



Influence of implementation of climate-resilient critical infrastructure on effective project management practices - South African Context

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

03 November 2025

Plagiarism Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

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03 November 2025

Abstract

The increasing risk of climate change has increased the demand of climate-resilient critical infrastructure (CRCI) that promotes sustainability, socio-economic stability, and adaptive project delivery systems. In the South African context, the occurrence of extreme weather events on a regular basis has exposed vulnerabilities in the infrastructure planning and management, highlighting the need to harmonise the project management practices with the principles of resilience. This research is aimed at exploring the effects of CRCI implementation on effective project management practices in South Africa, determining the areas of project management that are most impacted by resilience integration, and creating a contextual framework that can be used to inform resilience-based infrastructure delivery.

The qualitative exploratory study based on the interpretivist philosophy and narrative inquiry research strategy was used to explore the lived experiences and views of professionals engaged in the delivery of climate-resilient infrastructure. Semi-structured interviews with 13 professionals working in the infrastructure sector were used to collect data, and thematic analysis was used to analyse the data inductively.

The results indicate that resilience integration does not only change the project management models, which are mostly static and efficiency-based, but also encourages adaptive, participatory, and system-based practices that focus on early risk detection, lifecycle cost-efficiency, and inclusivity of stakeholders. The framework was created with seven components, which included policy alignment, collaboration, capacity building, institutional accountability, socio-political integration, financial sustainability and adaptive management. The research concludes that the integration of resilience in project management improves sustainability, governance coherence, and long-term project performance of the critical infrastructure in South Africa.

Keywords: Climate-resilient infrastructure, project management, adaptive governance, agile, sustainability.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

The growing effects of climate change in the global arena are becoming a challenge to the sustainability and resilience of infrastructure systems. Nations are compelled to implement climate-resilient infrastructure that will guarantee long-term sustainability, safeguard communities, and protect economic investments. Extreme weather events like flooding, heatwaves, droughts, and cyclones have been on the increase in recent years, exposing the vulnerability in the design, planning, and management of infrastructure projects (Hallegatte et al., 2020). In this scenario, climate-resilient infrastructure has emerged as a major global priority that promotes societal wellbeing, economic sustainability, and sustainable development.

South Africa, like many developing economies, faces more risks that are associated with climate variability. According to Ngepah et al. (2022) and Nhamo et al. (2025), disasters associated with the climate have cost the country billions of Rands, and the greatest effects have been property and land damage, loss of life, loss of livelihoods, displacement, and interference with basic amenities such as roads, bridges, and water. The impacts of these damages are far-reaching on productivity, livelihoods, and the national economy. According to scholars like Ziervogel et al. (2022), South African cities can take the initiative to implement the measures of climate adaptation instead of merely responding to the disasters once they have happened. This proactive approach would not only save the reconstruction costs but also guarantee the long-term functionality of the critical infrastructure.

In this regard, the use of climate-resilient infrastructure has far-reaching consequences when it comes to project management practices. Project managers must incorporate climate risk assessment, adaptive planning, and sustainable design principles in all the phases of the project, i.e., from conception to operation and decommissioning. This research aims to explore the role of the introduction of climate-resilient critical infrastructure in the context of effective project management in South Africa, identify gaps, challenges, and possible frameworks of sustainable delivery.

1.2 Background of the Study

The frequency and severity of extreme climate events have been increasing at an alarming rate across the world in the last decade. The susceptibility of South Africa to these events

can be specifically seen in the KwaZulu-Natal floods, which hit the country, destroying houses, transport networks, and industries (Akomea-Frimpong et al., 2023). The fact that such events happen repeatedly suggests that the traditional methods of infrastructure development are too inflexible and reactive to cope with the dynamic insecurities of climate change. According to scholars like Sharma & Gupta et al. (2024), robust and resilient infrastructure needs to be planned and built in such a way that it can reduce the imminent rise in extreme events.

This necessity in the South African context is overlapped by the broader issue of how to deal with the lack of infrastructure, with limited financial means. The Southern African Development Community (SADC) region, among other developing economies, presents untold demands to bridge the infrastructure gaps that are bound to depress their economic expansion (Ngepah et al., 2022). However, these countries must do so with constrained financial resources and the ever-increasing cost of debt. Dorsouman (2024) says that these circumstances require more effective, sustainable, and adaptive project management practices as a means of making sure that infrastructure is implemented in time, on budget, and to quality standards.

In addition, the Sustainable Development Goals (SDGs) offer an international platform of resilience and sustainability. SDG 9 proposes sustainable and resilient infrastructure by funding, technology, and technical support to developing countries (Halkos & Gkampoura, 2021). This is complemented by SDG 11, which advocates disaster resilience policies in urban areas. The international priorities can be aligned with the findings of Hallegatte et al. (2020), who state that social and economic development can be promoted through infrastructure that is climate resilient because it enhances the access to health, education, and employment opportunities.

Nevertheless, the difficulty is to convert these international frameworks and make them practical and context-specific in the South African context. The institutional, financial, and environmental environment in the country requires nation-specific frameworks of resilient infrastructure provision. The increasing number of extreme weather incidents necessitates the need to adopt more agile planning and management strategies where resilience is introduced at each stage of infrastructure development (Matikinca et al., 2024).

1.3 Problem Statement

The negative effects of climate change are becoming a big threat to the infrastructure of South Africa and thus are causing massive social and economic costs. The vulnerability of the current infrastructure is highlighted by the fact that, because of flooding and other extreme events, vital infrastructure like roads, bridges, and water systems have been lost (Nhamo et al., 2025). Even with many policy frameworks and strategies aimed at adapting to climate change, the country still experiences project failures and destruction of infrastructure, which demonstrates the flaws in the design and management system.

Ziervogel et al. (2022) note that South African cities usually react to climate disasters instead of preparing against them. This reactive culture, together with the lack of a prompt response to climate action, increases the cost of reconstruction and the vulnerability of the economy. Moreover, Allam et al. (2024) point out that cities that were previously perceived to be drivers of growth have become the centres of climate-related disasters, such as Durban. The issue that continues to exist is how infrastructure development and project management practices will adapt to counter these recurrent crises.

These shortcomings can be solved by the adoption of climate-resilient infrastructure. Nevertheless, the success of the implementation of project management practices is determined by the degree to which the project management practice incorporates flexibility, risk management, and adaptive models. The current research on resilient infrastructure in the Global South is insufficient, and not many studies examine how project management principles can be aligned with the resilience objectives in the context of South Africa (Pretorius et al., 2023). There are no practical frameworks linking climate resilience and project management, thus representing one of the greatest gaps in academic and professional knowledge.

1.4 Purpose Statement

The main aim of the study is to examine how the implementation of climate-resilient critical infrastructure could impact the proper project management practice in South Africa. According to the Organisation for Economic Co-operation and Development (cited in Tshadu, 2023), climate-resilient infrastructure is a process that comprises adaptive planning, design, construction, and operational processes, targeted to respond to and anticipate the changing climate conditions. The research seeks to find out why some of the South African infrastructure projects cannot withstand climatic forces, especially

flooding, and to come up with management-based solutions whereby future projects become sustainable, adaptive, and robust. Ultimately, the study aims to add value to the sustainable development of South Africa through the improvement of the alignment between climate resilience and quality project implementation.

1.5 Study Scope

The study is interested in understanding the overlap between the practice of project management and climate-resilient infrastructure development in South Africa. It looks at how climate adaptation concepts can be incorporated into infrastructure projects by project managers, engineers, policymakers and contractors. The scope covers important infrastructure areas like transport, energy, and water systems, which are the focus of national development and are very susceptible to climatic conditions. The geographical focus of the research is the metropolitan regions and provinces in South Africa, such as KwaZulu-Natal and the Western Cape, which have been greatly affected by climatic disturbances. In theory, the study combines resilience theory, sustainability frameworks, and project management practices, and it seeks to produce a comprehensive insight into the best practices to deliver climate-resilient infrastructure.

1.6 Business Need for the Study

From a business and economic perspective, there is an urgent demand for climate-resilient infrastructure in South Africa. Infrastructure investments are massive financial commitments, and their failure to withstand the climate-related risks results in devastating financial losses. Resilient infrastructure implementation helps preserve the public investments, ensure the livelihood of communities, and ensure the continuity of vital services. According to Clark et al. (2022), the lack of resilience principles integration raises the costs of reconstruction and damages their reputation, as well as discourages investors.

Furthermore, there are various limitations when it comes to delivering a project in an emerging market, such as a lack of budget, bureaucratic inefficiencies, and environmental unpredictability (Lakmeeharantner et al., 2020). Hence, the project managers need to use agile and adaptive methodologies that involve the environmental, political, and social aspects. Through improvement of capacity building to manage projects, South Africa will be able to shorten project durations, minimise cost overruns and improve the dependability and sustainability of its infrastructure. To close the infrastructure gap in the

SADC region, innovative and climate-aware delivery systems are to be used (Ngepah et al., 2022). The study, therefore, offers practical recommendations to policymakers and practitioners who want to increase resilience by effectively managing projects.

1.7 Theoretical and Academic Need of the Study

Academically, there is very little literature that explores how project management models can incorporate the principles of climate resilience in developing economies. The majority of the current resilience models are developed within a developed country's setting, with strong institutions, high-level technology, and sufficient financial resources (Pretorius et al., 2023; Svejvig & Andersen, 2015). As a result of this, they are not effective when they are applied directly to the context of South Africa.

According to Atli & Krystallis (2025), the decision to handle complex and interrelated infrastructure projects must incorporate the application of integrated frameworks which interconnect social, technical, environmental, and economic aspects. These frameworks help the project managers to navigate through the uncertainty by linking the decision-making processes to the sustainability goals (Stanitsas et al., 2021). Equally, to operate future design and implementation models, Dong et al. (2024) remind that the lessons learned during project failures and climate disruptions must be used.

This research plays a role in the academic discourse because it creates a context-reduced framework of adapting project management approaches to resiliency principles applicable in South Africa. It attempts to bridge the theory to practice through the provision of empirical results and theoretical confirmation of resilience-based project management. It also adds the knowledge base on climate adaptation and infrastructure resilience to the Global South (Atli & Krystallis, 2025).

1.8 Research Objectives

The study's objectives are structured to address both theoretical and practical aspects of climate-resilient infrastructure and project management:

- To design a project management framework that enhances the South African built environment sector's resilience, sustainability, and adaptability.
- To identify and assess standardised indicators and metrics that measure resilience and sustainability in infrastructure development projects.

- To develop agile and adaptive project management methodologies suited to large-scale infrastructure initiatives in South Africa.
- To examine the role of government, political contexts, and stakeholder participation in ensuring infrastructure resilience and sustainability.

1.9 Chapter Outline

Chapter One presents the background of the research, the problem, the purpose, and the objectives of the research and gives the business and academic rationale behind the study. The second chapter provides a literature review of climate resilience, sustainable infrastructure, and PM structures. The research questions and hypotheses are described in Chapter Three. Chapter Four describes the research methodology, which includes research design, data collection, and analysis processes. Chapter Five presents and describes research findings. Chapter Six will give the discussion of results, and Chapter Seven will give conclusions, policy implications, and recommendations to future research and practice.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The chapter is an in-depth review of the theoretical and empirical literature about the effects of applying climate-resilient critical infrastructure (CI) to successful project management (PM) practices in the South African context. The general aim of this review is to create a strong base for the study by clarifying what is known, pinpointing major findings of the study, outlining major gaps that exist in the scholarly and practical arena, and aligning this research to help in closing these gaps. The literature review has been arranged in such a way that it will first discuss the theoretical basis of resilience and project management, then conceptualise climate-resilient critical infrastructure, empirically investigate the relationship between resilience features and PM practices (informing research questions 1 and 2), review of frameworks of integration (informing research question 3), and lastly a contextualisation of the South African built environment. To ensure that the discussion remains critical and focused, the chapter uses an information-prominent approach, backed by references, and compares perspectives using the author-prominent approach where necessary.

Climate resilience, project management, and critical infrastructure convergence are the heart of the study, as climate change is generating increasingly concerning risks to core services such as transport, water, and energy (Commonwealth of Australia, 2010). Traditional project management, which is mostly considered to be deterministic and has predictable results (Padalkar & Gopinath, 2016), cannot cope with the high level of unpredictability of climate-related threats. Consequently, the incorporation of resilience qualities into CI projects requires a paradigm shift in the conventional PM practices into adaptive and flexible ones, and thus, the intersection is crucial in ensuring the sustainability of development in the South African built environment. This review will logically cover the nature of this influence and the practices that are most affected, hence preparing the ground which has been greatly missing to devise a much-needed integration framework.

2.2 Theoretical Frameworks Underpinning Climate-Resilient Infrastructure and Project Management

2.2.1 Systems Resilience Theory

Systems Resilience Theory is what allows viewing the capacity of critical infrastructure. The conceptual definition of resilience is the capacity of a system to continue functioning despite disruption (Fiksel, 2006; Mayar et al., 2024). This means resilience is the key feature of the persistent functioning of CI in the time of climate disasters. The resilience concept goes further, incorporating the absorptive, adaptive, and recoverability dimensions, which Francis & Bekera (2014) highlight to be key to understanding systems holistically. In the case of infrastructure projects, this system-based thinking applies directly to design and recovery, where the project managers must be proactive in coordinating and planning projects (Commonwealth of Australia, 2010; Ellis et al., 2023). Thus, the theory of systems resilience changes the PM perspective of timely and budget-compliant project completion and instead makes the functionality of the final asset in response to a range of potentially unpredictable and undetermined future shocks a priority (Andersson et al., 2021).

Moreover, the fact that the system-wide properties are highlighted shows that the concept of resilience is not a single feature but is connected throughout the project lifecycle and across the various infrastructure sectors. According to Watson and Ahn (2022), the need to revise processes and involve stakeholders is essential to deal with the uncertainty of complex systems, which is supported by Linkov et al. (2022), who recommend scenario-based testing to learn how climate affects interconnected CI. Nevertheless, Curt & Tacnet (2018) emphasise that resilience can be effectively integrated due to constraints that are, however, most frequently, economic, political, and social in nature, as the PM systems may be too rigid to implement the required changes in the system. This tension between the theoretical ideal of system resilience and the practical limitation of its implementation frames a central challenge that the current study seeks to address in the South African context.

2.2.2 Adaptive Management Theory

Adaptive Management Theory provides a methodological and philosophical counterpart to resilience thinking, especially when dealing with dynamic and uncertain climate change. It is defined as a structured method of enhancing management through learning by observing the results of the implemented practices, thereby enhancing iterative learning

and dynamic risk evaluation, which are essential in the South African climate context that is fast changing (Williams & Brown, 2014; Roux et al., 2025). The theory, advocated by such researchers as Linkov et al. (2022) and Sharma & Gupta (2024), encourages a flexible and responsive project environment, in which feedback loops and real-time data influence changes, not the fixed initial plan. As an example, the research on river flow regulation and invasive species illustrates the tangible success of adaptive management in environmental contexts (Bradford et al., 2023; Foxcroft & McGeoch, 2011).

More importantly, the Adaptive Management Theory is quite consistent with the flexible and non-deterministic project management practices that are required in building climate resilience. Whereas traditional project management may be resistant to corrections during the process, adaptive management accepts them as learning opportunities at the organisation and project level (Edmondson & Fanning, 2022). As a result, the adoption of resilience characteristics requires project managers to move away from rigid, linear processes and instead incorporate dynamic decision-making and continuous evaluation of climate risks and adaptation measures. This coincidence is important to comprehend the impact of resilient infrastructure projects on the implementation of efficient PM, as it mandates a new set of skills and a different cultural approach to risk.

