuest | Nigeria |
| Delay in Construction its Causes and Mitigation: A review | Akshay M. Tayade, Parag S. Mahatme | International Research Journal of Engineering and Technology | 2020 | ProQuest | Egypt |
| Delays and Cost Overruns Causes During Construction of Palm Oil Refinery Projects | Muhammad Sani Abdullah, Wesam S Alaloul , Mohd Shahir Liew, Bashar S Mohammed | MATEC | 2018 | ProQuest | South Africa |
| Delays in construction projects - Causes and impacts | Amílcar Arantes, Pedro Fernandez da Silv, Luís Miguel D. F. Ferreira | IESM | 2015 | ASCE Library | Nigeria |

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|---|---|---|---|---|---|
| Effects of construction projects schedule overruns: A case of the Gauteng Province, South Africa | Mulenga Mukuka, Clinton Aigbavboa, Wellington Thwala | Procedia Manufacturing | 2015 | Science Direct | South Africa |
| Effects Of Infrastructure Project Cost Overruns And Schedule Delays In Sub-Saharan Africa | Paul Terna Gbahabo & Oluseye Samuel Ajuwon | ICSS | 2017 | ProQuest | South Africa |
| Efficient Risk Management: Cause And Effect Analysis Of Key Risks Of Complex Construction Projects In Egypt | Khodeir, Laila Mohamed | Khodeir, Laila Mohamed | 2017 | ASCE Library | Egypt |
| Estimation of the Overall risk in Residential Building in Egypt | Mohamed Fergany, Omar El-Nawawy, Mohamed Badawy | International Journal of Scientific & Engineering Research | 2020 | ASCE Library | Egypt |
| Evaluation of the Effects and Risks of Cost Estimation on Project Costs and Claims: A Study in Imo State, Nigeria | Tobechi B. Ejekwu, Chioma P. Ekweani, Ezinne J. Oha | International Journal of Environement, Engineering and Education | 2022 | ProQuest | Nigeria |
| Evaluation of the impact of risk management on project performance in small construction firms in South Africa: the case study of construction systems | Christopher Amoah, Prof Leon Pretorius | Journal of Engineering, Design and Technology | 2019 | Emerald Insight | South Africa |
| Examining the role of value management in controlling cost overrun [application on residential construction projects in Egypt] | Laila M. Khodeir, Alaa El Ghandour | Ain Shams Engineering Journal | 2019 | Science Direct | Egypt |
| Exploring delay causes of road construction projects in Egypt | Remon F. Aziz, Asmaa A. Abdel-Hakam | Alexandria Engineering Journal | 2016 | Science Direct | Egypt |
| Exploring the benefits of cloud computing for sustainable construction in Nigeria | Ayodeji Emmanuel Oke, Ahmed Farouk Kineber, Ibraheem Albukhari, Idris Othman, Chukwuma Kingsley | Journal of Engineering, Design and Technology | 2021 | Emerald Insight | Nigeria |
| Exploring the critical frequent factors of rework and assigning strategies to mitigate their occurrence in the Egyptian construction projects | Ahmed Yousry Akal, Amr Metwally El-Kholy | ournal of King Saud University – Engineering Sciences | 2021 | Science Direct | Egypt |
| Extraction of underlying factors causing construction projects delay in Nigeria | Christian Nnaemeka Egwim and Hafiz Alaka, Luqman Olalekan Toriola-Coker, Habeeb Balogun, Saheed Ajayi, Raphael Oseghale | Journal of Engineering, Design and Technology | 2021 | Emerald Insight | Nigeria |
| Factors affecting construction productivity: a 30 year systematic review | Abid Hasan, Bassam Baroudi, Abbas Elmualim and Raufdeen Rameezdeen | Engineering, Construction and Architectural Management | 2018 | Emerald Insight | South Africa |
| Factors Causing Cost Overrun In Administrative Construction Projects Of Egypt | E. F. Rashed, E. N. Shaqour | Journal Of Engineering And Applied Science | 2014 | ProQuest | Egypt |
| Factors causing cost variation for constructing wastewater projects in Egypt | Remon Fayek Aziz | Alexandria Engineering Journal | 2013 | Science Direct | Egypt |
| Identification and assessment of risk factors affecting construction projects | Mohamed Sayed Bassiony Ahmed Abd El-Karim , Omar Aly Mosa El Nawawy ,Ahmed Mohamed Abdel-Alim | Housing and Building National Research Center | 2015 | Science Direct | Egypt |
| Identifying and Mitigating delay factors in Engineering, Procurement and Construction Phases: With special reference to Solar Projects | Sachin Mittal, Dr. Naaz Gorowara | Journal of Archaeology of Egypt | 2020 | Taylor and Francis | Egypt |
| Identifying the Risk Impact on Cost and Time of the Egyptian Non-Residential Buildings Projects | Medhat M. A. Osman, Usama H. Issa, Ayman M. Zakaria Eraq | International Journal of Scientific Research in Science, Engineering and Technology | 2020 | ProQuest | Egypt |
| Impact of variation on project delivery in Oyo state, Nigeria | Abdulmalik Mayowa Bello, Abdullahi Babatunde Saka | World Scientific News | 2017 | ProQuest | Nigeria |
| Implementation of Construction 4.0 in Nigeria: Evaluating the Opportunities and Threats on the Workforce | Omoseni Oyindamola Adepoju, Clinton Ohis Aigbavboa | Academic Journal of Interdisciplinary Studies | 2020 | Taylor and Francis | Nigeria |

