MSC IN MAJOR PROGRAMME MANAGEMENT

AN INTEGRATED RISK EVALUATION OF AN INTER-REGIONAL AFRICAN RAIL MEGAPROJECT - A CASE OF KENYA STANDARD GAUGE RAILWAY

Fig 01 cover image: (Kenya Railways, 2023)

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Abstract:

Governments globally are facing a growing infrastructure demand. To fill this infrastructure gap, many governments including Kenya, are venturing into construction of mega infrastructure projects. Kenya through their development 'vision 2030' strategy, has prioritized various megaprojects. However, most of them have had varied challenges thus threatening their effective implementation. Kenya's vision 2030 aimed to expand and enhance the capacity of railway to manage the freight cargo transportation of 25 million tonnes (50%) from the port of Mombasa in Kenya through the cities of Nairobi, Kisumu, Malaba and eventually to countries Uganda and Rwanda and this led to the conceptualization and construction of Kenya Standard Gauge Railway. This study set out to have an integrated risk assessment of the Kenya standard gauge railway of the already constructed phases 1 and 2A.

The study uses the method of systems thinking to evaluate dynamics and structure of Kenya's Standard Gauge Railway megaproject to identify key risk factors relationships within the system. It utilizes a mixed method of qualitative and quantitative methods to determine potential risks and this involves expert interviews, project managers interviews, evaluation of secondary historical data and case analysis. As an interregional megaproject, it evaluates the impact assessment of potential social, economic and environmental risk effects of SGR on the wider Kenyan and African region and establishes extensive strategies for risk mitigation on the determined risks and these can be utilized to sustain project resilience in other subsequent phases of the SGR megaproject yet to be constructed.

Because of their varied project objectives and distinct character attributes, rail megaprojects manage more complex and intricate risks than traditional projects and they have strong and significant correlation with related risk factors. Risk assessment models for rail megaprojects, in prior studies, neglected the risk interconnectedness impacts which are the risk interactions effects that increases the levels of risk. This study uses a risk interconnectedness framework for rail megaproject's risk assessment based on a system theory. A list of risk factors is developed from a review of literature and a confirmation of the risk factors and examination of their relationships done by use of local expert interviews and case analysis. Analysis of risk factors is done by use of equations of system dynamics. The framework application is done by applying it to the Kenya Standard Gauge railway phases 1 and 2A with the hope of examination and evaluation of the risk levels in the rail megaproject in the constructed phases.

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LIST OF ABBREVIATIONS & SYMBOLS

- IMP Interregional Mega Project
- Megaproject – MP
- HSR – High Speed Rail
- SGR - Standard Gauge Railway
- KRC- Kenya Railways Corporation
- R= Project risk level
- V= Vulnerability of project
- T= Threat
- A = Project Objective value (project objective importance)
- P= Possibility of risk occurrence
- V^c= Vulnerability availability degree
- I = Project system impact after risk occurrence in the project
- V^*= vulnerability severity $\otimes$ - Multiplication √ - Square root *- Multiplication

CHAPTER ONE

1.00 INTRODUCTION

1.1 Background of the Study

Globally governments are committing significant investments in public megaprojects to reverse an existing substantial service and infrastructure gaps, for example within Africa, approximately 600million people face electricity unavailability, approximately 380million people face clean water unavailability and transport infrastructure is deteriorated or in some places non-existent (OECD, 2011). Public demand for these needed infrastructures and the diminishing capacity for public funding for many governments, has levelled much pressure onto governments to execute, complete and realize these megaprojects in the agreed duration and budget (Flyvbjerg, 2014).

Interregional mega projects (IMP) are infrastructure projects of a large scale that cover more than one region and their impacts are huge and substantial to the economy and the social development of the nation for example, high-speed railways, power transmission projects, expressways and bridges (Wan, et al., 2022). IMP projects have an important function of facilitating regional growth and integration as they enhance and improve social welfare, therefore governments nationally and locally must avail resources for investing in IMPs and ensure there is collaboration in its management (Hetemi, Gemunden, & Ordieres, 2020).An IMP's external environment is complex, ever evolving and dynamic, due to it spanning in several regions and this results in several risk events that affects it (Xue & Xiang, 2020).A few examples of risk events are; delays have been experienced repeatedly in high speed rail construction project in the US because of differing perspectives of the federal government and the different states on its construction (Minn, 2013). The Hongkong-Zhuhai-Macao Bridge's construction was halted because of various queries from the residents emanating from the environmental impact assessment report (Xue, Shen, Li, Wang, & Zafar, 2020).

Risk management is strenuous and difficult to the IMP managers in both national and regional governments because compared to normal projects, IMP projects have a system which is complex with interdependent subsystems (Xiang, Xia, & Xianya, 2022). Navigating through this unprecedented and exceptional context is crucial to extensively assess the IMP's risks and ensure IMP's risk management strategies are effectively developed.

As a result of IMP's character and attributes which include spanning several regions, complex and large in scale, there exists both internal and external risks in the IMP's system (Sanchez-Cazorla, Alfalla-Luque, & Irimia-Dieguez, 2017). In the IMP's internal system, there are various different stakeholders from different regions with varied expectations for the project leading to increased complexity and coordination difficulty (Witz, Stingl, Wied, & Oehmen, 2021). Externally IMP projects are faced with varied economic, ecological, social institutional environments resulting in varied risks that affect the project realization (Xue, Xiang, Jia, & Liu, 2020).Additionally, this IMP complex system has varied risks that are interconnected and consistently change and thus the occurrence of risk can influence other associated risks. As a result of the IMP system complexity, risks measurement and risk management of IMPs is becoming more and more challenging (Xiang, Xia, & Xianya, 2022).

1.2 Problem Statement

Several IMP's have been constructed in Kenya in the last few decades and one of the largest is the Kenya's standard-gauge railway (SGR) whose first construction phase was a 472km rail that joins the Kenya's Mombasa city to the centrally placed Nairobi city traversing various county regions, and a further phase 2A which was a 120km extension of the rail, constructed and completed in 2019 to make a total of 592km at a cost of approximately US$4.5 billion, which at the time was amongst the most expensive infrastructure in Kenya (Taylor, 2020).

Kenya's Standard Gauge Railway (SGR) was initially sanctioned by the national governments of Kenya, Uganda, South Sudan and Rwanda when all the nations committed to build a "high capacity, cost effective railway infrastructure to connect the Indian Ocean seaport Mombasa - Kenya to the inner landlocked East African countries" (Otele, 2021). Every one of these nations were responsible for building their sections of the railway within their territories and joining it with the neighboring nations. Kenya had a bilateral agreement with Uganda, in October 2009, to the develop the section that links Mombasa City - Kenya to Kampala City - Uganda and subsequent to that, Kenya, Uganda and Rwanda in 2013 signed a tripartite agreement to commence construction of the railway to their cities (Zheng, 2022).

Kenya's section of developing the SGR included constructing the rail from Mombasa city to Malaba town in two phases: Phase one segment; Mombasa city to Nairobi city (construction started in 2014 to 2017) and Phase 2; Nairobi city to Malaba town segment split into three subsegments; Phase 2A which was Nairobi city to Naivasha town; Phase 2B which was Naivasha town to Kisumu city; Phase 2C which was Kisumu city to Malaba town (Taylor, 2020). The construction of the first two phases (phases 1 and 2A) is completed and currently in operation.

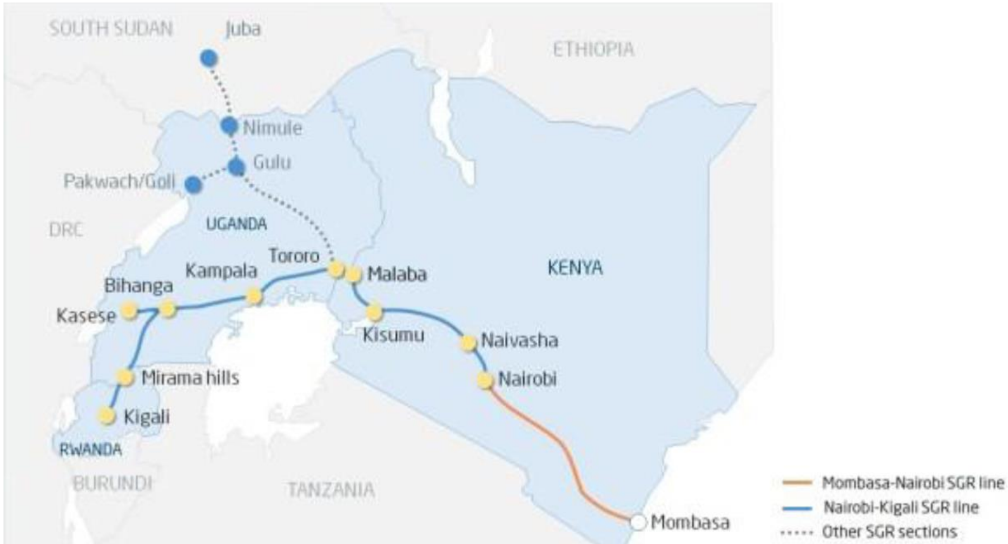


Fig 1.1 illustrates the Standard Gauge Railway traversing the East African countries (Kenya, Uganda, South Sudan and Rwanda) (Taylor, 2020)

According to Flyvbjerg et al. (2003),‘megaproject paradox’ exists in the contradiction that increasingly megaprojects are constructed in spite of project’s performance records that are in most times poor in terms of; environmental records, economic records and public approval or endorsement. In the book, Flyvbjerg et al. (2003) connects the concept of megaprojects with the risk idea and recognizes the primary contributors of megaproject paradox to be; insufficient consideration of risk and insufficient accountability in decision making process of the project. In addition, Flyvbjerg et al. (2003) suggests that the scale of megaprojects today, both physically and economically, has the potential to affect entire countries by the failure or success of these projects since they take a huge cost compared to the nations GDP for example the Kenya standard gauge railway project at an estimated cost of US$4.5 billion is 4.1% of the country Kenya’s GDP of US$110.3 billion in 2021. With the megaproject paradox and its impacts in the country’s economy in mind, these megaprojects must have risk assessment for proper management of risks. Since Phases 1 and 2A in Kenya’s SGR has been constructed, and there are other pending phases to be constructed namely; phases 2B and 2C, there is need to have risk assessment of the constructed phases 1 and 2A to establish extensive strategies for risk mitigation on the determined risks. These can be utilized to sustain project resilience in other subsequent phases of the SGR megaproject yet to be constructed.

The risks in rail megaprojects are strongly related within the system environments, both internal and external, due to the dynamic complexity of the system. Project Managers with lack of knowledge in these potential risk interactions may not entirely comprehend these risks hence they may lessen the quality and efficiency of management of risk (Marle, Vidal, & Bocquet, 2013).

Varied methods have been recommended to study megaproject's risks, but these studies have ignored the distinct project risks in IMPs especially in African megaprojects. Determining and analyzing the risks of IMP effectively is crucial in enhancing performance of megaprojects (Xiang & Chang, 2015). Therefore, this study seeks to determine a risk assessment framework for interregional rail megaproject in Africa specifically Kenya using the Kenya's standard gauge railway project as a case study, using the systems theory by analyzing the 'interconnectedness interactive relationship' between the internal system vulnerabilities and the threats from external and their effect on the objectives of the projects.

1.3 Significance of the Study;

This study will confirm the risk assessment approach of IMPs to enhance the risk measurement in the project system. IMP's risk source factors determined will be used as a reference to the management of risks in IMPs. The main risks mitigation strategies identified from the study, is going to be beneficial to African countries in their supervision and management of megaproject delivery. It will contribute valuable perspectives to megaproject managers, policymakers and project stakeholders involved in comparable megaprojects within Africa and globally.

CHAPTER TWO

2.00 Literature Review; -

2.1 Prelude

The chapter illustrates a literature review of previous researchers' writings about risk assessment & risk factors within the sector of megaprojects and railways. Theoretical framework, IMP risk system and the conceptual framework used are discussed.

2.2 Risk Assessment and literature review in Megaprojects

Mega projects (MP) need effective risk management in its construction and so it is critical to recognize and detect possible variances and divergences in the process of achieving its objectives so as to facilitate its delivery within schedule and budget (Nabawy & Khodeir, 2020). The possibility of higher risks occurrence in megaprojects is due to their high level of complexity and uncertainties in addition to a dynamic and active internal and external environments (Yang, Lou, & Zhao, 2021). The effect of these risks is not only on the megaproject's cost, quality, schedule and safety but also on the domestic economy, ecology and society (Hwang, Zhao, & Toh, 2014). To ensure efficient delivery of megaprojects, risk identification and risk analysis are considered critical functions of risk management (Menendez & Gharaibeh, 2017).Various studies have been done on the risks in megaprojects.

Nabawy & Khodeir (2020) contends that MP requires both qualitative and quantitative analyses derived from practice and knowledge and the paper systematically reviews literature, within the timeline of 2013 to 2018,that deals with quantitative analysis in MP construction globally with the intention of enhancing quantitative risk analysis practitioner's knowledge of MP contractors. As a result, the paper critically analyzes techniques of quantitative risks practiced within the timeline and observes that Monte Carlo, as a technique, majorly was used by project managers to highlight variances and divergences in the process of achieving MP objectives.

