A review of risk management techniques and challenges of implementation in harbour and port expansion projects

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By

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Declaration

I declare that this Mini-Dissertation is my own work and that it has not been submitted, in any previous application for a degree or qualification from this or any other university or institute of learning. I am aware of and understand the university's policy on plagiarism, all contributions from previous studies have been indicated by referencing.

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Student name and Signature

Date: 12/05/2017

The research was done under the guidance and supervision of Dr H Nel, at the University of Johannesburg. In my capacity as supervisor of the candidate's mini dissertation, I certify that the above statements are true to the best of my knowledge.

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Date: 12/05/2017

Abstract

Risk management is an essential part of infrastructure projects. Seaports and harbours are facilities that serve over 80% of world trade. The complex nature of these projects presents the inevitable wide range of risks and uncertainties. 65% of global projects are considered as either a failure, delayed or over budget. Attributed to this is poor risk management and appropriate planning for risk mitigation.

This negative statistic on project outcomes motivated an inquiry into risk management techniques and their implementation challenges in harbour and seaports construction projects. Beyond the year 2020, additional seaport facilities and rehabilitation of existing ones will be required in Africa. This requirement could potentially be met if seaport and harbour projects are executed with effective risk management frameworks.

A systematic literature review was employed on articles that reported on risk management techniques and their implementation limitations. Different risk identification, assessment and treatment methods were identified. Amongst the techniques identified were Analytical hierarchy-based techniques (AHP), Enterprise risk management (ERM), Construction risk management system (CRMS), Major infrastructure assessment framework (MIRAF), Dynamic risk management and Innovative risk management. Impediments in the implementation of risk management plans were found to be political influence, technical complications, environmental constraints and lack of adequately skilled personnel.

These identified risks and challenges have the potential to broaden and improve the risk management frameworks developed by the managers. Project risks and their sources were researched, identified and documented in this research.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AHP	Analytical hierarchy process
ERM	Enterprise risk management.
GDP	Growth development product
MoR	Management of risk
NASA	National aeronautics and space administration
PERT	Project evaluation and review technique
PMBOK	Project management body of knowledge
PMI	Project management institute
PPID	Private participation in infrastructure database
PPP	Public- private partnership
PRAM	Project risk and management,
PRINCE2	Projects in controlled environments
RAMP	Risk analysis and management for projects
RBS	Risk breakdown structure
RAMP	Risk Analysis and management for projects
SANRAL	South African national road agency limited

TEUs	Twenty-foot equivalent units. An inexact unit of ship cargo capacity, with the following measurements Length: 20-foot-long (6.1 m), Height: up to 9 feet 6 inches (2.90 m), Width: up to 8 feet (2.44 m)
USA	United States of America

Chapter 1: Introduction

1.1 Background

Infrastructure projects are characterised by both technical and human complexity (Boateng, Chen and Ogunlana, 2012; Dunović, 2015). This complexity gives rise to high risks and uncertainties in terms of design and cost estimations which can lead to poor project performance (Dunović, 2015). The uniqueness in these projects requires risk management techniques to be thorough and more precise in comparison to the general construction projects, which can adapt risk strategies from related prior projects (Maru, 2015).

Project success is vital in infrastructure projects such as seaports and harbour expansions. They involve substantially high investments in terms of both finance and time (Dunović, 2015). Globally, 65% of large-scale projects are classified as failures and project objectives are rarely met due to cost and schedule overruns, which can be as high as 25% (Willem and Zhuwakinyu, 2013). Africa's contribution towards these statistics includes South Africa's Durban and Heidelberg product pipeline, a project by Transnet, which had a final cost of R23 billion from its initial budget of R12.7 billion and a delay of three years (Willem and Zhuwakinyu, 2013). The Durban seaport dig-out project, also by Transnet, worth US$7.5 billion, has been halted due to unexpected slow economic growth (Edinger, McDonald and Sakoor, 2016). Tanzania's US$11 billion rand Bagamoyo port project, was also suspended by the new government in 2015. Its funds were diverted to the previously delayed smaller projects such as the port of Dar es Salaam and Mtwara (Edinger, McDonald and Sakoor, 2016). These examples emphasise on the need for effective risk management frameworks to combat risks that can emerge from political interferences, environmental, economic and technological changes.

One of the reasons behind these negative project outcomes is unclear project delivery objectives and inadequate managerial skills (Shunmugam and Rwelamila, 2014). In South Africa, risk management is said to be impeded by minimum knowledge and skills base especially at the implementation stage. The risk management tools and their implementation are areas with minimum exploration from a research perspective (Chihuri and Pretorius, 2010). The subject of risk management is misunderstood and the major challenges faced include ignorant attitudes, inadequate skills, cost and time constraints (Shunmugam and Rwelamila, 2014). There is poor budgetary allocation for risk mitigation, which contributes to the poor implementation of risk plans (Beckers, Silva and Flesch, 2013). Proper training is lacking and use of detailed analysis tools is only partially implemented (Allen and Carpenter, 2015).

Effective risk strategy implementation can potentially improve project performance as risk responses directly affect the project's scope, schedule and cost (Allen and Carpenter, 2015). Anchoring on this, Lark (2010) highlighted that risk management plays a vital role in ensuring success in each of the project's three pillars of scope, schedule and cost (Lark, 2010). The project scope often covers the defined project objectives, design and quality specifications. The project schedule is the stipulated timeline for project completion and project cost involves the resources used for the project inception, execution and completion. The critical aspects to be addressed by the project delivery team during strategy implementation are internal, system, people and environmental aspects (Radomska, 2014).

Generally, a risk management continuum exists according to the Financial Management Institute of Canada (Lark, 2010). This continuum classifies risk management in the categories of reactive, comprehensive, and proactive. In reactive risk management, the crisis is dealt with after the events have occurred, thus it is an after-event response by the organisation. In comprehensive risk management, risks are managed on a business unit individual basis. Under proactive, risk management is incorporated into a daily strategic plan within the organisation.

Another risk management approach based on enterprise risk management implementation follows the Deming cycle (Lark, 2010). The cycle begins with a risk 'Plan', which establishes the objectives and necessary processes in accordance with desired output. The next step is the 'Do', which is the implementation of the plan. The following step is the 'Check', that measures and compares the obtained results against the expected ones. The last step in the cycle is the 'Act', which assesses the difference between obtained results and expectations as well as determining possible areas of improvement (Lark, 2010).

Quantitative and qualitative tools exist in planning and managing risk. These plans are often adapted to different organisational disciplines. There has been extensive research on risk management in large infrastructure projects such as rail, roads, airports but few studies focused on seaport developments. Seaports facilitate about 80% of world trade and over US$70 billion in investments have been made in global seaport construction projects (The World Bank, 2015). These statistics motivated the focus to be on seaports which are the key drivers of global trade and the economy. The next section presents and describes the research problem.

1.2 Problem statement

Seaports and harbour facilities enhance global trade and contribute significantly towards economic growth. There has been a worldwide upsurge in ship sizes and growing cargo volumes which has imposed a strain on existing facilities. Over US$70 billion has been invested globally in the construction of new, and rehabilitation of existing seaports (The World Bank, 2015). Successful management of these projects can enhance trade and open investment opportunities; however, risk is an indisputable factor that affects project success, particularly complex ones. Research conducted on infrastructure construction projects highlighted that risk management is poorly implemented (Chihuri and Pretorius, 2010; Renuka, Umarani and Kamal, 2014; Shunmugam and Rwelamila, 2014; Allen and Carpenter, 2015). Over 65% of projects are considered delayed or a failure. Contributing to this figure is South Africa and Tanzania's seaport projects worth a combined U$18 billion. The projects have since been paused due to risks arising from political changes and economic fluctuations. Since risks management essentially affects project performance, the techniques and their challenges will be identified and assessed.

1.3 Research purpose

The purpose of the research was

- To assess and identify available risk management techniques applicable in harbour and port construction projects.
- To determine the challenges faced during risk plan implementation in these types of projects and give possible recommendations.

1.4 Research questions

Literature has indicated the need for additional seaports and harbour facilities in the future to enhance world trade and improve the economy. Construction of these complex facilities presents a wide range of risks related to economics, politics, technology and the environment. With the high levels of delayed and failed projects being reported, the aim and purpose of this research are to probe and explore risk management techniques used in these infrastructure projects. The research questions are:

- What are the risk management techniques used in seaport and harbour construction and expansion projects?
- What are the challenges and limitations faced during implementation of these risk management techniques?

1.5 Research objectives

The objective is to assess applicable risk management techniques and challenges and propose recommendations, in harbour and ports construction projects. The findings can potentially guide managers in formulating a risk management strategy for future projects in the sector. This study could be beneficial to risk and project management practitioners within this sector.

1.6 Research design

Research design summarises and outlines the procedures of inquiry to be taken by the researcher in addressing the research question. There are three main designs available, namely qualitative, quantitative, and mixed methods. The quantitative enquiry is used for experimental designs or correlational designs to describe or measure relationships within variables. They are used in numerically analysing and answering research questions. Qualitative research is descriptive research with analysis of textual data, images or behaviour observation. The types of qualitative research available, which are also considered traditional (Thomas, 2003), are narrative, phenomenology, grounded theory, ethnographies or case study (Creswell, 2014). A systematic literature review is another type of qualitative research methodology. It is textual data analysis and synthesis of findings from previous studies, on a topic of interest (Pacheco and Garcia, 2012). Mixed methods tend to merge the two qualitative and quantitative methods and are often convergent, sequential and explanatory or exploratory, transformative, embedded or multiphase.

Literature available on risk management techniques focused on general large infrastructure projects (Alessandri, Ford and Lander, 2004; Shunmugam and Rwelamila, 2014). However, there is limited articles that focused on port and harbour construction and expansion projects, as these are facilities that contribute mostly in global trade. The systematic literature review was employed as a method of inquiry in this research. It brought together prior studies, describing and integrating the findings to answer the research questions. A systematic method was used to identify, select, critically appraise, collect and analyse information presented by relevant articles. Figure 1.1 shows the systematic literature review steps taken in information gathering and analysis.

1.7 Main characteristics of the systematic literature review

The following characteristics best describe the methodology.

- There was no establishment of theory or hypotheses.

- The researcher was the key instrument: the researcher collected data through the examination of documents and previous studies. No questionnaires or instruments derived from other researchers were used.
- Sources of data: The data was gathered through a literature search in journal articles, newspaper articles, working papers, books and company reports.
- Holistic study: an analysis and representation of previous research findings on risk management techniques and challenges.

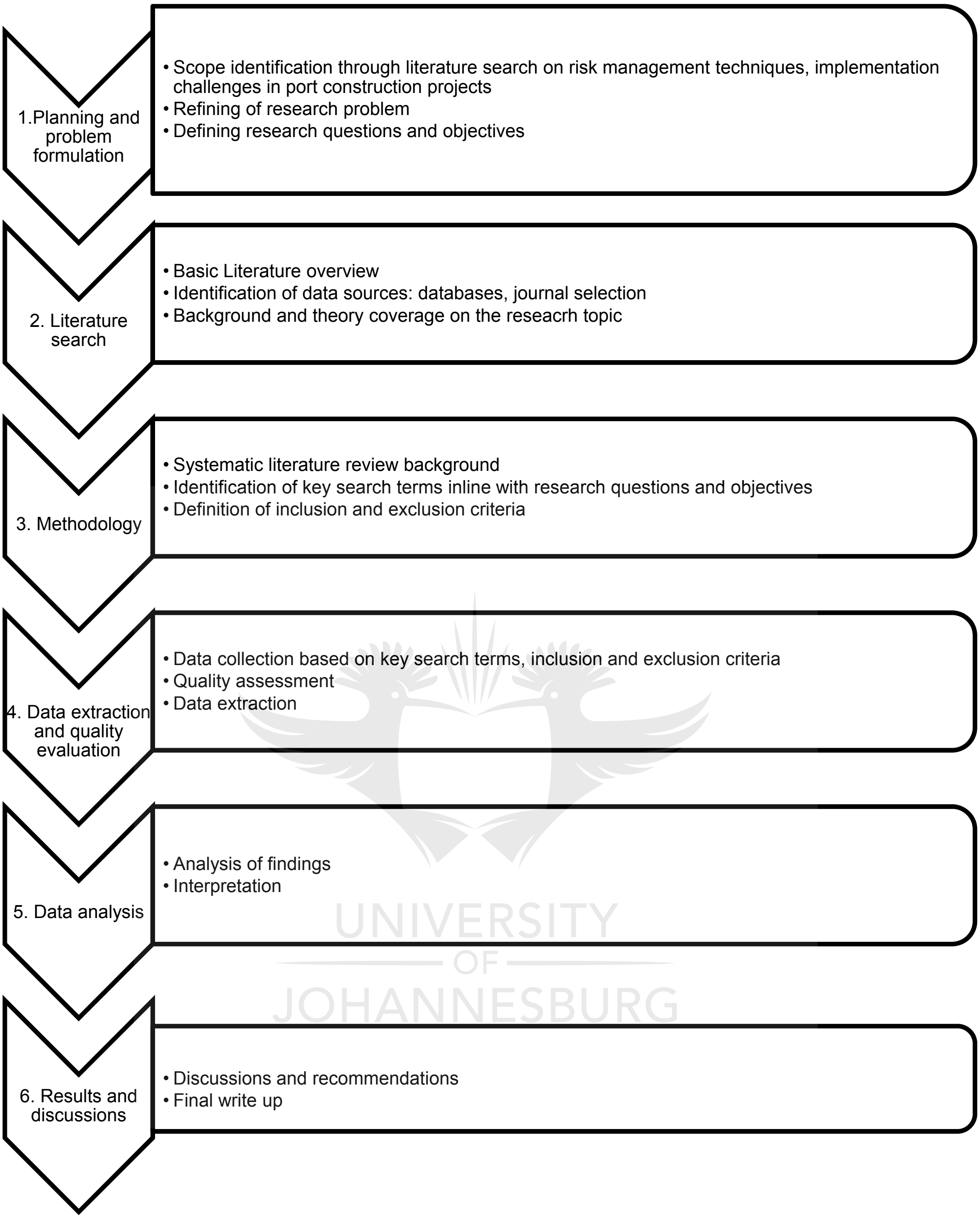

Figure 1.1 Research design, a systematic literature review (Creswell, 2014)

The research was designed such that it located existing literature on the research problem, screened and evaluated the individual contributions towards answering this study's research questions. The contributions were synthesised and analysed to report an overall, holistic overview of the topic. Recommendations were drawn from the risks, challenges faced, and techniques identified. These recommendations could contribute positively to the seaport construction risk management team.