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|---|---|---|---|---|---|
| Industry 4.0 Concepts and Lean Methods Mitigating Traditional Losses in Engineer-to-Order Manufacturing with Subsequent Assembly On-Site: A Framework | Felix Schulzea, Patrick Dallasega | Procedia Manufacturing | 2020 | Science Direct | South Africa |
| Industry 4.0 Fostering Construction Supply Chain Management: Lessons Learned From Engineer-to-Order Suppliers | Patrick Dallasega | IEEE ENGINEERING MANAGEMENT REVIEW | 2018 | ASCE Library | Egypt |
| Investigation of Project Delay in Construction Projects in the South African Rail Industry | Itumeleng Gladwell Motlhatlhedi, Hannelie Nel | Industrial Engineering and Operations Management | 2019 | ProQuest | South Africa |
| Key driving factors of cost overrun in highway infrastructure projects in Nigeria: a contextbased perspect | Abba Tahir Mahmud, Stephen O. Ogunlana, W.T. Hong | Journal of Engineering, Design and Technology | 2020 | Emerald Insight | Nigeria |
| Key factors affecting the decision-making process for buildings projects in Egypt | Shanshan Zhong ,Hosam Elhegazy, Hazem Elzarka | Ain Shams Engineering Journal | 2022 | Science Direct | Egypt |
| Most Critical Factors Responsible For Cost Overruns In Nigeria Building Construction Industry | Oluyemi-Ayibiowu, B. D, Aiyewalehinmi, O. E, Omolayo,O.J | Journal of Multidisciplinary Engineering Science Studies | 2019 | ProQuest | Nigeria |
| Optimising building performance through integrating risk management and building information modelling during the design process | Ayman Ahmed Ezzat Othman, Fatma Othman Alamoudy | Journal of Engineering, Design and Technology | 2021 | Emerald Insight | Egypt |
| Perceived claim sources in the Nigerian construction industry | AbdulLateef A. Olanrewaju, Paul J. Anavhe | Built Environment Project and Asset Managemen | 2014 | Emerald Insight | Nigeria |
| Prioritizing Delay Mitigation Strategies for Road Projects in Nigeria | Frederick Nosakhare Ogbeide, Jacob Odeh Ehiorobo | American Journal of Sciences and Engineering Research | 2022 | Taylor and Francis | Nigeria |
| Project Cost Overrun in the South African Construction Sector: A case study of Johannesburg Metropolis | Ramaloko Mulalo, Kidoge Ibrahimu, Eveth Nwobodo-Anyadiegwu | Industrial Engineering and Operations Management | 2018 | ProQuest | South Africa |
| Project-specific constraints influencing productivity of tradespeople in the Nigerian construction industry | Rex Asibuodu Ugulu, Andrew Arewa, Stephen Allen | Built Environment Project and Asset Management | 2020 | Emerald Insight | Nigeria |
| Revisiting Causative Factors of Project Cost Overrun in Building Construction Projects in Nigeria | O Akinradewo, C Aigbavboa, O Akinradewo | Sustainable Infrastructural Development | 2019 | ProQuest | Nigeria |
| Risk Analysis for Construction Contractors in Egypt and Yemen | Ibrahim Abdul Rashid, Abdel Moneim Sanad, Mohammed Alhazmi | Journal of Engineering and Computer Sciences | 2015 | ProQuest | Egypt |
| Risk identification framework in construction of Egyptian mega housing projects | Mohamed Nabawy, George O, Maged Morcos, Charles Egbu | Ain Shams Engineering Journal | 2020 | Science Direct | Egypt |
| Risks assessment using structural equation modeling: mega housing projects construction in Egypt | Ahmed Gouda Mohamed, Mohamed Helmy Ammar, Mohamed Nabawy | International Journal of Construction Management | 2022 | Taylor and Francis | Egypt |
| Risks Leading to Cost Overrun in Building Construction from Consultants' Perspective | Ibrahim Mahamid, Nabil Dmaidi | Organization, technology & management in construction: an international journal | 2013 | ProQuest | Nigeria |
| Significant Causes And Effects Of Project Delays In The Niger Delta Region, Nigeria | B.P. Sunjka, U. Jacob | SAIIE25 Proceedings | 2013 | ProQuest | Nigeria |
| Significant Factors Causing Time and Cost Overruns in Construction Projects in the Gaza Strip: Contractors' Perspective | Adnan Enshassi, Mohan Kumaraswamy, Jomah Al-Najjar | International Journal of Construction Management | 2014 | Taylor and Francis | Egypt |
| South African construction industry's perception of mitigation measures for addressing avoidable delay factors | Emmanuel Funanani Matodzi | Acta Structilia | 2015 | ProQuest | South Africa |
| Study on the factors of delay in construction works | Andre Brasil Carvalho, Luiz Mauricio Furtado Maues, Felipe de Sa Moreria, Caio Jose Losada Reis | Techbology and Construction | 2021 | ProQuest | South Africa |