Caltrans (2012) contends that in complex projects, quantitative analysis of risk is paramount and important and this has aided in identifying possible variances and divergences in MP objectives. Van de Kujip (2017) identified the knowledge gap concerning risk analysis to infrastructure projects in Africa and highlighted the significance of relating quantitative analysis with the varying standard practices procedure. Nabawy & Khodeir (2020) identifies the significance of the use of case studies in analysis development keeping in mind the control variables and performance of in-depth analysis concerning MP.

The study for Rados & Rados (2017) measured construction risks and quantified them to highlight which ones impacted the MP objectives the greatest. They concluded that the crucial risks that were highest in creating failure in MP delivery were existing economic policies & developmental plans, policy and institutional components, services management provision.

Boateng, Chen, & Ogunlana (2015) proposed a holistic risk quantification model through incorporation of risk uncertainty and complexity for risk prioritization in construction of megaprojects. Wang & Pitsis (2020) recommended and validated two models in connection with megaproject's crisis management. The study inferred that crisis awareness and crisis orientation were major antecedents of improved prediction of crises in megaprojects. Akcay (2021) developed an analytic network process (ANP)- derived from a framework of assessment of risk for hydropower projects. The research established that contractor's risks, operator risks and legal risks are the main crucial risk factors. Chen, Deng, & Niu (2022b) put forward a risk analysis model based on network analysis to examine the main risk factors of underground engineering which included lack of routine supervision and inspection processes, low safety consciousness of the personnel and impractical construction technology and staffing structure in safety management in an organization.

Several existing studies have determined the various kind of risks of construction of megaprojects and the various unique techniques and models have been presented to enhance risk sources prioritization. Nevertheless, it is inadequate for risk management of interregional megaprojects (IMPs) since IMPs have several distinct project risks. Risk evaluations of IMPs have been neglected in comparison to the normal megaprojects risk assessment. IMPs traverse several regions and includes a huge population with varied interests and expectations of persons from different county regional and national governments (Bahadorestani, Karlsen, & Farimani, 2019). Winch & Leiringer (2016) established that most failures in delivery of most megaprojects in infrastructure are generated by the public partner project owner since in the IMP, several regions that the project span across participate in the project, these several public owners face a complex challenge in management and decision making of the infrastructure. In Hetemi et al. (2020) study of Spain's HSR between Madrid- Barcelona project which focused on evaluation of integration and actor's behaviors, he proposed that in the project's institutional context, actor's interdependencies and roles, merits greater focus to lower the uncertainties and improve project productivity. In the investigation of the wide-ranging, localized effects of China's South to North Water Transfer IMP, Wan, et al. (2022) analyzed the opinion of the public, and the results indicated that the people from the region donating the water and people from the regions receiving the water had varied views and opinions on the IMP project which largely relied on the different regional social environments they were in and how the project affected them. Xiang & Li (2016) used a hierarchical holographic model, derived from a sustainability point of view, to determine the risk factors of IMP with regard to the social, environmental and economic subsystems.

Various frameworks of risk analysis exist for example neural network framework (Patel & Jha, 2014), genetic algorithms (Pfeifer, Barker, Ramirez-Marquez, & Morshedlou, 2015), system dynamics (De Marco, Rafele, & Thaheem, 2015), fuzzy and hybrid analysis (Islam, Nepal, Skitmore, & Attarzadeh, 2017), social network evaluation application to genetic algorithms (Wang, Sun, Qian, Goh, & Mishra, 2020), network model (Chen, et al., 2020), analytic hierarchy process (Akcay, 2021) and Monte Carlo application (Chen, Zhu, Hu, Chen, & Zheng, 2022a) that can enhance the risk analysis function and performances of a project.

There has been a gradual increase in research on risk of the MP construction system as it continually becomes complex. Risk management of system vulnerability and threats has captured researcher's interest for decades and from this point of view, risk is defined as an overlay of internal vulnerabilities and external threats or as an output of collaboration between risk sources and system fragility (Deng & Low, 2013).

From a system point of view, vulnerability theory is progressively integrated into risk management to address the issue of variable risks and their unique relationship complexities (Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021). Birch & McEvoy (1992) proposed an integrated risk analysis utilizing the Structured Risk Analysis model and highlighted that the risk was activated by interactions between the vulnerability and threats. Furthermore Haimes (2006) referred to risk as detrimental severe impacts on a vulnerable system due to threats. Hence in risk assessment, it is efficient to include the vulnerability and threat interactions and various related methods have been used widely.

Chandra (2015) developed a relationship model in risk management field utilizing the structural equation framework to investigate the varied risk factors impacting megaproject success. Xiang & Li (2016) presented a model for investigating IMP's vulnerability and gave reference for decision making and management of risks. Various researchers have analyzed project risks in the construction industry by simply multiplying threats and vulnerabilities in the project system (Chang, Deng, Hwang, & Zhao, 2019). Vulnerability factors relationships with threat factors have been neglected in development of risk management strategies, hence an interconnectedness relationship between vulnerability and threat factors is a primary factor in analyzing risk levels and is a crucial feature in the integrated risk evaluation model by Xiang, et al. (2022) for cross regional MP in China.

2.3 Rail Project's Risk Source Factors;

In their research of critical factors of risk in Thailand's underground rail using factor analysis, Ghosh & Jintanapakanont (2004) identified 35 risk factors including delay in contractual problem solving, funds unavailability, ecological limitations, changes in design, unexpected site challenges, et cetera. In their study of risks in international joint ventures in underground rail project constructions, Zhao et al. (2013) identified the most crucial factors of risk as; dispute in profit and loss accounting, mistrust between employees, dispute over certain contract terms, materials and equipments restrictions in imports, insufficient management experience and competence.

Feng et al. (2021) researched on the evaluation of risk on PPP projects of urban rail in China and identified 27 risk factors and grouped them into 9 groups; legal, environmental, financing, relationship, force majeure, political, economic, market and project promotion risks.

Furthermore, he identified legal, project promotion and political risks as the most significant and force majeure and relationship risks as the least.

Patil et al. (2019) researched on the risks in Pune-India's metro rail project and identified 25 risk factors and grouped them in four; socio-political-environmental-surrounding, construction, financial and technical risks. The top five significant risk factors were; project insurances, political pressure, risk of relocating people from project site, problems with traffic diversions and problems related to preservation of historical buildings. Karmarkar et al. (2022) in their study on assessment of risk on metro projects, both underground and elevated in India, they identified 25 risk factors which showed that the there were two significant risk factors which were; project approval delays and economic crisis.

Xiang et al. (2022) researched on the ZW high speed rail in China and highlighted 24 risk source factors, 12 as threat factor and 12 as vulnerability factors. The significant risk factors were regional government's conflict of interest and a hostile natural environment.

2.4 Theoretical Framework;

2.4.1 Vulnerability Theory

This is a theoretical framework concentrating on comprehending and dealing with vulnerabilities or susceptibilities that groups or individuals or systems encounter in society. The concept acknowledges that some groups or systems are vulnerable and prone to harm because of varied factors like political, economic, social or environmental factors (Mattson & Jenelius, 2015). Risk and vulnerability theory are interconnected and are frequently researched jointly to comprehend the factors that influence groups or systems prone to different risks. This theory explores the root causes and factors that make certain groups or systems susceptible or vulnerable to harm while risk assessment analyses the probability, likelihood and effects of certain threats (Haimes, 2006). Further, vulnerability theory focuses on recognizing the systemic elements that produce vulnerabilities within a system which can be political, economic, social, cultural or environmental elements. After identification of the vulnerabilities in a system one can develop an understanding into the underlying conditions of risks and how various differing groups or systems are impacted. According to Zakour & Gillespie (2013), vulnerability theory acknowledges that groups or systems may encounter numerous levels of vulnerabilities and as a result, numerous risks. Therefore, understanding the interconnectedness of various vulnerabilities is critical in developing thorough mitigation strategies or risks.

2.4.2 Systems Theory

This is a theory that examines and explores the organization complex system's behaviors. The central concept of this theory is that complex organizations can be interpreted as systems comprised of interconnected and interlinked parts that function jointly to attain a collective and shared objectives (Parnell, Driscoll, & Henderson, 2011). A system is a collection or group of components or factors that are interlinked and function jointly as a collective cohesive entity. Subsystems are smaller units of a larger system with distinct roles and interactions. Systems theory assists in identification of vulnerabilities that may lead to risk occurrence within the system. According to Chen et al. (2019), systems thinking acknowledges the interconnectedness of risks and indicates that an alteration or disturbance in one segment of the system has progressive impacts on other sections. The interconnectedness needs an integrated approach to assessment of risk.

2.4.3 Sustainable Development Theory

This is a theory that directs the incorporation of economic, environmental and social factors to attain development that fulfills the present needs without interfering with any future generation's needs. The theory acknowledges that the three dimensions, economic, environmental and social factors, are interconnected and interrelated (Shi, Han, Yang, & Gao, 2019). This theory was used to formulate the objectives of the project in this study.

2.5 IMP System and Conceptual Framework for Integrated Risk Evaluation

2.5.1 IMP Risk system;

In accordance with vulnerability and system theories, the elements of an IMP mutually interact and interdepend on one another; the internal system being vulnerable while the external environment to the system threatens. Hence due to the fragility of the system, the interference of the environment externally creates a quantitative effect which ultimately develops into a risk (Xiang, Xia, & Xianya, 2022). Consequently, for a clearer insight and understanding of the risks of IMP, the risk management system composition should be analyzed from a systems approach (Boateng P. , Chen, Ogunlana, & Ikediashi, 2012). According to Boateng et al. (2012), the components of a system are three; the structure, environment and behavior of the system.

The structure of the system is defined by the formation of the various elements comprising the system and their interaction. The internal structure and formation of an IMP system consists of organization, technology and management subsystems and their existing interactive relationships amongst themselves. Additionally, the main stakeholders that form part of the IMP are also internal elements (Xiang, Xia, & Xianya, 2022). In the Kenyan context, the national government, the regional county governments and the enterprise organizations related to the IMP are crucial managers of the MP because of their managerial and decision-making responsibility in the project.

The system environment of risk of IMP is defined by the formation of various elements external to the system with whom they possess direct and indirect associations. IMP risk system environment comprises of social, natural, economic and political environments (Witz, Stingl, Wied, & Oehmen, 2021). The social environment comprises societal and cultural background contexts from the various regions the IMP crosses and the varied opinions the public has on the project. The natural environment are the physical, geographical and ecological spaces the IMP operates on. The economic environment refers to regional development levels and factors of the economy that the project has impacted. The political environment refers to the levels of government and their relationships and impact to the project.

System behavior is the outcome and intake in the IMP system to maintain a systematic balance. As a result of interactive relationships, the resources and information transfer amongst the internal and external of an IMP system is enhanced (Xiang, Xia, & Xianya, 2022).In accordance with the analysis above, the internal formation of a system is connected to the risk system structure of an IMP and the external connected to the environment of the system as per below figure 2.1 showing the relationship.