1.8 Study layout

The following chapter two will introduce the infrastructure projects in general together with the risk management techniques. Risk management and challenges in global construction projects will be reviewed. Projects with a minimum of budget of US$500 million were considered, this is the standard definition of large infrastructure projects (Kardes, Ozturk, Cavusgil and Cavusgil, 2013; Dunović, 2015). Chapter three will discuss the research methodology. Sources of data selection will be explained with details on the databases, key search terms, definition of inclusion and exclusion criteria and article selection. Chapter four contains data extraction done on selected and eligible articles. Analysis of findings and discussion followed in Chapter five including the conclusion and recommendations. Excluded articles are listed in Appendix A.

1.9 Chapter summary

Risk management in general infrastructure and seaport projects was introduced. There is minimum literature available reporting on how risk is managed in ports and harbour construction projects. World trade relies on these facilities and they contribute to the growth of the gross domestic product. Projects have been reported as delayed or failed due to poor risk management and this motivated the research questions: What are risk management techniques and challenges faced in seaport and harbour projects. The research design was also explained. The following chapter outlines the literature review.

Chapter 2: Literature Review

2.1 Introduction

Harbour and port expansions have long-term economic and operational growth potential with significant benefits. One of the significant benefits is the increase in gross domestic product (GDP), with a growth of 1% per 10% rise in infrastructure assets (Beckers, Silva and Flesch, 2013). Harbour expansions are critical infrastructure resources with statistics indicating that between 80% and 90% by volume of international trade is carried out by sea, ports and offshore terminals (Mokhtari and Ren, 2011; Dyer, 2014).

Over the past two decades, there has been a steady increase in ship sizes, in addition to growing cargo volumes (Marsh and McLennan, 2014). These have placed increased pressure on existing cargo infrastructure and terminal handling capacities especially in African ports. The facilities already have capacity constraints, poor transport infrastructure and connectivity (Marsh and McLennan, 2014). Underdeveloped infrastructure presents one of the biggest challenges for economic growth and social development worldwide (Beckers, Silva and Flesch, 2013). In response to the mentioned demand in improved seaports and harbour facilities, investments have been made into these infrastructure projects.

Risk management plays a vital role in project success. It is has been reported that in construction projects, where a risk management culture is encouraged, the organisation, has added value towards achieving project success (Shunmugam and Rwelamila, 2014). It is imperative to avoid and minimise pitfalls that could delay or fail projects. The pitfalls range from market competition from neighbouring countries, unclear or misplaced project priorities, political issues, environmental, financial, procurement or contractual complications (Dunović, 2015). Large infrastructure projects such as ports construction have poor management of risk throughout the lifecycle of the project (Beckers, Silva and Flesch, 2013). An example of this being, poor risk assessment and risk allocation through contracts with the builders and financiers in the concept and design stage of the project, which can lead to higher risks and private financing shortages (Beckers, Silva and Flesch, 2013). Most African ports have inadequate infrastructure, which puts African ports at the bottom list of the world's top seaports (Construction review online, 2015).

There is evidence indicating that despite much emphasis on risk management and planning, there is unsuccessful execution of the risk plan (Shunmugam and Rwelamila, 2014). This was confirmed by a study which concluded that the South African construction project environment lacks adequate implementation of risk management policies (Chihuri and Pretorius, 2010). Construction organisations in developing countries such as Sub-Saharan Africa, tend to approach project risk management with insufficient practices (Serpell, Rubio and Arauzo, 2015). This was reiterated by subsequent research on harbour and ports projects, which concluded that there is a lack of efficient risk assessment methods in evaluating hazards in harbour engineering, leading to a rise in fatal accidents (Zhi-qiang and Ya-mei, 2016).

Seaport and harbour industry enables global trade in industries such as mining, manufacturing, automobiles, apparel, chemicals, oil and agricultural products. The following section explains more about the seaport trade and investments made in construction and rehabilitation projects.

2.2 Overview of global port and harbour industry

Over the past decades, there has been an improvement in global trade mainly in logistic chains, new hub concepts and containerisation with an introduction and use of large ships (Guasch, Suárez-Alemán and Trujillo, 2016).

Some of the major port operations are in Latin America and the Caribbean. The notable ports in this area are namely Callao-San Lorenzo Island port in Peru, Cartegena Port in Colombia, Balboa and Rodman ports in Panama, Punta Colonet and Baja California ports in Mexico, as well as Cuba and Chile. The gulf Arabic has Abu Dabhi-Khakifa Port in Dubai, Kuwait and Qatar. There are also major ports like Darkata port in Indonesia, and twenty-six ports in China. Australia also operates the Gladstone port amongst others (Guasch, Suárez-Alemán and Trujillo, 2016).

Africa also has several ports with nine in South Africa, four in Nigeria, three in Mozambique, two each in Namibia, Angola, and Cameroon. Other countries with at least one operational port are Benin, Togo, Ghana, Cote D'Ivoire, Guinea, Madagascar, Tanzania, Kenya and Mauritius. Cameroon has begun a new seaport construction project with an investment of US$675 million (Africa Research Bulletin, 2016).

The largest port in the world is Shanghai, which handled 32 million twenty-foot equivalent Units (TEUs) per annum as of 2013. The port of Singapore handled 29.37 million TEUs with an annual growth of 6.1% as of 2013. The port of Tanjung Pelepas in Malaysia, which is comparable to South Africa’s ports, handled 7.5 million TEUs with a 15% annual growth. The Port of Los Angles handled 7.9 million TEUs in 2011 (Maharaj, 2013).

In South Africa, Durban Container Terminal is reported to be the fastest growing terminal in Africa and the second largest in the Southern Hemisphere, behind Brazil's Port of Santos. It contributes 65% of South Africa's container traffic (Transnet, 2014). Durban's port is the main import centre for wheat and rice as well as fertilisers and oil cake, animal feed, inputs into agriculture, meat and poultry, petroleum products and machinery including automobiles. The exports include iron and steel products, chemicals and automobiles (Maharaj, 2013). The Port of Richards Bay is one of the largest in South Africa by tonnage. It handled 89 million tonnes of cargo per year as of 2014. This equates to 40% of South Africa's total port demand (Transnet, 2014). The thirty-year forecast from 2014, predicted over 170 million tonnes of cargo per year will be handled in South Africa.

2.3 Global Investments into harbour and seaport construction

Reports from the *Private Participation in Infrastructure Database* (PPID), which is a subsidiary of the World Bank Organisation, summarised the total amount of investment made in seaports brownfield, greenfield and divestiture projects, globally as illustrated in the figure below, Figure 2.1. Over US$30 Billion dollars was invested globally in rehabilitations, and US$46 Billion was invested in new developments. Sub- Saharan African countries invested at least USD$9 Billion, in both new projects and expansion and improvement of existing ones. The Pacific, East Asia, Latin America, and the Caribbean experience high tonnage of goods per year, thus they have the most investment owing to trade and operational demand. East Asia and Pacific region had the most green-field projects.

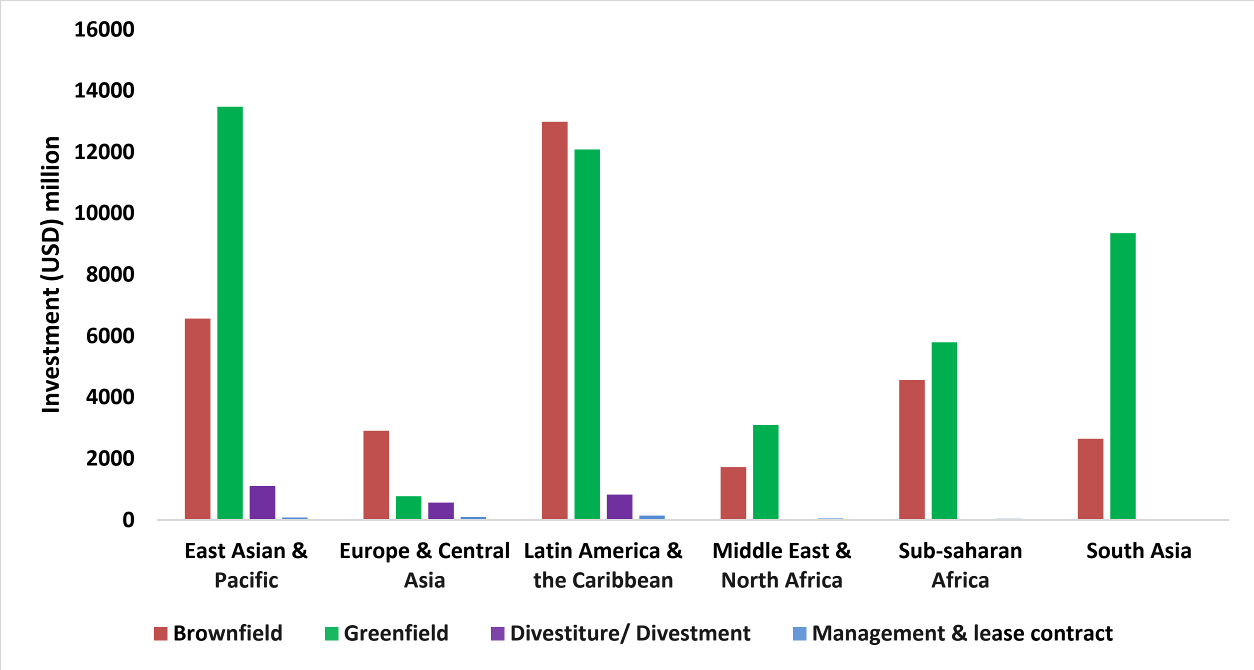

Figure 2.1 Investment overview of world ports projects(The world bank 2015)

In Africa, the following seaport projects are underway. Nigeria's Onne port expansion, Lekki deep Seaport and Apapa Container terminal concession. Kenya is also involved in the development of the Lamu project with a budget of US$1 billion (Edinger, McDonald and Sakoor, 2016). The Durban dig-out project by Transnet in South Africa has been halted due to slow economic growth. The project had an investment of US$7.5 billion. Tanzania's Bagamosho project was also halted with funds diverted to previously delayed projects. The Bagamosho project was valued at US$11 billion.

These investment figures emphasise the need for thorough and more effective risk management frameworks in place. It is evident that infrastructure development is key to global economic growth considering its capability to increase GDP growth. There seems to be a lack of risk management focus during project execution. To identify risk management techniques, it is essential to first explain the project lifecycle involved in infrastructure and port construction projects. The life cycle of the project explains and details activities involved in each project phase.

2.4 General large infrastructure project life cycle

A typical capital infrastructure project begins with project inception and feasibility phase. The project is assessed at this conceptual stage with the project proposal and budget drafting. During the design stage, technological specifications are defined. Procurement is done according to the project's contracts and procurement policies. Development phase involves the actual construction and delivery or handover of the project. Commissioning and maintenance can be part of the exit stage in accordance with the contract. These phases are summarised in Figure 2.2. Seaport construction project life cycle ranges between thirty to forty-two months (Africa Research Bulletin, 2016). This time frame is dependent on the size of the facilities and is subject to risks and uncertainties.

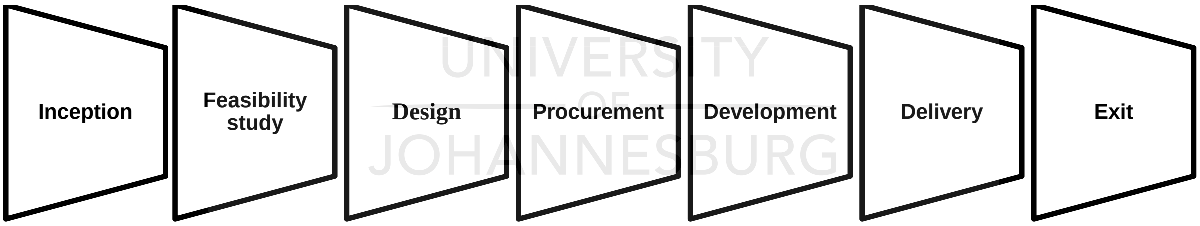

Figure 2.2 Lifecycle stages of a typical infrastructure project(Devan, 2005)

McKinsey and Company, an organisation with decades of experience in capital projects risk management, stated that most infrastructure projects entail the following project phases (Beckers, Silva and Flesch, 2013):

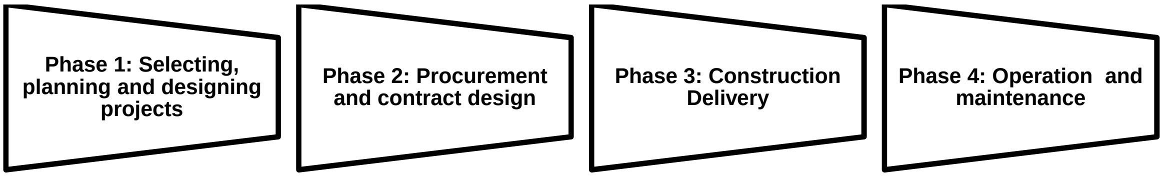

Figure 2.3 Infrastructure project phases(Beckers, Silva and Flesch, 2013)

It is emphasised that risk assessment should be conducted from the first phase, as a thorough continuous process throughout the four stages. The first phase, selection, involves project planning and application of robust design procedures. The second phase involves procurement and contract design based on phase one of the project. The contract is negotiated and drawn between the contractor and owner. Depending on the type of contract, some of the risks in this phase lie within the contractor (Devan, 2005). Phase three is construction and delivery and the last phase is hand over, operations and maintenance.