2.2.3 Project Management Theories

The theories of project management (PM) have experienced a tremendous transformation where the highly deterministic, schedule-based and cost-based approaches (Classic Project Management, CPM) are replaced with the more flexible and adaptive ones. Svejvig & Andersen (2015) emphasized this change, introducing such a concept as Rethinking Project Management (RPM) that promotes flexibility and situational adjustment of the complex project environment. Padalkar & Gopinath (2016) also trace this development of PM through deterministic, explanatory, and non-deterministic eras, each emphasizing the growing importance of integration, risk, and communication. The ideas of complexity and uncertainty become relevant in the non-deterministic era, and in most cases, PM methods should be capable of managing ambiguous and changing requirements (Padalkar & Gopinath, 2016).

The most recent aspect of resilience is the emergence of Agile Project Management (APM), which, despite its origins in software development, has become useful in terms of promptly adjusting to change, flexibility, and teamwork (Dong et al., 2024). The iterative and incremental nature of APM allows it to be highly suitable in addressing the uncertainty

involved in climate-resilient infrastructure, in which design requirements could be changed as new climatic data or circumstances on the ground are revealed (Kineber et al., 2024). Nonetheless, the practical validation of the use of APM in the non-IT domain, especially at a large-scale infrastructural level, is scarce (Dong et al., 2024). This theoretical development creates a clear connection, which implies that the desire to make the built environment climate-resilient is driving the built environment industry towards adopting adaptive PM frameworks, thus addressing the question of how resilient features affect PM.

2.2.4 Theory–Practice Link

The conceptual and practical connection between the resilience theory and the project management theory is the key to the effective integration of climate resilience into infrastructure projects. The main characteristic that has cemented this relationship is the focus on adaptability, learning, and collaboration as the key success factors in complex and uncertain environments (Francis & Bekera, 2014; Svejvig & Andersen, 2015). The weaknesses of traditional PM include the absence of flexibility (Svejvig and Andersen, 2015), which can be addressed by the inclusion of adaptive principles in the organisation and the project (Osei-Kyei et al., 2022). Consequently, the resilience capacities, including the possibility to predict and respond to climate shocks, have a direct relationship with project success factors, which guarantee not only the timely delivery but also the long-term usefulness of the asset (time, cost, and quality) under the conditions of a changing climate.

This theory-practice integration denotes that project success needs to be refined and resilience outcomes to be added to the success. To achieve a climate-resilient CI project, success will not only be an ability to address project-specific constraints, but it will also require the successful execution of resilience-enhancing options such as adaptive risk management and flexible design options (Linkov et al., 2022). Combining these theoretical outcomes, this research will go beyond the general discussion of the adaptability concept and present tangible evidence of how PM practices should evolve to apply the theoretical concepts of systems resilience and adaptive management to South African CI projects. As such, the essence of research is to be able to apply these abstract theories to the practical framework of the built environment.

2.3 Conceptualising Climate-Resilient Critical Infrastructure

2.3.1 Definition and Components of Critical Infrastructure

Critical Infrastructure (CI) is defined as infrastructure that is key for its long-term role in society; the important sectors covered in the definition include transport, water, energy, and communication, whose disruption will have crippling effects on the national security, economy, and public health (Commonwealth of Australia, 2010). The elements of CI are complex, and they go beyond the physical facet of the aspects to cover technical, social, financial, and sustainability aspects (Osei-Kyei et al., 2022). An example of a resilient water supply system would incorporate both the physical piping and pumps (technical) as well as the governing institutions and interactions with the community (social) to maintain it and guarantee equitable operation. It is the integrity of these interrelated components that render CI projects complex and require a sophisticated, resilience-based PM approach.

2.3.2 Characteristics of Climate-Resilient Infrastructure

Climate-resilient infrastructure (CRI) is a design approach that extends beyond normal designs to incorporate the ability to predict, respond, and recover quickly to climatic hazard events at all project lifecycle stages (Linkov et al., 2022). Such features as adaptive design, which can be modified to future requirements (e.g., increase in sea levels or extreme temperatures), application of innovation and high-tech materials, and strong dependence on stakeholder engagement and evidence-based decisions (Shafei et al., 2024). As an example, a resilient road project would be to apply climate-wise risk modelling to choose materials that do not heat or cool down in temperature, and to set up drainage patterns that can handle heavier-intensity rainfall (Oruc et al., 2024). These features are inherently problematic to the traditional, fixed-scope PM since they bring in dynamic variables, demand more interdisciplinary cooperation, and, in many cases, necessitate preliminary investment to attain the long-term societal and economic gains (Ziervogel et al., 2022).

2.3.3 Frameworks for Analysing Infrastructure Resilience

There are several different frameworks which have been created to analyse and improve the infrastructure resilience in a systematic manner, though there is no global standard. The resilience capacity framework outlined by Francis & Bekera (2014) that describes the capacity of systems to withstand, adapt, and recover has been extensively cited for its

conceptual clarity. Moreover, the connection to sustainability and life-cycle approach is emphasised, and project managers are encouraged to view resilience as the concept that needs to be considered during the stages of creation up to the decommissioning of the project (Bocchini et al., 2014; Hsu & Mostafavi, 2024). Nevertheless, these frameworks have significant issues of implementation, such as economic, political, and institutional constraints, which in many cases restrict the resources and mandate to pursue detailed resilience planning (Curt & Tacnet, 2018). Though international organisations such as the World Bank promote integrated models, the main constraint is that no context-driven instruments are available to develop third world countries, and this is an academic void that this study aims to fill by focusing on South Africa.

2.4 Empirical Literature Review

2.4.1 Influence of Climate-Resilient Features on Project Management Effectiveness

The consideration of the climate-resilient aspect of the critical infrastructure projects inherently affects the application of effective project management by creating a rise in the complexity of the projects and the need to adopt an approach of dynamism and adaptability (Naderpajouh et al., 2020). Research indicates that resilience integration enhances the results of a project because it requires more flexibility in leadership (Atli & Krystallis, 2025) and emphasises risk management procedures (Linkov et al., 2022). In particular, the necessity to plan and respond to unpredictable effects of climate change implies that PM teams need continuous review and variation of plans, which supports an emergent type of project resilience (Piperca & Floricel, 2023). Thus, the introduction of resilient characteristics serves as a catalyst, and the project managers are forced to leave the deterministic planning and embrace the principles of agility, which directly inform Research Question 1.

2.4.1.1 Effect on Project Performance Metrics (Time, Cost, Quality)

Resilience-oriented design also influences more conventional project performance measures and may necessitate a trade-off between short-term costs and long-term benefits. The cost and time of the project may initially rise due to early-stage resilience integration, e.g., climate-informed material choice or redundant system design, which must be justified via a life-cycle cost analysis (Lotfi et al., 2022). Nonetheless, the upfront investment can result in better quality and delivery of a project in the long term as fewer resources are spent on restoring the damage after the disaster and fewer resources are

spent on the interruption of the service (Ziervogel et al., 2022; Lee et al., 2025). Contrasting views draw attention to the fact that although time-cost trade-off problems may be complicated by environmental issues (Banihashemi et al., 2021; Feng et al., 2018), green building and resilience practices will eventually be associated with the overall success and sustainability of the project (Abdelkhalik & Azmy, 2022). The impact, therefore, is a recalibration of performance indicators with relatively less emphasis on the initial spending and instead on long-term value and the survival of the system (Seidu et al., 2025).

2.4.1.2 Adaptive and Risk-Based Planning Approaches

The first impact that resilient features make is the necessity of adaptive and risk-based approaches to planning, which changes the planning practice at its core. Adaptive methods of project management have proven to be essential to infrastructure resilience because they enable constant monitoring and predicting of the plans according to the changes in climate forecasts and the functioning of systems (Singh et al., 2023; Scharte, 2025). This requires a transformation of the traditional contingency planning to the dynamic and iterative risk identification and response, which is essential in managing the consequences of climate-related hazards, such as greater floods or excessive heat (Shafi, 2024). A good example is adaptive control of resource flow, which is controlled by such sophisticated technologies as deep reinforcement learning, which allows optimising construction work and cash flows based on the dynamic situation (Jiang et al., 2023). The necessity of overall adaptive capacity is thus an important one, proving that the effective implementation of resilient CI projects is impossible without the use of flexible PM planning strategies.

2.4.1.3 Stakeholder Engagement and Collaboration

The stakeholders involved in resilience-oriented projects attach an unbelievably high level of importance to the inclusive stakeholder engagement and cooperation, which radically alters the conduct of communication management (Eisenhauer et al., 2024). The complexity and systemic nature of CI resilience imply that successful outcomes require the incorporation of the needs, knowledge, and resources of a diverse population, such as local communities, governments, and partners in the private sector (Erkul et al., 2020). Through case studies, the need of community involvement to enhance the resilience outcome is emphatic, especially when it involves the introduction of local knowledge, as well as on-the-ground knowledge, in the planning and design (Eisenhauer et al., 2024;

Johnston et al., 2024). The key to effective PM in this area, therefore, will involve the development of strong multi-level feedback systems, the promotion of a collaborative culture beyond simple exchange of information, and collaborative decision-making to create equitable resilience. This change requires new skills of collaboration, which is one of the major changes in PM practice.

2.4.1.4 Sustainability and Post-Disaster Recovery

The interdependence of resilience integration and sustainability, and especially with respect to post-disaster recovery, highlights the post-disaster recovery advantages of proper project management. Resilient infrastructure, by its design, is supposed to ensure service continuity and significantly minimise the costs and time-consuming repairs after a climate event (Chester et al., 2021). It is placed on active preparedness, and the disaster response is changed to a proactive one because the resilient projects are cheaper to operate and maintain throughout their lifetime. As an illustration, sustainability planning based on resilience and sustainability of water networks helps to minimise the reconstruction costs and guarantee the reliability of the services (Assad et al., 2021; Poudel & Dubey, 2018). Although the disaster recovery PM deals with the immediate post-disaster period (Hsu & Mostafavi, 2024), success in the long term depends on the ability of the initial project to survive the shock, which is a direct association of the project team's success in implementing resilience features.

2.4.2 Project Management Practices Affected by Climate Resilience Integration

Climate resilience integration has a significant effect on a certain set of project management practices. Managing uncertainty and the necessity to make their services function over the long term make PM teams reconsider their traditional methods of leadership, resource management, communication, and quality control more critically (Piperca & Floricel, 2023; Zhang et al., 2023). Though this affects all PM functions, the literature identifies adaptability and risk-related functions to be the most significantly transformed. In particular, the application of digital technologies is increasingly regarded as one of the means to improve the climate resilience of critical infrastructure, which directly influences the way PM teams gather, process, and respond to the information (Argyroudis et al., 2022).

2.4.2.1 Leadership and Decision-Making Flexibility

The resilience integration has a serious influence on the flexibility of leadership and decision-making, as the project leaders need to develop an adaptive culture of management. The leadership in resilience initiatives must be highly adaptive and capable of steering through the ambiguity competently (Atli & Krystallis, 2025). An inflexible management culture often acts as a chokepoint, or bottleneck, to the required mid-project changes necessitated by new climate data or unforeseen events, but flexible design choices are a direct result of this type of leadership (Buhl & Markolf, 2023). Moreover, the development of a strong organisation is conditioned by the leadership style that promotes network results and learning (Kim et al., 2021), which directly correlates project resilience with organisational resilience (Huzooree & Yadav, 2025). It is a great change from the traditional PM leadership, where a strict adherence to the initial plan is often the priority, and it shows that the project leaders are major change agents in the field.

2.4.2.2 Resource Allocation and Financial Planning

The process of climate resilience integration requires a strategic change in resource distribution and financial strategy, where it goes beyond least-cost approaches and into investments that are value-based. The necessity to achieve innovative and flexible approaches towards investment to cover resilient CI upgrades is affecting this practice (Osei-Kyei et al., 2022; Tetteh et al., 2025). Budgets used in projects should also be flexible to accommodate unexpected resilience changes or upgrades, which has been a challenge to the conventional fixed-budget approach of PM. As an illustration, continuous monitoring, adaptive technologies, and the ability to adjust the flow of resources via tools like online deep reinforcement learning, reflecting the dynamic nature of resilient construction (Jiang et al., 2023). Financial planning is turned into an adaptive process, which balances the initial cost and long-term, measurable benefits of the reduced climate risk.

2.4.2.3 Collaboration, Communication, and Learning

The introduction of resilient aspects requires an increased emphasis on communication, collaboration, and learning as the main practices of project management. The multi-stakeholder characteristics of resilience-oriented projects and their high uncertainty level contribute to a greater necessity of effective communication and sound feedback

(McNaught, 2024). This is translated into a high focus on organisational learning and knowledge transfer, whereby lessons learned in a project are informed by those of the next, and this creates what is referred to as organisational learning capabilities (Jia et al., 2024; Padalkar & Gopinath, 2016). Moreover, the climate resilience motivation necessitates the project teams to undergo an unlearning and relearning process to get rid of the past, rigid practices (Pedde et al., 2025; Sarvestani & Millar, 2024). Knowledge and collaboration management then becomes a critical success factor towards resilience.

2.4.2.4 Risk and Quality Management

Risk and Quality Management is, perhaps, the most affected practice of PM because it demands an explicit incorporation of the complicated and long-term climate risks into traditional frameworks (Farahmand et al., 2024). This is a basic change of project implementation risk management to long-term, asset-level climate-adaptation risk (Linkov et al., 2022; Chang & Hossain, 2024). The definition of quality assurance needs to be redefined according to the objectives of resilience, which means that the infrastructure assets should not only be specified as they are but also be capable of withstanding the stresses of the future climate (Tetteh et al., 2025). Such integration demands novel approaches, such as probabilistic network analysis, to include climate projections in transport resilience planning (Farahmand et al., 2024). Ultimately, organisational embedding is the key to successful implementation of climate resilience both in risk and quality management (Lonsdale et al., 2024; Jiao & Bu, 2024).

2.4.3 Frameworks and Models for Integrating Climate Resilience in Project Management

To inform Research Question 3, it is necessary to analyse the existing frameworks to incorporate climate resilience, which is a very important step to creating a much-needed South African framework. The existing literature offers several conceptual and practical models (Prasad et al., 2019; Rahi, 2019), but it is still impossible to reach a universal model which can be applied to all infrastructure projects. These frameworks usually build the integration on major stages such as risk assessment, design change, and post-disaster recovery (Shammin et al., 2022). As an example, resilience can be quantified in some models using infrastructure recovery as a resource-constrained project scheduling problem (Johnson et al., 2024), whereas other models are concerned with incorporating projections of probabilistic climate models into the environmental risk assessment (Moe et al., 2024).

2.4.3.1 Existing International Frameworks

Comparative analysis of global models reveals that the developed countries have gone a long way in determining the resilience criteria and performance measures of critical infrastructure (Curt & Tacnet, 2018; Osei-Kyei et al., 2022). As an example, the USA and European frameworks tend to be based on advanced data analytics, life-cycle analysis, and established governance systems to incorporate resilience (Forino et al., 2015). These international standards and indicators, however, are usually formulated in contexts where there is more project management maturity, availability of data, and financial capacity (Majlingova & Kádár, 2025). Therefore, as much as these models offer good conceptual advice, they are not always transferable to developing contexts due to institutional and resource limitations.

2.4.3.2 Framework Gaps and Limitations

Although there are global models, one of the gaps in academics is the lack of combined frameworks that specifically and operationally connect climate resilience and successful project management in developing situations (Atli & Krystallis, 2025). Most of the available frameworks are either very theoretical or technically oriented to resilience, which does not imply the necessary adjustments in PM practices, such as leadership, communication, and resource distribution. There is a significant demand for context-sensitive tools and measures that may be used to measure and benchmark project flexibility and adaptability, which are crucial to achieving success in resilience. This is the weakness identified by Curt & Tacnet (2018) and Pretorius et al. (2023), who state that the research conducted by the global North tends to ignore the peculiarities of the socio-economic and institutional issues of the global South.