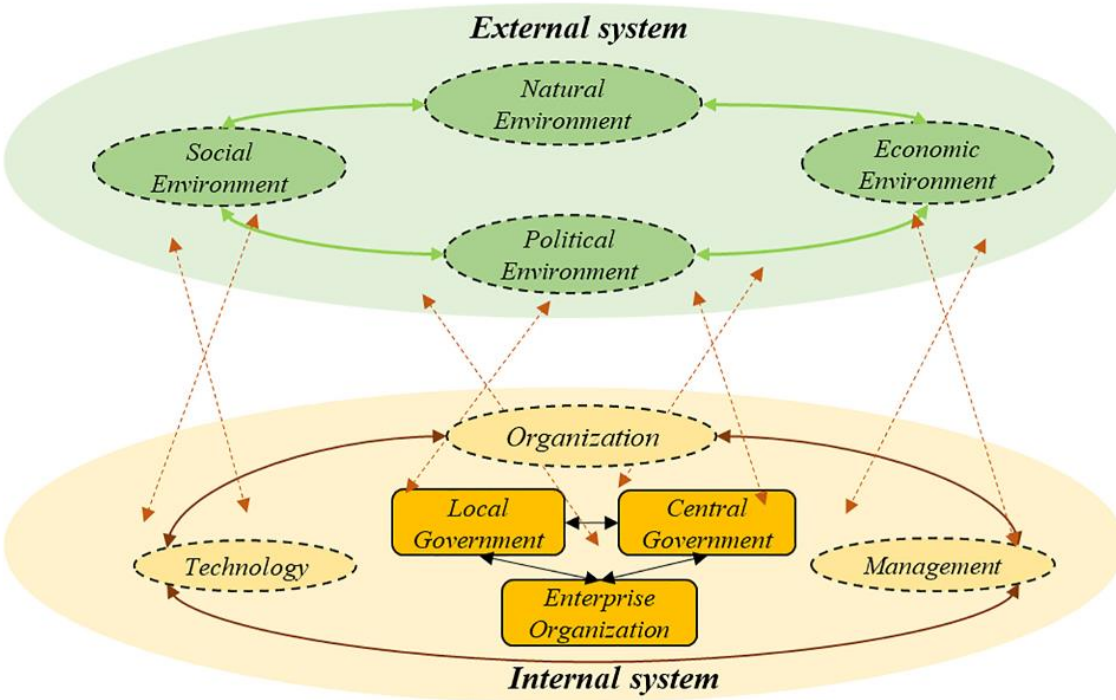


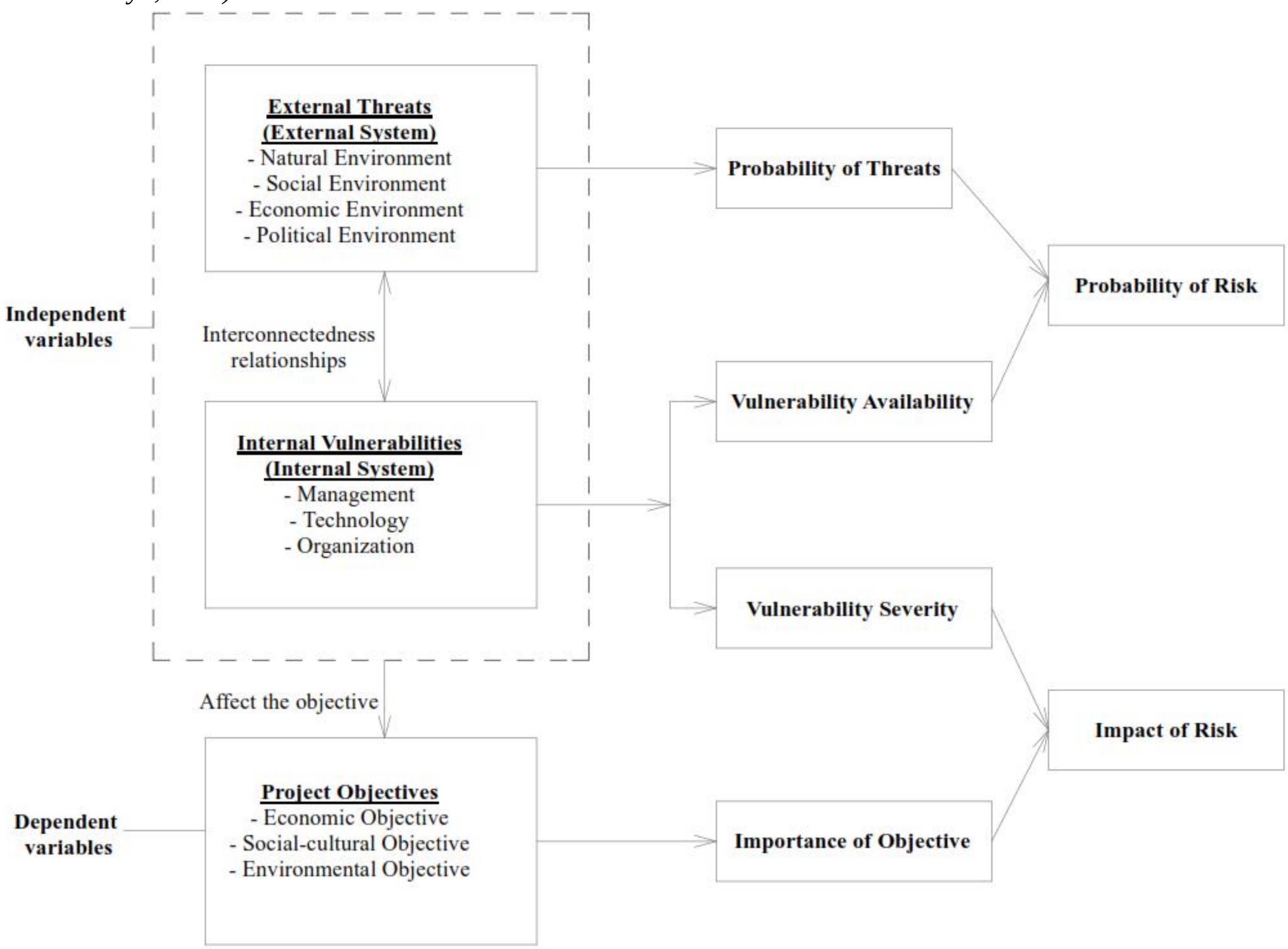
Fig2.1 illustrates the external and internal formations of the IMP system: (Xiang, Xia, & Xianya, 2022)

2.5.2 Conceptual Framework for IMP integrated risk assessment;

In accordance with the IMP risk system analysis, risk refers to the influences on project objectives threatening the utilization of vulnerabilities in the project system. Risk composition in an IMP arises from vulnerabilities in the system and external threats. As per the risk system of IMP, threats emanate from the external which comprise of the social, natural, economic and political environments. Conversely system vulnerabilities are associated with the internal formation system which consists of organization subsystem, technology subsystem and management subsystem (Xiang, Xia, & Xianya, 2022).

Kardes et al. (2013) uses classical theory to indicate that risk is identified by its probability of occurrence and scale of incurred loss. Hence from this determination, project risks quantification will be obtained by getting the exploitation probability of the internal vulnerability by the project threats and the scale by which the objectives of the project are impacted. Even though vulnerability is represented in the project system, it also comprises the degree or extent of availability and the level of vulnerability severity. Additionally, if the level of objective of the project's impact is integrated within the framework of risk evaluation and assessment, there will be a significant impact of risk events occurrences to the attainment of the project objectives and the resultant calculations will be more exhaustive and precise. Hence, the conceptual framework for the IMP integrated risk evaluation is as per shown below in fig 2.2

Figure 2.2 Conceptual Framework for IMP integrated risk evaluation adopted partly from (Xiang, Xia, & Xianya, 2022)



In accordance with the risk system analysis and the development of the conceptual model for the risk assessment, the study formulated the following guidelines for risk measurement;

i) IMPs have varied objectives, the greater the number of prerequisites needed for achievement of the objectives, the higher the importance of the objective;

ii) The greater the number of objectives to be achieved, the higher the risk it might experience;

iii) The greater the number of external threats that the IMP experience, the higher the possibility of risk;

iv) The greater the number of project vulnerabilities, the higher the possibility of threats exploitation; and

v) The reduction and avoidance of risks can be achieved through measures of prevention and control and this will reduce risk impact on project objectives.

2.6 Research Questions:

From the foregoing, this study aims to answer the following research questions;

i) To examine effects of external threats and determine its impact on project objectives of Kenya SGR megaproject;

ii) To examine effects of vulnerability risks and determine its impact on project objectives of Kenya SGR megaproject;

iii) To examine effects of interconnectedness relationships of external threats and vulnerabilities and determine its impact on project objectives of Kenya SGR megaproject;

CHAPTER THREE

3.00 METHODOLOGY; -

3.1 Prelude

This chapter illustrates the research design of choice, the study population, identification of IMP's source factors of risk, identification of project system's risk interconnectedness relationships, integrated risk evaluation framework and research data collection and analysis. Finally, the ethical approvals of the study are highlighted.

3.2 Research Design;

A research design is a guide and structure of a study (Cooper & Schindler, 2014). It helps the researcher in choosing an acceptable approach to use (Kothari, 2004). In this study a case study method was utilized to examine the research problem. This is a method that involves a detailed in-depth assessment of a case(s) in a practical context (Bryman, 2016). Risks in megaprojects has been studied widely by the use of case study method (Boateng P. , Chen, Ogunlana, & Ikediashi, 2012; Chen, Zhu, Hu, Chen, & Zheng, 2022a).

This study concentrates on the risk assessment in IMPs. The following are the stages;

i) firstly, the identification of internal vulnerabilities, external threats and objectives of the project as source factors of risk is done. Subsequent confirmation of the interconnectedness relationship of vulnerability factors and threat factors is also done. Both activities are done using literature review which summarizes the findings from existing research to set the foundation for theory. Additionally, case study analysis and use of interviews from experts' pinpoints risks sources in a specific context;

ii) secondly, consideration of the relationship interconnectedness of vulnerabilities and threats factors, is done by assessing the possibility of risks which is dictated by the threat's probability of occurrence and availability of vulnerability;

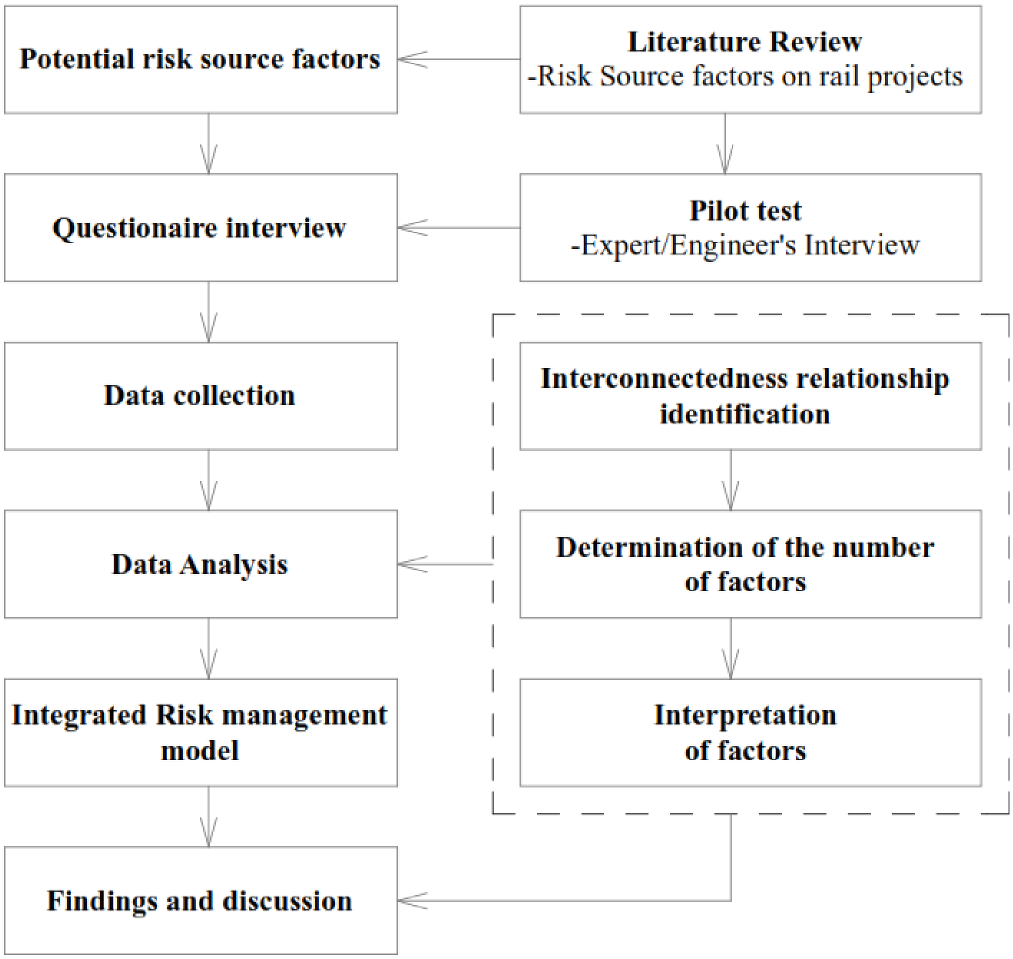
iii) thirdly, an assessment of the impacts or effects of risk based on the objectives of the project's importance and its severity inflicted by its vulnerabilities;

iv) eventually, the evaluation of risk of the Kenya's SGR IMP would be done by employing the integrated evaluation model adopted herein. The integrated model adopted for this study was developed by Xiang et. al (2022) in their assessment of risk of a Chinese high-speed rail project. Their main limitation in their study was that the model concentrated to the region of China and hence they recommended that future further studies should explore different regions globally. This study seeks to explore the model in the context of Kenya in Africa using the Kenya standard gauge railway as a case study. The positive aspect of this evaluation model is the consideration made for the interconnectedness relationships on the source factors of risk.

3.3 Study Population

Kenya Railways Corporation (KRC) is a Kenyan state organization set up in 1977 which owns the Kenya's SGR project (Nyumba T. , 2021). The study targeted the engineers from KRC who managed the construction of Kenya's SGR IMP megaproject. There were 15 Engineers in KRC who managed the SGR project. 15 questionnaires were sent to them for a response (Kenya Railways, 2023). Four experts were also interviewed for confirmation of the risk source factors.

Fig 3.1 below shows a summary of the research process stages as it will be carried out



3.4 Identification of IMP Source Factors of Risk

A total of 25 number source factors of risk were determined from a systematic review of literature, considering the IMP's distinct and unique traits, only limited number of researches that met the description of IMP were incorporated into the review of literature in this study.

This study adopts the following table from literature review and the risk source factors act as a base source for our study. These base risk source factors in below table were taken through the expert's interview in Kenya to confirm and regularize the factors to the Kenyan and African context.