Renuka (2014) listed in his research the following life cycle in mega projects, the lifecycle is summarised in Figure 2.4.

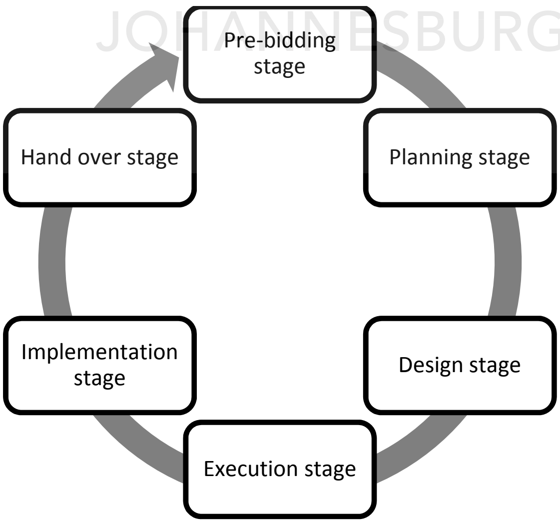

Figure 2.4 Infrastructure Project Life Cycle (Renuka, Umarani and Kamal, 2014)

The main phases identified are inception, design, procurement and construction, commissioning and project termination. Different risks are encountered in each phase. For risk and project managers to fully understand the concept of risk management, it is important to grasp the difference between uncertainty and risk.

This can enable the team to select and plan a more effective response strategy or technique. Uncertainty and risk are closely related however, they are two distinct entities and thus should be handled accordingly. The following section explains the main differences between the two concepts.

2.5 Risk and uncertainty management in projects

Risk and uncertainty are related as they both have a possible impact on the project outcome. For risk management personnel to be successful in risk mitigation, it is essential for them to have a clear understanding of risk and uncertainty. The two terms are distinct in precision but often do overlap in the project and strategic management (Alessandri, Ford and Lander, 2004). All quantifiable factors surrounding a capital project represent risks, on the other hand, qualitative factors that affect decision-making process in project estimates, represent uncertainties (Alessandri, Ford and Lander, 2004).

Risk and uncertainty both pose threats to a project's defined objectives. During execution of construction projects, it is essential to have a thorough analysis of possible risks and uncertainties, to improve project success. Risk management is defined by the Project management body of knowledge (PMBOK), as an uncertain event or condition that if it occurred, could lead to a positive or negative effect on one or more of the project's defined objectives which are scope, schedule quality or cost (Project Management Institute, 2013).

The Project management institute (PMI) encourages organisations to adopt a consistent proactive risk management attitude to ensure success in managing and mitigating risks. Risk is also defined as the probability distribution of the consequences of an alternative, whereas uncertainty is when the consequences of an alternative belong to some subset of all possible consequences, such that the decision maker cannot assign a definite probability to the occurrence of a particular outcome (Alessandri, Ford and Lander, 2004). Uncertainty in project management is defined as the lack of certainty on the occurrence of events and is regarded as immeasurable because of vagueness and ambiguity with the lack of data and facts. Comparatively risk, on the other hand, was said to be predicted and measured on existing previous data related to similar project environments (Atkinson, Crawford and Ward, 2006). In construction projects, uncertainties of risk events are attributed to the lack of sufficient data related to the chances of their occurrence in addition to the associated potential consequences, and moreover, uncertainties are inherently random in nature (Choi, Cho and Seo, 2004).

Another comparison of the two concepts explained that risk has uncertain parameters that are controlled by known probability distributions. Uncertainty, however, has unknown parameters or probability information. The difference between risk and uncertainty is usually expressed in terms of whether it is possible to quantify the inexactness with which future values of a particular quantity are known (Ustinovičius, 2007).

In view of the above, it was concluded that uncertainty management involves managing perceived threats, opportunities and their risk implications as well as managing the various sources of uncertainty which give rise to risk, threat and opportunity (Ustinovičius, 2007). In recent developments in some organisations, risk management approaches have been moved from risk management towards an integrated uncertainty management (Burcar Dunovic, Radujkovic and Vukomanovic, 2016). It is important for risk management practitioners to understand and manage both risk and uncertainty, an integration of the two entities could be worthwhile in projects.

2.6 Types and sources of risks in infrastructure projects

Large infrastructure projects are complex and similarly to other projects, are prone to risks (Guo, Chang-Richards and Wilkinson, 2014). They involve multiple stakeholders entering the project life cycle at different stages with different roles, responsibilities, risk-management capabilities, risk-bearing capacities, and often-conflicting interests (Beckers, Silva and Flesch, 2013). While the complexity of these projects requires a clear allocation of roles and responsibilities among contractors and operators, this leads to significant risks among the various stakeholders throughout the life cycle of the project (Beckers, Silva and Flesch, 2013). These must be anticipated and managed to avoid project failure or delay.

Ports and harbours have services such as customs, joint inspection, and pilotage. Possible risks that are faced in this environment are throughput capacity, which is affected by the breakdown of cranes, forklifts, labour disputes, and extreme weather conditions. Risks in port construction could be either infrastructural or operational. Operational risks in ports are susceptible to economic, trade and tariff regulations. Ports can also be largely affected by political risk as they are often the main gateways to some countries (Lam, 1999). In 2013, a study was conducted on a new port of Walvis Bay in Namibia. The risks identified in this report were as follows (Oumarou and Wadda-senghore, 2013):

- Financial and throughput risk posed by competing ports and routes. This type of risk called for a thorough analysis of markets and trends with clear strategies for reaching project objectives.
- The risk of failure by the government to commit and implement the development plans.
- The risk of supporting infrastructures like railroads and operations.
- The risk of project delay due to late procurement procedures.
- Construction risks.
- Social risk relating to environmental compliance and legislation.

During construction and expansion, ports projects face legal risk, where legislation and regulations, governing the projects change. These are inherent risks which cause delays in the approval of contracts. Some risks emerge from non-compliance in contracts, quality and efficiency (Mokhtari, Ren, Roberts and Wang, 2012).

From an environmental perspective, the impacts to be considered in seaport and harbour projects are altering weather changes with the possibility of hurricanes and sea level rise which, for example, caused extensive damage in North East Coast in the *United States of America* (USA) (Ramos, 2014).

During the project's conceptual phase, the internal risks identified were poor project scoping, improper documentation, minimum stakeholder input in the project's objectives, insufficient time and budget allocation during feasibility studies, insufficient information during the pre-design stage, inadequate investigation of the sites. One of the most relevant risks identified was a lack of a structured risk management framework for risk identification and mitigation. More risks were a lack of transparency during key decision-making processes and non-alignment of project objectives with risk management plans.

During the planning phase, insufficient information was a limitation in quantifying risks. There was a lack of a system needed to identify risks during the bidding procedure as part of the procurement process. There was an inadequate evaluation of technical and legal risks associated with vendor selection. More risks lie in the use of unproven technology and suppliers. Marsh and McLennan (2014) suggested that project and risk managers should allocate sufficient time in analysing risk and risk transfer strategies (Marsh and McLennan, 2014).

A *Public-private partnership* (PPP) was established during the Rotterdam port expansion in Netherlands (Van Ham and Koppenjan, 2001). Risks faced by the public party were financial, discontinuity from the private party, and political. The private party faced challenges associated with exploitation, delays and complications in construction, discontinuity from the public party, social issues, administrative and policies changes (Van Ham and Koppenjan, 2001).

Different risks emerge at different stages of the project. Potential risks involved in each project phase are shown in Table 2.1.

Table 2.1 Risks associated with each project phase (Beckers, Silva and Flesch, 2013)

Selection, planning and design stage	Procurement and contract design	Construction delivery	Operation and maintenance
• Incorrect forecasts and assumptions • A limited understanding of market dynamics and lack of willingness to plan for volatility and adverse scenarios • Overestimating revenue and growth potential	• Governments are the main stakeholders in this phase • Failure to select the optimal risk-return ownership structure ahead of the procurement stage • Risk appetite of private players is frequently neglected or poorly understood • Limited transparency of risk cost, risk ownership, and risk-return trade-offs	• Main stake holders are the Asset owners and financiers • Construction contractors fail to meet their contracts, resulting in cost overruns, delays, and defects • Poor original planning and performance management of resources and cost • Disconnection between contractual obligations and transparency about a contractor's ability to deliver	• Failure to meet contractually agreed-upon service quality resulting in delays and increased costs

2.7 General risk management techniques

A generic risk management plan involves the following steps: identification, analysis and assessment, evaluation and management (Choi, Cho and Seo, 2004; Searle, 2013). Risk is identified, assessed and evaluated using a risk matrix register. Another risk assessment technique is the bowtie method which provides a visualised structure on how to approach risk (Müller, 2015). Some risk assessment methods, such as the risk matrix register, are subjective. This subjectivity is a disadvantage since the method becomes dependent on the estimator's experience. The estimator's experience is determined by personal beliefs, attitudes, judgement, feelings and educational background and experience (Roumboutsos and Anagnostopoulos, 2008).

Other risk identification methods are brainstorming, development of prompt lists, structured interviewing and use of a hypothetical project cycle which simulates events and relationships. This process makes relevant risks to be apparent (Lam, 1999). A study of historical projects is done to draw past casual relationships while developing meaningful scenarios. The scenarios are then used for the simulation technique. A pattern of inherent risks is often observed (Lam, 1999).

An example of risk management technique is one used by National Aeronautics and Space Administration (NASA), which makes use of probabilistic risk assessment analysis. This technique uses a modelling process that allows decision makers to assess and compare different possible risk scenarios, and also identify factors that contribute to the level of risk associated with different scenarios (Kwak and Dixon, 2008). Other risk assessment techniques were analytical hierarchy process (AHP) and risk prioritisation approach (Mokhtari and Ren, 2011).

The fuzzy logic system is a method used for project risk ranking in large programs. It has the following methodology: identification of risk factors, assessment of risk factor weights and estimation of risk exposure per project (Zacharias, Panou and Askounis, 2014).

Different risk management approaches are often used in different construction environments. *Project management body of knowledge* (PMBOK), is a guide used in the development of risk management frameworks. Other guides are *Projects in Controlled Environments* (PRINCE2), *Project Risk and Management* (PRAM), *Enterprise Risk Management* (ERM).

ERM is a process effected by the board of directors, management and its personnel, through setting strategies across the organisation. This identifies potential events that may affect the organisation (Zhao, Hwang and Low, 2015). This framework considers all possible risks including those that are outside the project environment, such as the well-being of the personnel, which can potentially affect the project's objectives. The main components of an integrated ERM are insight or risk transparency and ownership, the risk is allocated according to risk appetite and strategy (Beckers, Silva and Flesch, 2013). Risk processes are then outlined.

Another risk management strategy emphasised the importance of four elements that need to be managed in an engineering project. This strategy requires management of risk in each of these elements, these are: (Baron and Pate-Cornell, 1999):

- System design: risks are identified throughout the whole system.
- Operations and maintenance policies: risks are managed with a close monitoring of demand versus capacity schedule.
- Management of abnormal events: policies regarding management of abnormal events including decision making.
- Personnel management: risks in operator selection and training.

Risk Breakdown Structure (RBS) is another risk management method which uses a hierarchically organised summary of the project activities (Rasool, Franck and Denys, 2012).

Table 2.2 Shows the risk management steps in PMBOK, PRINCE2, PRAM and ERM. Risk management steps are identified in each of the techniques. Risk planning and identification is the initial step with PRAM. It also involves consolidation of existing data in relation to identification of sources of risk in a project. ERM emphasised on the risk transparency and insight at the initial stage. Risk in then analysed qualitatively according to all the techniques. PRAM had the most detailed process, which also included risk ownership establishment between contractor and client. Risks are then estimated and evaluated. Risk monitoring and control were the last two stages of the process.

Table 2.2 Comparison of risk management techniques used in multidisciplinary industries (Baron and Pate-Cornell, 1999; Beckers, Silva and Flesch, 2013; Project Management Institute, 2013; Zhao, Hwang and Low, 2015)

STEPS	PMBOK	PRINCE2	PRAM	ERM
1	Risk plan	Identify	Define: consolidation of existing information on the project	Insight and risk transparency
2	Risk identification	Estimate	Focus: making a clear scope and strategy for risk management plan at an operational level	natural ownership, risk appetite and strategy
3	Qualitative risk analysis	Evaluation and monitoring	Identify: identification of all possible risk sources and developing proactive and reactive response plans	Risk decisions and processes establishment
4	Quantitative risk analysis	Response action compilation	Structure: testing and simplifying assumptions made on the project	Risk organisation and governance
5	Risk response planning	X	Ownership: a clear client and contractor division of ownership and management of all unidentified and identified risks	Risk culture and performance transformation
6	Risk Control	X	Estimate: identify all areas of uncertainty	X
7	X	X	Evaluate: evaluation and synthesis of the preceding phase (estimate)	X
8	X	X	Plan: compilation of the risk management plan to be implemented during project execution	X
9	X	X	Manage: this phase involves, monitoring, and control	X

Other risk management techniques used in large infrastructure projects include *Management of risk* (MoR) and *Risk Analysis and management for projects* (RAMP) (Burcar Dunovic, Radujkovic and Vukomanovic, 2016). In RAMP risks are arranged according to risk category and subcategory, indicating various areas and causes of potential risks (Rasool, Franck and Denys, 2012).