2.4.3.3 Conceptualising a South African Framework

To inform Research Question 3, it is important to conduct an analysis of existing models of integrating climate resilience as an important step in creating the very much needed South African models. The existing literature has offered several conceptual and practical models (Prasad et al., 2019; Rahi, 2019), but it has been unable to come up with a generally applicable model, particularly in infrastructure projects. These frameworks generally organise the integration into significant stages such as risk evaluation, design change, and disaster recovery (Shammin et al., 2022). As an example, it has been

demonstrated that resilience has been measured by some models as a resource-constrained project scheduling problem (Johnson et al., 2024), whereas others have been interested in how probabilistic climate model predictions can be integrated into environmental risk assessment (Moe et al., 2024).

2.5 Contextualising the Study

2.5.1 Global Trends in Climate-Resilient Infrastructure

A growing number of high-profile climate disasters have driven global trends in climate-resilient infrastructure and increased the number of resilience studies and policy efforts (Osei-Kyei et al., 2022). Developed countries have been at the forefront in incorporating resilience in the management of infrastructure, usually by standardised risk assessment, the establishment of dedicated resilience offices, and the application of advanced data models to predict the effects of climate. The main lesson of these situations is that resilience integration needs to be a whole-of-government strategy and a change in the project governance to focus on long-term asset value rather than short-term savings. Nonetheless, the scholarly sources reveal that there is a great controversy about the most effective ways of funding these upgrades, and it is agreed that the multi-stakeholder and life-cycle approach is the key to success.

2.5.2 Regional (African) and South African Perspectives

Contrary to global trends, the literature reveals a notable lack of empirical research on CI resilience and project management in developing economies, particularly in Africa (Pretorius et al., 2023). This poses a significant knowledge gap, as the continent is highly susceptible to the effects of climate change. The African context is also complicated by poor project management maturity, poor coordination between planning and implementing agencies, inadequate local data, and technical skills (Clark et al., 2022; Pretorius et al., 2023). This local approach highlights the reason why generic international models are insufficient because they fail to capture these systemic limitations. The absence of context-specific research that is integrated implies that project managers in South Africa are currently functioning without adequate guidance, which constrains the successful implementation of climate resilience in a sector of the critical infrastructure that is already under intense pressure.

2.5.3 The Built Environment Sector in South Africa

The South African built environment sector is a vital component of the economy, comprising a complex network of stakeholders, including government, construction firms, and professional bodies (Adebowale & Agumba, 2023; Aliu et al., 2025). This sector is under intense pressure from increasing climate change adaptation pressures, such as water scarcity, rising temperatures, and more frequent severe weather events. While there is a growing awareness of the need for resilient and adaptive practices, the actual integration into project management remains challenging. Among them, the absence of a national resiliency assessment tool that is standardised, unwillingness to accept higher initial costs, and an overall shortage in climate-informed PM skills can be listed (Lakmeharantner et al., 2020). Thus, the location of this study in South Africa will enable the creation of a framework that would be specific to the national institutional and climatic conditions of a middle-income nation and provide practitioners with specific, localised, and actionable information.

2.6 Summary of Literature Gaps

This review has managed to explain what is known about the theoretical relationship between resilience and project management and empirically determined the PM practices that are most responsive to resilience integration. Nonetheless, there are still some vital gaps, and the proposed study aimed at filling them.

2.6.1 Academic Gaps

The main gap in the literature is the absence of operationally defined frameworks of climate resilience and project management in a developing-country setting that are empirically validated (Atli & Krystallis, 2025; Curt & Tacnet, 2018). As much as a conceptual connection is made, literature does not give a step-by-step approach that practitioners should follow. Moreover, the applicability of global PM models in the unique African environment has not been empirically studied (Pretorius et al., 2023) to prove or disprove it. Lastly, adaptive and agile project management techniques that, in theory, fit resilience are not used in real-world settings outside of the software and IT sectors and must be validated in large-scale infrastructure projects (Dong et al., 2024). This research will build upon the conceptual work in offering the lacking empirical evidence of South Africa and synthesising a workable, integrated framework.

2.6.2 Business and Practice Gaps

The academic gaps are also reflected in the business and practice gaps, which are the physical barriers to the implementation of resilience. In particular, the lack of standardised, localised resilience assessment instruments that are accessible to the project managers within the South African built environment is explicit. This is compounded by the poor capacity-building pipeline and the absence of professional project managers who are trained in climate-resilient practices, which worsens the issue of poor coordination and planning (Mapepeta, 2015; Lakmeeharantner et al., 2020). The current practice is characterised by the lack of coordination and the inability to translate the global resilience data into local, actionable insights and practice-based learning models. This study will specifically overcome these limitations by developing a South African model that will offer a foundation towards standardised assessment, local capacity development, and the use of data to make decisions, hence closing the gap between theory and practice.

2.7 Chapter Summary

The literature review was effective in ensuring that the theoretical basis of this study was based on the Systems Resilience Theory, the Adaptive Management Theory, and the evolution of Project Management Theories. It has given explicit and empirical insight into the impact of the introduction of climate-resilient features to effective project management through obliging a change of focus towards adaptive planning, flexible leadership, and collaborative stakeholder involvement (informing research question 1). The key project management practices that were identified through the review are adaptive risk management, flexible financial planning, and organisational learning (informing research question 2). The conceptual, although not the operational, nature of the available frameworks and the distinct empirical gap in the African setting, particularly in South Africa, is the most critical finding. Thus, the study has every reason to pursue it with the aim of creating a region-specific framework to improve the introduction of climate resilience considerations into the project management of critical infrastructure in the South African built environment (informing research question 3). The following chapter will present the research question that will be at the centre of the research.

CHAPTER 3: THE RESEARCH QUESTIONS

3.1 Introduction

This chapter outlines the research questions that guided the study. The research questions are expected to investigate the implications of the implementation of climate-resilient infrastructure on project management practices, decision-making, and policy implementation in South Africa. The chapter interconnects climate resilience, sustainability and project management theories to inform the inquiry. These theories can be applied to grasp the possibilities of designing infrastructural projects in such a way that they implement adaptive responses to climatic risks to achieve sustainable development and improved project outcomes (Hallegatte et al., 2020; Ngepah et al., 2022).

Research questions have been formulated to address the need to understand the relationship between climate adaptation strategies and successful project implementation. As South Africa is prone to extreme weather conditions, including flooding and droughts (Nhamo et al., 2025), this chapter describes the main areas of inquiry that make the contextualisation of the study possible. The questions are designed to come up with insights on how project managers can integrate resiliency principles, risk management and sustainability framework to ensure long-term infrastructural stability.

3.2 Research Questions

The research questions were formulated to meet the objectives and theoretical basis of the research. The questions are selected to analyse various facets of the impact of the implementation of climate-resilient infrastructure on the efficiency of project management and decision-making in South Africa.

Research Question 1: *How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices within the South African context?*

The question aims at identifying how integrating resilience-oriented design and planning influences factors of project success, such as time, cost, and quality performance. It looks at how project management practices, including risk assessment, adaptive planning, and stakeholder engagement, are adjusted to meet climate resilience objectives (Ziervogel et al., 2022; Sharma and Gupta, 2024). The question further addresses the topic of adaptive

management that will increase the sustainability of the project and decrease the costs of reconstruction after the disaster.

Research Question 2: *What are the key project management practices most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?*

This question determines what aspects of project management are the most affected by resilience considerations: resource allocation, leadership, communication, and quality control. The question emanates from the assumption that the effectiveness of project management is determined by flexibility and proactive risk management (Dorsouman, 2024). These relationships can be understood to determine the managerial skills and structures that are required to develop infrastructure that can resist disruptions caused by climate.

Research Question 3: *What framework can be developed to enhance the integration of climate resilience considerations into the project management of critical infrastructure in the South African built environment industry?*

The question is about developing a contextualised framework that helps to match the resilience principles to project management techniques. This is meant to create a model that complies with the socio-economic and environmental conditions of South Africa to enhance successful application in infrastructure sectors. Atli and Krystallis (2025) explain that these frameworks should have technical, environmental, and institutional dimensions to inform decision-making processes in the face of uncertainty. The proposed framework will offer practical information to project managers, policymakers, and engineers so that they can deliver climate-adaptive infrastructure (Pretorius et al., 2023).

3.3 Chapter Summary

This chapter has presented the research questions that have guided the research on the impact of introducing climate-resilient critical infrastructure on the effective practice of project management in South Africa. The research questions are based on the Systems Resilience Theory, Adaptive Management Theory and Project Management theories and are aimed at comprehending how project management practices such as adaptive planning and risk management can be integrated into the development of infrastructure.

In chapter 4, the research methodology will be provided, which includes the study design, data collection, and analysis procedures that will answer these questions.

CHAPTER 4: THE RESEARCH METHODOLOGY

4.1 Introduction

In this chapter, the research methodology to be used in the research is outlined to examine the impact of the implementation of climate-resilient critical infrastructure on proper project management practices in South Africa. It starts by outlining and explaining the exploratory research design as suitable in this research, as the topic under study is a relatively under-researched domain of linking project management and climate resilience in emerging economies. The chapter goes on to describe the interpretivism research philosophy, which is appropriate in terms of researching the underlying dynamics that influence the outcome of the project. A justification of the inductive research method is then presented, and the narrative inquiry research strategy and the cross-sectional time horizon are mentioned. Lastly, the chapter outlines the planned method of doing the research, such as the population, unit of analysis, sampling method, sample size, measurement instrument, data collection process, data analysis procedure and quality checks. There is also consideration of ethics and limitations of the study.

4.2 Choice of Methodology

4.2.1 Research Design

The research employed an exploratory study design, which was particularly suitable because the topic of resilient critical infrastructure and its connection to project management in the South African and emerging economies context had very little existing literature. Exploratory research aims to discover new insights into an unknown phenomenon (Saunders & Lewis, 2018), which aligned perfectly with the main goal of the study: to determine effective project management approaches for implementing climate-resilient critical infrastructure projects. This design allowed for a broad investigation of the phenomenon before focusing on specific, significant aspects. The exploratory nature enabled the collection and simplification of data to improve understanding of the topic.

4.2.2 Research Philosophy

The research used interpretivism philosophy. According to Saunders and Lewis (2018), interpretivism analyses social phenomena in a natural setting. It is concerned with the behaviour of social actors- people who gather at a certain moment to form a particular social phenomenon. Although they cannot be generalised, the results added to the

knowledge of the way such projects should be managed and how to surmount the complexity and uncertainty that resilient critical infrastructure project implementation entails. Interpretivism was suitable since it enabled the researcher to learn about the project management practices through the eyes of the individual qualified practitioner working on the climate-resilient infrastructure projects (Creswell & Creswell, 2017).

4.2.3 Research Approach

An inductive research approach was employed. This approach was suitable because the study aimed to develop a new project management model and identify standardised indicators and metrics for assessing resilience and sustainability in South African infrastructure development. Inductive reasoning clarified project management as a novel phenomenon in the development of resilient critical infrastructure. By referring to well-known theories such as Agile Project Management and Rethinking Project Management, infrastructure resilience, and sustainability, the study sought to develop new and an effective project management model that met the needs of critical infrastructure projects in South Africa. Data collected through this approach often inspires changes to the research, allowing for new theories to emerge and answer the research questions (Saunders & Lewis, 2018).

4.2.4 Methodological Choice

A qualitative research methodology was selected since the study answered questions concerning perceptions and the How and Why behind the utilisation of specific methodologies and standards in climate-resilient construction projects. Qualitative research was suitable to examine the peculiarities of the topic and the reliance on proficient individuals, and it was necessary to use personal interviews (Creswell and Creswell, 2017). The use of open-ended questions facilitated participants' comfort, revealing new insights and innovative methods used in projects (Saunders & Lewis, 2018).

4.2.5 Research Strategy

This study used a narrative inquiry approach as opposed to a case study. This approach was appropriate since it entailed the interviewees responding to questions regarding the How, why, and What of the application or non-application of some approaches, criteria, and innovations in climate resilient construction projects. Saunders & Lewis (2018) argue that a narrative inquiry enables the participants to make sense of a series of events in the

form of stories, which is critical to comprehending the project management practices in terms of climate-resilient infrastructure in South Africa. The narrative inquiry approach allowed the researcher to gain a deeper understanding of the lived experiences of the participants by the stories that they gave during the interviews, their learning, choices, and views on the adoption of climate-resilient infrastructure projects (Yin,2017). The researcher also conducted an extensive literature review and individual interviews and paid a visit to a site of infrastructure to see how climate resilience is put into practice.

4.2.6 Time Horizon

The study employed a cross-sectional design. This decision was made due to the limited time available for a longitudinal study. The data collection process took about one to two months. Also, interviewees were asked about current and recently completed climate-resilient infrastructure projects, so their responses were not supposed to vary, which made it unnecessary to use a longitudinal approach. The cross-sectional study was a snapshot, which looked at a particular point in time at the time of the research (Saunders & Lewis, 2018).

4.3 Proposed Research Methodology

4.3.1 Population

The study sample included professionals working on rehabilitation and new construction projects which implement climate-resilient features at all planning, design, construction, and operational phases. This team of professionals included project managers, engineers, quantity surveyors, client representatives, and contractors. The selection was limited to candidates who had worked on projects that utilised new or innovative construction methods to meet climate-resilience in development, as cited by Akomea-Frimpong et al. (2023). Roads Agencies, Ministry of Public Works and Transport, City or Town Municipal Councils, Contractors and Engineering Consultants in South Africa were the institutions involved. Participants were approached to share their personal experiences and insights rather than represent their organisations.

4.3.2 Unit of Analysis

This study examined how a skilled team implements climate-resilient infrastructure for the best outcomes in a project. The unit of analysis was the professionals (project managers,

engineers, quantity surveyors, client representatives, and contractors) who shared their insights and experiences about the challenges they faced, the solutions they applied, and the success of those efforts in achieving equitable outcomes previously (Yin, 2017). Their recommendations to enable climate resilience is integrated into all upcoming projects for infrastructure development were also sought.

4.3.3 Sampling Method

In accordance with the earlier outlined interviewee requirements, selection followed specific criteria based on expertise, experience, and participation in particular project types. Therefore, the chosen sampling method was non-probabilistic purposive sampling (Saunders & Lewis, 2018). The selected sampling method, purposive sampling, was the most suitable as it helps in finding people who have firsthand experience related to the research topic (Verma & Verma, 2020; Knechel, 2019). Participants were accessed through professional networks and industry contacts within the identified organisations. Initial contacts were made through email, with telephone calls used to schedule participant interview times and locations.

The sample was selected from various national, local government and private projects. The researcher believed that by doing so, their interviewees would have sufficient and diverse information to analyse (Bazen et al., 2021). There was a total of 13 people in the study, so themes were identified without creating an overwhelming amount of data (Sebele-Mpofu, 2020). Participants for the study were chosen in manageable numbers, as qualitative standards advise that data is more fully revealed with smaller groups (King, Keohane & Verba, 2021).

4.3.5 Measurement Instrument

The researcher developed a semi-structured and open-ended interview guide based on the literature review that is relevant to the research. The measuring instrument was this interview guide, which was applied in all the interviews to achieve uniformity in measurement. The guide consisted of three parts: demographic data, organisational data, and necessary adaptations when handling climate-resilient infrastructure projects. Questions were also in line with the current body of literature (Barrett & Twycross, 2018) and served to keep the discussion relevant, but also provided the opportunity to explore new information (Karatsareas, 2022; Moore & Llompart, 2017). Three participants were interviewed in pilot interviews to test the interview guide before the actual interviews. The

sample was created in a way that would be diverse to ensure maximum variation (Saunders & Lewis, 2018).

4.3.6 Data Gathering Process

The researcher used one interview guide to conduct face-to-face and one-on-one interviews with the 13 participants. Interviews took approximately 45 minutes, with the possibility of taking up to an hour in case of the need to clarify questions. The appointments were made at least a week in advance, and a reminder was sent a day before. The interviews were conducted at a convenient time and place for the participants. Anonymity and confidentiality were stressed, and a consent form was signed to assure the participants and encouraged them to express themselves. The researcher started off with greetings and introductions, a general talk was an icebreaker, and a general discussion was facilitated before the researcher moved on to the actual interview topics.