Table 3.1. Initial compilation of Source factors of Risk of IMP from literature review

Components	Num	Subcomponent Layer	citations
T01: Political	T01a	Coordination absent among national & county regional governments	(Feng, Guo, Wei, & Chen, 2021)
	T01b	Competing Interests and conflicts between National and county regional government	(Xiang & Chang, 2015)
	T01c	Competing Interests and conflicts between county regional governments	(Patil, Saharkar, & Salunkhe, 2019)
T02: Natural	T02a	Carrying capacity of the environment	(Xiang & Li, 2016)
	T02b	Ecosystems fragility	(Flyvbjerg, Bruzelius, & Rothengatter, 2003)
	T02c	Harshness of the environment	(Flyvbjerg, Bruzelius, & Rothengatter, 2003)
T03: Social	T03a	Unfair and unregulated competition	(Xiang, Xia, & Xianya, 2022)
	T03b	Grabbed resources of development	(Xue, Xiang, Jia, & Liu, 2020)
	T03c	Different region's conflicting ethical challenges	(Xue, Shen, Li, Wang, & Zafar, 2020)
	T03d	Diverse interpretations and perspectives of authority, function and relevance	(Feng, Guo, Wei, & Chen, 2021)
	T03e	Varied sociological contexts	(Ghosh & Jintanapakanont, 2004)
T04: Economic	T04a	Asymmetrical and disproportionate economic development	(Xiang, Xia, & Xianya, 2022)
	T04b	Unreasonable ecological compensation	(Xiang, Xia, & Xianya, 2022)
	T04c	Unfair and unacceptable cost sharing	(Xiang, Xia, & Xianya, 2022)
V01: Technology	V01a	Technology complexity	(Boateng P. , Chen, Ogunlana, & Ikediashi, 2012)
	V01b	Technical standards inconsistency	(Chen, Deng, & Niu, 2022b)
	V01c	Technical design changes	(Ghosh & Jintanapakanont, 2004)
	V01d	Difficulty in innovation of technology	(Chen, Deng, & Niu, 2022b)
V02: Organization	V02a	Insufficient experience	(Xiang & Li, 2016)
	V02b	Unacceptable structure of organization	(Hetemi, Gemunden, & Ordieres, 2020)
	V02c	Disinterest in coordination mechanism	(Xiang & Li, 2016)
	V02d	Insufficient guidelines and directives	(Xiang & Chang, 2015)

V03: Management vulnerability	V03a	Uncertain leadership obligations	(Xiang, Xia, & Xianya, 2022)
	V03b	Numerous levels of procedures for management	(Xiang, Xia, & Xianya, 2022)
	V03c	Unadvanced management mode	(Xiang, Xia, & Xianya, 2022)
	V03d	Interference from Government	(Xiang, Xia, & Xianya, 2022)
O1^: Economic Objective	O1^a	Variance of cost	(Hwang, Zhao, & Toh, 2014)
	O1^b	Schedule delays in the Project	(Boateng P. , Chen, Ogunlana, & Ikediashi, 2012)
	O1^c	Funds availability	(Ghosh & Jintanapakanont, 2004)
O2^: Socio-cultural Objective	O2^a	Quality of the Project	(Xue & Xiang, 2020)
	O2^b	Safety goals of the project	(Wan, et al., 2022)
	O2^c	Social acceptability and suitability of the project	(Xiang, Xia, & Xianya, 2022)
O3^: Environment/ Ecological Objective	O3^a	Desirable living environment within the project	(Ghosh & Jintanapakanont, 2004)
	O3^b	Desirable ecological environment	(Patil, Saharkar, & Salunkhe, 2019)
	O3^c	Compliance with Environmental Regulations:	(Patil, Saharkar, & Salunkhe, 2019)

In accordance with IMP's risk system analysis, the source factors of risk were categorized into the following groups; internal vulnerability risk factors from the internal part of the system and threat factors external to the IMP system.

In accordance with IMP's risk system analysis in chapter 2, the external threat factors comprise; social factors (T03a–T03e), natural factors (T02a–T02c), economic factors (T04a–T04c) and political factors (T01a–T01c). The IMP's internal vulnerability factors comprise; organizational factors (V02a–V02d), technology factors (V01a–V01d) and management factors (V03a–V03d). Furthermore, from the review of literature and interviews of experts, 9 number project objectives were recommended. The project objectives are grouped into socio-cultural objectives (O2^a–O2^c), economic objectives (O1^a–O1^c) and environmental objectives (O3^a–O3^c) as per the sustainable developmental theory as defined in section 2.4.3.

To determine and confirm the final working list of project objectives, vulnerability and threats as source factors of risk for this study, four experts were identified from Kenyan construction industry and universities who have expertise and experience in IMP research and management. The experts assessed the initial compilation of risk source factors on table 3.1, from their experience in the construction of the SGR rail system in Kenya. A questionnaire survey was conducted using the google workspace link https://forms.gle/yRyNYVxWhdT2kfSm6 which was sent to them online to assess, confirm and or revise the factors in January-February 2024 to regularize the list to a Kenyan context specific to the Kenya's SGR project. The main topic areas for the expert interview's for source factor of risk proposed were;

i) The expert's perspectives on the IMP's source factors of risk proposed or highlighted from the literature review if it applies to Kenya's SGR project;

ii) The expert's confirmation opinion to add or remove particular source factors of risk as it relates to the project;

3.5 Identification of Project System's Risk Interconnectedness relationship;

As per fig 2.2, the IMP's risks are defined as where the project objectives are impacted by the external threats existing through the exploitation of the internal vulnerabilities of the system. Further, the existing interconnectedness relationship between the internal vulnerability and threats from external environment are not fixed, depicting complexities and fluctuating character attributes (Xiang & Chang, 2015). Hence determining vulnerabilities and external threat's interconnectedness relationships, forms the foundation for an efficient and productive risk assessment. For instance, an IMP facing a threat T01c of 'competing interests and conflicts between county regional governments'; if equally within the same project there is an internal vulnerability of V2c of 'disinterest in coordination mechanism', this interconnectedness of the vulnerability and threat will lead to risk occurrence impacting the objectives of the project like leading to overrun in costs (O1^a), schedule delays in the project (O1^b) meaning the interconnectedness relationship impacts the economic objectives of the project.

Consequently, the principle of integrated risk evaluation is the identification and determination of the interconnectedness relationship amongst vulnerability, threat and project objectives. On the premise of data from the initial compilation of risk factors, this study proposes a list preliminary for interconnectedness relationships in table 3.2 below between the rail SGR megaproject vulnerabilities and threats in the study. This preliminary list was adopted from literature review but will be put through a questionnaire interview to the engineer participants involved in the construction of the Kenya's SGR to confirm the interconnectedness relationships that they encountered in the project.

Table3.2 Initial compilation of relationships interconnectedness between threat and vulnerability from literature review (Xiang, Xia, & Xianya, 2022);

T	**V**	**T**	**V**	**T**	**V**	**T**	**V**
T01a	V02a	T02a	V01a	T03a	V02a	T04a	V02a
	V02b		V01b		V02b		V02c
	V02c		V01c		V02c		V02d
	V02d		V01d		V02d		V03a
	V03a		V03c		V03c	T04b	V02a
	V03d	T02b	V01a		V03d		V02c
T01b	V02a		V01b	T03b	V02c		V03a
	V02b		V01c		V02d	T04c	V02a
	V02c		V01d		V03c		V02b
	V03b		V02a		V03d		V02c
	V03d		V02d	T03c	V02a		V02d
T01c	V02a	T02c	V01a		V02b		V03a
	V02b		V01b		V02c		
	V02c		V01c		V02d		
	V03a		V01d		V03a		
	V03d		V02a		V03b		
			V02d		V03c		
			V03c		V03d		

T= threats and V= vulnerability;

3.6 Integrated Risk Evaluation framework

Risk is defined as the uncertainty and unpredictability of an event's occurrence (Xiang, Xia, & Xianya, 2022). The risk can be computed as below;

$$R = f(T, V, A) = f(\mathrm{P}(\mathrm{T}, \mathrm{V}^c), \mathrm{I}(\mathrm{A}, \mathrm{V}^*)) \quad \text{……………. } \textit{(Equation 001)}$$

- R= Project risk level
- V= Vulnerability of project
- T= Threat
- A = Project Objective value (project objective importance)
- P= Possibility of risk occurrence
- V^c= Vulnerability availability degree
- I = Project system impact after risk occurrence in the project
- V^*= vulnerability severity

To calculate the project risk of an IMP as per the stages highlighted in 3.2, firstly project objectives, vulnerabilities and threats identification is key, evaluation of scores is done individually. Then measurement of risk probability is done, and the risk loss impact is done. Eventually, the evaluation of risk of the Kenya's SGR IMP would be done by employing the integrated evaluation model adopted herein.

Multiplication approach is used in computing integrated risk evaluation for Kenya's SGR project applying the Kuzminykh et al. (2021)'s 'information security risk assessment' theory. When establishing two or more components value, multiplication is used for instance $C=f(a,b)$. Based on the multiplication fundamentals, when $C=f(a,b)= a\otimes b$. In this study, component's value is computed $C=f(a,b)= \sqrt{a*b}$.

As per conceptual framework fig 2.2, the possibility of risk event is derived from possibility of threat occurring and availability of internal vulnerability, hence will be computed by *P (threat, vulnerability)* $=f(T,V^c)$. Evaluation indicators will be based on suitable analysis datasets and the probability of threat occurrence dataset $T=(t_1,t_2,t_3\ldots\ldots,t_n)$ and availability of vulnerability

$V^c=(v^c{}_1,v^c{}_2\ldots\ldots v^c{}_n)$ and the degree vulnerability availability and probability of threat occurrences and will be acquired from tables 3.3 and 3.4

Table 3.3 Assessment of probability of threat to occur

Rank	Probability degree	Narrative	Numeric representation of Probability
05	Extremely probable	Will inevitably occur for sure - definite or unavoidable	0.9
04	Possible	Likely or to occur	0.6
03	Probable	Occurs occasionally and will only happen in specific conditions	0.3
02	Hardly probable	Hardly occurs, and normally it is less probable to happen	0.1
01	Extremely improbable	It scarcely occurs, may happen only in very extreme conditions	0.05

Table 3.4 Assessment of level or degree of availability of vulnerability

Rank	Vulnerability Degree or level	Narrative	Numeric representation of Availability
05	Extremely High	Extremely vulnerable to threats	05
04	High	Vulnerable to be exploited by threats	04
03	Medium	It might be available for misuse by threats	03
02	Low	Not readily misused by threats	02
01	Extremely Low	It is inconceivable for vulnerability to be misused by threats	01

Based on the multiplication fundamentals, the risk event possibility can be computed. In a scenario where there are *m* threats and *n* vulnerabilities, '$p_{ij}=t_i \otimes v^c{}_j, (i=1,2\ldots\ldots\ldots,m;$ $j=1,2\ldots\ldots n)$'; obtain matrix $(P_{i*j})_{mn}$ where p_{ij} symbolizes the probability of risk happening under the interconnectedness of the i^{th} threat and the j^{th} vulnerability

$$(P_{i*j})_{mn} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1j} \\ p_{21} & p_{22} & \cdots & p_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ p_{i1} & p_{i2} & \cdots & p_{mn} \end{bmatrix} \quad \ldots\ldots\ldots(Equation\ 002)$$

The impacts of risk or the adverse effects of a risk occurrence will be computed in accordance with the project objectives importance and vulnerability severity which can be stated as

$I=I(A,V^*)$.The dataset of objectives of the project are $A=(a_1,a_2\ldots\ldots\ldots\ldots a_m)$ and the severity of vulnerability's are '$V^*=(V^*_1,V^*_2\ldots\ldots\ldots V^*_n)$'.

In a similar manner, supposing there are q objectives of the project and n internal vulnerabilities, obtain the matrix $(I_{i*J})^T_{qn}$ in which $i_{ij}=a_q\otimes v^*_n$, $(i=1,2\ldots\ldots\ldots,q;\ j=1,2\ldots\ldots\ldots,n)$ and i_{ij} symbolizes the adverse effects of a risk occurrence by the i^{th} project objective subject to the j^{th} internal vulnerability.

$$(I_{i*j})^T_{qn} = \begin{bmatrix} i_{11} & i_{12} & \ldots & i_{1j} \\ i_{21} & i_{22} & \ldots & i_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ i_{i1} & i_{i2} & \ldots & i_{qn} \end{bmatrix}^T \quad \ldots\ldots\ldots\ldots\ldots \text{(Equation 003)}$$

$$r_{ij} = \sum_{k=1}^{n} T_i V_k A_j = \sum_{k=1}^{n} (p_{ij})_{mn} (i_{ij})_{qn} (i=1,2,\ldots,m;\ j=1,2,\ldots,q) \text{-------------(Equation 004)}$$

Table 3.5; Assessment of level or degree of severity of vulnerability

Rank	Severity level or Degree	Narrative	Numeric representation of Severity
05	Extremely High	It will result in severe/substantial loss to the objectives, if under threat;	05
04	High	It will result considerable loss to the objectives, if under threat;	04
03	Medium	It will result broad/generalized loss to the objectives, if under threat	03
02	Low	It will result in minimal loss to the objectives, if under threat	02
01	Extremely Low	If under threat, the loss could be ignored	01

Table 3.6; Assessment of the objective of the project's importance

Rank	Importance level or Degree	Narrative	Numeric representation of importance
05	Extremely High	Extremely important, if not attained, it will result substantial/ severe harm	05
04	High	Important, if not attained, will result in considerable harm	04
03	Medium	Slightly important, if not attained, it will result in broad/generalized harm	03
02	Low	Unimportant, if not attained, will result in minimal harm	02
01	Extremely Low	If under threat, the harm could be ignored	01

Using the explanation of what risk is, to compute the risk values, equations 001 and 004 can be combined and a matrix adjusted to $(R_{i*j})_{mq}$,

Where r_{ij} is the collective effect anticipated on the j^{th} project objective impacted by i^{th} external threats exploited by n internal vulnerabilities within the system. Breaking down equation 004, T_iV_k *and* V_kA_j aligns with P_{ij} and i_{ij} in matrices 002 and 003 respectively.

$$(R_{i*j})_{mq} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} \\ r_{21} & r_{22} & \cdots & r_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{mq} \end{bmatrix} \text{------------}(\textit{Equation 005})$$

3.7 Research Data Collection and Analysis;

In accordance with the methodology of research, a questionnaire survey was used to gather the scores of threats, vulnerabilities and values of interconnectedness relationships between vulnerability and threat and values of project objectives to assess the level of risk in the Kenya SGR megaproject. Each indicator's criteria of scoring were clarified and defined in the questionnaire, and the scores ranged from 01 to 05 as per tables 3.3,3.4,3.5 and 3.6

15 engineers who are directly managing the Kenya SGR Phase 1 and 2A construction from Kenya Railways Corporation were invited to participate in the interviews administered through questionnaires which were shared online via the google workspace and a link https://forms.gle/aAYUs9zgDcSjX6uV9 was forwarded to participant's email and online social platforms for a response. The data was collected between December 2023 to February 2024.