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|---|---|---|---|---|---|
| Supply Chain Management Practices in Construction Procurement: Perceptions of Professional Quantity Surveyors in Ondo State, Nigeria | Aje Olaniyi, Aderibole Bosede, Ogunsina Olusola | PM World Journal | 2015 | ProQuest | Nigeria |
| Systematic processing framework for analyzing the factors of construction projects' delays in Egypt | Hayssam O. Elhusseiny, Ibrahim Nosair, A. Samer Ezeldin | Ain Shams Engineering Journal | 2021 | Science Direct | Egypt |
| The impact of cost overruns and delays in the construction business | M Dlamini, R Cumberlege | Earth and Environmental Science | 2021 | ProQuest | South Africa |
| The Investigation of the Role of RFID in Mitigating Delay Factors in Construction Projects | Luqman Ibrahim Azeez, Mehrshad Radmehr | Technicki vjesnik | 2022 | ProQuest | Technology |
| The Moderating Effect of Project Risk Mitigation Strategies on the Relationship Between Delay Factors and Construction Project Performance | Suhaiza Zailani Hazrina Aziz Md, Ariffin Mohammad Iranmanesh, Soroush Moeinzahed, Masoomeh Iranmanesh | Journal of Science and Technology Policy Management | 2016 | Emerald Insight | Nigeria |
| The role of implementing BIM applications in enhancing project management knowledge areas in Egypt | E.N. Shaqour | Ain Shams Engineering Journal | 2021 | Science Direct | Egypt |
| The top 10 universal delay factors in construction projects | Youcef J.-T. Zidane, Bjorn Andersen | International Journal of Managing Projects in Business | 2018 | Emerald Insight | South Africa |
| Time and Cost Overruns on Large Projects: Understanding the Root Cause | Sitwala Simushi, Jan Wium | Journal of Construction in Developing Countries | 2020 | ProQuest | South Africa |
| Time-Overrun Factors In Nigerian Construction Industry | Augustine Uche Elinwa, Mangvwat Joshua | Journal of Construction Engineering and Management | 2010 | ASCE Library | Nigeria |
| Underlying causes and mitigation measures of delays in construction projects An empirical study | Amílcar Arantes, Luís Miguel D.F. Ferreira | Journal of Financial Management of Property and Construction | 2020 | Emerald Insight | Egypt |
| Understanding Construction Projects' Schedule Overruns in South Africa | Mulenga Mukuka, Clinton Aigbavboa, Wellington Thwala | Journal of Construction Engineering and Management | 2015 | ASCE Library | South Africa |
| Using BIM as a lean management tool in construction processes – A case study | Ahmed.M. Eldeep, Moataz.A.M. Farag, L.M. Abd El-hafez | Ain Shams Engineering Journal | 2022 | Emerald Insight | Egypt |