4.3.7 Data Analysis Approach

The study used thematic data analysis on transcripts. Throughout data analysis, the data and themes were continually assessed against the study's research question. The process followed the six steps for thematic analysis described by Braun & Clarke (2021) as familiarisation with the data, drafting initial codes, comprehensive theme search, overview of the themes, defining the main themes, and producing the final report. Thematic analysis was applied because it allowed for the easy and orderly discovery of patterns in qualitative data (Braun & Clarke, 2021). Atlas ti, as the data management tool, was utilised to arrange and organise interviews as it enables coding and data arrangements, making the analysis task smoother and coding more open when working with extensive interview datasets (Braun & Clarke, 2025).

4.3.8 Quality Controls

Validity and reliability are the main aspects that the researcher regularly checked to guarantee research quality. Reliability entails confirming that interviewees comprehend the questions, enabling accurate responses (Lincoln & Guba, 2004). It therefore involved consistently using a single interview guide across all sessions (Creswell & Creswell, 2017). Putting trustworthy conditions in place was very important for qualitative research. The study relied on Lincoln & Guba's (2004) four criteria of credibility, transferability, dependability, and confirmability. These are explored next.

4.3.8.1 Credibility

Credibility refers to the accuracy and believability of the study's findings (Guba, 1981). To achieve credibility, the researcher engaged in practices such as triangulation, member checks, and data saturation (Guba & Lincoln, 1985). In the current research, to ensure credibility, there was member checking, where participants commented on the transcripts and preliminary findings, to verify and enhance what has been found (Lincoln & Guba, 2004).

4.3.8.2 Dependability

Dependability refers to the repeatability and consistency of results across time (Guba, 1981). To ensure dependability, the current research meticulously documented all methodological procedures that include the data collection and analysis approaches, enabling others to replicate the study (Guba & Lincoln, 1989). This study implemented a pilot test on participants to adjust the questions for clarity and reliability. By recording every stage of the research process, the results become verifiable and replicable by future researchers, thus ensuring stability in the research outcomes. To ensure dependability, all methodology choices were written in an audit trail (Lincoln & Guba, 2004).

4.3.8.3 Confirmability

Confirmability ensures that the research findings are the result of the participants' input rather than the researcher's biases (Guba, 1981). To achieve confirmability, both participants reviewed the research findings, and the researcher reflected in a reflective journal throughout the process (Lincoln & Guba, 2004). To achieve confirmability, the researcher kept an audit trail of all decisions, including analytic choices and justifications (Ghafouri & Ofoghi, 2016). By meticulously adhering to the approved research methodologies without any data manipulation, the study produced credible findings. This approach obviously supports the neutrality and transparency of the research results, making them accessible for verification.

4.3.8.4 Transferability

Transferability is defined as the extent to which the research findings are applicable to other contexts or populations (Guba, 1981). To support transferability, the researcher made sure that a detailed description of the study was provided, allowing future researchers to assess whether the findings apply to their settings (Cypress, 2017; Lincoln & Guba, 2004). Detailed contexts also enable researchers to relate these findings to

similar settings (Ghafouri & Ofoghi, 2016). Thick, detailed information concerning research participants and their environment strengthens the transferability of study findings (Lincoln & Guba, 2004). To further guarantee the study's quality, the researcher not only recorded the audio during interviews but also observed unspoken body language and gestures when posing questions, allowing for deeper insights into the research topic (Creswell & Creswell, 2017).

4.4 Ethical Considerations

Ethical compliance was maintained to protect participants and ensure research integrity (Kwame & Petrucka, 2024). Approval was obtained from GIBS. Participants received informed consent, detailing the study objectives, risks, and procedures (Kwame & Petrucka, 2024). Confidentiality and anonymity were ensured through data handling procedures. Voluntary participation was emphasised, allowing withdrawal without penalty. Risk assessment was conducted to minimise any physical or emotional harm.

4.5 Limitations

A primary limitation of the research was the inherent subjectivity that characterises qualitative research, which typically lacks quantifiability and cannot be substantiated with absolute numerical values. Furthermore, the research exhibited burden pertaining to reproducibility across different contexts, institutions and projects. Also, due to subjectivity, establishing causality was difficult, if not impossible. Additionally, participants in the interviews could modify their answers due to their feelings or an attempt to maintain a particular role and spotlight on the topic being discussed (Theofanidis & Fountouki, 2018).

4.6 Chapter Summary

The methodology of the research was explained in this chapter. The research approach used an interpretivism philosophy, an exploratory design, and an inductive approach, and used a qualitative narrative inquiry strategy whose time horizon was cross-sectional. The sample included professionals working on climate-resilient projects, and the unit of analysis was their perspectives, knowledge, and experiences. The sample of 13 participants was obtained by non-probabilistic purposive sampling. The semi-structured interview guide was used to gather data that was analysed using thematic analysis with the help of Atlas.ti. The quality controls were achieved by the trustworthiness criteria of Lincoln & Guba (2004). Ethical issues and limitations of the study were also discussed. The design of the methodology was aimed at giving deep, rich insights into how the

implementation of climate-resilient critical infrastructure affects the effective practices of project management within the South African context.

CHAPTER 5: PRESENTATION OF FINDINGS

5.1 Introduction

The chapter provides the results of the study that was developed to comprehend the impact of establishing climate-resilient critical infrastructure on efficient project management practices in the South African context. The study studied the way in which project managers, engineers, consultants, and government agencies incorporate climate-resilience concepts across the project lifecycle- planning, design, implementation and post-construction evaluation.

The main research question guided the research:

“How does the implementation of climate-resilient critical infrastructure influence effective project management practices within the South African context?” This was explicitly explored using the following specific research questions:

RQ1: How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices within the South African context?

RQ2: What are the key project management practices that are most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?

RQ3: What framework can be developed to enhance the integration of climate resilience considerations into the project management of critical infrastructure in the South African built environment industry?

The results of the semi-structured interviews are reported in accordance with the following research questions and are organised on a thematic basis, which is divided into Sections 5.3 to 5.5. All the themes and subthemes are based on professional experiences and sectoral knowledge on client infrastructure resilience integration. The chapter, therefore, brings the empirical results to the overall objective of establishing a systematic framework of climate-resilient project management in the critical infrastructure sector in South Africa.

5.2 Data Description

5.2.1 Overview of the Sample

Table 5.1 shows the demographic data of thirteen participants who were selected based on various organisations that are engaged in the design, planning, implementation, and management of critical infrastructure projects in South Africa. These encompass government department professionals, government infrastructure, consulting engineering firms, and contractors in construction, environmental, and sustainability departments.

Table 5-1: Demographic Distribution of Participants

Participant	Role / Title	Sector/Focus	Project Involvement Stage	Years of Experience	Education Level	Understanding of Climate-Resilient Infrastructure	Climate Resilience Emphasis
1	Project Engineer	Water & Energy Infrastructure	Design & Feasibility	10–15 years	Bachelor's Degree	Infrastructure designed to withstand extreme weather and remain reliable over time	Moderate
2	Site Manager	Civil Construction	Construction & Delivery	10+ years	Bachelor's Degree	Infrastructure must withstand climate extremes and minimise environmental footprint.	Moderate
3	Design Engineer	Water Infrastructure	Design & Technical Supervision	15+ years	Master's Degree	Designing infrastructure to resist climate events like flooding and erosion	High
4	Civil Engineer	Transport Infrastructure	Design & Implementation	12+ years	Bachelor's Degree	Infrastructure must be physically robust and strategically planned for future risks.	High
5	Infrastructure Planner	Urban & Public Works	Planning & Design	10+ years	Bachelor's Degree	Infrastructure must withstand and adapt to floods, droughts, and environmental shifts.	High

6	Senior Engineer	Water & Sanitation	Design & Execution	10–15 years	Bachelor's Degree	Infrastructure should withstand climate change impacts (e.g., flooding)	Moderate
7	Project Architect	Building & Facilities Design	Design & Client Liaison	8–10 years	Bachelor's Degree	Use of materials and methods to withstand climate and temperature extremes	Moderate
8	ESG Analyst	Mining & Energy	Feasibility & Studies	10–15 years	Master's Degree	Infrastructure resilient to climate and social impacts; includes ESG aspects.	Very High
9	Structural Engineer	Transport & Public Works	Design & Supervision	15+ years	Bachelor's Degree	Infrastructure must endure extreme weather and climatic changes	High
10	Project Manager	Construction & Civil Works	Planning & Implementation	10–12 years	Bachelor's Degree	Projects should withstand adverse weather and be scheduled considering seasonal patterns.	Low
11	Site Engineer	Stormwater & Drainage Systems	Construction	7–10 years	Bachelor's Degree	Infrastructure should absorb or withstand climate impacts	Low
12	Senior Project Engineer	Multisector Infrastructure	Lifecycle (Planning to Commissioning)	10–15 years	Master's Degree	Infrastructure designed to absorb and recover from climate impacts	Very High
13	Civil Engineer	Roads & Bridges	Design	10+ years	Bachelor's Degree		

The participants' roles ranged from project engineers, planners, and site managers to architects and ESG analysts, covering sectors such as water, energy, construction, transport, mining, and urban infrastructure. Their inclusion ensured that perspectives captured both technical and managerial dimensions of climate-resilient project delivery.

Most participants possessed over ten years of experience in their respective sectors and held at least a bachelor's degree, indicating a high level of professional expertise. Although predominantly based in South Africa, one participant from Eswatini contributed regional comparative insights. Participants' understanding of climate-resilient infrastructure emphasised durability, adaptability, sustainability, and the ability to maintain functionality under changing climatic conditions. While awareness of resilience integration was strong, its implementation varied across stages of the project lifecycle, often being more consistent during the feasibility and design phases than during construction or post-implementation. Overall, the sample reflected a growing recognition of climate resilience as a core component of effective project management and infrastructure sustainability, though progress is constrained by budget limitations, inconsistent policy enforcement, and variable technical capacity across organisations.

5.2.2 Thematic Analysis Procedure

The study employed thematic analysis using Atlas.ti software to examine qualitative data collected from interviews with thirteen professionals engaged in South Africa's critical infrastructure sectors. The purpose was to identify key patterns, themes, and subthemes that explain how climate resilience is being operationalised and how it affects project management practices. Thematic analysis was chosen for its flexibility and its ability to link lived professional experiences to each of the three research questions (RQ1–RQ3). This approach enabled a rich and structured interpretation of data related to resilience integration, adaptive management, capacity development, and institutional frameworks.

5.2.2.1 Analytic Logic, Codebook, and Consolidation of Codes

The analysis was inductive in nature, for the themes were not pre-determined but rather emerged out of the insights of the participants. All the transcripts were analysed in relation to RQ1, RQ2, and RQ3, paying attention to the way in which the participants explained the integration, challenges, and framework development to climate-resilient project management. The identification of key phrases which describe resilience integration, adaptive methods, and project governance were coded at the first order and reduced to second-order codes followed by grouping them into thematic groups.

Atlas.ti helped in the management, visualisation, and tracking of the correlation between codes that work in keeping with the rigour of the analysis. There was no pre-defined codebook, but coding was developed inductively based on the raw data, making it

responsive to the views of the participants, so a Master Table was developed to show relationships between codes, subthemes, and overall themes (see Appendix 3) to ensure transparency and traceability in the analysis process. About 200 first-order codes were first identified, for these codes included the areas of climate risk management, adaptive project planning, institutional frameworks, stakeholder engagement, and technical capacity development, and all these codes were professional interpretations of resilience in project management. With the process of refinement, similar first-order codes were combined into 90 second-order codes, which represent distinct conceptual meanings, for this merger reduced redundancy and focused on unique knowledge regarding the implementation of climate resilience, project efficiency, and sustainability.

5.2.2.2 Themes and sub-themes and Logic behind Symmetry

The final analysis yielded 21 major themes, 42 subthemes, and was categorised according to the three research questions as presented in Table 5.2.

Table 5-2: Themes and Subthemes

Research Question (RQ)	Themes	Subthemes	Description
RQ1: How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices within the South African context?	5	10	Focuses on how climate resilience principles are embedded across various project lifecycle stages (initiation, planning, execution, monitoring, and closure) and integrated into management practices.
RQ2: What are the key project management practices that are most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?	9	18	Examines specific project management functions—such as risk management, stakeholder engagement, resource allocation, and sustainability planning—that are influenced by incorporating climate resilience measures.
RQ3: Framework Development for Enhancing Climate-Resilient Project Management	7	14	Involves synthesising findings to develop a structured framework or model that strengthens project management effectiveness and resilience to climate-related disruptions.

Each research question contained a set of interconnected themes addressing aspects such as policy alignment, governance, capacity development, financial planning, stakeholder engagement, and adaptive project methodologies. This structure provided a symmetrical and logically coherent thematic framework, aligning resilience

implementation with project management dynamics in the South African infrastructure sector.

5.2.2.3 Data Saturation

All 13 interviews were analysed, and data saturation was reached when no additional codes, themes, or subthemes were identified beyond this point. The cumulative data saturation plot shows codes, sub-themes, and themes identified across 13 interviews. Lines plateau after Interview 12 and flatten at 13, indicating no new insights. A dashed red line marks saturation, confirming that data collection was sufficient and further interviews would not yield additional meaningful information.

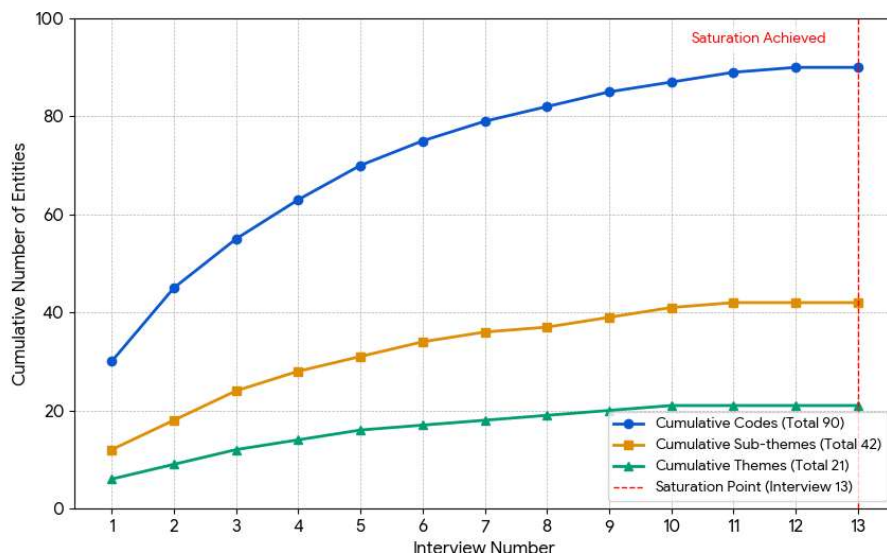


Figure 5-1: Saturation Plot: Cumulative Entities Across Interviews

Figure 5.1 is the saturation plot, a visual representation of the cumulative growth of the new data entities, codes, sub-themes and themes that have been identified in a sequential order in relation to the 13 interviews that were carried out. All lines on the graph are straight, which means that each of them represents one entity type, and all entities are built and established quickly in the beginning and then gradually, or on a plateau. Importantly, all three curves show a full flattening after the 12th interview, which involves a steady maximum at the 13th interview, which is specifically reinforced with a vertical line, which confirms the fact that the saturation of the data was evenly completed at this stage. This graphical demonstration of the end of the new data stream confirms the claim in the research that the collected data was sufficient analytically and exhaustive to answer research questions.

5.3 Research Question 1 Findings

In the following section, the findings of RQ1: *How does the introduction of climate-resilient features in critical infrastructure projects impact the use of effective project management practices in the South African context?* are presented. To describe the experiences and views of the participants, the analysis is organised into five major themes with subthemes. These themes were developed based on the open-ended qualitative data and are presented with the help of verbatim quotes.