3.8 Ethical Approvals

Ethical Approval was obtained from the University of Oxford Central University Research Ethics Committee (CUREC) with a reference of SSH_SBS_C1A_24_0. Additionally, a local Kenyan regulatory body ethics approval was obtained from the National Commission for Science, Technology, and Innovation (NACOSTI) with a research license number NACOSTI/P/24/33032.

CHAPTER FOUR

4.00 FINDINGS

4.1 Prelude

This chapter illustrates data analysis and findings in accordance with the research objectives and questions. Data collection was through questionnaires and secondary data reviews.

A study population anticipated was 15 engineers from Kenya Railways Corporation. 09 responses from the questionnaires were received and subsequently used for analysis.

In accordance with Bryman (2016), a response rate of 50% is adequate, 60% is good and for a rate of over 70% very good for analysis. In this study, response rate was 60% which is an appropriate threshold to proceed and conduct analysis.

4.2 General Details of Participants

The general details in the expert's questionnaire collected were; two university professors from the University of Nairobi and two Engineers from the Kenyan industry. All had over 15 years' experience in the field.

The general details in the engineer's questionnaire collected were gender, years of management, role in the organization, age and level of education.

Gender distribution of the survey participants was that male participants were 06 (66.7%) and female 3 (33.3%).

Years of management experience in KRC by Engineer participants who had less than 10 years' experience were 3 (33.3%) and the participants with more than 10 years were 6 (66.7 %).

The participant's **academic level** indicated that those with bachelor's degree were 3 (33.3 %) and 6 (66.7 %) for those with master's degree.

The age classification showed that 4 (44.4%) respondents were 40-50 years, 4 (44.4%) were between 30-40 years, 1 (11.2%) was below 30 years old.

On the positions, 5 (55.6%) were in middle level management and 4 (44.4%) were in lower level management.

4.3 Research Data Collection and Analysis

Table 4.1 shows the result of the expert's confirmation of the final risk source factors as queried from the expert's questionnaire. These were the factors used in the follow-up questionnaire to the Engineer participants.

Table 4.1; Final compilation of Source factors of Risk of IMP from literature review

Components	Num	Subcomponent Layer
T01: Political	T01a	Coordination absent among national & county regional governments
	T01b	Competing Interests and conflicts between National and county regional government
	T01c	Competing Interests and conflicts between county regional governments
T02: Natural	T02a	Carrying capacity of the environment
	T02b	Ecosystems fragility
	T02c	Harshness of the environment
T03: Social	T03a	Unfair and unregulated competition
	T03b	Grabbed resources of development
	T03c	Different region's conflicting ethical challenges
	T03d	Diverse interpretations and perspectives of authority, function and relevance
	T03e	Varied sociological contexts
T04: Economic	T04a	Asymmetrical and disproportionate economic development
	T04b	Unreasonable ecological compensation
	T04c	Unfair and unacceptable cost sharing
V01: Technology	V01a	Technology complexity
	V01b	Technical standards inconsistency
	V01c	Technical design changes
	V01d	Difficulty in innovation of technology
V02: Organization	V02a	Insufficient experience
	V02b	Unacceptable structure of organization
	V02c	Disinterest in coordination mechanism
	V02d	Insufficient guidelines and directives
V03: Management vulnerability	V03a	Uncertain leadership obligations
	V03b	Numerous levels of procedures for management
	V03c	Unadvanced management mode
	V03d	Interference from Government

O1^: Economic Objective	O1^a	Variance of cost
	O1^b	Schedule delays in the Project
	O1^c	Funds availability
O2^: Socio-cultural Objective	O2^a	Quality of the Project
	O2^b	Safety goals of the project
	O2^c	Social acceptability and suitability of the project
O3^: Environment/ Ecological Objective	O3^a	Desirable living environment within the project
	O3^b	Desirable ecological environment
	O3^c	Compliance with Environmental Regulations:

Collection of data score values for this study of threats, internal vulnerabilities, project objectives and threat + vulnerability interconnectedness relationships were gathered via survey responses that were administered through questionnaires. Guidelines in allocation of scores for individual indicators were clearly explained in the questionnaire as per tables 3.3,3.4,3.5 and 3.6. Fifteen Engineers from the main Government body involved in the Kenya's SGR project – Kenya Railways Corporation (KRC) were invited for questionnaire interviews. The questionnaire survey was distributed by using google workspace link https://forms.gle/aAYUs9zgDcSjX6uV9 which was sent to the participants through electronic mail and social media platforms for a response between December 2023 and February 2024. Table 4.2 shows calculations of means/averages and statistical evaluations of the threat probability, availability of vulnerability availability, severity of vulnerability and project objectives importance. The most threatening element's average score are less than 0.6 highlighting that not many external threats to the system of SGR can occur. From the findings, the availability of vulnerability and severity of vulnerability mean scores vary from 2.22 to 4.33, which indicates that most of the vulnerability risk source factors in Kenya's SGR project may be activated and instigated by the external threat risk source factors and hence have a great impact in the attainment of the objectives of the project. In addition, the project objective with the importance top score was O2b with 4.66 and the lowest mark of importance score was O1b with 3.66 These figures will be used to calculate the risks in the integrated model.

Threats Probability		Availability of Vulnerability		Severity of Vulnerability		Objectives Importance	
Factor	Mean score	Factor	mean score	Factor	Mean score	Factor	Mean score
T01a	0.311111111	V01a	3.8888889	V01a	4.33333333	O1^a	3.777777778
T01b	0.3	V01b	3	V01b	3.44444444	O1^b	3.666666667
T01c	0.305555556	V01c	3.2222222	V01c	3.55555556	O1^c	4.555555556
T02a	0.477777778	V01d	3	V01d	3.22222222	O2^a	4.555555556
T02b	0.388888889	V02a	3.2222222	V02a	3.77777778	O2^b	4.666666667
T02c	0.3	V02b	3	V02b	3.33333333	O2^c	4.222222222
T03a	0.127777778	V02c	2.2222222	V02c	3	O3^a	4.222222222
T03b	0.344444444	V02d	2.4444444	V02d	3.11111111	O3^b	3.888888889
T03c	0.322222222	V03a	2.7777778	V03a	3.44444444	O3^c	4
T03d	0.45	V03b	3.6666667	V03b	3.55555556		
T03e	0.455555556	V03c	2.8888889	V03c	3.11111111		
T04a	0.35	V03d	4	V03d	4.33333333		
T04b	0.222222222						
T04c	0.255555556						

Table 4.2 statistical analysis of vulnerability, threats and project objective

4.4 Risk Interconnectedness relationship Identification and cases;

To analyze the model for risk assessment effectively, interconnectedness risk relationships that threaten exploitation of the system vulnerabilities and make a significant impact on project objectives (social, environmental and economic) should be involved.

Consequently, based on the preliminary compilation of interconnectedness risk relationships in table 3.2, participant engineers were required to choose from the preliminary list the interconnectedness relationships that were in the project and to highlight the project objective factor/s that were affected by the interconnectedness relationships in the list. They were also at liberty to add to or remove from the list any factors relationships in the context of Kenya's SGR. A final list of interconnectedness relationships was generated after the interviews as per below table 4.3. The objectives affected by these interconnectedness relationships were also highlighted after the interview.

Threats	Vulnerability	Threat	Vulnerability	Threat	Vulnerability	Threat	Vulnerability
T1a	V2a	T2a	V1a	T3a	V2a	T4a	V2a
	V2b		V1b		V2b		V2c
	V2c		V1c		V2c		V2d
	V2d		V1d		V2d		V3a
	V3a		V3c		V3a		V3c
	V3b	T2b	V1a		V3b	T4b	V2a
	V3c		V1b		V3c		V2c
	V3d		V1c		V3d		V3a
T1b	V2a		V1d	T3b	V2a	T4c	V2a
	V2b		V2a		V2c		V2b
	V2c		V2d		V2d		V2c
	V2d		V3c		V3c		V2d
	V3a	T2c	V1a		V3d		V3a
	V3b		V1b	T3c	V2a		V3d
	V3c		V1c		V2b		
	V3d		V1d		V2c		
T1c	V2a		V2a		V2d		
	V2b		V2d		V3a		
	V2c		V3c		V3b		
	V2d				V3c		
	V3a				V3d		
	V3b						
	V3c						
	V3d						

Table 4.3 Final list of interconnectedness relationships

Objectives	Threats	Vulnerabilities	Risk	Objectives	Threats	Vulnerabilities	Risk
O1	T1a	V2a	R1			V1b	R49
		V2b	R2			V1d	R50
		V2c	R3			V3c	R51
		V2d	R4		T2c	V1a	R52
		V3a	R5			V1b	R53
		V3b	R6			V1c	R54
		V3c	R7			V1d	R55
		V3d	R8			V2a	R56
	T1b	V2c	R9		T3a	V2a	R57
		V2d	R10			V2b	R58
		V3a	R11			V3a	R59
		V3b	R12			V3b	R60
		V3d	R13			V3c	R61
	T1c	V2a	R14			V3d	R62
		V2b	R15		T3b	V2a	R63
		V2c	R16			V2c	R64
		V2d	R17			V2d	R65
		V3c	R18			V3c	R66
		V3d	R19			V3d	R67
	T2a	V1a	R20	O3	T3c	V2a	R68
		V1b	R21			V2c	R69
		V1c	R22			V2d	R70
		V2a	R23			V3a	R71
	T2b	V1a	R24			V3b	R72
		V1b	R25			V3c	R73
		V1c	R26			V3d	R74
		V1d	R27		T4a	V2a	R75
		V3b	R28			V3a	R76
		V3c	R29			V3c	R77
		V3d	R30		T4b	V3a	R78
	T2c	V1a	R31		T2a	V1a	R80
		V1b	R32			V1b	R81
		V1c	R33			V1c	R82
		V1d	R34			V1d	R83
		V2a	R35			V3c	R84
		V2d	R36		T2b	V1a	R85
	T3b	V3c	R37			V1c	R86
		V3d	R38			V1d	R87
	T4a	V2c	R39			V2a	R88
		V3b	R40			V2d	R89
	T4b	V2a	R41			V3c	R90
		V3a	R42		T2c	V1a	R91
	T4c	V2b	R43			V1b	R92
		V2c	R44			V1c	R93
		V2d	R45			V1d	R94
		V3a	R46			V2a	R95
		V3d	R47			V2d	R96
O2	T2a	V1a	R48			V3c	R97

Table 4.4 Interconnectedness relationships between threat, vulnerability and project objectives

4.5 Integrated Risk Assessment;

In consideration of identifying interconnectedness relationships and gathering scores of external threats, internal vulnerabilities and project objectives from the questionnaire survey, the values of 96 risks – as shown in table 4.4, were assessed using the model of integrated risk assessment as proposed by Xiang et al. (2022) and explained in section 3.6. As per the results findings, the significant risks for the Kenya's SGR were selected from the list of risks that ranked at highest 30% and their scores were noted to be also above average. As per the summary of the table 4.6, the risks were classified in accordance with the projects objectives that were impacted; the economic objective (objective 1) was affected by 13 risks and these were R20,R30,R24,R38,R23,R22,R8,R19,R13,R28,R31,R21 and R40 with their values ranging from 4.27221861 to 5.67501201 indicating that the most impacted objective was objective 1(economic); the environmental objective was affected by 9 significant risks with values ranging from 4.24107168 to 5.70122468 and these were R79,R84,R74,R81,R90,R80,R87,R82 and R85; and the social objective (objective 2) was affected by 7 significant risks which included R48,R67,R52,R49,R50,R51 and R63 and hence least impacted.