In conclusion, the basic principle behind most of the techniques is tailoring and integrating risk management into a more structured process that improves a project's complexities and uncertainties (Guo, Chang-Richards and Wilkinson, 2014). Different risks are associated with each phase throughout the lifecycle of the project. One of the challenges faced in projects is risk planning and management. Project delay and failure have been a result of poor implementation of risk strategies. The section below lists the challenges faced in implementing risk management techniques.

2.8 Challenges of implementing risk management techniques.

The challenges faced during project execution are a result of lack of professional predetermining risk management framework (Scott-Young and Samson, 2008; Beckers, Silva and Flesch, 2013). However, according to Beckers, Silva and Fletch (2013), it is possible to predict all possible risks and to avoid them (Beckers, Silva and Flesch, 2013). Despite this possibility, it is common practice in infrastructure projects for risks to be misplaced. The following were notable and common challenges which contribute greatly to risk management failure (Beckers, Silva and Flesch, 2013):

- Overestimating revenue and growth potential due to skewed incentives among project originators.
- Sponsors and developers fail to plan delivery and stakeholder and project management in a sufficiently professional way.

- Engineering and construction companies pay insufficient attention to mitigating and controlling risk during the design phase.
- Financiers lack confidence in the ability of sponsors and other stakeholders to manage risks professionally and are not able to monitor developments and emerging risks themselves.

Complex interfaces within large projects such as port expansion are a contributing factor to poor risk mitigation. Lack of prior experience by the project team, along with differences in stakeholders interests gave rise to difficulties in managing risks (Guo, Chang-Richards and Wilkinson, 2014).

2.9 Chapter conclusion

Evidently, infrastructure projects are important in advancing trade. Whilst ports serve in global trade, they also contribute greatly to the increase of GDP. According to the World Bank, many investments are made into port developments globally. These investments range between US$ 1 billion and US$ 13.8 billion. Poor management of risks exists in port construction and other infrastructure projects considering reports of numerous unsuccessful and delayed projects.

Project life cycle involved in infrastructure projects and port developments were explored. This enabled identification of key high-risk areas along the project phases. General risk management techniques were identified and laid out. With this literature base and the objective to identify the risk management techniques and their challenges in seaport projects, the research methodology is explained in chapter three.

Chapter 3: Research Methodology

3.1 Background on systematic literature review

A systematic literature review is an evaluation and interpretation of published studies pertaining to a research topic of interest (Pacheco and Garcia, 2012). It is a thorough inquiry into the findings of prior studies. Its purpose is to enhance knowledge building and theory-generating in various fields of study (Finfgeld-Connett and Johnson, 2013). It gives new insights and perspectives whilst clarifying any issues on existing published studies (Pacheco and Garcia, 2012).

The systematic literature review will extensively enquire into the various risk management frameworks developed and implemented in seaports construction projects. There will be identification of similarities and differences between the techniques and implementation challenges, observing possible trends. The review has a potential to identify possible causes of dissimilar results (Goftar, Asmar and Bingham, 2014).

A literature review can either be through meta-analysis or a quality centric approach. Meta-analysis is traditional and limited studies are selected based on predetermined quality standards that need to be met before an article is considered and included in the research (Meline, 2006). Quality centric critical evaluation approach presents wide and broad literature sources, which can include published and unpublished studies (Meline, 2006).

3.2 Benefits of the methodology

This approach enables extensive exploration of risk management techniques and challenges of their implementation in projects. The method highlights the research subject on a broader perspective

3.3 Disadvantages of the methodology

There is a possibility of bias towards publication of studies with significant or positive findings and discarding those with results which are regarded as negative (Kenley, 1998; Pacheco and Garcia, 2012). Aggregating and analysing studies of different methodologies could pose difficulties in drawing comprehensive conclusions. There could be a limited number of studies done on risk management in port and harbour construction projects.

3.4 Bias consideration

Bias was minimised by reviewing relevant both published and unpublished research, guided by inclusion and exclusion criteria. During article content assessment, there was an extensive but critical assessment of these studies including white papers. This was achieved by reviewing the study design and execution, results and how the type of study influenced the conclusions drawn (Pannucci and Wilkins, 2010)

3.5 Systematic literature review: steps outline

The following steps were followed in gathering information on risk management techniques and challenges: (Boland, Cherry and Dickson, 2014).

- Refining review questions and performing scoping search
- Database and source selection, identification of key search terms
- Literature search. Identification of both published and unpublished papers from databases.
- Screening titles and abstracts. Appraisal of titles and abstracts of all papers identified and eliminating irrelevant ones, as per refined review questions.
- Retrieving papers. This step involves retrieving full-text papers identified in step 3.

- Selecting full-text papers. This step involves a strict and thorough application of the inclusion criteria to the full-text papers, leaving out those that are outside of the inclusion criteria.
- Quality assessment. This step involves quality assessment of each included full-text paper, using a selected quality assessment tool.
- Data extraction. This is the stage involving identification of the data required in-line with the review question, accurately summarising this data in designed tables.
- Analysis and synthesis. This step involves synthesising and scrutinising of the data narratively.
- Final write-up and editing. This final step involves writing up of the background of the study, methods used, results and discussions

Figure 3.1 illustrates the systematic literature review steps taken in screening and selecting eligible studies.

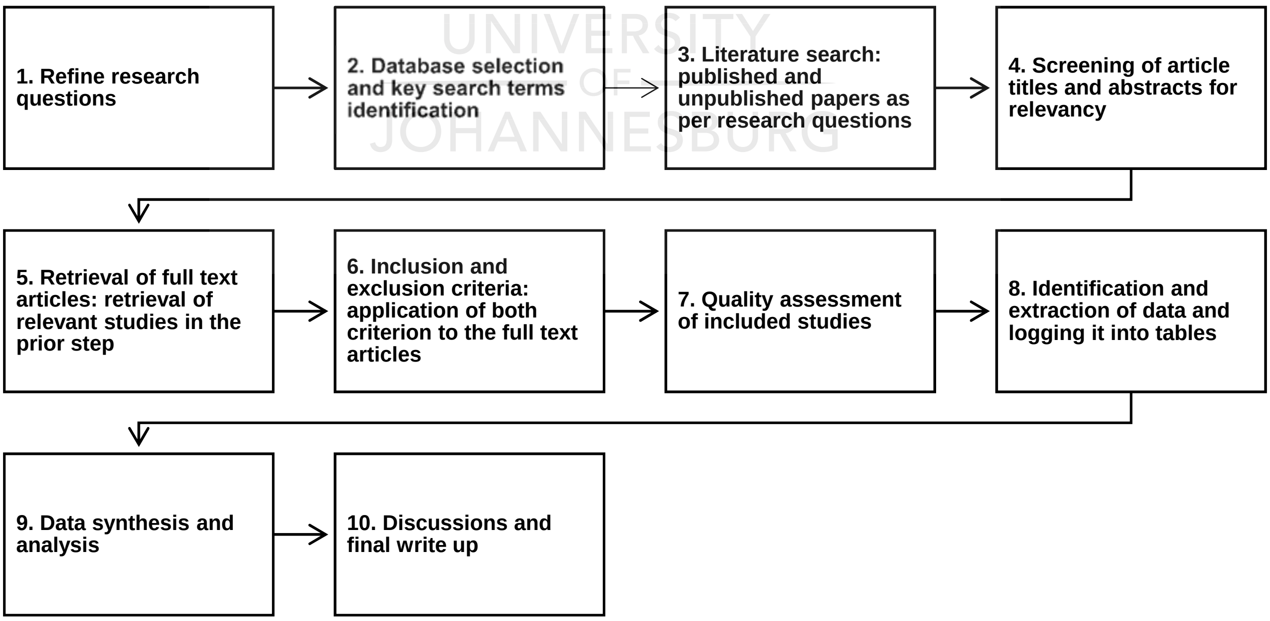

Figure 3.1 Systematic literature review steps (Boland, Cherry and Dickson, 2014)

3.5.1 Database selection

It is essential for the databases to be rationalised and described fully (Finfgeld-Connett and Johnson, 2013). The databases from the University of Johannesburg was used. Relevant and credible data was located and selected for analysis. The University of Johannesburg database is broad with a wide range of journals, conference articles and news sources, with international standards publications. Some articles were published in *American society of Civil Engineers* (ASCE), IEEE, Science direct, Springer and Knovel.

3.5.2 Key search terms

The search terms used in article selection were derived from the research questions. From the research questions

- What are the risk management techniques used in seaport and harbour construction and expansion projects?
- What are the challenges and limitations faced during implementation of these risk management techniques?

The following key search terms were generated: risk management techniques, infrastructure construction projects, port expansion/ construction projects, infrastructure risk mitigation strategies, risk management implementation challenges. Key term generation was developed using synonyms searched from the online English dictionary Thesaurus. The following Table 3.1 shows the keywords. To limit the results and retrieve relevant articles, the Boolean operatives AND, OR, NOR, NOT were used with the key terms

Table 3.1 Key search terms

Key search terms		
• Risk management	• Risk management techniques	• Risk management strategies
• Risk management implementation challenges	• Port expansion/ construction projects	
• Infrastructure construction projects	• Delayed and over budget port construction projects	

3.5.3 Literature search strategy

Systematic reviews need to maintain a total transparency during literature search, as this gives more credibility to the method (Finfgeld-Connett and Johnson, 2013). Article selection is essential because it dictates the scope and validity of the systematic review's conclusions (Meline, 2006). Search strategy can either be exhaustive or expansive. Exhaustive approach involves an integrative combination of existing literature to produce findings that are more generalizable. In contrast, the expansive search is suitable for studies involving emergent ideas with search criteria that evolve along with the progression of ideas (Finfgeld-Connett and Johnson, 2013). Exhaustive approach was used and the articles were screened using the key search terms. At this stage, only titles and abstracts were considered and relevant articles were retrieved for further assessment.

3.5.4 Inclusion criteria

Inclusion criteria are conditions, requirements or characteristics that a prospective study must have to be considered relevant. If the inclusion criteria are too broad, poor quality studies are included leading to low confidence in the conclusion and the result of the study. If the criteria are highly rigorous, few articles are included and the results may not be generalizable from too small a sample (Meline, 2006). Both published and relevant unpublished articles were evaluated to avoid bias as well as optimally retrieve as much relevant data as possible.

The following criteria were developed:

- Articles on risk management techniques in infrastructure projects in brownfield and greenfield projects.
- Articles on project lifecycle in seaport construction and expansion projects.
- Articles on risks faced in seaport construction and expansion projects.
- Articles focusing on delayed, over-budget or failed seaport construction and expansion projects.
- Studies from any geographical location.
- General Infrastructural projects with a minimum budget of US$500 Million.

3.5.5 Exclusion criteria

Exclusion criteria are conditions, requirements or characteristics that disqualify irrelevant studies from the selection of articles. Articles on large infrastructure projects were considered. A large infrastructure project is defined as a large-scale investment project concept that typically costs more than US$ 520 million (Kardes, Ozturk, Cavusgil and Cavusgil, 2013; Dunović, 2015). Another definition of a megaproject is any project with a budget exceeding US$1 billion US dollars (Zidane, Johansen and Ekambaram, 2013). This study considered a minimum budget of US$0.5 billion. The exclusion criteria are as follows:

- Articles on risk management in infrastructure projects with a budget less than US$ 0.5 Billion.
- Articles on non-infrastructural projects, despite their budget being above the US$0.5 Billion.

3.6 Literature search termination

There was termination of literature search when no more new information pertaining to the research questions was found.

3.7 Chapter summary

A systematic literature review methodology was discussed. It is a qualitative and exploratory analysis of textual data. It relays a holistic and overview picture of previous studies on a common topic. The steps taken were outlined. The steps included search strategy, defining of the inclusion and exclusion criteria and search terms generation. The benefits and disadvantages of the study were explained. The next chapter proceeds with the data extraction.

Chapter 4: Data Extraction

Data extraction is done to gather the relevant information relating to the research questions. It is a crucial process that requires rigour since the information gathered affects and determines the overall results and conclusions. Articles were selected using key search terms and Boolean operators. The titles and abstracts were assessed. Eligible articles selected during this stage were subject to the inclusion and exclusion criteria. The inclusion criteria were:

- Articles on risk management techniques in infrastructure projects in brownfield and greenfield projects.
- Articles on project lifecycle in seaport construction and expansion projects.
- Articles on risks faced in seaport construction and expansion projects.
- Articles focusing on delayed, over-budget or failed seaport construction and expansion projects.
- Studies from any geographical location.
- General Infrastructural projects with a minimum budget of US$500 Million.

The exclusion criteria were:

- Articles on risk management in infrastructure projects with a budget less than US$ 0.5 Billion.
- Articles on non-infrastructural projects, despite their budget being above the US$0.5 Billion.