Results of RQ1 indicate that the implementation of climate-resilient infrastructure projects needs to be integrated early, with financial planning, alignment of governance, capacity building of technical capacity, and stakeholder cooperation. The findings, namely, early-stage integration (Theme 1), lifecycle economics (Theme 2), governance coherence (Theme 3), human capital development (Theme 4), and stakeholder collaboration (Theme 5), are examples of systemic interdependence, which reflects the theoretical interlinkage of resilience capacity, feedback learning, and flexible governance. All themes and subthemes' findings reveal that implementing climate-resilient features in South African critical infrastructure fundamentally enhances project management effectiveness by embedding adaptability, financial foresight, and collaborative governance across all stages of the project lifecycle. Early integration during design and planning fosters proactive risk identification and resource efficiency, while long-term financial strategies and policy alignment ensure sustainability and compliance. Furthermore, human capital development and inclusive stakeholder engagement strengthen technical competence and community ownership, making resilience not just a technical requirement but a holistic management philosophy that promotes sustainable, adaptive, and socially responsive infrastructure delivery. The presented Table 5.3 gives a systematic description of the themes and subthemes.

Table 5-3: Themes and Sub-Themes on Research Question One

Research Question One (RQ1)	Themes	Sub-Themes
How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices?	1, Integration of Climate Resilience in Project Lifecycle Stages	1,1 Early-stage incorporation for long-term adaptability 1,2 Continuous design refinement & agile adaptation
	2, Financial & Economic Implications of Climate-Resilient Implementation	2,1 Long-term cost efficiency & lifecycle savings 2,2 Budget constraints & undervaluation of resilience
	3, Governance, Policy, & Regulatory Alignment	3,1 Legislative & contractual drivers for climate resilience 3,2 Institutional gaps & lack of standardisation
	4, Human Capital, Knowledge, & Technical Capacity	4,1 Need for specialised skills & continuous professional development 4,2 Information availability & climate data integration
	5, Stakeholder Collaboration & Communication Practices	5,1 Inclusive engagement & local knowledge integration 5,2 Interdisciplinary coordination & team collaboration

Then, the key themes and subthemes are expounded to bring out the role of climate-resilient characteristics in good project management practices in South African critical infrastructure projects.

5.3.1 Theme 1: Integration of Climate Resilience in Project Lifecycle Stages

Participants show that the incorporation of climate resilience in the project life cycle phases highlights the importance of adaptive project management throughout the project life cycle. Study participants emphasised the need to integrate resilience in the initial phases of project planning. As an illustration, Participant 1 said, "*The inception and design phases are the most crucial because this is when decisions can have a lasting impact on resilience.*" Equally, Participant 4 observed, "*We should filter climate risk at an early stage, even during concept design. Multidisciplinary specialists should be used in the design process.*" Furthermore, the importance of early planning was supported by Participant 10:

" Between the concept and design phase, you can influence design and construction methodology, collect accurate data, and ensure the client is prepared." All these insights prove that the integration at the early stage enables long-term flexibility and more robust project results.

5.3.1.1 Subtheme 1.1: Early-stage incorporation for long-term adaptability

Participants noted that the resilience of infrastructure is affected by decisions made during the inception and design stages. Results show that if climate-resilient features are to be introduced early in the project, this will allow the project team to predict the risks and take preventive actions. Participant 1 emphasised, *" The inception and design phases are the most crucial because this is when decisions can have a lasting impact on resilience."* Similarly, Participant 4 said, *"We should filter climate risk at an early stage, even in concept design. Multidisciplinary specialists should be involved in the design process."* This proactive solution will make sure that the infrastructure is constructed to resist climate pressures and will maximise resources and reduce future disruptions.

5.3.1.2 Subtheme 1.2: Continuous design refinement and agile adaptation

Another important point made by the participant is that resilience needs iterative and agile project management. Instead of adhering to strict linear processes, the participants claimed that continuous improvement is the way to ensure flexibility and adaptability. Participant 5 observed, *"Agile methods refine processes through iteration—test, implement, learn, adjust, and repeat. This continuous refinement works very well with climate-resilient projects."* Relatedly, Participant 3 went on to add, *"Implementing coordinated meetings (similar to agile feedback loops) ensures designers, construction, and management teams collaborate from the start."* Participant 11 further added, *"Infrastructure is designed but not tested against climate events. We need to add a step for testing and refining designs to account for climate risks."* These remarks indicate that iterative design will increase the resilience of the project and make it more aligned with the changing climate considerations.

5.3.2 Theme 2: Financial and Economic Implications of Climate-Resilient Implementation

Results show that finance is one of the core factors to be considered in establishing the degree of resilience within projects. Participants disclosed that resilience can save money

in the long term, but is not without challenges because of budget limitations and undervaluation. As an example, Participant 2 said, *"The greatest advantage is the lowering of future expenses in maintenance and replacement... resilient infrastructure that lasts longer reduces this burden."* In the same vein, Participant 4 pointed out the advantages: *"Benefits include reduced maintenance and disaster recovery costs, protection of lives and livelihoods."* Nevertheless, financial constraints were also highlighted. Participant 6 said, *"Budget limitations are the number one challenge. Clients often have underpriced the project, leaving insufficient funds for resilience."* These results clearly show that although climate resilience has the potential to provide economic benefits, financial planning and client awareness are essential to effective implementation.

5.3.2.1 Subtheme 2.1: Long-term cost efficiency and lifecycle savings

The participants viewed climate-resilient infrastructure as a long-term efficiency investment. To illustrate, Participant 9 said, *"Well-constructed, robust infrastructure still operates even when other systems are down, mitigating risk for both users and government."* Likewise, Participant 2 emphasised that resilient infrastructure lessens the cost of constant maintenance, *"The greatest advantage is that resilient infrastructure saves on future costs in maintenance and replacement... resilient infrastructure that is long-lasting saves this cost burden."* Therefore, the integration of resilience will help in saving the lifecycle, which will be economically and operationally beneficial to the project stakeholders.

5.3.2.2 Subtheme 2.2: Budget constraints and undervaluation of resilience

Results show that financial barriers are also a significant challenge despite the apparent long-term benefits. Participant 2 said, *"Clients may not see resilience as value for money, and contractors often compete on the lowest bids."* Participant 10 also pointed out, *"Clients resist higher upfront costs even when long-term benefits outweigh them."* These assertions indicate that cost restrictions and a lack of knowledge of the benefits of resilience can hinder the implementation of climate-resilient aspects in critical infrastructure projects.

5.3.3 Theme 3: Governance, Policy, and Regulatory Alignment

Results show that governance structures, policy frameworks and regulatory mandates are very powerful factors that contribute to effective climate-resilient project management. The

participants repeatedly pointed out that the integration of resilience in project practices is driven by legislation, policy and standards. According to participant 8, *“It is mainly legislative frameworks. Without a legislative impetus, few will voluntarily take on the burden of additional studies and design hours.”* On the same note, Participant 5 emphasised, *“The role of government is primarily to enforce compliance by policy, regulation and standards.”* Participant 7 also added, *“If planning is inadequate, the project will encounter difficulties in the future. Resilience should be a weighted factor in policies, as economic empowerment.”* These insights demonstrate that regulatory and governance systems offer the required platform to instil resilience in every stage of the project.

5.3.3.1 Subtheme 3.1: Legislative and contractual drivers for climate resilience

The participants observed that government mandates and policy requirements are important in implementing climate-resilient practices. Results show that in the absence of legislative support, project teams will have little reason to focus on resilience. Participant 8 said, *“It is mainly legislative frameworks. If there is no legislative push, few will voluntarily take on the burden of additional studies and design hours.”* Participant 5 shared the same view, stressing compliance with standards, regulations, and policies. *“The role of government is primarily to enforce compliance by policy, regulation and standards.”* P5. Therefore, legislative and contractual drivers serve as a driving force towards systematic resilience integration, which guarantees that the projects are delivered to the expectations of the country and the industry.

5.3.3.2 Subtheme 3.2: Institutional gaps and lack of standardisation

Although governance is crucial, the participants found a lack of institutional capacity and inconsistent standards. Participant 9 noted, *“In Europe, standards are clear. Some of the standards are still under development in South Africa.”* Similarly, Participant 11 remarked, *“The political will and budget are usually constraining. It is all about delivery instead of creating long-term resilience.”* Participant 10 also contributed by stating that *“There are no official rules or gazetted requirements that require climate-resilient practices.”* These assertions show that institutional loopholes and non-standardisation may slow down the consistent implementation of climate-resistant strategies, and thus, there should be unified policies and enforcement systems.

5.3.4 Theme 4: Human Capital, Knowledge, and Technical Capacity

Results show that the technical skills and the continuous training of human capital are important in the successful execution of climate-resilient infrastructure. The participants emphasised that to succeed in climate-resilient infrastructure projects, it is necessary to possess specialised skills, continuous professional growth, and access to the appropriate data. Participant 6 said, *"Project managers should make sure that their human resources attend more courses on how to design with climate change in mind."* Participant 7 continued, *"One key aspect is human capital alignment, having professionals that are aware of climate resilience."* In addition, Participant 13 said, *"Climate resilience implementation needs new skills. Engineers should be given flexibility to optimise designs for robustness."* Together, these lessons indicate that the technical capacity and knowledge development are the key to successful project management in the climate resilience environment.

5.3.4.1 Subtheme 4.1: Need for specialised skills and continuous professional development

The participants highlighted the need to have new technical and managerial skills to deal with the risks of climate change. Results show that continuous learning will make sure that the project teams have the most up-to-date information on climate-resilient design and implementation. Participant 6 said, *"Project managers need to ensure their resources attend more courses on climate change-friendly design."* Participant 7 also emphasised the need to align human capital: *"One key aspect is human capital alignment, having professionals that are aware of climate resilience."* P7. On the other hand, Participant 13 emphasised the need to have flexibility in engineering designs, *"Implementing climate resilience needs new skills. Engineers should be given flexibility to optimise designs for robustness."* P13. These sentiments imply that capacity-building initiatives and professional development are part and parcel of having a competent workforce that can provide climate-resilient infrastructure.

5.3.4.2 Subtheme 4.2: Information availability and climate data integration

Results show that the availability of sound climate data is a fundamental determinant of resilience planning. Participant 1 complained, *"One significant challenge is that there is no organised data... to design a resilient hydropower, historical climate data is needed."* Participant 12 added, *"Information availability and awareness prior to execution is paramount."* Participant 11 also added, *"We need research to understand our climate and develop predictive systems similar to those in other countries."* These results suggest that

project management processes must incorporate the correct climate data to enable informed decisions and proactive risk mitigation.

5.3.5 Theme 5: Stakeholder Collaboration and Communication Practices

Results show that the success of climate-resilient infrastructure projects depends on collaboration, communication, and the sharing of knowledge among the stakeholders. Participants emphasised that the integration and implementation of projects are enhanced by the successful interaction with communities, interdisciplinary teams, and other stakeholders. Participant 3 pointed out that “*Greater engagement is needed with local landowners and communities that have valuable knowledge.*” Participant 4 observed that “*Community engagement is essential in order to learn about the past climatic occurrences.*” Moreover, Participant 10 mentioned that “Planning should incorporate the research that highlights *the pros and cons of project location in terms of climate and local conditions.*” This theme illustrates that stakeholder cooperation will lead to informed decisions and will make the project implementation smoother.

5.3.5.1 Subtheme 5.1: Inclusive engagement and local knowledge integration

The participants recognised the importance of engaging the local communities and integrating the traditional knowledge. Results show that interaction with the stakeholders assists the project teams in determining the local climate risks and optimising the project location and design. Participant 3 underlined, “*Greater engagement is needed with the local landowners and communities with rich knowledge.*” Participant 4 concurred, “*Community engagement is essential to learn about the past climate events.*” Participant 10 further mentioned, “*planning should involve research that shows the pros and cons of project location in terms of climate and local conditions.*” Participant 3 and Participant 4 emphasised the significance of local knowledge and the significance of learning about past climate events, respectively. Participant 10 proposed that research that examines the conditions of project sites promotes the accuracy of planning. Thus, results show that inclusive participation guarantees that the projects are contextually and socially acceptable and improves resilience outcomes.

5.3.5.2 Subtheme 5.2: Interdisciplinary coordination and team collaboration

Results show that cross-functional cooperation between project teams is one of the enablers of resilience integration. Participant 3 said, “*Implementing coordinated meetings*

ensures that the designers, construction and management teams would work together from the start.” Participant 9 noted, *“You are adding new considerations - stakeholders are being involved in a different way and climate factors are being included in every conversation.”* Participant 12 further explained, *“Integration guarantees proactive responses and aligning the expectations of the stakeholders, minimising conflicts and making the execution smoother.”* These results show that interdisciplinary and collaborative practices can help in effective project management through the ease of information flow and coordinated actions to address climate risks.

5.4 Research Question 2 Findings

The thematic analysis identified nine broad themes and eighteen subthemes, each of which is a dimension of the ways in which climate resilience integration changes the project management practices in critical infrastructure projects. All these themes underline the changes in the project structures, approaches, stakeholder involvement, and institutional support mechanisms that would be required to make the projects sustainable and adaptable in the South African environment. The data yielded the following key themes and subthemes as summarised in Table 5.4 below.

The thematic results indicate that the incorporation of climate resilience has transformed the conventional project management practice in the infrastructure sector of South Africa. Themes 1 to 9 all point to the fact that the integration of climate resilience significantly transforms core project management practices, shifting from static and linear approaches to adaptive, data-driven, and participatory models. Key areas affected include dynamic risk management, hybrid project frameworks, sustainability measurement, technological innovation, and human capacity development. Flexible procurement, inclusive stakeholder collaboration, and coherent policy alignment further enhance institutional accountability and social legitimacy. Collectively, these evolving practices establish a systemic approach where environmental foresight, economic prudence, and inclusivity become central pillars of effective and sustainable project management in South Africa’s climate-sensitive infrastructure sector. The findings, therefore, form a holistic basis for developing a conceptual framework to inform resilience-based project management practice in the South African context.

Table 5-4: Themes and Sub-Themes on Research Question Two

Research Question (RQ2)	Themes	Subthemes
<i>What are the key project management practices that are most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?</i>	1. Risk Management Integration for Climate Adaptation	1.1 Enhanced Climate Risk Identification and Mitigation 1.2 Flexibility in Risk Response and Monitoring
	2. Evolving Frameworks and Methodologies	2.1 Hybrid Project Management Approaches 2.2 Systems Thinking and Integration Across Phases
	3. Sustainability and Resilience Measurement Practices	3.1 Standardised Indicators and Benchmarks 3.2 Lifecycle and Performance Evaluation
	4. Technological Tools and Innovation	4.1 Use of Climate Modelling and Data Analytics Tools 4.2 Research and Development for Contextual Adaptation
	5. Stakeholder Collaboration and Governance	5.1 Inclusive Multi-Stakeholder Coordination 5.2 Policy and Institutional Support
	6. Human Capacity and Skills Development	6.1 Specialised Climate Expertise and Training 6.2 Continuous Professional Development and Knowledge Transfer
	7. Procurement and Cost Management Flexibility	7.1 Adaptive Procurement Strategies 7.2 Long-Term Financial Planning and Maintenance Funding

	8. Community and Cultural Considerations	8.1 Social Engagement and Inclusion 8.2 Equity and Local Benefits
	9. Policy, Standards, and Regulatory Alignment	9.1 Standardisation and Compliance Audits 9.2 Legislative and Institutional Frameworks

5.4.1 Theme 1: Risk Management Integration for Climate Adaptation

This theme explains how climate resilience has transformed conventional risk management methods by expanding them to encompass environmental, social, and climate-related risks. Participants emphasised that risk management has become the core of adaptive project delivery, in which the ability to predict the effects of climate and develop adaptable mitigation strategies is crucial to maintain the continuity of the project and its stability over the long term.