O1^: Economic Objective		O3^: Environment/ Ecological Objective		O2^: Socio-cultural Objective	
Risk	Value	Risk	Value	Risk	Value
R20	5.67501201	R79	5.70122468	R48	6.0068611
R30	5.19258731	R84	5.14360904	R67	5.1726303
R24	5.11996013	R74	4.74843126	R52	4.7598717
R38	4.88686827	R81	4.70084378	R49	4.7037474
R23	4.82324049	R90	4.51768359	R50	4.5494841
R22	4.67923059	R80	4.46441501	R51	4.3867911
R8	4.64439128	R87	4.37159663	R63	4.3347728
R19	4.60273671	R82	4.31800073		
R13	4.5607017	R85	4.24107168		
R28	4.50331382				
R31	4.49691252				
R21	4.44388885				
R40	4.27221861				

Table 4.5 Critical risks of the Kenya's SGR rail megaproject

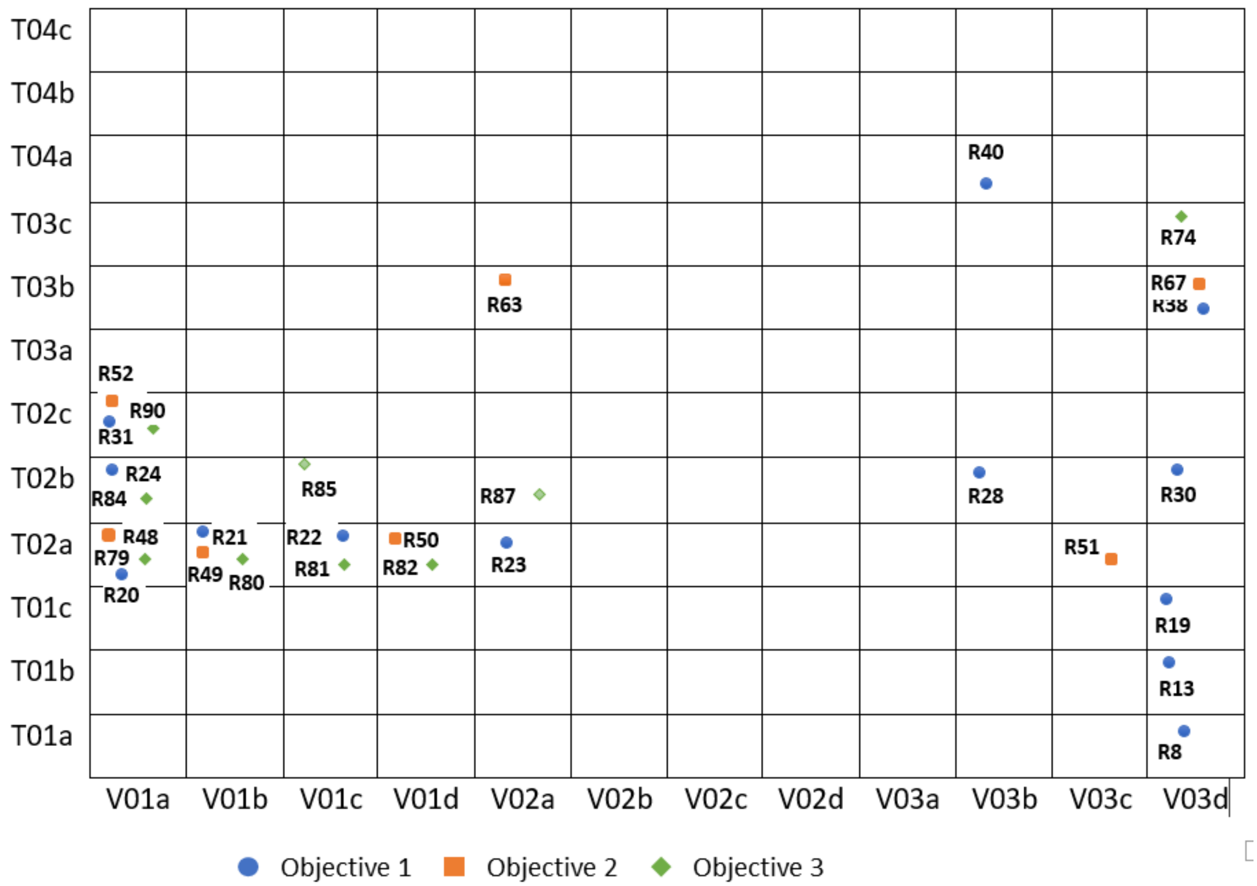


Fig 4.1 Bubble chart showing critical risks of the Kenya's SGR rail megaproject

The effects of vulnerabilities and threats to the project objectives leads to the composition of risks and hence bubble chart of risks incorporating the threats, vulnerabilities and objectives was developed as per fig 4.1 with the y axis displaying external threats and the x axis displaying internal vulnerabilities. The major external threats emanate from T02a and T02b since out of the 29 significant risks affecting the objectives, they were linked with 12 and 6 risks respectively. In addition, V01a and V03d were the main internal vulnerabilities exploitable with them having 8 and 6 risks associated with them, V01b, V01c, V01d, V02a were also easily exploitable vulnerabilities in the pack. T02a-V01a, T02b-V01a, T02c-V01a, T02a-V01b, T02a-V01c, T02a-V01d, T03b-V03d were the seven coupled relationships that had more than a single risk portraying that they impacted the most.

CHAPTER FIVE

5.00 DISCUSSION

5.1 Prelude

This chapter connects my findings in Chapter 4 to the research questions and strive to explain how comprehensively we have addressed them.

5.2 Economic Objective – Objective 1

From the analysis of critical risks affecting the SGR as per table 4.6 and subsequently fig 4.1, the economic objective are impacted by the following key external threats; T02a (carrying capacity of the environment), T02b (ecosystems fragility), T02c (harshness of the environment), T01a (cooperation lacking between national and county regional governments),T01b (competing interests and conflicts between national and county regional government),T01c (competing interests and conflicts between county regional governments),T03b (grabbed resources of development) and T04a (asymmetrical and disproportionate economic development). From the bubble chart in fig 4.1, T02a was the external threat that majorly affected objective 1 followed by T02b and the rest T02c, T01a, T01b, T01c, T03b and T04a affected the objective equally. Hence the carrying capacity of the environment and the ecosystem fragility are the external threats that affected the economic objective the most. The aforementioned external threats will exploit many vulnerabilities within the IMP system by interconnecting with them to lead to major risks. V03d - interference from government was the most exploited internal vulnerability, with the most coupled external threats affecting it. V01a (technology complexity) then V03b (numerous levels of procedures for management) followed V03d, then V01b (technical standards inconsistency), V01c (technical application's lack of experience) and V02a (insufficient experience of the organization), lead to the main risks in the Kenya's SGR megaproject.

T02a (carrying capacity of the environment) and T02b (ecosystems fragility) interconnected with V01a (technology complexity) and V03d (interference from government) led to the greatest risks to occur in the Kenya's SGR project.

According to the review of the case data, AWEMAC (2012), the environmental impact assessment (EIA)of the Kenya's SGR analyzed and considered environmental elements like the terrain, biodiversity, water resources, soil stability and effects to the domestic ecosystems. Various mitigation measures were proposed and were supposed to be implemented to reduce ecological effects and alleviate any concerns about the project surpassing the environmental carrying capacity. It was noted by Achuka (2022) that the proposed recommendations were not completely executed attributing it to various challenges. From the case data review, the findings that carrying capacity of the environment and ecosystem fragility being the main external threats to the economic objective are consistent with the case facts. The SGR cuts through a large area of Kenya's ecological ecosystems that are fragile and important for example SGR passes through the Tsavo National park (whose ecosystem sustains 40% of the country's elephant population) and Nairobi National Park. It was also reported that the SGR's construction and operation had damaged, disintegrated and eradicated vital ecosystems. To safeguard the integrity of the ecosystems and seek a solution, technological intervention which is one of the vulnerabilities (V1a,V1b and V1c) that was interconnected with the threats by redesigning and revision of the initial designs and construction drawings and details and various bridges within the national parks were installed and other construction techniques were used to take care of the wildlife movement and water bodies which was a major variation of the engineering cost which caused a financial strain to the project (Freitas, 2021). Further from Olingo (2017), the environmental terrain of the SGR Kenya made it to be the second country in Africa with the lengthiest railway tunnel in Africa with a 7.1km tunnel. The technological complexity of this was achieved by Engineers using the New Austrian Tunneling Method (NATM). This affected the economic cost objective of the project

In addition from the risk assessment findings, T02c – harshness of the environment, T03b - grabbed resources of development and T04a- asymmetrical and disproportionate economic development are also main external threats to the Kenya's SGR IMP for they exploit vulnerabilities V01a - technology complexity,V03d- interference from Government and V03b - numerous levels of procedures for management respectively to affect economic objectives. The Kenya's SGR harsh environment demands advanced complex technology and management (Ombuor, 2018). It is practical to grow risk management strategies from the point of view of threats exploiting vulnerabilities

5.3 Environmental Objective – Objective 3

The environmental objectives are impacted by the following key external threats; T02a (carrying capacity of the environment), T02b (ecosystems fragility), T02c (harshness of the environment) and T03c (different region's conflicts of interest). T02a was the external threat that affected the objective 3 the most, followed by T02b and the rest T02c and 3c affected the objective equally. Hence the carrying capacity of the environment and the ecosystem fragility are the external threats that affected the environmental objective the most. The aforementioned external threats will exploit many vulnerabilities within the IMP system. V01a - technology complexity was the most exploited internal vulnerability, with the most coupled and interconnected external threats affecting it. V01c (technical application's lack of experience) then V01b (technical standards inconsistency), V01d (difficulty in innovation of technology), V02a (insufficient experience of the organization), V03d (interference from government) followed.

The Kenya's SGR cuts through a large area of Kenya's ecological ecosystems that are fragile and important for example SGR passes through the Tsavo National park (whose ecosystem sustains 40% of the country's elephant population) and Nairobi National Park. Technical interventions like viaducts, bridges and tunnels designs were built to accommodate this environmental objective (Freitas, 2021). The design consortium improved designs to protect environmental landscape and this showed that IMP's construction needs flexibility to accommodate realities on the environment.

5.4 Social Objective – Objective 2

The social objectives are impacted by the following key external threats; T02a (carrying capacity of the environment), T03b (grabbed resources of development) and T02c (harshness of the environment). T02a was the external threat that affected the objective 2 the most followed by T03b and then T02c. Hence the carrying capacity of the environment and the grabbed resources for development are the external threats that affected the social objective the most. The aforementioned external threats will exploit many vulnerabilities within the IMP system by coupling with them to lead to major risks. V01a (technology complexity) was the most exploited internal vulnerability with the most coupled external threats affecting it. V01b (technical standards inconsistency), V01d (difficulty in innovation of technology), V02a (insufficient experience of the organization), V03c (unadvanced management mode) and V03d (interference from government) lead to the main risks in the Kenya's SGR megaproject.

CHAPTER SIX

6.00 CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

6.1 Prelude

In this chapter illustrates conclusions and recommendations of this research as formulated by the findings and discussions in chapters 4 and 5 and by further evaluating research background and objectives.

6.2 Conclusion

Because IMPs extend across multiple regions and majorly affects the economic and social progress of nations, an impactful risk assessment technique is critical in enhancing efficiency of projects. Existing techniques of risk assessment disregard different interrelation between project's threats and vulnerability. In accordance with systems theory, this study adopted an integrated risk assessment model which incorporated threats, vulnerabilities and project objective's importance and implemented it to examine risks on the Kenya's SGR megaproject. Based on the findings, the integrated assessment technique was successful thus enhancing the risk management of the Kenya's SGR IMP.

Based on detailed case study of the SGR; firstly, economic objectives of the project are mostly impacted followed by environmental then social objectives so management of threats impacting these objectives should be managed giving attention to the order of importance. Secondly, it has been noted that since the Kenya's SGR IMP traverses several regions in its construction it is impacted by harsh, unstable and unpredictable environmental conditions. Based on the results, the three objectives in this study are affected by T02a - carrying capacity of the environment, T02b -ecosystems fragility and T02c-harshness of the environment as common threat factors to all. The study concludes that the natural threat significantly impacts all the project objectives in

Kenya's SGR. This gives an opportunity for the project's technological enhancement and innovation to manage the natural external threats. Thirdly, political threats; T01a (cooperation lacking between national and county regional governments), T01b (competing interests and conflicts between national and county regional government), T01c (competing interests and conflicts between county regional governments) mainly have an impact on the economic objectives of the project and there should be a mechanism for coordination of the interests. Fourthly, compelling public interest petitions and opinions from different regions should be accommodated for environmental impact and coordinated development. Finally, broad-ranging and versatile environmental conservation strategies have been used in IMPs in Kenya to lower risks for long term sustainability of projects which can be replicated in future phases.

In conclusion, this study has the following key contributions;

i) a risk assessment is done to an IMP rail SGR project in Kenya based on vulnerability theory using a systems approach including internal vulnerabilities within the system, external threats out of the system, project objectives and interconnectedness relationships of elements in rail MP enhancing rail megaprojects studies;

ii) from the system's perspectives, the sources of risk of IMPs are recognized and identified and these include 14 external threat factors and 12 internal vulnerability factors providing precise direction for management of risk and relevant studies for IMPs;

iii) fundamental risk factors and strategies of management validated and substantiated by the Kenya's SGR case study, will be helpful to different governments in varied regions especially in Africa and rail managers to improve oversight, administration and management of SGR megaprojects.

The limitations of the study are that; firstly, the context environment of analysis of the case study is Kenya hence the point of reference for evaluation of the results is limited. Secondly, the IMP proposed is limited to rail projects, various other IMP exists and should be studied. Thirdly, data collection was limited to secondary data from the internet and questionnaire assessment.