After application of the criteria, articles were further narrowed down. At least seventy articles were selected and twenty two of these were identified and used for extracting actual details on risk management techniques and challenges in seaport and infrastructure projects. Figure 4.1shows the steps taken: final article selection, data extraction and analysis.

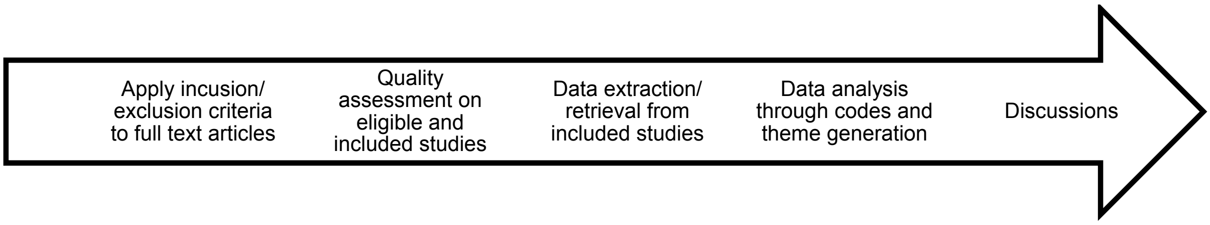

Figure 4.1 Summary of data selection, extraction, and analysis process

The following Table 4.1 below represents a summary of articles obtained during each stage of the screening process:

Table 4.1 Summary of article statistics during each screening stage

	Number of articles
Database search using defined key search terms	214
After de-duplication of studies	159
After full screening of titles	121
After full screening of abstracts	92
Application of inclusion criteria to full-text articles and selecting those to be used for the study.	70
Articles used	70
*Articles used for detailed risk management techniques and implementation challenges.	*22

*These articles are included in the total number of articles.

4.1 Quality assessment

Articles underwent quality assessment to determine their validity and relevancy. The quality of the articles was assessed based on the type of study design used, its relevance to the research questions and whether the results and conclusion are reliable and valid. Each study's quality was assessed under the following categories:

- The type of study design used.
- Clarity in the research questions.

- Clarity in data collection procedures.
- Clarity in data synthesis.
- How conclusions were supported by the presented data.

Table 4.2, represents the results quality assessment done on the studies. Each study was assessed under each of the categories. The quality was rated as either Yes, No, partially defined or Not applicable.

✓ - yes, well defined.

✗ - No, not well defined.

P - partially defined.

n/a – Not applicable

Table 4.2 Quality assessment of the selected articles

Author	Title	Study type	Defined Study design	Defined Research questions	Adequate Data collection	Adequate Data synthesis	Clear Results	Do conclusions accurately reflect evidence presented by data
(CH2M HILL, 2014)	Anchorage port Modernization Project Concept: A cost and schedule risk analysis	Case study: Empirical field research	✓	✓	✓	✓	✓	✓
(Gajendran and Ganesh, 2016)	Regression modelling of risk factors and its Impact on progress of activities in infrastructure projects	Quantitative analysis: Empirical study	✓	✓	✓	✓	×	P
(Wang et al., 2016)	A major infrastructure risk-assessment framework: Application	Systematic review	✓	✓	✓	✓	✓	✓
(Marowa, 2015)	Risk assessment in infrastructural projects	Case study	×	✓	✓	×	P	P
(Irimia-Diéguez, Sanchez-Cazorla and Alfalla-Luque, 2014)	Risk Management in Megaprojects	Systematic review	✓	✓	✓	✓	✓	✓
(Renuka, Umarani and Kamal, 2014)	A Review on Critical Risk Factors in the Life Cycle of Construction Projects	Systematic review	×	✓	P	×	P	P
(Van Staveren, 2014)	Innovative Ways to Implement Risk Management in Infrastructure Projects	Mixed methods	P	✓	×	×	P	P

Author	Title	Study type	Defined Study design	Defined Research questions	Adequate Data collection	Adequate Data synthesis	Clear Results	Do conclusions accurately reflect evidence presented by data
(Port of Townsville Limited, 2013)	Port Expansion	Field research	n/a	✓	×	×	P	P
(Chhibber, 2005)	Project Performance Assessment Report: Tanzania port modernisation	Field research	n/a	✓	×	×	✓	P
(Guo et al., 2014)	Effects of project governance structures on the management of risks in major infrastructure projects: A comparative analysis	Two case study	✓	✓	✓	✓	✓	✓
(Zhang and Fan, 2014)	An optimisation method for selecting project risk response strategies	Qualitative	P	✓	P	✓	✓	P
(Park, Gardoni and Biscontin, 2010)	Dynamic Risk Management System for Large Project Construction in China	Systematic review	✓	P	P	P	✓	P
(Batson, 2009)	Project risk identification methods for construction planning and execution	Systematic review	P	✓	P	P	✓	P
(Schaufelberger, 2005)	Risk management on build-operate-transfer projects	Systematic review	P	✓	P	P	✓	P
(The World Bank, 1995)	Implementation completion and results report: Madagascar for a ports rehabilitation project	Field research/ Empirical study	n/a	✓	×	×	✓	P

Author	Title	Study type	Defined Study design	Defined Research questions	Adequate Data collection	Adequate Data synthesis	Clear Results	Do conclusions accurately reflect evidence presented by data
(Al-Bahar and Crandrall, 1991)	Systematic risk management approach for construction Projects	Mixed methods	×	✓	×	×	P	P
(Heider, 2012)	Project performance assessment report Mozambique railways and ports restructuring project	Field research/ Empirical study	n/a	✓	×	×	✓	P
(The World Bank, 1983)	Project completion report: Ecuador: second Guayaquil port project	Field research/ Empirical study	n/a	✓	×	×	✓	P

4.2 Data extraction: Risk management techniques

After the quality assessment, information was gathered from each of the selected articles. The first research question is:

- What are the risk management techniques used in seaport and harbour construction and expansion projects?

Risk management techniques were identified. Methods of identification, assessment and treatment were recorded. Table 4.3 represents the information gathered. Some articles reported on the types and sources of risks in both general infrastructure and seaport projects.

4.3 Data extraction: Risk management implementation challenges

The second research question is:

- What are the challenges and limitations faced during implementation of these risk management techniques?

The challenges faced during implementation of risk management in projects were identified and logged in Table 4.4. Some risks and their sources were also identified and recorded.

Table 4.3 Data extraction: risk management techniques

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
(CH2M HILL, 2014)	Anchorage Port Modernization Project Concept: A Cost and Schedule Risk Analysis	University of Alaska Anchorage College of Business and Public Policy Dept. of Logistics and Port of Anchorage, Municipality of Anchorage, CH2MHILL	Alaska USA	Case study/ Empirical study	N/A	• Risk identification using Formal project delivery team meetings. The team included project team from disciplines such as project and program managers in the environmental, civil, structural, geotechnical, and hydraulic design, Cost and schedule, project sponsors. Informal meetings were held, as needed, throughout the risk analysis process to further facilitate risk factor identification, market analysis, and risk assessment. Use of professional judgment from the project delivery team and empirical data from similar projects was • The risk analysis through Monte Carlo technique to determine probabilities and contingency. • Use of Oracle crystal ball software. • Use of checklists or historical databases of common risk factors • Risk factor impacts were quantified using probability distributions, as risk factors were entered on to the Crystal Ball software in the form of probability density functions • The quantifying risk factor impacts included: maximum and minimum possible value for the risk factor, statistical most likely value • nature of the probability density function was used for estimating risk factor uncertainty • Mathematical correlations between risk factors affected cost estimate and schedule elements
(Gajendran and Ganesh, 2016)	Regression Modelling of Risk Factors and its Impact on Progress of Activities in Infrastructure Projects	International Research Journal of Engineering and Technology (IRJET)	India	Quantitative/ Empirical study	• Unforeseen site conditions, poor projects. • inexperienced or incompetent estimating project team members • Sometimes there is work overload caused by taking on too many contracts at the same time, • shortage of skilled labour	N/A
(Wang, Wang, Zhang, Huang and Li, 2016)	A major infrastructure risk-assessment	Elsevier Science Direct	China	Systematic Literature Review	• Environmental risks • Implementation risks	Major infrastructure risk assessment framework (MIRAF) based on an adapted Analytic Hierarchy Process (AHP) risk assessment model with use of

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
	framework: Application to a cross-sea route project in China				• decision-making risks related to strategy	• Fuzzy analytical hierarchy process • Evidential reasoning approach • Fuzzy set theory • Expected utility • Fault tree analysis, decision tree analysis
(Marowa, 2015)	Risk assessment in infrastructural projects	International Association for Management of Technology IAMOT 2015 Conference Proceedings	South Africa	Case study mixed method approach	Risks classified as • Human: skills set • Technological: likelihood of technology failure and unreliability • Organisational: Caused by different stakeholders with different perceptions of risk	• Risk identification through brainstorming sessions and use of experts. • Risks, their causes and impacts are then documented • Risks occurrence probability and impact assessed, as well as impact on project's period, risk tolerance • Risks prioritised as per probability and impact matrix
(Irimia-Diéguez, Sanchez-Cazorla and Alfalla-Luque, 2014)	Risk Management in Megaprojects	Elsevier Science Direct	Worldwide	Systematic literature review	• Cost risk, • Demand risk, • Financial market risk, • Political risk, • Construction risk, • Operation and maintenance risk, • Legal and contractual risk, • Income and financial risk	• Risk identification • Evaluation and quantification • Risk classified according to affordability • Affordable risks allocated to project team and funders • Unaffordable risks are distributed as per contract
(Renuka, Umarani and Kamal, 2014)	A Review on Critical Risk Factors in the Life Cycle of Construction Projects	Journal of Civil Engineering Research	India, UK, US, Australia, China, Hong Kong, Korea, Turkey, Mexico, Malaysia, Thailand	Systematic literature review	• Legal risk • Technical and non-technical	•Combined fuzzy Failure mode and effect analysis (FMEA) and Fuzzy AHP •analytical hierarchy process and decision tree analysis •Project Evaluation and review technique (PERT) •Probability and Impact (P&I), •Monte-Carlo simulation (MCS) •Likelihood occurrence of risk (LR),
(Van Staveren, 2014)	Innovative Ways to Implement Risk Management in Infrastructure Projects	•American Society of Civil Engineers •Proceedings of the Second International Conference on Vulnerability and Risk Analysis and Management (ICVRAM) • The Sixth International Symposium on	Netherlands	Not specified	N/A	An innovative risk management implementation approach, with the following four steps: • A three-dimensional conceptual model for risk management implementation: Highlights the interdependency between risk management approach, project organisation i.e. structure, culture etc. and risk management users • A process model for risk management implementation design: Risk implementation should be considered a project with well-planned organisational

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
		Uncertainty Modeling and Analysis (ISUMA)				design and change. Implementation steps should be awareness, decision making, execution and learning • An assessment instrument for judging the presence of key conditions: • shared and uniform risk management understanding • Interdisciplinary risk management application. • Risk management that is formally embedded in working procedures. Formal risk management cooperation with external parties • Selection of purposeful actions required for the effective implementation process. Such actions as motivation for all risk users within the organisation through, for example participation in RM task force learning by peer group evaluation
(Port of Townsville Limited, 2013)	Port Expansion Project EIS Appendix U3 Risk Management Process and Criteria	AECOM Civil Engineering Company	Australia	Empirical study	N/A	Risk management technique followed: • Context establishment • Risk assessment of all risks associated with design, build operations and decommissioning of the project. • Risk identification: input from stakeholders and data from prior work • Risks analysis: quantitative and qualitative. Use of a consequence analysis with consequence rating against the following categories: Health and Safety, Environmental, Community or Reputation, Asset loss and Schedule Impact. Also, uses probability analysis, risk matrix • Risk evaluation • Treat Risks •Continuous processes throughout the stages were: Communication and consultation as well as monitoring and review
(Chhibber, 2005)	Project Performance Assessment Report: Tanzania port modernisation	The World Bank	Tanzania	Empirical study	• Project delayed due to government privatising state-owned enterprises, and the project had to be restructured. • Project components were constantly altered due to lack of preparation	N/A

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
(Guo, Chang-Richards and Wilkinson, 2014)	Effects of project governance structures on the management of risks in major infrastructure projects: A comparative analysis	Elsevier Science Direct International Journal of Project Management	China	Case study	• delays and budget overruns due to unique site conditions • delays caused by hidden transaction costs • disputes among the project parties	Elements of risk management in infrastructure projects: ●incorporating stakeholders' relational risks into a project governance structure ●safety ●Environmental conservation ●Investment viability ●Schedule Life-cycle risk management was used, through risk model software, Active Risk Manager (ARM). ARM provides a systematic picture of the whole project Benefits: greater visibility, better risk communication, control and monitoring of risk information within the organisation.
(Park, Gardoni and Biscontin, 2010)	Dynamic Risk Management System for Large Project Construction in China	American Society of Civil Engineers GeoFlorida 2010: Advances in Analysis, Modelling & Design	China	Systematic literature review	N/A	**The dynamic risk management system** is composed of six parts: • Event database, risk database, risk identification, risk assessment, risk pre-control, risk tracking • Dynamic risk management system improves and modifies results from pre-assessment, along with alteration of engineering construction, peripheral environment, dynamic monitoring of identified risk • Events and risk sources arranged at any time to meet the target of risk • Management for the whole lifecycle in order to reduce the risk value to lower levels Benefits: it clearly develops trends of each risk event
(Batson, 2009)	Project risk identification methods for construction planning and execution	American Society of Civil Engineers Construction Research Congress 2009	N/A	Systematic literature review	N/A	●Front-end planning of risk management ●During project execution phase: earned value analysis is the best method to identify emerging risks from readily available project databases ●project participants must discuss risks, quantify severity, determine causes, and decide on necessary risk management actions.
(Schaufelberger, 2005) Accessed 28/10/2016	Risk management on build-operate-transfer projects	American Society of Civil Engineers Construction Research Congress 2005	Asia	Systematic literature review on total of seven case study	• General risks: political environment, economic condition, the legal system, taxation, or fluctuations in currency exchange rate. • Project-specific risks: defects in the request for proposal;	• Purchase political risk insurance policies • Use lump-sum contracts for construction • Obtain standby credit as contingency • Obtain assistance in obtaining permits and approvals • Provision for shortfall financing should there be project revenue falling below target values • Provision of early completion bonus