## Appendix G

Table 48: Risk assessment for the identified construction supply chain risks

| Risk Group | Risk Description | Severity | Severity Score | Likelihood | Likelihood Rank |
|---|---|---|---|---|---|
| Client | Delayed Payments | Very High | 5 | Very Likely | 5 |
| Client | Financial Difficulties | Very High | 5 | Very Likely | 5 |
| Client | Change Orders and Scope Changes | Major | 4 | Very Likely | 5 |
| Client | Awarding The Project to the Lowest Bidder | Very High | 5 | Likely | 4 |
| Client | Unrealistic Project Duration | Major | 4 | Likely | 4 |
| Client | Poor Pre-project Feasibility and Planning | Very High | 5 | Possible | 3 |
| Client | Lack of Construction Experience | Moderate | 3 | Likely | 4 |
| Client | Poor Project Management | Moderate | 3 | Likely | 4 |
| Client | Slow Decision Making | Moderate | 3 | Likely | 4 |
| Client | Poor Communication | Major | 4 | Possible | 3 |
| Client | Poor Contract Management | Major | 4 | Possible | 3 |
| Client | Claims | Moderate | 3 | Possible | 3 |
| Client | Delay in Approving Documents | Moderate | 3 | Possible | 3 |
| Client | Disputes | Moderate | 3 | Possible | 3 |
| Client | Lack of Insurance & Contingencies | Moderate | 3 | Possible | 3 |
| Client | Owner Interference | Moderate | 3 | Possible | 3 |
| Client | Suspension of Work | Major | 4 | Unlikely | 2 |
| Client | Delay in Site Handover | Minor | 2 | Possible | 3 |
| Client | Owner Death | Very High | 5 | Rare | 1 |
| Consultant | Incorrect Estimate | Major | 4 | Likely | 4 |
| Consultant | Poor Planning and Scheduling | Major | 4 | Likely | 4 |
| Consultant | Slow Inspection of Works | Major | 4 | Likely | 4 |
| Consultant | Inadequate Consultant Experience | Major | 4 | Possible | 3 |
| Consultant | Poor Communication & Coordination | Major | 4 | Possible | 3 |
| Consultant | Poor Contract Management | Major | 4 | Possible | 3 |
| Consultant | Poor Management | Major | 4 | Possible | 3 |
| Consultant | Delay In Document Preparation & Submission | Moderate | 3 | Possible | 3 |
| Consultant | Incomplete Documents | Moderate | 3 | Unlikely | 2 |

| Risk Types | Description |
|---|---|
| Consultant | Risks caused by the Consultant |
| Contractor | Risks caused by the Contractor |
| Design | Risks caused by the Designers |
| External/PS | Risks caused by External or PS elements |
| Material | Risks caused by the materials |
| Equipment | Risks caused by the equipment |
| Client | Risks caused by the Client |

| Severity | Description |
|---|---|
| Very Low | No Impact on Project |
| Minor | Minimal Impact Project |
| Moderate | Some Impact on Project |
| Major | Significate Impact on Project |
| Very High | Excessive Impact on Project |