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APPENDICES

APPENDIX 01

QUESTIONAIRE:

Section -I: General Information

01. Choose gender;

Male ☐ Female ☐ Abstain answer ☐

02. Years of management experience in KRC organization;

Above 20 years ☐

16-20 years ☐

11-15 years ☐

6-10 years ☐

0-5years ☐

03. Role within the KRC organization;

Executive Management (CEO, VP,) ☐

Mid-level management (Directors and Equals) ☐

4. Highest level of education completed

Doctorate (PhD) ☐

Master's degree ☐

Bachelor's degree ☐

5. Age Bracket

40 - 50 year(s) old ☐

30 - 40 year(s) old☐

Below 30 year(s) old☐

<u>Section -I: Experts Interview: - Confirmation of Risk source factors from Literature review</u>

Instruction: Please confirm the risk source factors by ticking appropriately Yes or No in relation to the statements below linked to the confirmation if the risk source factors affect the Kenya's Standard Gauge Railway objectives (1.1) Kindly (√) tick properly on a scale of 1-5 that most accurately articulate your view. Also add or suggest removal of any of the factors;

Table. Risk source factors confirmation from expert interviews

External Threats risks			**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Components	Num	Subcomponent Layer					
T01: Political	T01a	Coordination absent among national & county regional governments					
	T01b	Competing Interests and conflicts between National and county regional government					
	T01c	Competing Interests and conflicts between county regional governments					
T02: Natural	T02a	Carrying capacity of the environment					
	T02b	Ecosystems fragility					
	T02c	Harshness of the environment					
T03: Social	T03a	Unfair and unregulated competition					
	T03b	Grabbed resources of development					
	T03c	Different region's conflicting ethical challenges					
	T03d	Diverse interpretations and perspectives of authority, function and relevance					
	T03e	Varied sociological contexts					
T04: Economic	T04a	Asymmetrical and disproportionate economic development					
	T04b	Unreasonable ecological compensation					
	T04c	Unfair and unacceptable cost sharing					
Vulnerability risks							
V01: Technology	V01a	Technology complexity					
	V01b	Technical standards inconsistency					
	V01c	Technical application's lack of experience					
	V01d	Difficulty in innovation of technology					
V02: Organization	V02a	Insufficient experience					
	V02b	Unacceptable structure of organization					
	V02c	Disinterest in coordination mechanism					
	V02d	Insufficient guidelines and directives					
V03: Management vulnerability	V03a	Uncertain leadership obligations					
	V03b	Numerous levels of procedures for management					
	V03c	Unadvanced management mode					
	V03d	Interference from Government					
Project Objectives							
O1^: Economic Objective	O1^a	Variance of cost					
	O1^b	Schedule delays in the Project					
	O1^c	Achievement of economic benefits					
O2^: Socio-cultural Objective	O2^a	Quality of the Project					
	O2^b	Safety goals of the project					
	O2^c	Social acceptability and suitability of the project					

O3^: Environment/ Ecological Objective	O3^a	Desirable living environment within the project					
	O3^b	Desirable ecological environment					
	O3^c	Compliance with Environmental Regulations:					

Keys: 1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree

<u>Section -II: External Threats: - Assessment of probability of threat to occur</u>

Instruction: Please assess probability of threat to occur in 2.1 by ticking appropriate level from extremely improbable to extremely probable with respect to the following statements associated with external threat risk factor components of Kenya's Standard Gauge Railway (2.1) Kindly (√) tick properly on a scale of 01-05 that most accurately articulate your view.

Table; Assessment of probability of threat to occur

Rank	Probability degree	Narrative	Numeric representation of Probability
05	Extremely probable	Will inevitably occur for sure - definite or unavoidable	0.9
04	Possible	Likely or to occur	0.6
03	Probable	Occurs occasionally and will only happen in specific conditions	0.3
02	Hardly probable	Hardly occurs, and normally it is less probable to happen	0.1
01	Extremely improbable	It scarcely occurs, it can only happen in very extreme conditions	0.05

Keys: 1-Extremely improbable, 2-Hardly probable, 3-Probable, 4-Possible, 5-Extremely probable

2.0 External Threats risks							
2.1 Assessment of probability of threat to occur			**01**	**02**	**03**	**04**	**05**
External Threats risks			**Extremely Improbable**	**Hardly probable**	**Probable**	**Possible**	**Extremely probable**
Components	Num	Subcomponent Layer					
T01: Political	T01a	Coordination absent among national & county regional governments					
	T01b	Competing Interests and conflicts between National and county regional government					
	T01c	Competing Interests and conflicts between county regional governments					
T02: Natural	T02a	Carrying capacity of the environment					
	T02b	Ecosystems fragility					
	T02c	Harshness of the environment					
T03: Social	T03a	Unfair and unregulated competition					
	T03b	Grabbed resources of development					
	T03c	Different region's conflicting ethical challenges					
	T03d	Diverse interpretations and perspectives of authority, function and relevance					
	T03e	Varied sociological contexts					
T04: Economic	T04a	Asymmetrical and disproportionate economic development					
	T04b	Unreasonable ecological compensation					

	T04c	Unfair and unacceptable cost sharing					

Keys: 1-Extremely improbable, 2-Hardly probable, 3-Probable, 4-Possible, 5-Extremely probable

Section -III: Vulnerability: -

3.1 Assessment for the degree or level of availability of vulnerability

Instruction: Please assess the degree or level of availability of vulnerability in 3.1 by ticking appropriate level from extremely low to extremely high with respect to the following statements associated with vulnerability risk factor components of Kenya's Standard Gauge Railway. Kindly (√) tick properly on a scale of 1-5 that most accurately articulate your view.

Table; Assessment for the degree or level of availability of vulnerability

Rank	Vulnerability Degree or level	Narrative	Numeric representation of Availability
05	Extremely High	Extremely vulnerable to threats	05
04	High	Vulnerable to be exploited by threats	04
03	Medium	It might be available for misuse by threats	03
02	Low	Not readily misused by threats	02
01	Extremely Low	It is inconceivable for vulnerability to be misused by threats	01

Keys: 1-Extremely Low, 2-Low, 3-Medium, 4-High, 5-Extremely High

3.0 Vulnerability risks							
3.1 Assessment for the degree or level of availability of vulnerability			**01**	**02**	**03**	**04**	**05**
Vulnerability – risks factors			**Extremely low**	**Low**	**Medium**	**High**	**Extremely High**
V01: Technology	V01a	Technology complexity					
	V01b	Technical standards inconsistency					
	V01c	Technical application's lack of experience					
	V01d	Difficulty in innovation of technology					
V02: Organization	V02a	Insufficient experience					
	V02b	Unacceptable structure of organization					
	V02c	Disinterest in coordination mechanism					
	V02d	Insufficient guidelines and directives					
V03: Management vulnerability	V03a	Uncertain leadership obligations					
	V03b	Numerous levels of procedures for management					
	V03c	Unadvanced management mode					
	V03d	Interference from Government					

Keys: 1-Extremely Low, 2-Low, 3-Medium, 4-High, 5-Extremely High

3.2 Assessment of level or degree of severity of vulnerability

Instruction: Please assess level or degree of severity of vulnerability in 3.2 by ticking appropriate level from extremely low to extremely high with respect to the following statements associated with vulnerability risk factor components of Kenya's Standard Gauge Railway. Kindly (√) tick properly on a scale of 1-5 that most accurately articulate your view.

Table; Assessment of level or degree of severity of vulnerability

Rank	Severity level or Degree	Narrative	Numeric representation of Severity
05	Extremely High	It will result in severe/substantial loss to the objectives, if under threat;	05
04	High	It will result considerable loss to the objectives, if under threat;	04
03	Medium	It will result broad/generalized loss to the objectives, if under threat	03
02	Low	It will result in minimal loss to the objectives, if under threat	02
01	Extremely Low	If under threat, the loss could be ignored	01

Keys: 1-Extremely Low, 2-Low, 3-Medium, 4-High, 5-Extremely High

3.0 Vulnerability risks							
3.2 Assessment of level or degree of severity of vulnerability			**01**	**02**	**03**	**04**	**05**
Vulnerability – risks factors			**Extremely low**	**Low**	**Medium**	**High**	**Extremely High**
V01: Technology	V01a	Technology complexity					
	V01b	Technical standards inconsistency					
	V01c	Technical application's lack of experience					
	V01d	Difficulty in innovation of technology					
V02: Organization	V02a	Insufficient experience					
	V02b	Unacceptable structure of organization					
	V02c	Disinterest in coordination mechanism					
	V02d	Insufficient guidelines and directives					
V03: Management vulnerability	V03a	Uncertain leadership obligations					
	V03b	Numerous levels of procedures for management					
	V03c	Unadvanced management mode					
	V03d	Interference from Government					

Keys: 1-Extremely Low, 2-Low, 3-Medium, 4-High, 5-Extremely High

Section -IV: Project Objectives: - Assessment of the objective of the project's importance

Instruction: Please assess the objective of the project's importance in 4.1 by ticking appropriate level from extremely low to extremely high with respect to the following statements associated with project objective risk factor components of Kenya's Standard Gauge Railway. Kindly (√) tick properly on a scale of 1-5 that most accurately articulate your view.

Rank	Importance level or Degree	Narrative	Numeric representation of importance
05	Extremely High	Extremely important, if not attained, it will result substantial/ severe harm	05
04	High	Important, if not attained, will result in considerable harm	04
03	Medium	Slightly important, if not attained, it will result in broad/generalized harm	03
02	Low	Unimportant, if not attained, will result in minimal harm	02
01	Extremely Low	If under threat, the harm could be ignored	01

Table; Assessment of the objective of the project's importance

4.0 Project Objectives							
4.1 Assessment of the objective of the project's importance			**01**	**02**	**03**	**04**	**05**
Project Objective - Risk Factors			**Extremely Low**	**Low**	**Medium**	**High**	**Extremely High**
Components	Num	Subcomponent Layer					
O1^: Economic Objective	O1^a	Variance of cost					
	O1^b	Schedule delays in the Project					
	O1^c	Achievement of economic benefits					
O2^: Socio-cultural Objective	O2^a	Quality of the Project					
	O2^b	Safety goals of the project					
	O2^c	Social acceptability and suitability of the project					
O3^: Environment/ Ecological Objective	O3^a	Desirable living environment within the project					
	O3^b	Desirable ecological environment					
	O3^c	Compliance with Environmental Regulations:					

<u>Section -V: Risk Interconnectedness Relationships: - Assignment for Confirmation of Risk Interconnectedness Relationships</u>

Instruction: Below shows the preliminary list of interconnectedness relationships between Threats (T) and Vulnerabilities (V). Please confirm if the interconnectedness relationships apply to the Kenya's SGR and if not make necessary changes to one or all of them. Kindly (√) tick properly on a scale of 1-5 that most accurately articulate your view. Remember to add any interconnectedness relationship not in the list that you feel is left out.

T	**V**	(√) tick yes or (X) no	**T**	**V**	(√) tick yes or (X) no	**T**	**V**	(√) tick yes or (X) no	**T**	**V**	(√) tick yes or (X) no
T1a	V2a		T2a	V1a		T3a	V2a		T4a	V2a	
	V2b			V1b			V2b			V2c	
	V2c			V1c			V2c			V2d	
	V2d			V1d			V2d			V3a	
	V3a			V3c			V3c		T4b	V2a	
	V3d		T2b	V1a			V3d			V2c	
T1b	V2a			V1b		T3b	V2c			V3a	
	V2b			V1c			V2d		T4c	V2a	
	V2c			V1d			V3c			V2b	
	V3b			V2a			V3d			V2c	
	V3d			V2d		T3c	V2a			V2d	
T1c	V2a		T2c	V1a			V2b			V3a	
	V2b			V1b			V2c				
	V2c			V1c			V2d				
	V3a			V1d			V3a				
	V3d			V2a			V3b				
				V2d			V3c				
				V3c			V3d				

APPENDIX 02

Risk calculations

Sorted Risks (in a descending order), top 30% highlighted

Objective	Threat	Vulnerability	Risk	Risk calculated
O2	T02a	V01a	R48	6.006861138
O3	T02a	V01a	R79	5.701224676
O1	T02a	V01a	R20	5.67501201
O1	T02b	V03d	R30	5.192587309
O2	T03b	V03d	R67	5.172630303
O3	T02b	V01a	R84	5.143609036
O1	T02b	V01a	R24	5.119960134
O1	T03b	V03d	R38	4.886868269
O1	T02a	V02a	R23	4.823240491
O2	T02c	V01a	R52	4.7598717
O3	T03c	V03d	R74	4.748431262
O2	T02a	V01b	R49	4.703747448
O3	T02a	V01c	R81	4.700843778
O1	T02a	V01c	R22	4.679230589
O1	T01a	V03d	R8	4.644391281
O1	T01c	V03d	R19	4.602736706
O1	T01b	V03d	R13	4.5607017
O2	T02a	V01d	R50	4.54948406
O3	T02c	V01a	R90	4.51768359
O1	T02b	V03b	R28	4.503313823
O1	T02c	V01a	R31	4.496912521
O3	T02a	V01b	R80	4.464415009
O1	T02a	V01b	R21	4.443888854
O2	T02a	V03c	R51	4.386791127
O3	T02b	V02a	R87	4.371596629
O2	T03b	V02a	R63	4.334772837
O3	T02a	V01d	R82	4.318000731
O1	T04a	V03b	R40	4.27221861
O3	T02b	V01c	R85	4.241071683
O1	T02b	V01c	R26	4.2215724
O1	T04c	V03d	R47	4.209337064
O3	T02a	V03c	R83	4.163585814
O3	T04a	V02a	R75	4.147260708
O3	T03c	V03b	R72	4.118115858
O2	T02c	V02a	R56	4.045455036
O1	T01a	V03b	R6	4.027886333
O1	T02b	V01b	R25	4.009248567
O3	T03c	V02a	R68	3.979285131
O1	T01b	V03b	R12	3.95530586
O2	T02c	V01c	R54	3.924667863
O3	T02b	V01d	R86	3.895673095
O1	T01a	V02a	R1	3.892097442
O1	T02b	V01d	R27	3.877761859