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
					planning and approval delays; errors in economic and or technological assessment, the risk of losing the tender to another proposing sponsor delays in completion time and cost overruns • Revenue risk	
(The World Bank, 1995)	Implementation completion and results report: Madagascar for a ports rehabilitation project	The World Bank	Madagascar	Empirical Study	•Damage caused by cyclones to port infrastructure •Lack of competencies from project team •Inadequacy of preliminary studies for the dredging component •Devaluation of the Malagasy Franc •Political events creating gaps in decision-making •Weakness in project monitoring leading to difficulty in project management and follow-up • Only 50% of dredging objectives were met due to change of enterprise and slow bidding process • There were technical difficulties which were missed during project appraisal	N/A
(Al-Bahar and Crandrall, 1991)	Systematic risk management approach for construction Projects	American Society of Civil Engineers		Not specified	N/A	Quantitative Risk management model: Construction risk management system (CRMS). Risks analysed and evaluated prior to project implementation, using • influence diagramming technique • Monte Carlo simulation. • Risk identification: done systematically and continuously in the following manner: Uncertainty assessment, preliminary checklist compilation, risk events consequence scenarios, risk mapping, risk categories compilation

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
						Risk analysis and evaluation: conducted in order of data collection, • Modelling of uncertainty, assessment of probability distribution and potential consequences, evaluation of risk potential and risk impact • Response management through risk avoidance. loss reduction and risk prevention, risk retention, risk transfer • System administration: formulation of Corporate risk management policy
(The World Bank, 1983)	Project completion report: Ecuador: second Guayaquil port project	The World Bank	Ecuador	Empirical study	• Actual project cost was about 12% greater than appraisal estimates due mainly to design changes • Design of the dredging slope was not suitable to the adverse soil conditions which caused disputes amongst consultants, government procurement association, GPA and the bidder, this resulted in renegotiations and design changes • Increased construction costs of about US$13.4 million in addition to an eight-month delay.	N/A
(Zou, Wang and Fang, 2008)	A life-cycle risk management framework for PPP infrastructure projects	Emerald insight	Australia China	Theoretical research and literature Reviews plus case study methodologies	•Identified the following risks: financial, government's political and public's acceptance/ rejection risks, corruption risk, technology risks, management and health risks •Construction risk /income risk whereby project could not be finished on time or could not reach the prospective quality standard	•Optimal risk identification, assessment, allocation, and management from a life-cycle perspective risk management during feasibility, planning and execution. •Construction risk /income risk whereby project could not be finished on time or could not reach the prospective quality standard. Strategy 1: The project company transferred the completion risk to the construction contractor by delivering the project with design and build method Other strategies: Retain certain risks, purchase risk insurance, or try to mitigate those risks

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Risk management technique
(Zhang and Fan, 2014)	An optimisation method for selecting project risk response strategies	Elsevier Science Direct	China	Qualitative	N/A	Work breakdown structure as a risk management strategy: • Specify scope • Determine scope of each work activity on the project • Estimate effects of risk events on the work activities • Propose potential risk response strategies based on results of 3rd step • Estimate effects of strategies on work activities • Develop the risk model for each potential strategy • Opt for strategy with desired potential outcome, or else if step 7 results are unsatisfactory, repeat step 6 with possible trade-offs and changes

Table 4.4 Data extraction: Implementation challenges of risk management

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Implementation challenges
(The World Bank, 1999)	Implementation completion report: republic of Angola infrastructure rehabilitation engineering project	The World bank	Angola	Empirical study	• Project execution was difficult because of Civil war • Delayed project implementation and reforms • Delayed works and increased costs increased contributed to the long delays in overall work commencement resulting in partially outdated pre-defined technical specifications. • inadequate transfer of procurement knowledge and skills to the Project unit staff that was required to procure major project contracts	Factors Outside Government Control. ●Project implemented during a period of great economic and political conflicts. ●Constant uncertainty on several fronts which affected critical project decisions. ● Technical specifications prepared by the consultants during identification and definition of the scope of the rehabilitation were incomplete and not thoroughly done. ●There was NO continuous restructuring of Risk management along with project scope evaluation.
(Dunović, 2015)	Risk in the Front End of Megaprojects	European cooperation in Science and Technology University of Leeds	Multiple-- Europe	Case study methodology	N/A	• Lack of historical data on similar projects making it difficult to come up with sensible assumptions on the critical variables and probability distributions
(Marowa, 2015)	Risk assessment in infrastructural projects	International Association for Management of Technology IAMOT 2015 Conference Proceedings	South Africa	Case study mixed method approach. 45 questionnaires distributed amongst infrastructural project managers of Company A.	Risks classified as Human: skills set Technological: likelihood of technology failure or unreliability Organisational: Caused by different stakeholders with different perceptions of organisational risk	●Projects were delayed because of imprecise scope ● 60 % of project managers experienced difficulties in adapting to change caused by project's change of scope and or budget ●Company A had poor change management systems in place ● Company A, had inadequate skills set
(Heider, 2012)	Project performance assessment report Mozambique railways and ports restructuring project	The World Bank	Mozambique	Empirical study	●Initial implementation was slow, partly due to the complex and evolving nature of issues underlying the Ports and Railways of Mozambique Portos e Caminhos de Ferro de Moçambique (CFM) restructuring the program ●Total project cost was US$130.7 million, which was higher than the	

Author, Year	Title	Publications	Country	Study design/ methodology and Data analysis used	Risks identified	Implementation challenges
					original US$120 million estimated at appraisal ● The project period was extended four times by a total of four years, there were changes in project scope, but not in its objectives: causes of delay were failure of the private parties to achieve financial closure, breakdown in the internal structure of consortiums when the major partner and key player in the region pulled out from the consortium, discrepancies of opinion regarding contractual clauses and government handling of these delayed the takeover. Direct political interference in the functioning of the Port sector limited the authority and effectiveness of its management	N/A
(The World Bank, 2009)	Implementation completion and results report to the state of Eritrea for a ports rehabilitation project	The World Bank	Eritrea	Empirical study	War between Eritrea and Ethiopia two months after project effectiveness delayed the project implementation by two years Slow project progress due to staff shortage	• Original task team not qualified for adequate risk management • Evidence of insufficient efforts by project team to make alternatively hire consultants after failing to get at least key persons for after the end of the war to resume the work at Massawa port • Inadequate Bank management inputs in the context of the severity of problems facing the project

4.4 Chapter summary

Data extraction on the selected articles on risk management techniques implementation challenges was presented. Key information retrieved included identification, assessment, or treatment tools. The types of risks were also identified and recorded. Quality assessment was conducted on the articles and the results presented in Table 4.2. Although fewer than 50% of the articles focused on the targeted seaport and harbour construction projects, the quality assessment indicated good relevancy and sufficient information was gathered. The types of risks in seaport projects were identified and presented in Table 4.3 and Table 4.4. These risks are summarised and presented Table 4.5. Political disputes, war breakouts and economic changes were reported. War affected projects in Angola and Eritrea. Policy changes affected project schedules in Tanzania. Madagascar's project was affected by extreme weather conditions. Ecuador's project was 12% over budget due to conflicts between stakeholders. The next chapter shows analysis and discussions of the information.

Table 4.5 Risks identified in seaports and harbour projects

Country	Risks identified	Risk plan implementation challenges
Angola	Civil war break out Delayed works leading to outdated technical specifications	Political and economic conflicts Poor knowledge and skills transfer
Mozambique	Project cost overrun by US$ 10.7 million. Project delayed by 4 years due to change in project scope, failure of private parties to achieve financial closure. Discrepancies of opinion regarding contractual clauses. Government intervention	complexity presented by restructuring of railways and ports program
Eritrea	The war between Eretria and Ethiopia delayed the project by 2 years. Slow project progress due to staff shortages.	
Tanzania	Project delayed due to government privatising state-owned enterprises, which required restructuring of the project. Project components were constantly altered due to lack of preparation	
Madagascar	Weather risks cyclone damaged infrastructure, a setback for the project. Lack of competency from the project team. Inadequate preliminary studies for the dredging component. Economic instabilities. Political events delaying decision-making. Inadequate project monitoring which leads to difficult project follow-up and management. Slow bidding process	
Ecuador	The project was 12% over budget. Dredging design unsuitable for the adverse soil conditions. Disputes amongst consultants, government and procurement association, which led to renegotiations and redesign. Construction costs increased by US$13.4 million. Project delayed by 8 months.	

Chapter 5: Analysis of Findings and Discussion

Risk management techniques used in infrastructure and seaport projects were identified and presented in the previous chapter. The eligible studies ranged between the years 1983 and 2016. The studies reported on seaport projects in Alaska, Madagascar, Eretria, Ethiopia, Mozambique, Namibia, and Angola. Statistics on the articles employed was assessed. Article statistics, techniques, and challenges are presented in the following sections.

5.1 Statistics on articles used and the type of studies employed

These statistics give an overall impression and transparency of the literature sources used. 21% of the articles were published in Elsevier Science direct, followed closely by company publications with 15%. Included in the company publications were Price water house Coopers (PWC), Deloitte, Transnet, CH2M HILL, Marsh and McLennan, The World Bank and McKinsey and company. 10% of the articles were compiled under the category 'other'. Included were the Association of Researchers in Construction Management in Australia, International Association for Management of Technology, IAMOT in Cape Town, Journal of Business Chemistry, Walter de Gruyter in Germany and Asia-Pacific Journal of Operational Research. The World Bank and American Society of Civil Engineer each contributed almost 9% of the total seventy articles. This information is represented in Figure 5.1.

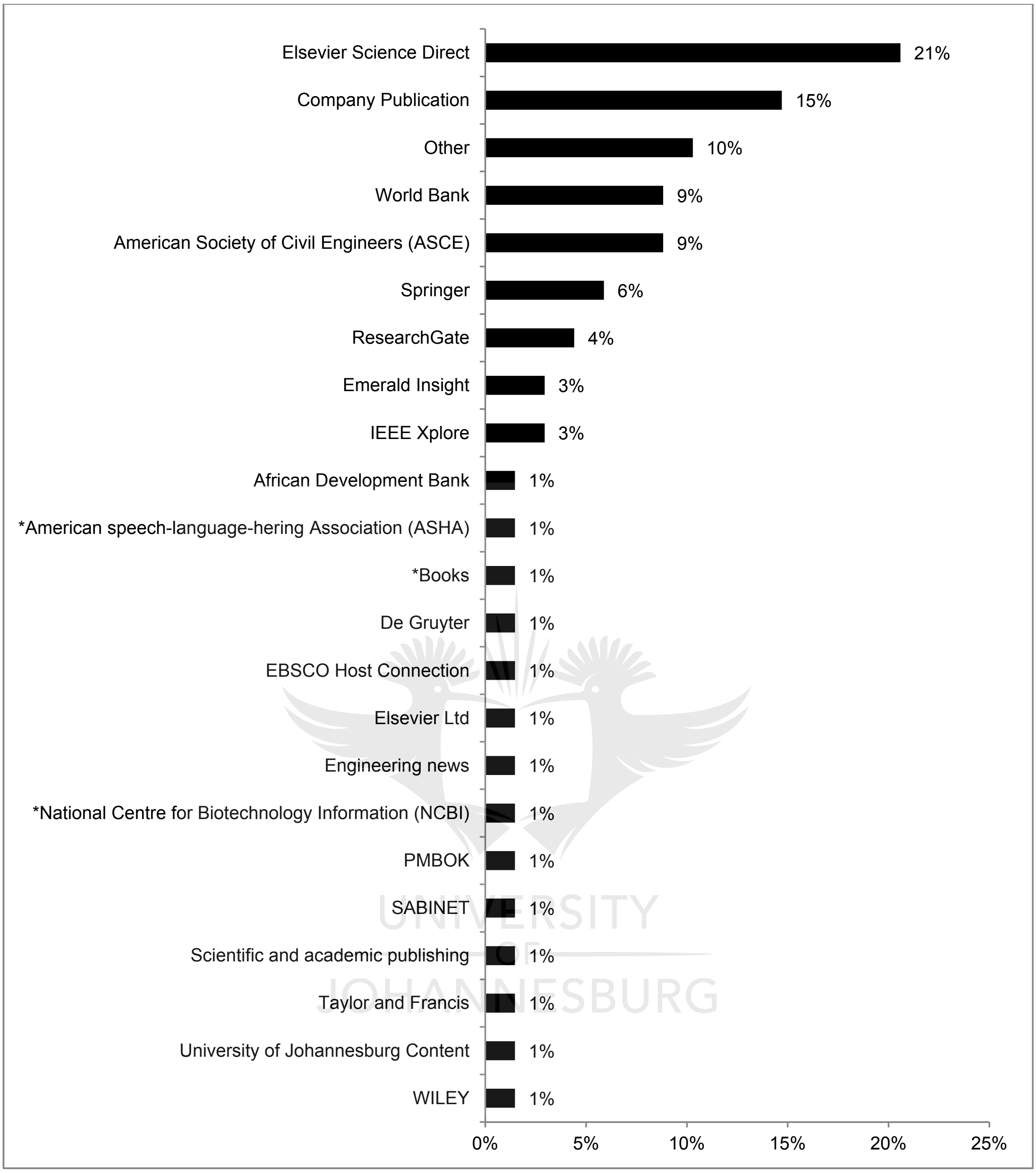

Figure 5.1 Article distribution per database/ source

*Literature review source.