| Likelihood | Description |
|---|---|
| Rare | Risks that almost never occur |
| Unlikely | Risks that don't occur often |
| Possible | Risks that may occur from project to project |
| Likely | Risks that may occur often |
| Very Likely | Risks highly likely to occur |

| | | | | | |
|---|---|---|---|---|---|
| Contractor | Inadequate Contractor Experience | Very High | 5 | Very Likely | 5 |
| Contractor | Poor Site Management | Very High | 5 | Very Likely | 5 |
| Contractor | Financial & Cash-flow Difficulties | Major | 4 | Very Likely | 5 |
| Contractor | Improper Planning & Coordination | Major | 4 | Very Likely | 5 |
| Contractor | Shortage of Skills or Labour | Major | 4 | Very Likely | 5 |
| Contractor | Poor Communication | Major | 4 | Likely | 4 |
| Contractor | Poor Contract Management | Major | 4 | Likely | 4 |
| Contractor | Poor Project Management | Very High | 5 | Possible | 3 |
| Contractor | Poor Labour Productivity | Moderate | 3 | Likely | 4 |
| Contractor | Subcontractor Issues | Moderate | 3 | Likely | 4 |
| Contractor | Errors/Mistakes Leading to Rework | Moderate | 3 | Possible | 3 |
| Contractor | Unskilled Management Team & Labour | Moderate | 3 | Possible | 3 |
| Contractor | Inappropriate Construction Methods | Moderate | 3 | Unlikely | 2 |
| Contractor | Insufficient Quality Control | Moderate | 3 | Unlikely | 2 |
| Contractor | Labour Dispute or Strike | Moderate | 3 | Unlikely | 2 |
| Contractor | Low Motivation | Moderate | 3 | Unlikely | 2 |
| Design | Design Changes | Major | 4 | Very Likely | 5 |
| Design | Variation Orders | Moderate | 3 | Very Likely | 5 |
| Design | Design Errors | Major | 4 | Possible | 3 |
| Design | Incomplete Designs | Major | 4 | Possible | 3 |
| Design | Delay in Changes | Moderate | 3 | Possible | 3 |
| Design | Poor Communication | Moderate | 3 | Possible | 3 |
| Design | Changes in Specification | Moderate | 3 | Unlikely | 2 |
| Design | Structural Variations | Moderate | 3 | Unlikely | 2 |
| Equipment | Equipment Shortage | Very High | 5 | Likely | 4 |
| Equipment | Delay in Equipment Delivery | Major | 4 | Likely | 4 |
| Equipment | Equipment Price Escalation | Major | 4 | Possible | 3 |
| Equipment | Ineffective Procurement | Moderate | 3 | Possible | 3 |
| Equipment | Equipment Breakdown | Moderate | 3 | Unlikely | 2 |
| Equipment | Poor Equipment Operator Skills | Moderate | 3 | Unlikely | 2 |
| Equipment | Poor Equipment Productivity | Moderate | 3 | Unlikely | 2 |
| Equipment | Theft | Moderate | 3 | Rare | 1 |
| Equipment | Wrong Equipment | Moderate | 3 | Rare | 1 |