5.4.1.1 Subtheme 1.1: Enhanced Climate Risk Identification and Mitigation

Participants have consistently described risk management as the bedrock of climate-resilient project delivery. Results show that climate resilience introduces a new concept of risks beyond engineering failures to include climate change impacts such as flooding, heatwaves, and droughts. Participant 3 highlighted, “*Risk management refers to comprehensive identification and alleviation of the effects of climate change. A risk matrix ought to assess and convey climate risks to all stakeholders.*” Participant 8 also said, “*I would retain the traditional framework but include climate change as other risks in the risk register.*” These views suggest that the most effective mitigation measures involve identifying risks at an early stage and regularly updating risk registers in line with new climate data. This was supported by participant 9, who said that “*Risk management, particularly after commissioning, is critical because you are unable to alleviate all potential risks but need to be ready to be resilient.*” Thus, risk identification and mitigation have changed to become dynamic and anticipatory rather than reactive.

5.4.1.2 Subtheme 1.2: Flexibility in Risk Response and Monitoring

Adaptive monitoring and flexibility were identified as key features of effective risk management in climate-resilient infrastructure. Participant said, *“The answer is to integrate flexibility and adaptive strategies to adapt to changing climatic conditions.”* Participant 11 concurred and stated that, *“Once research is used to inform the future conditions to be expected, agile and adaptive methods can be adapted to enhance the results.”* Participant 12 also added, *“Adaptive techniques enable changes to the project as it goes on, and the climate effects are better accommodated compared to rigid models.”* The preceding sentiments suggest that flexibility allows the managers to modify interventions and reassign resources in case of unexpected environmental changes. Therefore, adaptive risk monitoring helps to engage in the continuous learning process and make sure that project teams are sensitive to the anticipated and unforeseen climate changes.

5.4.2 Theme 2: Evolving Frameworks and Methodologies

The theme is based on the necessity to change project management frameworks to adapt to climate uncertainties using flexible and hybrid strategies. The participants emphasised that the traditional linear models are being supplemented by the agile and adaptive models that enable the teams to react to the changing conditions in the environment without affecting accountability.

5.4.2.1 Subtheme 2.1: Hybrid Project Management Approaches

The participants highlighted the necessity of hybrid project management strategies that would integrate traditional control systems and agile flexibility. Participant 1 noted, *“A hybrid approach may be effective, with fixed components and adaptive strategies.”* Participant 7 followed up by saying, *“Agile and adaptive methods are workable but must be planned; change in the middle of the project may lead to claims and delays.”* Participant 12 noted, *“Large-scale infrastructure may benefit more from adaptive than purely agile approaches.”* These assertions imply that hybrid methods can combine predictability and adaptability so that there is resilience throughout the project lifecycle. This means that project managers need to come up with frameworks that will enable them to do both proactive planning and reactive adjustments to the disruption caused by the climate.

5.4.2.2 Subtheme 2.2: Systems Thinking and Integration Across Project Phases

Results show that systems thinking has become an important instrument for considering climate in a range of project phases and disciplines. Participant 4 said, “We’ve used Integrated Project Delivery to coordinate multi-stakeholders and systems thinking. Participant 9 explained, “*Systems thinking, lean practices, and Six Sigma minimise waste, enhance efficiency and incorporate several aspects effectively.*” Participant 7 concurred by saying that “*Integrating project management principles such as PMBOK at an inter-system level makes the system accountable.*” Such understandings are signs of the realisation that climate resilience cannot be attained on a singular level but must encompass systematic and thriving systemwide engagement. This leads to systems integration that encourages consistency in design, implementation, and maintenance, thereby strengthening resilience across the infrastructure lifecycle.

5.4.3 Theme 3: Sustainability and Resilience Measurement Practices

It is a theme that investigates the process of measuring and assessing climate resilience and sustainability performance using standardised quantifiers and lifecycle analysis using standardised indicators in project teams. The participants acknowledged that performance indicators can be used to compare success, monitor progress, and justify investments in resilience to stakeholders.

5.4.3.1 Subtheme 3.1: Standardised Indicators and Benchmarks

Participants highlighted the need for standardised measures to assess the performance of climate resilience across projects. Participant 10 elaborated that, “*the Key indicators include water consumption, energy consumption, and carbon emissions.*” Participant 2 continued, “*Design life is important... we need to design for longer life expectancy as worsening events may reduce present design life by half.*” Participant 12 said, “*Climate impacts are controlled with the help of standardised indicators and regular audits.*” The combination of these indicators not only enhances accountability but also enhances the use of data-driven decisions. Thus, standardised benchmarks are key instruments for comparing project resilience in different regions and sectors.

5.4.3.2 Subtheme 3.2: Lifecycle and Performance Evaluation

Another important aspect of sustainable infrastructure management, as mentioned by participants, was lifecycle performance monitoring. Participant 9 noted, “*Infrastructure availability in times of crisis, maintenance cycles and lifecycle costs were critical*

indicators." Participant 6 commented, *"Maintenance is a major risk in South Africa; maintenance plans should have proper management plans to make sure that infrastructure has a life cycle."* Participant 11 also said, *"Infrastructure that will still be operational after events implies resilience even though small repairs may be necessary."* These remarks underline the fact that monitoring after construction is crucial to learning and gaining resilience in subsequent projects. Lifecycle evaluation, therefore, makes sure that climate-resilient projects not only endure the environmental shocks but also maintain their operational performance.

5.4.4 Theme 4: Technological Tools and Innovation

This theme shows that the incorporation of technology and innovation has been crucial in integrating climate resilience in project management practices. According to the participants, predictive modelling, scenario planning, and informed decision-making during the project lifecycle are possible due to the use of advanced technological tools. The results indicate that digital technologies (GIS, BIM, data analytics platforms, etc.) are being used more often to model the possible effects of climate change and develop the necessary adaptive strategies. In addition, research and development make it possible to innovate solutions that are based on the unique environmental conditions of South Africa. Collectively, technology and innovation are essential in the process of shifting from reactive to proactive management of climate-related risks in critical infrastructure projects.

5.4.4.1 Subtheme 4.1: Use of Climate Modelling and Data Analytics Tools

The participants underlined the primary importance of data-driven tools in climate-resilient project planning and implementation. Participant 1 said, *"GIS in mapping and climate modelling tools help in adaptive planning."* Participant 4 repeated, *"Climate risk assessment should be based on hazard mapping and flood modelling."* Participant 9 said, *"Such tools as BIM are useful to visualise the effects and plan in the implementation."* The results show that these technology tools allow the teams to predict possible hazards and prepare adaptive actions before the construction starts. Therefore, data analytics will improve evidence-based decision-making, whereas the visualisation technologies will improve the awareness of the stakeholders about climate vulnerabilities. Thus, technology is a diagnostic and strategic resource in the provision of resilient project results.

5.4.4.2 Subtheme 4.2: Research and Development (R&D) for Contextual Adaptation

Results also found research and innovation (R&D) as an essential facilitator to the creation of localised solutions that would fit the South African climate. Participant 7 responded, *"I would integrate research and development and resource-based views in the project framework."* Relatedly, participant 11 pointed out that, *"research is core; without it, methods are reactive."* Participant 6 concluded, *"Infrastructure fit to the African region should be supported by research-funded initiatives to support graduates."* These assertions underscore the fact that R&D promotes learning, experimentation, and the development of tools and materials specifically tailored to survive the region's climatic conditions. Moreover, the current academic-industrial research collaborations facilitate the constant improvement of standards and methodologies. In this way, contextual adaptation and long-term project innovation rely on R&D.

5.4.5 Theme 5: Stakeholder Collaboration and Governance

This theme shows that good collaboration and governance are among the pillars that can be used to instil climate resilience into project management systems. Participants noted that climate-resilient projects require the coordination of various factors, including government institutions, private contractors, communities, and researchers. This kind of cooperation leads to the sharing of resources, collective problem-solving and consensus decision-making. On the same note, sound governance systems guarantee proper implementation and enforcement of policies and frameworks relating to climate. Thus, inclusive governance offers the basis of transparency, accountability, and shared ownership towards the realisation of resilience goals.

5.4.5.1 Subtheme 5.1: Inclusive Multi-Stakeholder Coordination

The participants found the need to work together inclusively as a means of aligning the objectives of different stakeholders in resilience-oriented projects. Participant 4 noted, *"Integrated Project Delivery improves coordination and resilience of the system."* Relatedly, Participant 5 pointed out, *"Stakeholder involvement guarantees that there is alignment with development objectives and elimination of delays."* Participant 7 further stated, *"Awareness creation through collaboration will guarantee the attainment of sustainability benchmarks."* These reflections demonstrate that teamwork not only enhances productivity but also fosters mutual learning between partners. In addition, multi-stakeholder engagement will ensure that the principles of resilience are incorporated

at the initial stage of the project life cycle, which will reduce the number of conflicts in the future. Thus, the ability to establish inclusive coordination enhances the overall ability to implement adaptive and sustainable practices.

5.4.5.2 Subtheme 5.2: Policy and Institutional Support

It was noted that robust institutional and policy support is essential to facilitate effective project delivery in the changing climate conditions. According to participant 12, *“Governments need to establish adaptive standards that are in line with global sustainable objectives.”* Participant 5 warned, *“Regulatory organisations need to set up CPD that is generally affordable and also focus on knowledge-sharing.”* Participant 3 added, *“External benchmarking models of well-known organisations provide validation and guidance.”* These reactions suggest that national and local governments play a crucial role in mainstreaming climate resilience through policies, guidelines, and enforcement mechanisms. Resource mobilisation and continuity of project cycles are also facilitated by institutional support. As such, policy congruency and institutional strengthening are key to scaling climate-resilient practices throughout the sector.

5.4.6 Theme 6: Human Capacity and Skills Development

This theme explores how enhancing human capital and professional capacity is crucial to the successful implementation of climate-resilient projects. The results show that the lack of climate-sensitive professionals restricts the ability of project teams to plan, execute, and evaluate adaptive actions. Participants emphasised that professional skills and lifelong learning are essential in maintaining the resilience of a project in the long term. In addition, capacity-building programs allow institutions to bridge the technical and social knowledge gaps within the infrastructure ecosystem. Human development, therefore, becomes a precondition and a trigger of resilient project management practices.

5.4.6.1 Subtheme 6.1: Specialised Climate Expertise and Training

The participants emphasised the necessity of having expert climatologists to analyse the data and offer effective design solutions. Participant 1 described it as follows: *“Hire climate experts to analyse data and come up with strong solutions.”* Participant 10 pointed out, *“Environmental and energy experts must be involved.”* Participant 5 added, *“Cultural dynamics and community expectations require social officers to handle them.”* These views affirm that multidisciplinary teams, which include engineers, environmental

scientists, and social officers, are in a better position to deal with the complex issues of climate resilience infrastructure. The specialised training will make sure that the team members will be able to implement climate data in the design and construction processes. Thus, the capacity-building efforts are focused on enhancing the technical basis of resilience implementation.

5.4.6.2 Subtheme 6.2: Continuous Professional Development (CPD) and Knowledge Transfer

The participants also stressed the need to remain adaptive through continuous learning and institutionalised knowledge-sharing. Participant 5 contended, "*CPD programs ought to be free and available to increase technical competence.*" Participant 11 also observed, "*The knowledge of the future climate conditions through research informs design, skills, and standards.*" Participant 12 further contributed by stating that "*Effective implementation of adaptive standards requires education and training.*" These insights show that continuous professional growth cultivates a culture of innovation and responsiveness within organisations. Moreover, CPD ensures the dissemination of best practices across industries and project generations. Therefore, long-term investment in learning is crucial for institutionalising climate infrastructure resilience thinking in project management.

5.4.7 Theme 7: Procurement and Cost Management Flexibility

This theme examines how adaptive procurement and cost management systems increase the capacity of projects to survive climate uncertainties. The participants concurred that the conventional procurement models are not always flexible enough to adapt to scope changes or unpredictable environmental risks. Results show that project managers need to adopt agile financial planning strategies that prioritise long-term sustainability over short-term savings. Effective cost management not only makes the project viable but also facilitates the integration of climate adaptation measures throughout the project lifecycle. Therefore, economic and environmental resilience is based on procurement flexibility.

5.4.7.1 Subtheme 7.1: Adaptive Procurement Strategies

The participants noted that it is essential to modify procurement processes to respond to the dynamic nature of climate risks effectively. Participant 4 said, "*The flexibility of costs and procurement enables adaptation to climate change.*" Relatedly, participant 9 noted, "*Scope, schedule, and cost management are significant; resilience should be consistent with budget reality.*" Similarly, participant 7 said, "*The efficiency can be measured by*

comparing costs between traditional and resilient methods.” These assertions demonstrate that flexible procurement contracts enable the integration of new climate data, materials or methods without interfering with project schedules. Adaptive procurement also promotes value-based selection, which focuses on quality and performance in the long run rather than the lowest cost. Thus, procurement innovation will be integral to achieving climate-resilient outcomes.

5.4.7.2 Subtheme 7.2: Long-Term Financial Planning and Maintenance Funding

Long-term financial planning was also mentioned by participants as one of the main elements of sustainable resilience implementation. Participant 6 said, *“Maintenance costs should be considered so that infrastructure can be used to its maximum design life.”* Participant 2 also contributed, saying that *“...the balance between longevity and sustainability is important when it comes to project budgets.”* Relatedly, Participant 9 emphasised, *“Future climate performance and operational risks should be included in lifecycle cost assessment.”* These views highlight the need to integrate the maintenance and adaptation funds into the original financial structure. Long-term budgeting obviously averts depreciation of assets and makes sure that projects are operational during their planned life. Therefore, the active financial policies guarantee financial accountability and climate sustainability.

5.4.8 Theme 8: Community and Cultural Considerations

This theme reveals the need to incorporate social and cultural dynamics in climate-resilient project planning. The participants emphasised that local communities are not only beneficiaries but also active stakeholders, whose values, traditions, and involvement significantly determine the project's success. Significant involvement will guarantee that the projects meet the local priorities and reduce opposition during implementation. Additionally, cultural sensitivity fosters trust and enables the long-term custodianship of infrastructure assets. Therefore, it is important to incorporate the community's views to ensure that technical solutions are aligned with human and cultural realities.

5.4.8.1 Subtheme 8.1: Social Engagement and Inclusion

The participants repeatedly stressed that communities should be involved to make climate-resilient infrastructure acceptable and sustainable. Participant 5 explained, *“Communities might not be willing to relocate ancestral graves or trees; social officers*

need to consult and mediate on these matters." Participant 4 said, *"Involving communities whose needs change with time will keep the projects on track."* Participant 7 said, *"Awareness programs associate community well-being with infrastructure sustainability."* These highlights point out that social interaction not only reduces conflict but also fosters ownership and shared responsibility. Project teams can also align the community priorities with resilience goals through constant communication. Therefore, inclusion is a process and a product of effective project management.

5.4.8.2 Subtheme 8.2: Equity and Local Benefits

The participants also associated social inclusion with the fair allocation of project benefits. Participant 2 noted, *"Harmonising all stakeholders by having common goals brings together clients, designers and communities."* Relatedly, Participant 5 said, *"...it is about managing culture, politics and expectations of the beneficiaries or the affected."* Participant 12 pointed out that *"...governments should make inclusive standards to ensure that climate resilience is equally beneficial to all stakeholders."* These insights suggest that climate-resilient infrastructure should offer tangible socio-economic benefits to local communities. Equity promotes fairness in access to opportunities, participation and distribution of resources during project cycles. Thus, equitable and culturally responsive implementation leads to the development of trust among the population and enhances sustainability in the long term.

5.4.9 Theme 9: Policy, Standards, and Regulatory Alignment

This theme weighs the role of policy frameworks, regulatory standards, and institutional structures in mainstreaming climate resilience in project management practices. Participants stressed that the absence of effective legislation and standardisation makes resilience efforts disjointed and reactive. Harmonisation of policies at national and organisational levels would be the way to have uniform enforcement and monitoring of adaptive practices. Moreover, compliance systems provide accountability measures to assess project performance and ensure quality assurance. Therefore, successful policy alignment is the foundation for institutionalising resilience in the South African built environment sector.