O1	T01c	V02a	R14	3.857190033
O3	T02c	V02a	R94	3.839617322
O1	T02c	V02a	R35	3.821963816
O3	T02b	V03c	R89	3.756360928
O1	T02b	V03c	R29	3.739090212
O2	T02c	V01b	R53	3.727276833
O3	T02c	V01c	R92	3.724975948
O2	T03b	V03c	R66	3.724719525
O1	T02c	V01c	R33	3.707849531
O3	T04a	V03a	R76	3.676831527
O2	T02c	V01d	R55	3.605037628
O3	T04a	V03c	R77	3.563596874
O3	T02c	V01b	R91	3.537628417
O3	T03c	V03a	R71	3.527909639
O1	T01a	V02b	R2	3.527668415
O1	T02c	V01b	R32	3.521363372
O1	T03b	V03c	R37	3.518947342
O1	T01c	V02b	R15	3.496029494
O3	T02b	V02d	R88	3.455349494
O1	T01a	V03a	R5	3.450611763
O2	T03b	V02d	R65	3.426243636
O3	T02c	V01d	R93	3.421608892
O3	T03c	V03c	R73	3.419261304
O1	T02c	V01d	R34	3.405877273
O1	T01b	V03a	R11	3.388433485
O1	T01a	V03c	R7	3.344343955
O1	T01c	V03c	R18	3.314349233
O3	T02c	V03c	R96	3.299249613
O1	T04b	V02a	R41	3.289422713
O2	T03b	V02c	R64	3.207929134
O1	T04c	V02b	R43	3.197221016
O2	T03a	V03d	R62	3.150500211
O3	T03c	V02d	R70	3.14526294
O1	T04c	V03a	R46	3.127382494
O1	T01a	V02d	R4	3.076349002
O1	T04a	V02c	R39	3.055050463
O1	T01c	V02d	R17	3.048757871
O3	T02c	V02d	R95	3.034868241
O1	T01b	V02d	R10	3.02091475
O1	T02c	V02d	R36	3.02091475
O3	T03c	V02c	R69	2.944852057
O3	T04b	V03a	R78	2.929769488
O1	T04b	V03a	R42	2.916299213
O1	T01a	V02c	R3	2.880329199
O1	T01c	V02c	R16	2.854496129
O1	T01b	V02c	R9	2.828427125
O1	T04c	V02d	R45	2.788178061
O2	T03a	V03b	R60	2.732297081
O2	T03a	V02a	R57	2.640185348
O1	T04c	V02c	R44	2.610520028
O2	T03a	V02b	R58	2.392976692
O2	T03a	V03a	R59	2.340705687
O2	T03a	V03c	R61	2.268619437

APPENDIX 03

Risk calculations - Details

Interconnected Relationships			
O1	T01a	V02a	R1
O1	T01a	V02b	R2
O1	T01a	V02c	R3
O1	T01a	V02d	R4
O1	T01a	V03a	R5
O1	T01a	V03b	R6
O1	T01a	V03c	R7
O1	T01a	V03d	R8
O1	T01b	V02c	R9
O1	T01b	V02d	R10
O1	T01b	V03a	R11
O1	T01b	V03b	R12
O1	T01b	V03d	R13
O1	T01c	V02a	R14
O1	T01c	V02b	R15
O1	T01c	V02c	R16
O1	T01c	V02d	R17
O1	T01c	V03c	R18
O1	T01c	V03d	R19
O1	T02a	V01a	R20
O1	T02a	V01b	R21
O1	T02a	V01c	R22
O1	T02a	V02a	R23
O1	T02b	V01a	R24
O1	T02b	V01b	R25
O1	T02b	V01c	R26
O1	T02b	V01d	R27
O1	T02b	V03b	R28
O1	T02b	V03c	R29
O1	T02b	V03d	R30
O1	T02c	V01a	R31
O1	T02c	V01b	R32
O1	T02c	V01c	R33
O1	T02c	V01d	R34
O1	T02c	V02a	R35
O1	T02c	V02d	R36
O1	T03b	V03c	R37
O1	T03b	V03d	R38
O1	T04a	V02c	R39
O1	T04a	V03b	R40
O1	T04b	V02a	R41
O1	T04b	V03a	R42
O1	T04c	V02b	R43
O1	T04c	V02c	R44
O1	T04c	V02d	R45
O1	T04c	V03a	R46
O1	T04c	V03d	R47
O2	T02a	V01a	R48
O2	T02a	V01b	R49
O2	T02a	V01d	R50
O2	T02a	V03c	R51
O2	T02c	V01a	R52
O2	T02c	V01b	R53
O2	T02c	V01c	R54
O2	T02c	V01d	R55
O2	T02c	V02a	R56

Items	Value	Threat	V_Availability	V_Severity	Objective	Risk	Risk calculated
T11	0.311111	0.311111	3.222222222	3.777777778	4	R1	3.89209744
T12	0.3	0.311111	3	3.333333333	4	R2	3.52766841
T13	0.305556	0.311111	2.222222222	3	4	R3	2.8803292
T21	0.477778	0.311111	2.444444444	3.111111111	4	R4	3.076349
T22	0.388889	0.311111	2.777777778	3.444444444	4	R5	3.45061176
T23	0.3	0.311111	3.666666667	3.555555556	4	R6	4.02788633
T31	0.127778	0.311111	2.888888889	3.111111111	4	R7	3.34434395
T32	0.344444	0.311111	4	4.333333333	4	R8	4.64439128
T33	0.322222	0.3	2.222222222	3	4	R9	2.82842712
T34	0.45	0.3	2.444444444	3.111111111	4	R10	3.02091475
T35	0.455556	0.3	2.777777778	3.444444444	4	R11	3.38843348
T41	0.35	0.3	3.666666667	3.555555556	4	R12	3.95530586
T42	0.222222	0.3	4	4.333333333	4	R13	4.5607017
T43	0.255556	0.305556	3.222222222	3.777777778	4	R14	3.85719003
V11	3.888889	0.305556	3	3.333333333	4	R15	3.49602949
V12	3	0.305556	2.222222222	3	4	R16	2.85449613
V13	3.222222	0.305556	2.444444444	3.111111111	4	R17	3.04875787
V14	3	0.305556	2.888888889	3.111111111	4	R18	3.31434923
V21	3.222222	0.305556	4	4.333333333	4	R19	4.60273671
V22	3	0.477778	3.888888889	4.333333333	4	R20	5.67501201
V23	2.222222	0.477778	3	3.444444444	4	R21	4.44388885
V24	2.444444	0.477778	3.222222222	3.555555556	4	R22	4.67923059
V31	2.777778	0.477778	3.222222222	3.777777778	4	R23	4.82324049
V32	3.666667	0.388889	3.888888889	4.333333333	4	R24	5.11996013
V33	2.888889	0.388889	3	3.444444444	4	R25	4.00924857
V34	4	0.388889	3.222222222	3.555555556	4	R26	4.2215724
V11	4.333333	0.388889	3	3.222222222	4	R27	3.87776186
V12	3.444444	0.388889	3.666666667	3.555555556	4	R28	4.50331382
V13	3.555556	0.388889	2.888888889	3.111111111	4	R29	3.73909021
V14	3.222222	0.388889	4	4.333333333	4	R30	5.19258731
V21	3.777778	0.3	3.888888889	4.333333333	4	R31	4.49691252
V22	3.333333	0.3	3	3.444444444	4	R32	3.52136337
V23	3	0.3	3.222222222	3.555555556	4	R33	3.70784953
V24	3.111111	0.3	3	3.222222222	4	R34	3.40587727
V31	3.444444	0.3	3.222222222	3.777777778	4	R35	3.82196382
V32	3.555556	0.3	2.444444444	3.111111111	4	R36	3.02091475
V33	3.111111	0.344444	2.888888889	3.111111111	4	R37	3.51894734
V34	4.333333	0.344444	4	4.333333333	4	R38	4.88686827
O11	3.777778	0.35	2.222222222	3	4	R39	3.05505046
O12	3.666667	0.35	3.666666667	3.555555556	4	R40	4.27221861
O13	4.555556	0.222222	3.222222222	3.777777778	4	R41	3.28942271
O21	4.555556	0.222222	2.777777778	3.444444444	4	R42	2.91629921
O22	4.666667	0.255556	3	3.333333333	4	R43	3.19722102
O23	4.222222	0.255556	2.222222222	3	4	R44	2.61052003
O31	4.222222	0.255556	2.444444444	3.111111111	4	R45	2.78817806
O32	3.888889	0.255556	2.777777778	3.444444444	4	R46	3.12738249
O33	4	0.255556	4	4.333333333	4	R47	4.20933706
O1	4	0.477778	3.888888889	4.333333333	4.481481	R48	6.00686114
O2	4.481481	0.477778	3	3.444444444	4.481481	R49	4.70374745
O3	4.037037	0.477778	3	3.222222222	4.481481	R50	4.54948406
		0.477778	2.888888889	3.111111111	4.481481	R51	4.38679113
		0.3	3.888888889	4.333333333	4.481481	R52	4.7598717
		0.3	3	3.444444444	4.481481	R53	3.72727683
		0.3	3.222222222	3.555555556	4.481481	R54	3.92466786
		0.3	3	3.222222222	4.481481	R55	3.60503763
		0.3	3.222222222	3.777777778	4.481481	R56	4.04545504

O2	T03b	V02a	R63
O2	T03b	V02c	R64
O2	T03b	V02d	R65
O2	T03b	V03c	R66
O2	T03b	V03d	R67
O3	T03c	V02a	R68
O3	T03c	V02c	R69
O3	T03c	V02d	R70
O3	T03c	V03a	R71
O3	T03c	V03b	R72
O3	T03c	V03c	R73
O3	T03c	V03d	R74
O3	T04a	V02a	R75
O3	T04a	V03a	R76
O3	T04a	V03c	R77
O3	T04b	V03a	R78
O3	T02a	V01a	R79
O3	T02a	V01b	R80
O3	T02a	V01c	R81
O3	T02a	V01d	R82
O3	T02a	V03c	R83
O3	T02b	V01a	R84
O3	T02b	V01c	R85
O3	T02b	V01d	R86
O3	T02b	V02a	R87
O3	T02b	V02d	R88
O3	T02b	V03c	R89
O3	T02c	V01a	R90
O3	T02c	V01b	R91
O3	T02c	V01c	R92
O3	T02c	V01d	R93
O3	T02c	V02a	R94
O3	T02c	V02d	R95
O3	T02c	V03c	R96

0.344444	3.222222222	3.777777778	4.481481	R63	4.33477284
0.344444	2.222222222	3	4.481481	R64	3.20792913
0.344444	2.444444444	3.111111111	4.481481	R65	3.42624364
0.344444	2.888888889	3.111111111	4.481481	R66	3.72471952
0.344444	4	4.333333333	4.481481	R67	5.1726303
0.322222	3.222222222	3.777777778	4.037037	R68	3.97928513
0.322222	2.222222222	3	4.037037	R69	2.94485206
0.322222	2.444444444	3.111111111	4.037037	R70	3.14526294
0.322222	2.777777778	3.444444444	4.037037	R71	3.52790964
0.322222	3.666666667	3.555555556	4.037037	R72	4.11811586
0.322222	2.888888889	3.111111111	4.037037	R73	3.4192613
0.322222	4	4.333333333	4.037037	R74	4.74843126
0.35	3.222222222	3.777777778	4.037037	R75	4.14726071
0.35	2.777777778	3.444444444	4.037037	R76	3.67683153
0.35	2.888888889	3.111111111	4.037037	R77	3.56359687
0.222222	2.777777778	3.444444444	4.037037	R78	2.92976949
0.477778	3.888888889	4.333333333	4.037037	R79	5.70122468
0.477778	3	3.444444444	4.037037	R80	4.46441501
0.477778	3.222222222	3.555555556	4.037037	R81	4.70084378
0.477778	3	3.222222222	4.037037	R82	4.31800073
0.477778	2.888888889	3.111111111	4.037037	R83	4.16358581
0.388889	3.888888889	4.333333333	4.037037	R84	5.14360904
0.388889	3.222222222	3.555555556	4.037037	R85	4.24107168
0.388889	3	3.222222222	4.037037	R86	3.89567309
0.388889	3.222222222	3.777777778	4.037037	R87	4.37159663
0.388889	2.444444444	3.111111111	4.037037	R88	3.45534949
0.388889	2.888888889	3.111111111	4.037037	R89	3.75636093
0.3	3.888888889	4.333333333	4.037037	R90	4.51768359
0.3	3	3.444444444	4.037037	R91	3.53762842
0.3	3.222222222	3.555555556	4.037037	R92	3.72497595
0.3	3	3.222222222	4.037037	R93	3.42160889
0.3	3.222222222	3.777777778	4.037037	R94	3.83961732
0.3	2.444444444	3.111111111	4.037037	R95	3.03486824
0.3	2.888888889	3.111111111	4.037037	R96	3.29924961