| | | | | | |
|---|---|---|---|---|---|
| External/PS | Weather Conditions | Major | 4 | Very Likely | 5 |
| External/PS | Inflation | Very High | 5 | Likely | 4 |
| External/PS | Economic Risks | Major | 4 | Likely | 4 |
| External/PS | Environment Concerns | Major | 4 | Likely | 4 |
| External/PS | Law and Regulation Changes | Major | 4 | Likely | 4 |
| External/PS | Site Conditions and Location | Major | 4 | Likely | 4 |
| External/PS | Corruption | Very High | 5 | Likely | 3 |
| External/PS | Political Instability | Major | 4 | Possible | 3 |
| External/PS | Political Interference | Major | 4 | Possible | 3 |
| External/PS | Unforeseen Ground Conditions | Major | 4 | Possible | 3 |
| External/PS | Force Majeure | Very High | 5 | Unlikely | 2 |
| External/PS | Delay in Approvals from Council | Moderate | 3 | Possible | 3 |
| External/PS | Site Accident | Very High | 5 | Rare | 1 |
| External/PS | Delay in site preparation | Minor | 2 | Unlikely | 2 |
| External/PS | Arbitration | Major | 4 | Rare | 1 |
| External/PS | Litigation | Moderate | 3 | Rare | 1 |
| External/PS | Problem with Neighbours | Moderate | 3 | Rare | 1 |
| External/PS | Traffic Management | Very Low | 1 | Rare | 1 |
| Material | Material Price Escalation | Major | 4 | Very Likely | 5 |
| Material | Material Shortages | Very High | 5 | Likely | 4 |
| Material | Delay in Material Delivery | Major | 4 | Likely | 4 |
| Material | Poor Quality Materials | Moderate | 3 | Possible | 3 |
| Material | Ineffective Procurement | Major | 4 | Unlikely | 2 |
| Material | Incorrect Material Delivered | Moderate | 3 | Unlikely | 2 |
| Material | Theft | Moderate | 3 | Unlikely | 2 |
| Material | Poor Material Handling | Minor | 2 | Unlikely | 2 |
| Material | Unreliable Suppliers | Major | 4 | Rare | 1 |
| Material | Change in Material Specification | Moderate | 3 | Rare | 1 |

Table 49: Impact assessment for supply chain risks

| Impact Group | Impact Description | Severity | Severity Score | Likelihood | Likelihood Score |
|---|---|---|---|---|---|
| Construction | Stress on Contractor | Very High | 5 | Likely | 4 |
| Construction | Low Quality Work | Major | 4 | Possible | 3 |
| Construction | Construction Waste | Moderate | 3 | Possible | 3 |
| Construction | Lost Productivity | Major | 4 | Possible | 3 |
| Contract & Legal | Disputes | Moderate | 3 | Possible | 3 |
| Contract & Legal | Litigation | Major | 4 | Unlikely | 1 |
| Contract & Legal | Arbitration | Major | 4 | Unlikely | 1 |
| Contract & Legal | Contract Termination | Very High | 5 | Unlikely | 2 |
| Contract & Legal | Mediation | Moderate | 3 | Unlikely | 2 |
| Financial | Cost Overrun | Very High | 5 | Very Likely | 5 |
| Financial | Claims | Moderate | 3 | Possible | 3 |
| Financial | Reduced Profits | Moderate | 3 | Possible | 3 |
| Financial | Bankruptcy | Very High | 5 | Rare | 1 |
| Financial | Loss of Investment | Major | 4 | Unlikely | 2 |
| Financial | Uneconomical Projects | Moderate | 3 | Possible | 3 |
| Schedule & Time | Schedule Delays | Very High | 5 | Very Likely | 5 |
| Schedule & Time | Project Abandonment | Major | 4 | Unlikely | 2 |
| Schedule & Time | Extension of Time | Moderate | 3 | Likely | 4 |
| Schedule & Time | Project Acceleration | Minor | 2 | Likely | 4 |
| Social | Worsening Relationships | Major | 4 | Unlikely | 2 |
| Social | Bad Public Relations | Moderate | 3 | Possible | 3 |
| Social | Loss of Jobs and Income | Major | 4 | Unlikely | 2 |
| Social | Negative Perception | Moderate | 3 | Unlikely | 2 |
| Social | Loss of Customer Benefit | Moderate | 3 | Possible | 3 |

| Impact Group | Description |
|---|---|
| Construction | Construction Related Impact |
| Contract & Legal | Contract & Legal Related Impact |
| Financial | Financial Related Impact |
| Schedule & Time | Schedule & Time Related Impact |
| Social | Social Related Impact |

| Severity | Description |
|---|---|
| Very Low | No Impact on Project |
| Minor | Minimal Impact Project |
| Moderate | Some Impact on Project |
| Major | Significate Impact on Project |
| Very High | Excessive Impact on Project |

| Risk Likelihood | Description |
|---|---|
| Rare | Impacts that almost never occur |
| Unlikely | Impacts that don't occur often |
| Possible | Impacts that may occur from project to project |
| Likely | Impacts that may occur often |
| Very Likely | Impacts that are highly likely to occur |