5.2 Data analysis

Qualitative data analysis is diverse and complex. The analysis is often conducted in different ways depending on the type of data collected. Textual data was gathered systematically and presented in chapter four. The methods used for analysing qualitative and textual data are framework analysis, thematic and meta-ethnography (Gough, 2015). These methods are explained in the following paragraph:

> Framework analysis is a method that uses the research aims, interests and objectives to develop a predetermined framework. This method is explicit and sometimes developed as the research progresses. Meta-ethnography involves theoretical assumptions which frame the research analysis. It is often employed in studies with many theoretical data. Thematic analysis is exploratory and conducted inductively as the research progresses. It is characterised by limited presumptions made about the concepts to be configured (Gough, 2015).

Thematic analysis is a foundational method in analysis and it enables a flexible approach to data analysis (Braun and Clarke, 2006). No theoretical assumptions were made in the beginning of the study and risk management techniques and challenges were identified as reported by previous studies. No framework was predetermined as this study aimed to report on the findings of previous studies. This study adapted the thematic analysis method.

Thematic analysis involves identifying common themes within the data collected (Braun and Clarke, 2006; Thomas and Harden, 2006; Gough, 2015). It is referred to as a flexible approach to analysing data (Braun and Clarke, 2006). With this flexibility, this method was adopted in analysing this research's information. Inductive thematic analysis means that the themes developed are strongly related to the data collected, as opposed to fitting the data into a predetermined analysis framework. The following section further describes thematic analysis.

5.3 Thematic analysis steps

According to the Economic and social research council, thematic analysis follows three steps: (Thomas and Harden, 2006)

- Text and code identification. Textual data is assessed and codes are developed. The codes are a single phrase or symbols representing data with common meanings.
- Themes development. Themes are developed by grouping the above codes into common categories. These categories are assessed to identify similarities and commonalities.
- Generating themes. Thematic names are then given to the categories or themes developed in the above step.

Braun and Clarke (2006), expanded on the above steps and emphasised the importance of data familiarisation. This initial step is necessary for the researcher to generate initial category ideas. These initial categories are called codes (Braun and Clarke, 2006). Data coding can also be explained as a development of phrases or single words that descriptively represent material with common elements (Gough, 2015). The second step was selecting and populating data under the codes. The codes are then merged into themes as reported above by Thomas and Harden (2006). Thirdly, the themes are reviewed, assessed and named then a final report compilation is done (Braun and Clarke, 2006).

5.4 Code generation

Codes are developed from forming categories based on the shared elements within the data. Themes are formed from all the codes generated according to shared commonalities. Codes and themes are often merged or divided as the synthesis process progresses. All techniques were grouped according to the risk management process which involves identification, assessment, and treatment. Risk identification is the act of identifying possible risks within the project. Risk assessment is done to predict the consequence of the risks, either quantitatively or qualitatively. Risk treatment is done to minimise the impact of risk on the project. The three categories or codes used were:

Risk identification, RI.

Risk assessment, RA.

Risk treatment, RT.

Data was assessed and populated under each of the codes. The techniques had numerous data elements and eighteen articles were used in addressing the first research question which is, what are the risk management techniques used in seaports and harbour expansion projects. Risk management implementation challenges required no coding or theme development. This was because the second research question, what are the challenges faced in implementing risk management, was addressed by fewer articles thus coding of this data was unnecessary. Table 5.2, shows the risk management techniques methods gathered from Table 4.2 These methods were categorised into the three codes RI, RA and RT.

5.5 Theme development

Themes were developed from the data under the codes in Table 5.2. Looking at the data under each code group, methods were grouped according to similarities. The methods were either qualitative or quantitative. The themes developed under each code or category are explained in the following sections.

Table 5.1 Risk management techniques- categories and code generation

RI	RA	RT
• Brainstorming • Facilitated risk assessment meetings • Historical databases • Clear context and scope establishment according to project lifecycle • Earned value analysis method • Uncertainty assessmnet, preliminary checklist compilation, • Events consequency scenerios, risk mapping, risk categorisation • Monte carlo Analytical hierachy process • Fuzzy analytical hierarchy process • Combined failure mode and effect analysis FMEA and fuzzy AHP • evidential reasoning approach • Fuzzy set theory	• Monte carlo • historical databases of common risk factors • Risk register information collecting for use in Oracle crystal ball risk software • Analytical hierachy process • Fuzzy analytical hierarchy process • Combined failure mode and effect analysis FMEA and fuzzy AHP • evidential reasoning approach • Fuzzy set theory • Determination of risk probability, probability density funcion, impact • Decision tree analysis • Project evaluation and review technique • Likelihood of risk occurence (LR) • Consequency analysis tool comparing consequency rate in health and saftey, environmental reputation, asset loss, schedule impact • Influence diagramming technique • Use of objective statistical data and subjective proffessional judgement data • Modelling of uncertainty	• Risk managed through distributing them according to project contract between contractor and owner • Three dimensional conceptual model outlining clear interdependency between risk management approach and the organisational structure, culture and risk management users • Risk magement implementation to be considered as a project • Implementation steps were awareness, decision making, execution and learning. • Risk management to be embedded in working procedures • Constant communication and consultation thought risk management steps • Continuous monitoring and review • Use of active risk manager • Dynamic risk management system event database- risk database- risk identification- risk assessment- pre-control of risk- risk monitoring • Risks and events rearranged at any stage of project lifecycle to meet risk mitigation objectives • Front end risk management • Purchase political risk insurance • Obtain standby credit for contingency • Obtain relevant assistance in obtaing permits, approvals, and clearance • Risk avoidance • Risk prevention and loss reduction, risk retention and or transfer • formulation of corperate risk management policy • Use of work break down structure

.

5.5.1 Risk Identification themes

The following themes were developed based on Table 5.2. The themes developed were earned value analysis, influencing diagramming technique, brainstorming, historical databases and some quantitative tools. With these themes, article statistics was done to represent the percentage number of articles that reported on the same risk identification method. This is represented in Table 5.3 and Figure 5.3

Table 5.2 Risk identification methods

Reference	Risk identification technique	Article Frequency	% Articles
(Batson, 2009)	Earned value analysis	1	4.35%
(Al-Bahar and Crandrall, 1991)	Influencing diagramming technique	1	4.35%
(Marowa, 2015)(Port of Townsville Limited, 2013)	Brainstorming, experts and project delivery team input	2	8.70%
(Marowa, 2015)(Al-Bahar and Crandrall, 1991)(CH2M HILL, 2014)(Port of Townsville Limited, 2013)(Park, Gardoni and Biscontin, 2010)(Batson, 2009)	Checklist, historical databases	6	26.09%
(Al-Bahar and Crandrall, 1991; Port of Townsville Limited, 2013; CH2M HILL, 2014; Renuka, Umarani and Kamal, 2014; Marowa, 2015) (Wang *et al.*, 2016)(Renuka, Umarani and Kamal, 2014)	Quantitative tools*	8	34.78%

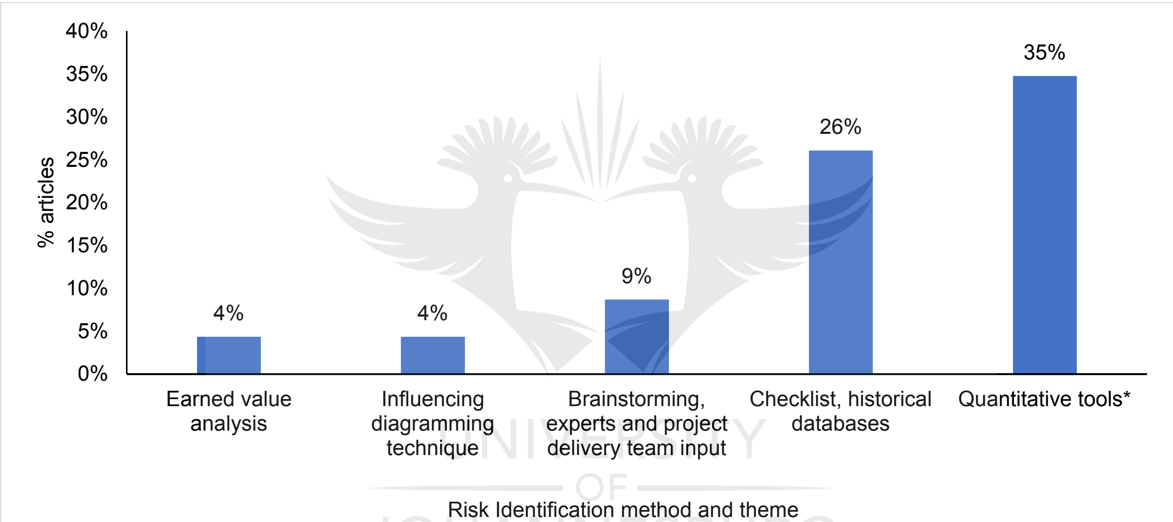

Figure 5.2 Risk identification methods

The quantitative tools include Monte Carlo, AHP, fuzzy set theory, evidential reasoning approach, Fault tree analysis, decision tree analysis, FMEA, Likelihood of occurrence of risk. The most common identification methods constituting 34.78% were numerical tools, which are AHP, fuzzy set theory, probability density functions, and Monte Carlo simulations, and decision tree analysis. 26.09% of the articles reported that checklist and historical databases served as starting points and were the second most frequent methods used. As part of the risk strategy, identification was reported to be a continuous review along with a restructuring of the risk plan in order to minimise risks as they emerged.

5.5.2 Risk assessment themes

Risk assessment themes developed were: consequence analysis, *project evaluation and review technique* (PERT), software, historical databases, brainstorming, quantitative methods. Table 5.5 And Figure 5.4 illustrates the percentage number of articles that reported on these themes.

Table 5.3 Risk assessment methods

References	**Risk assessment**	**Article Frequency**	**% Articles**
(Renuka, Umarani and Kamal, 2014)	PERT	1	4.55%
(Al-Bahar and Crandrall, 1991; Port of Townsville Limited, 2013)	Consequence analysis	2	9.09%
(Port of Townsville Limited, 2013; Guo, Chang-Richards and Wilkinson, 2014)	Software Oracle crystal ball, Active risk manager	2	9.09%
See Table 4.5	Historical databases	5	22.73%
(Pretorius, Steyn and Jordaan, 2012)	Quantitative tools	6	27.27%
(The World Bank, 1995; Zou, Wang and Fang, 2008; Guo, 2009; CH2M HILL, 2014; PWC, 2014; Marowa, 2015)	Brainstorming, expert input	6	27.27%

Quantitative tools include Monte Carlo simulation, AHP, fuzzy set point theory, decision tree analysis, sensitivity analysis, probability and impact matrices. These quantitative methods were reported by 27.27% of the articles and an equal percentage of articles also reported on brainstorming. 22.73% articles stated that historical databases were consulted during risk assessment. 9% of articles mentioned overall use of risk management software for assessment such as Oracle crystal ball software. The software used information gathered through sensitivity analysis, risk register and a three-point estimate (CH2M HILL, 2014). Consequence analysis was cited by 9% of the articles and PERT was mention in 4.5% of the articles.

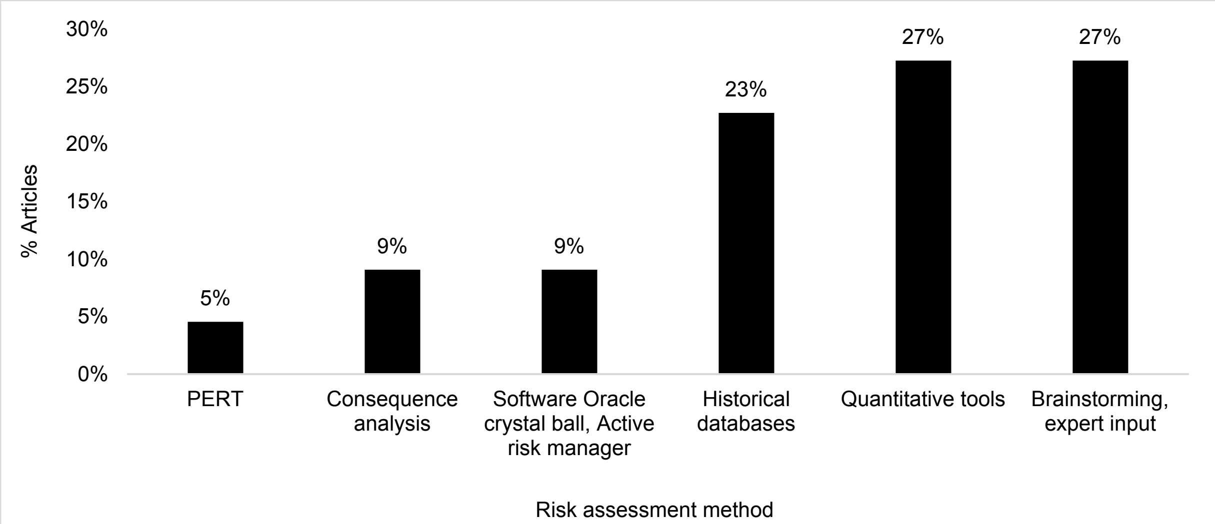

Figure 5.3 Risk assessment methods

5.5.3 Risk treatment

All the data represented by the risk treatment code was distinct hence themes were not necessarily developed. Instead, the data was represented in a table format. The risk treatment tools are summarised in Table 5.6. Risk control and monitoring was a continuous process throughout the project lifecycle, with constant communication and evaluation of all the risk management steps.