5.4.9.1 Subtheme 9.1: Standardisation and Compliance Audits

The participants found standardised compliance mechanisms to be essential in accountability and quality of the project. Participant 3 added, "*Climate resilience systems that are ISO-aligned are quality and compliant.*" Participant 12 said, "*Planned audits evaluate the efficiency of standards and policies.*" Participant 11 further stated, "*In the absence of predictive systems and research, regulatory standards are reactive, not preventive.*" These reactions suggest that compliance audits can be used to identify discrepancies between policy intent and actual practice. They also enable continuous improvement by incorporating feedback into the project design and monitoring cycles. Thus, standardisation provides a uniform system of attaining quantifiable and verifiable resilience results.

5.4.9.2 Subtheme 9.2: Legislative and Institutional Frameworks

Participants encouraged the need to have more legal and institutional frameworks to entrench resilience throughout the project phases. Participant 10 said, "*Laws might have to be adaptable to enable agile strategies.*" Participant 5 claimed, "*Professional councils should incorporate technical boards that have engineers and architects who are aware of climate resilience.*" Participant 12 concluded, "*Governments should ensure compliance and match standards with global sustainable objectives.*" These perceptions reveal that institutional cooperation is central to the reduction of the disparity between regulatory policy and field implementation. The integration of adaptive management principles into current construction and environmental regulations can also be achieved through legislative reform. Therefore, strong institutional structures guarantee continuity of policies, enforcement of the law and compliance with international resilience standards

5.5 Research Question 3 Findings

The findings in this section indicate the key dimensions that inform the development of a framework on how to incorporate climate resilience in project management practices in critical infrastructure in South Africa. Participants kept on reiterating the interdependence of governance, stakeholder collaboration, socio-political alignment, education and continuous improvement. As a result, the findings point to the fact that any successful framework should be multi-layered, implying the integration of policy coherence, institutional capacity, technical accountability, and community participation.

The results of Research Question 3 highlight the importance of a practical framework for climate-resilient critical infrastructure, which should be a combination of seven

interdependent elements: policy coherence, inclusive collaboration, capacity building, institutional accountability, socio-political alignment, financial innovation, and adaptive management. All these factors together constitute a holistic background for integrating climate resilience into the project management of essential infrastructure in the South African built environment sector. The main themes and subthemes are summarised in Table 5.5, and each is then described in detail.

Table 5-5: Themes and Sub-Themes on Research Question Three

Research Question 3 (RQ3)	Themes	Sub-Themes
What framework can be developed to enhance the integration of climate resilience considerations into the project management of critical infrastructure in the South African built environment industry?	1. Policy and Governance Alignment	1.1 Updating and enforcing legislative frameworks 1.2 Multi-level government coordination
	2. Stakeholder Engagement and Collaboration	2.1 Inclusive participation of local communities 2.2 Interdisciplinary collaboration and partnerships
	3. Capacity Building and Knowledge Sharing	3.1 Training and education on resilient design 3.2 Dissemination of research and best practices
	4. Institutional Accountability and Compliance	4.1 Monitoring and enforcement mechanisms 4.2 Professional and ethical accountability
	5. Socio-Political Integration and Community Awareness	5.1 Political will and policy prioritisation 5.2 Social awareness and behavioural change

	6. Financial and Resource Sustainability	6.1 Climate finance and funding mechanisms 6.2 Cost–benefit modelling for resilience investment
	7. Continuous Improvement and Adaptive Management	7.1 Dynamic standards and iterative learning 7.2 Integrating feedback loops into project lifecycles

5.5.1 Theme 1: Policy and Governance Alignment

The most common consensus among participants was that effective government leadership and coherent policy frameworks are essential for integrating climate resilience into infrastructure project management. The focus on good governance remained consistent across all interviews, with participants emphasising that the legislative environment needs to be revised, implemented, and coordinated at all tiers of government. Next are the two major subthemes.

5.5.1.1 Subtheme 1.1: Updating and Enforcing Legislative Frameworks

Some participants emphasised the necessity to modernise outdated legislation, claiming that it is a prerequisite for structured implementation. Participant 7 explained, “*Most of the acts are old-fashioned (50-60 years old). Enforcing updated legislation is capital-intensive but crucial for professionals to follow as a legal guide.*” Similarly, Participant 12 noted that “*Governments need to establish transparent, dynamic standards in line with international sustainable goals.*” These are the feelings that show that explicit and modern laws provide guidance to the professionals and ensure that they are applied consistently to projects. Additionally, Participant 10 supported this notion by saying, “*National government advances and gazettes climate-resilient standards and funds them.*” These opinions suggest that new laws and standards are necessary to implement projects in accordance with sustainability goals, and enforcement systems can be used to ensure the accountability and compliance of professionals.

5.5.1.2 Subtheme 1.2: Multi-Level Government Coordination

Integration between national, provincial and local government systems emerged as a common problem throughout participant sentiments. Participant 4 remarked, “...*Level of vertical integration will provide the coordination and project success.*” Participant 11 contributed by saying, “*Local authorities implement and enforce the policies, funding availability and monitoring are the keys to success.*” In the meantime, Participant 9 noted that “*The problem of fragmented responsibility between local, provincial, and national levels makes the joint efforts difficult.*” Those views contribute to the fact that better vertical and horizontal coordination may help to increase the efficiency of projects and policy consistency, which will facilitate the effective implementation of resilience actions. Thus, harmonisation of policies at all levels of the government has been a pillar towards continuity and uniformity in climate-resilient project management.

5.5.2 Theme 2: Stakeholder Engagement and Collaboration

The inclusivity of stakeholders was regarded as central to attaining sustainable and contextually relevant project outcomes. The participants often mentioned collaboration as a key element of shared ownership development, local relevance, and incorporation of various expertise into the project lifecycle. This theme was further subdivided into two sub-themes as presented next.

5.5.2.1 Subtheme 2.1: Inclusive Participation of Local Communities

The community involvement increases the sense of ownership and relevance in the development of infrastructure. According to participant 1, “*Stakeholders offer practical guidance and make sure the project serves the needs of the community.*” In the same way, Participant 6 also replied that “*Social involvement is very important in the success and sustainability of the infrastructure because it is built for them.*” Moreover, Participant 10 said, “*Local government engages communities, creates awareness, and ensures compliance.*” Such statements demonstrate that inclusiveness not only fosters trust but also ensures that project results accurately reflect the community's needs. Community empowerment, therefore, through participation, makes communities feel accountable, and they also contribute to the project's long-term sustainability.

5.5.2.2 Subtheme 2.2: Interdisciplinary Collaboration and Partnerships

The participants stressed that effective frameworks bring professionals, academics, and government institutions together. Participant 3 pointed out, *"Design teams, contractors, and SMMEs should have access to new research, guidelines, and best practices."* Participant 10 further put in that, *"cross-functional teams provide different expertise in order to make a project successful."* Participant 13 put a stress on, *"Identify all stakeholders—from end user to sponsor—and use change management, not directives."* A combination of these statements shows that cooperation can create mutual understanding between various disciplines and improve the technical integration of the project planning and implementation. Thus, the encouragement of partnerships and interdisciplinary cooperation will ensure that the framework of climate resilience is sound, inclusive, and evidence based.

5.5.3 Theme 3: Capacity Building and Knowledge Sharing

Knowledge dissemination and training were found to be key facilitators to the successful implementation of climate-resilient projects. There was a high degree of agreement among the participants that structured professional training and learning programmes are essential in the development of expertise at every level of practice. This theme is represented in two sub-themes.

5.5.3.1 Subtheme 3.1: Training and Education on Resilient Design

The participants had underlined the role of formal learning among professionals and community stakeholders. Participant 4 said, *"Training on resilient infrastructure ought to be compulsory for professionals and subcontractors."* Relatedly, Participant 6 observed, *"Training, conferences, and awareness should be properly budgeted in advance."* Participant 12 also concurred: *"Governments ought to educate, carry out campaigns and impose the relevant policies by monitoring."* These reflections reinforce the importance of the fact that continuous education leads to technical competence and adherence to changing standards, as well as enables practitioners to make informed decisions. Systematic training, therefore, means that resilience is integrated throughout the project development and management.

5.5.3.2 Subtheme 3.2: Dissemination of Research and Best Practices

The participants referred to the need to bridge the gap between research and implementation. Participant 3 noted, *"The research outputs are not connected to the*

practitioners." Participant 11 went on to state, *"Project outcomes will be enhanced by empowering research bodies to influence design and policy."* Participant 7 went ahead to substantiate it by stating that, *"Stakeholders such as industry bodies are central to a holistic policy formulation."* Such perceptions demonstrate that knowledge sharing and bringing academic research into practice should greatly help to improve evidence-based decision-making. Hence, the connection between research institutions and practitioners is that lessons learned will be shared and implemented in future projects in a systematic manner.

5.5.4 Theme 4: Institutional Accountability and Compliance

The participants emphasised the importance of effective accountability mechanisms in maintaining compliance, quality, and sustainability. Two subthemes —monitoring and enforcement mechanisms and professional and ethical accountability —highlight the role of institutional checks in ensuring integrity within the structure of infrastructure projects. These are presented next.

5.5.4.1 Subtheme 4.1: Monitoring and Enforcement Mechanisms

Results show that monitoring mechanisms were an essential part of ensuring compliance with the resilience standards. Participant 5 emphasised, *"Although the compliance may not be entirely achieved, at least monitoring and accountability should be in place."* Participant 11 confirmed, *"There should be effective monitoring, enforcement, and funding alignment in order to meet the goals."* Participant 9 contributed further and said that *"Bodies should have someone who visits project sites to provide information every now and then and not just using historical data."* All these statements indicate that frequent on-site checks and frequent reporting enhance compliance and reliability of the project. Thus, institutionalised surveillance leads to increased confidence and effectiveness in the implementation of resilience objectives.

5.5.4.2 Subtheme 4.2: Professional and Ethical Accountability

Professional ethics were found to be the key to supporting the quality and credibility of the project. Participant 6 said that the *"Stakeholders should make sure that the quality aspect of the project management triangle is never ignored."* Participant 10 observed, *"Guidelines, practice notes and cost recommendations on how gazetted changes should be implemented are offered by professional bodies."* Participant 13 added, *"Government*

should empower the institutions such as CIC and align policies to be implemented properly." These lessons help explain that professionalism and regulation contribute to the development of ethically sound decision-making and compliance with industry standards. Overall, institutional accountability fosters transparency, professionalism and project implementation.

5.5.5 Theme 5: Socio-Political Integration and Community Awareness

The respondents accepted the notion that the social-political alignment is a direct determinant of the project's sustainability and the overall embrace of resilience efforts. This theme examines the influence of political will and social awareness on the effectiveness of climate-resilient infrastructure.

5.5.5.1 Subtheme 5.1: Political Will and Policy Prioritisation

The participants also repeatedly noted that the issue of political commitment defines whether the policies of climate resilience are effective or not. Participant 8 explained, *"There will not be changes in regulations without political willingness, and the status quo will remain."* Participant 6 concurred by saying that "Government involvement is essential; lack of political buy-in means that the projects will not be prioritised on important planning documents." Participant 9 warned that the *"Lack of skills in the government restricts the capacity to lead."* A combination of these views suggests that political stability, leadership and capacity are all involved in creating sustainable transformation. Therefore, nurturing political will can help climate resilience become a key part of the national development agenda.

5.5.5.2 Subtheme 5.2: Social Awareness and Behavioural Change

Training on communities was mentioned as the basis of building sustainable infrastructure utilisation and minimising opposition. Participant 1 noted, *"Community and industry players should be educated on climate resilience as it will guarantee awareness."* Participant 13 followed up by saying, "We should educate and gain buy-in, as this way the society would realise *the impact of non-resilient structures.*" Participant 11 also added, *"Lack of informed communities can lead to resistance or abuse of the project."* These assertions indicate that awareness efforts and behavioural modification programs enable the society to be of meaningful involvement in resilience building. Widespread popular

education, therefore, guarantees the security and maintenance of infrastructural investments made in the long run.

5.5.6 Theme 6: Financial and Resource Sustainability

The economic aspect of resilience was also a re-emerging topic, as sustainability was associated with financial resources, budgeting, and the efficient use of resources on a long-term basis. This theme was split into two subthemes.

5.5.6.1 Subtheme 6.1: Climate Finance and Funding Mechanisms

The participants pointed out that the extent to which resilience features can be incorporated depends on the availability of funding. Participant 1 explained, *"...Government offers funding or grants, but stakeholders make sure that it is relevant on the ground."* Participant 10 added, *"funding and compliance is done by national government."* Participant 9 supported this by emphasising that *"investment in social services can shift budgets out of resilient infrastructure."* This shows that there is financial support, but strategic allocation and monitoring are essential to successful implementation. Therefore, it is necessary to ensure the provision of specific funding sources to support resilience initiatives in maintaining long-term infrastructure changes.

5.5.6.2 Subtheme 6.2: Cost–Benefit Modelling for Resilience Investment

The participants also discussed the importance of financial modelling in justifying resilience expenditures. Participant 8 commented, *"Models are expected to demonstrate the improvements of the return on investment and net present value with the inclusion of resilience measures."* Participant 7 also contributed, saying that *"Implementation of new laws is capital-intensive yet essential to professionals."* Participant 3 noted, *"Projects must consider resource constraints and be efficient and sustainable in design."* These considerations suggest that cost-benefit analysis offers decision-makers a clear picture of the long-term worth of resilience investments. Thus, the incorporation of financial models in the planning processes will facilitate the efficient utilisation of resources and increase the sustainability of projects.

5.5.7 Theme 7: Continuous Improvement and Adaptive Management

Participants emphasised the need for adaptive management to address changing climate conditions and emerging challenges. This theme emphasises the importance for

dynamic standards and feedback systems that promote continuous improvement and innovation.

5.5.7.1 Subtheme 7.1: Dynamic Standards and Iterative Learning

The participants recommended that the standards should be flexible and dynamic to new risks and technologies. Participant 9 pointed out, "*Standards must be continuously developed to consider new things.*" Participant 11 concurred with this and said, "*Clarity, enforceable standards and appropriate support increase the efficacy of professional bodies.*" Participant 12 further said, "*Regulations should be dynamic and in tandem with international sustainability goals.*" These answers indicate that frequent updates and reviewing processes enable project managers to embrace innovation and lessons learnt in previous projects. Therefore, creating dynamic standards means making resilience practices relevant, practical, and prospective.

5.5.7.2 Subtheme 7.2: Integrating Feedback Loops into Project Lifecycles

The feedback mechanisms were explained as critical to learning and adaptation in the project life cycle. Participant 3 opined that "*Adaptive capacity is developed through continuous monitoring frameworks and education.*" Participant 10 observed, "*Field research can be proactive in providing professional bodies with ideas on how to change.*" Participant 13 concluded by saying that "*we had to revert to first principles in engineering design while incorporating real-life events.*" Through these insights, it has been seen that feedback not only enhances technical performance but also enhances institutional learning and resilience in the long run. As a result, incorporating feedback loops into project cycles will provide each phase with information about the next one, creating a culture of continuous improvement.

5.6. Chapter Summary

The findings reveal that implementing climate-resilient features in South African critical infrastructure fundamentally enhances project management effectiveness by embedding adaptability, financial foresight, and collaborative governance across all stages of the project lifecycle. Early integration during design and planning fosters proactive risk identification and resource efficiency, while long-term financial strategies and policy alignment ensure sustainability and compliance. Furthermore, human capital development and inclusive stakeholder engagement strengthen technical competence and community ownership, making resilience not just a technical requirement but a holistic

management philosophy that promotes sustainable, adaptive, and socially responsive infrastructure delivery.