Table 5.4 Risk treatment methods

Risk treatment methods
• Risk distributed according to affordability and impact in line with the contract agreement
• Risk was linked to the organisational culture, risk was also incorporated into the project's operational procedures
• Risk was managed as a separate project. There were motivational sessions for the project delivery team
• Use of risk management software such as oracle crystal ball
• Purchase of political risk insurance and obtaining standby credit for contingency plans and plans were made to acquire assistance in prompt licensing and permit approvals
• Provision of early project completion bonus or incentives
• Formulation of risk management policy pertaining to the project
• Other methods: Risk avoidance, prevention plans, retention and transfer

Risks were said to be distributed according to the contract agreement. Sound risk management policy formulation was encouraged. Economic risks were managed through acquiring adequate contingency funds and purchasing insurance for political risks. Risk treatment was also done through avoidance, transfer, and acceptance.

5.6 Implementation challenges of risk management

The following Table 5.7 represents the challenges faced by risk management practitioners in implementing plans in projects. One of the main challenges faced was a constant change of project scope and manager's inability to adapt to the changes. This was said to be a result of lack of prior experience and inadequate change management systems. Lack of data from previous projects was also an obstacle faced by some managers. There was no restructuring of the risk management techniques along with scope changes. Poor change management systems hindered implementation of risk strategies, which led to negative project outcomes.

Table 5.5 Implementation challenges of risk management plans

Risk management implementation challenges
• Political and economic changes
• Uncertainty on stakeholders which affected decision making
• Lack of adequate historical data
• Incomplete technical specifications during project scope identification and definition
• No continuous restructuring of risk management along with project scope evaluation
• Project managers experienced difficulties in adapting to changed project scope
• Poor change management systems and inadequate skills set

5.7 Some of the identified risk management techniques in literature

The following Table 5.8 summarises the main risk management techniques identified in literature. They are techniques used in large infrastructure projects with a budget of at least US$500 million. These techniques can potentially be adapted in drafting risk management plans for port and harbour projects.

Table 5.6 Main risk management techniques in infrastructure projects

Technique	Author Year	Highlights
Construction risk management system (CRMS)	(Al-Bahar and Crandrall, 1991)	Uses influence diagramming technique
Enterprise risk management (ERM)	(Zhao, Hwang and Low, 2015)	Focuses on organisational structure and culture, adapted from project being implemented at an enterprise level. In addition to conventional risk management it adds Risk-aware culture and Training programs
Major infrastructure assessment framework (MIRAF)	(Wang, Wang, Zhang, Huang and Li, 2016)	Adapted to the AHP process with risks and impact listed and prioritised accordingly.
Dynamic risk management	(Park, Gardoni and Biscontin, 2010)	Risk management for the whole project life-cycle, easier to develop trends of each risk event, as project progress
Innovative risk management implementation approach	(Van Staveren, 2014)	Focuses on interdependencies between RM approach and organisational culture and structure. It is a clear-cut relation between Risk management and other managed disciplines within the project like safety, quality, finances, planning process.
Other techniques Use of Oracle crystal ball software Active risk manager (ARM) Software Work breakdown structure (WBS)	(Burcar Dunovic, Radujkovic and Vukomanovic, 2016) (Guo, Chang-Richards and Wilkinson, 2014),	Risk management software were used

5.8 Conclusion

Seaport and harbour projects present high complex yet profitable environment if executed successfully. Risk management lies at the heart of this success. Risk management techniques in infrastructure and seaport projects were reviewed. The types of risks faced in port developments were identified. These were found to be, political risks and lack of adequate skills to implement risk response plans, economic instabilities, environmental policies, scope changes and lack of supporting infrastructure. There were also reports of lack of preparation and funding which caused project delays.

The techniques identified revealed how each risk management technique is always tailor-designed for each type of project. Similar tools were common in each of the stages of the risk management process.

Risk identification, assessment and treatment tools were reviewed. Common tools were found to be brainstorming, expert consultation and use of historical risk databases. Quantitative risk analysis was conducted through Monte Carlo simulation, AHP, FMEA and a combination of both AHP and FMEA, fuzzy set point theory, decision tree analysis, evidential reasoning approach. Economic analysis used was earned value analysis. Risk treatment was done to minimise risk impact through avoidance, transfer, and acceptance. There was risk control and monitoring through communication and evaluation of the risk management steps during the whole project execution. Risk register and mapping facilitated the risk planning and management steps.

The first research question, (what are the risk management techniques applied in port and harbour expansion projects?), was partially answered. Some of the techniques identified were innovative risk management, the dynamic risk management technique, and major infrastructure risk assessment technique and construction risk management system. These techniques identified were applicable to large infrastructure projects with a budget of at least US$500 million. A limited number of articles were available which exclusively focused on techniques in port and harbour construction projects. However, this limited number of articles provided adequate information on types and sources of risk found within seaport construction project environment.

The second research question, (what are the challenges faced in implementation of risk management plans?), was answered. The selected articles reported on challenges faced in ports rehabilitation in countries like Eritrea, Ecuador, Angola, Mozambique and Madagascar. Political conflicts and project scope changes combined with inadequate knowledge and skills transfer contributed the most towards project delays and cost overruns. Risk plan implementation failure was caused by stakeholder and contract disputes which affected decision making, lack of adequate skills, poor project scoping and poor adaptation to scope changes. These results could be used in risk identification, assessment and treatment in future sea ports projects. Using the identified risks, project management can relook at possible strategies to combat political and social law changes.

Effective risk management could save and improve seaport and harbour projects. Project delivery team could benefit from addressing skill set shortages through engaging with external experts or consultants and ensure that there is adequate data gathering and knowledge transfer when it comes to risk management. Relationships between risk management techniques and project performance could be further researched in the future.

5.9 Recommendations

It is suggested that risk management is best integrated into operational processes in the whole project lifecycle through continuously evaluating risks as the project progresses. This continuous process of evaluating risks as they emerge or change in severity and dealing with them effectively can improve the project performance outcome. This would mean that each operational process as described in the project lifecycle, would have a rigorous risk and uncertainty assessment. The most common obstacle faced in infrastructure projects particularly in ports construction is political interferences, technical issues in design and procurement as well as the lack of adequate skill set. Risk management should essentially strategize through the creation of systems for robust information gathering, allocating project resources in-line with technical, political as well as social laws and regulations. This information gathering could be essential for risk planning and addressing the lack of skills and knowledge management in projects.

This study analysed data from fewer articles that focused on port construction projects. Most of the articles were focusing on general large infrastructure projects within the budget of US$500 million. With this outcome, generic infrastructure risk management practices can be adapted to seaport projects.

More research needs to be done in risk management techniques with a focus on seaports development projects. There is limited literature on relationships between risk techniques and project performance hence more studies could be done on their outcomes. Future studies could also focus on risk management process with a focus on each stage of the seaport project lifecycle and look at key success factors in seaport projects.

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APPENDIX A: Excluded studies

The following is a list of some of the considered but ultimately excluded articles.

They were bearing at least one of the defined exclusion criteria.

Table A.1 List of excluded studies

Author	Year	Title	Journal
Bentaleb, Fatimazahra	2015	A Multi-Criteria Approach for Risk Assessment of Dry Port-Seaport	
Mweemba Bruno	2015	Risks associated with Infrastructure Project Finance in Developing Countries-The case of Zambia	
Caldas, Carlos H.; Elkington, Richard W. T.; O'Connor, James T. & Kim, Jung-Yeol	2015	Development of a Method to Retain Experiential Knowledge in Capital Projects Organizations	Journal of Management in Engineering
Chapman, Chris	1997	Project risk analysis and management: PRAM the generic process	International Journal of Project Management
Chapman, Chris B.	1979	Large engineering project risk analysis	IEEE Transactions on Engineering Management
Chen, Hong Long	2015	Performance measurement and the prediction of capital project failure	International Journal of Project Management
Chileshe, Nicholas	2016	Critical success factors for managing infrastructure projects in Africa: A critical review and lessons learned critical success factors for managing infrastructure projects in africa	
De Marco, Alberto & Jamaluddin Thaheem, Muhammad	2014	Risk analysis in construction projects: A practical selection methodology	American Journal of Applied Sciences
Development, Port & Project, Environment Protection	2003	Mauritius: The Port Development and Environment Protection Project	
Eisma, Pieter	2014	Mapping fields of interest - A systematic literature review on public clients in construction	
Eken, Gorkem; Bilgin, Gozde; Dikmen, Irem & Birgonul, M. Talat	2015	A Lessons Learned Database Structure for Construction Companies	Procedia Engineering
Fineman, Milijana	2010	Improved Risk Analysis for Large Projects: Bayesian Networks Approach	
Freeman, Peter & Xu, Fang	2016	Lagos Urban Transport Project Performance Assessment Report	

Author	Year	Title	Journal
Galway, Lionel	2004	Quantitative Risk Analysis for Project Management	www. rand. org/pubs/workingpapers/2004/
Goftar, Vahid Nikou; Asmar, Mounir El & Bingham, Evan	2014	A Meta-Analysis of Literature Comparing Project Performance between Design-Build (DB) and Design-Bid-Build (DBB) Delivery Systems	Construction Research Congress 2014 ASCE 2014
Harding, Alan; Palsson, Gylfi & Raballand	2007	Port and Maritime Transport Challenges in West and Central Africa	Sub-Saharan Africa Transport Policy Program
Hartmann, Andreas & Doree, Andrew	2015	Learning between projects: More than sending messages in bottles	International Journal of Project Management
Hartono, Budi; Sulistyo, Sinta R.; Praftiwi, Poetry P. & Hasmoro, Danar	2014	Project risk: Theoretical concepts and stakeholders' perspectives	International Journal of Project Management
Hatefi, Mohammad Ali & Seyedhoseini, Seyed Mohammad	2012	Comparative Review of the Tools and Techniques for Assessment and Selection of the Project Risk Response Actions RRA	International Journal of Information Technology Project Management
Heravi, Gholamreza & Hajihosseini, Zeinab	2011	Risk Allocation in Public Private Partnership Infrastructure Projects in Developing Countries: Case Study of the Tehranâ Chalus Toll Road	Journal of Infrastructure Systems
Hyatali, Neisha & Fai, Kit	2016	Aligning project quality and risks into business processes: A review of challenges and strategies	West Indian Journal of Engineering
Jiang, Shaohua & Zhang, Jian	2013	Development of an Ontology-Based Semantic Retrieval Method for Construction Project Risk Management	ICCREM 2013
Kartam, Nabil a.	1996	Making Effective Use of Construction Lessons Learned in Project Life Cycle	Journal of Construction Engineering and Management
Khameneh, Amir-Hossein; Taheri, Alireza & Ershadi, Mahmood	2016	Offering a framework for evaluating the performance of project risk management system	Procedia -Social and Behavioural Sciences
Kivrak, Serkan; Arslan, Gokhan; Dikmen, Irem & Birgonul, M. Talat	2008	Capturing knowledge in construction projects: Knowledge platform for contractors	Journal of Management in Engineering
Lind Preben H. & Kringen, Jacob	2015	Risk governance of hazardous industrial ports and areas: a case study of industrial areas and harbours in Norway	Journal of Risk Research
Maharaj, Dr Ajiv	2013	Economic Development Position Paper on Port Expansion	Economic Development &Growth in Ethekwini
Mitra, Sumit & Wee Kwan Tan, A.	2012	Lessons learned from large construction project in Saudi Arabia	Benchmarking: An International Journal

Author	Year	Title	Journal
Noothout, Paul; Wiersma, Frank; Hurtado, Omar; Macdonald, Doug; Kemper, Jasmin & Van Alphen, Klaas	2014	CO2 pipeline infrastructure - lessons learnt	Energy Procedia
O'Connor, James T.; Choi, Jin Ouk & Winkler, Matthew	2016	Critical Success Factors for Commissioning and Start-Up of Capital Projects	Journal of Construction Engineering and Management
Pana, Nicolae-Alexandru & Simionescu, Lucian	2011	The Importance of Risk Management Process in Ensuring Successful Implementation of Projects Entrusted.	Revista Academiei Fortelor Terestre
Rodrigue, Jean Paul	2016	Maritime shipping	Port Technology
Roehrich, Jens K.; Lewis, Michael A. & George, Gerard	2014	Are public-private partnerships a healthy option? A systematic literature review	Social Science and Medicine
Rogers, Randy; Northwest, Pacific & Office, Alaska Gateway	2013	Proposed Port Infrastructure Development Program Framework	
Sigmund, Zvonko & Radujkovi{\'{c}}, Mladen	2014	Risk Breakdown Structure for Construction Projects on Existing Buildings	Procedia - Social and Behavioural Sciences
Vermaak, T. D.	2008	Critical success factors for the implementation of lean thinking in South African manufacturing organisations	
Zhang, G.a b & Zou, P. X. W.c	2007	Fuzzy analytical hierarchy process risk assessment approach for joint venture construction projects in China	Journal of Construction Engineering and Management
Zondi, Lucky	2010	Risk management for a rural electrification project: A systems engineering approach	