The integration of climate resilience significantly transforms core project management practices, shifting from static and linear approaches to adaptive, data-driven, and participatory models. Key areas affected include dynamic risk management, hybrid project frameworks, sustainability measurement, technological innovation, and human capacity development. Flexible procurement, inclusive stakeholder collaboration, and coherent policy alignment further enhance institutional accountability and social legitimacy. Collectively, these evolving practices establish a systemic approach where environmental foresight, economic prudence, and inclusivity become central pillars of effective and sustainable project management in South Africa's climate-sensitive infrastructure sector.

The study proposes a comprehensive, seven-component framework to strengthen the integration of climate resilience into project management, encompassing policy and governance alignment, stakeholder collaboration, capacity building, institutional accountability, socio-political integration, financial sustainability, and adaptive management. The framework emphasises coherent legislation, cross-sectoral coordination, inclusive participation, and continuous professional education as enablers of resilient infrastructure delivery. It also promotes financial innovation and iterative learning to ensure adaptability to emerging climate risks. Overall, the model advances a unified, multi-level approach that positions resilience as a guiding philosophy for sustainable, accountable, and future-oriented project management in South Africa's built environment industry.

In conclusion, this chapter has presented and analysed the empirical findings demonstrating that the implementation of climate-resilient critical infrastructure significantly influences effective project management practices within the South African context. The results revealed that embedding resilience across the project lifecycle enhances adaptability, sustainability, and long-term performance by integrating environmental foresight into planning, design, and execution. Financially, resilience promotes lifecycle cost efficiency but requires strategic investment, policy coherence, and institutional commitment. Governance and regulatory alignment emerged as essential enablers of standardisation and accountability, while human capacity development and access to reliable climate data underpin the technical and operational effectiveness of resilience-oriented projects. Furthermore, stakeholder collaboration, community

participation, and socio-political alignment were identified as critical to ensuring inclusivity and contextual relevance in infrastructure delivery. Collectively, the findings informed the development of a holistic framework comprising seven interlinked components—policy alignment, stakeholder engagement, capacity building, institutional accountability, socio-political integration, financial sustainability, and adaptive management—that together provide a systematic pathway for integrating climate resilience into project management. This framework positions resilience not merely as a design consideration but as a transformative management philosophy essential for sustainable infrastructure in South Africa’s climate-vulnerable environment.

CHAPTER SIX: DISCUSSION OF RESEARCH RESULTS

6.1 Introduction

The chapter presents a synthesis and critical interpretation of the research results in terms of the objectives and theoretical framework of the study. It makes conclusions based on the analyses made in the preceding chapters and converts them into policy, practice, and research recommendations. The discussion is organised based on the three research questions and summarises the effects of integrating climate resilience on project management practices, institutional frameworks, and governance systems in the South African critical infrastructure sector. This chapter connects empirical evidence with the Systems Resilience Theory, Adaptive Management Theory and Project Management Theory and shows how theoretical constructs intersect in practice and points to the contextual barriers that prevent complete implementation. Finally, it will seek to synthesise knowledge into a consistent framework that will promote climate-resilient project management and promote sustainable infrastructure governance in the South African built environment.

6.2 Discussion of Findings for Research Question 1

How does the introduction of climate-resilient features in critical infrastructure projects impact the use of effective project management practices in the South African context?

6.2.1 Discussion of Theme 1: Integration of Climate Resilience Across Project Lifecycle Stages

The results of Theme 1: Integration of Climate Resilience in Project Lifecycle Stages indicate that the introduction of resilience in the initial and design stages enhances responsiveness and sustainability in the major infrastructure projects. This is consistent with the Systems Resilience Theory (see Section 2.2.1), which considers resilience to be a feature that is developed throughout the stages of a lifecycle (Francis & Bekera, 2014; Linkov et al., 2022). The focus of the study on the Subtheme 1.1: Early-stage Incorporation for Long-term Adaptability confirms the theoretical assumption that prevention and preparedness improve the absorptive and adaptive capacities- the study indicates that early integration assists in anticipating climate risks and distributing resources more effectively (Fiksel, 2006). Equally, Subtheme 1.2: Continuous Design refinement and Agile Responsiveness reflect the Adaptive Management Theory (see Section 2.2.2), which

promotes iterative learning and design-by-feedback (Williams & Brown, 2014). These practices put theoretical adaptability into practice as project management processes.

These findings are supported by the literature, as Naderpajouh et al. (2020) and Sharma & Gupta (2024) have confirmed that adaptive and flexible planning is essential when dealing with complex infrastructure that functions under climatic uncertainty. The South African projects show how agile design iterations have changed deterministic models to learning-based management (Svejvig & Andersen, 2015). This shows that there is convergence both theoretically and empirically, but there are still gaps in institutionalising such practices on a national level. Overall, these results confirm that the integration of resilience changes the project lifecycle from fixed to adaptive and makes flexibility a performance parameter in climate-prone environments.

6.2.2 Discussion of Theme 2: Financial and Economic Dimensions of Resilience Integration

Results in Theme 2: Financial and Economic Implications of Climate-Resilient Implementation indicate that climate resilience is expensive over the short term, but it improves cost efficiency and lifecycle performance in the long term. This observation confirms the hypothesis of the Systems Resilience Theory that resilience investments can decrease the systemic vulnerability in the long term (Mayar et al., 2024). On Subtheme 2.1: Long-term Cost Efficiency and Lifecycle Savings, the participants emphasised the fact that initial investments in resilient materials and designs save money in the future through reduced maintenance and disaster recovery costs. The result aligns with the findings of Lotfi et al. (2022) and Seidu et al. (2025), who note that resilience redefines the metrics of project success to incorporate lifecycle value optimisation, instead of limited costs in the short term.

On the other hand, Subtheme 2.2: Budget Constraints and Undervaluation of Resilience highlight the point that low financial literacy and unwillingness to spend on resilience upfront impede resilience mainstreaming, similar to the findings of Curt and Tacnet (2018) that institutional and economic obstacles to resilience adoption exist in developing settings. The results are thus partly consistent with the theory, and they are in line with the fact that systemic and cognitive constraints limit adaptive financial planning. The findings also align with Adaptive Management Theory since financial agility and learning-based cost assessment are the key to climate-based project management. Practically, the

incorporation of cost-benefit analysis of resilience in the procurement and budgeting procedures would institutionalise economic rationality in the long term. Therefore, although the conceptualisation of South African projects is resilience-economics-based, the implementation is hampered by the short-term fiscal perspectives that underestimate the preventive investment.

6.2.3 Discussion of Theme 3: Governance, Policy, and Institutional Alignment

Theme 3: Governance, Policy, and Regulatory Alignment of the study emphasises the idea that regulatory and institutional coherence play a key role in the process of integrating resilience in the management of infrastructure. Results of Subtheme 3.1: Legislative and Contractual Drivers to Climate Resilience indicate that policy requirements and contractual commitments play a critical role in the implementation of resilience requirements. This confirms the Project Management Theories (see Section 2.2.3), especially the shift towards adaptive governance frameworks with an accent on accountability and flexibility (Padalkar & Gopinath, 2016). Equally, Subtheme 3.2: Institutional Gaps and Lack of Standardisation is in line with Osei-Kyei et al. (2022), who discovered that weak governance and fragmented policies hamper the implementation of resilience in developing areas.

This observation is supported by the literature (Pretorius et al., 2023; Majlingova & Kadar, 2025), where it is mentioned that although international frameworks are available, they are usually based on institutional maturity, which is not the case with the South African situation. The findings also echo Systems Resilience Theory because governance coherence is crucial to system-wide resilience (Francis & Bekera, 2014). Nonetheless, the institutional inconsistency and non-standardisation do not facilitate cross-sectoral learning and lessen the enforcement of policies. This gap explains the theory-practice gap outlined by Curt & Tacnet (2018), which indicates that a harmonised national resilience policy is required. Essentially, although the conceptual framework of governance forms the core of resilience integration, the practical implementation mechanisms are not well developed, which curtails the effectiveness of project management in the South African environment.

6.2.4 Discussion of Theme 4: Human Capital, Knowledge, and Technical Capacity

Theme 4: Human Capital, Knowledge, and Technical Capacity underscore the fact that human and informational resources are imperative facilitators of resilience-based project management. Results in Subtheme 4.1: Need for Specialised Skills and Continuous Professional Development indicate that effective adaptation to climate risks is predetermined by continuous learning and technical training. This conclusion is consistent with the Adaptive Management Theory that emphasises learning and skill improvement through repetition to cope with environmental uncertainty (Roux et al., 2025). Moreover, it verifies empirical research by Bradford et al. (2023) and Adebowale & Agumba (2023), who state that inadequate climate-related competencies restrict adaptive management in the built environment in South Africa.

Subtheme 4.2: Information Availability and Climate Data Integration is also supported in the literature, which highlights the necessity to have localised, reliable climate data to guide design and the assessment of risk (Jiang et al., 2023; Hsu & Mostafavi, 2024). This result supports the idea of the Systems Resilience Theory that feedback processes and information sharing contribute to the adaptive capacity (Linkov et al., 2022). The aggregate of evidence indicates that the human and data capacity constitutes the working foundation of strong project management. However, there is still little institutional investment in continuous professional development and open data systems. This highlights the gap between idealistic ideologies and real-life conditions, showing that technical resiliency must be supported by institutional and educational changes that are sustainable.

6.2.5 Discussion of Theme 5: Stakeholder Collaboration and Communication

Theme 5: Stakeholder Collaboration and Communication Practices demonstrates that comprehensive and integrated stakeholder engagement contributes to improved outcomes of resilience and better project management. The results of Subtheme 5.1: Inclusive Engagement and Local Knowledge Integration show that the use of community knowledge and participation promotes contextual adaptation and social legitimacy. This finding agrees with Systems Resilience Theory, which considers resilience as a socially constructed process by networked interdependencies (Watson, & Ahn, 2022). Likewise, the Adaptive Management Theory promotes the collaborative aspects that can be seen

here, since the mutual adaptation is facilitated through collaborative learning and sharing (Williams & Brown, 2014).

Subtheme 5.2: Interdisciplinary Coordination and Team Collaboration is a further endorsement of the Rethinking Project Management (RPM) movement, which proposes fluid, collaborative models instead of strict hierarchies (Svejvig & Andersen, 2015). These results are in line with the studies by Eisenhauer et al. (2024) and Johnston et al. (2024) that show that knowledge production between experts and communities leads to better adaptive outcomes. These dynamics resolve historical problems of stakeholder exclusion and fragmented decision-making, which exist in the South African context (Clark et al., 2022). Taken together, the results support theoretical hypotheses that communication and collaboration are the social structure of resilience. Nevertheless, the ongoing coordination obstacles indicate that the implementation of participatory PM needs more powerful institutional structures and communication standards.

6.2.6 Integrative Discussion and Theoretical Convergence based on RQ1

Synthesising the five themes, it can be stated that the introduction of climate-resilient features fundamentally changes the traditional project management practices into an adaptive, systemic, and participatory process. The results are all confirmed by the combination of the Systems Resilience Theory, Adaptive Management Theory, and Project Management Theory (Sections 2.2.1-2.2.3) as complementary theories to explain these transformations. The empirical findings, namely, early-stage integration (Theme 1), lifecycle economics (Theme 2), governance coherence (Theme 3), human capital development (Theme 4), and stakeholder collaboration (Theme 5) are examples of systemic interdependence, which reflects the theoretical interlinkage of resilience capacity, feedback learning, and flexible governance.

Moreover, the results are in line with the international literature on adaptive and holistic project management practices (Linkov et al., 2022; Dong et al., 2024). However, there are still divergences as theory dictates institutional coherence and constant learning, whereas South African practice is still characterised by resource constraints, disjointed governance, and the focus on one-off costs (Adebowale & Agumba, 2023; Pretorius et al., 2023). It means that the theoretical ideals are partially fulfilled, with the contextual limitations of skills deficit and policy inconsistency. Therefore, the research confirms the generalisability and the shortcomings of the resilience theories in the context of developing

countries and confirms the necessity to develop country-specific frameworks where the theoretical concepts can be applied to viable working models.

6.2.7 Concluding the discussion of findings on Research Question 1

To sum up, the Research Question 1, which is the following: How does the introduction of climate-resilient characteristics to critical infrastructure projects affect the use of effective project management practices in the South African context? has been fully addressed. The results indicate that climate resilience integration transforms project management towards proactive planning, adaptability, financial management, sound governance alignment, capacity building based on skills and an inclusive stakeholder working relationship. These changes represent a paradigmatic shift from deterministic, efficiency-focused management to adaptive, resilience-based practice.

The findings are very much in line with Systems Resilience Theory, which describes the necessity of interconnected, adaptive systems; Adaptive Management Theory, which describes the iterative learning and flexibility; and Project Management Theory, which supports agile and collaborative practices. Despite the financial and institutional conditions that restrict full actualisation, the results indicate that climate resilience is an indicator and cause of good project management in South Africa. Ultimately, systemic thinking, lifelong learning, and inclusivity of stakeholders are the results of resilience implementation, which are the characteristics of a contemporary and efficient project management that can withstand and maintain a critical infrastructure during climate uncertainty.

6.3 Discussion of Findings for Research Question 2

What are the key project management practices that are most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?

6.3.1 Discussion of Theme 1: Risk Management Integration for Climate Adaptation

Results in Theme 1 show that risk management has progressed as a compliance-oriented exercise into an adaptive and anticipatory practice and incorporates climate-related risks like flooding and heatwaves. This agrees well with the Systems Resilience Theory (Section 2.2.1) that perceives resilience to mean the ability of the system to absorb and bounce back after the disturbances (Fiksel, 2006; Francis & Bekera, 2014). The transition into proactive climate risk identification (Subtheme 1.1) and responsive planning (Subtheme 1.2) is reminiscent of the results of Linkov et al. (2022), who state that adaptive

risk governance will increase the life span of infrastructures and minimise vulnerability. On the same note, Singapore et al. (2023) established that continuous learning and real-time keep an eye on the adaptive capacity of climate-impacted projects. Nevertheless, contrary to developed settings where data systems are highly developed, practitioners in South Africa cited institutional constraints which slow the pace of data-driven adaptation. Thus, the findings support the theoretical idea that resilience-based risk management involves the need to coordinate on a systemic level but highlights barriers to contextual implementation. Altogether, this finding confirms the Adaptive Management Theory (see section 2.2.2) and proves that continuous learning lies at the heart of project delivery resilience.

6.3.2 Discussion of Theme 2: Evolving Frameworks and Methodologies

Theme 2 reveals that the incorporation of climate resilience has led to a paradigm shift in the linear models towards hybrid and agile models that can adapt to environmental uncertainty. This is consistent with the Rethinking Project Management (RPM) and Agile Project Management (APM) approaches outlined in Section 2.2.3, which focus on the flexibility, collaboration, and iterative decision-making (Svejvig and Andersen, 2015; Dong et al., 2024). The implementation of hybrid project management approaches (see Subtheme 2.1) will guarantee the balance between predictability and adaptability, whereas the idea of systems thinking (Subtheme 2.2) will enhance the integration of project lifecycles. This is empirically consistent with Osei-Kyei et al. (2022), who concluded that hybrid models increase governance coherence of African infrastructure projects. Nevertheless, the results are not in line with Padalkar and Gopinath (2016), who stated that deterministic approaches are also applicable to infrastructure development. The South African experience indicates that this is not the case, as uncertainty in climate information requires agile structures. In this way, climate resilience speeds up the process of changing PM approaches to systemic, adaptive, and integrated paradigms- entirely in line with Adaptive Management Theory and Systems Resilience Theory.

6.3.3 Discussion of Theme 3: Sustainability and Resilience Measurement Practices

Theme 3 emphasises the fact that incorporation of quantifiable sustainability measures, like carbon footprint and lifecycle resilience audits, has become a critical part of the management of climate-resilient infrastructure. This observation supports the idea of climate-resilient infrastructure (Section 2.3.2), where the feedback mechanisms must be

quantifiable to measure the performance (Watson, & Ahn, 2022; Linkov et al., 2022). Transparency and accountability through standardized metrics and periodic audits (Subtheme 3.1) and resilience within the system (Subtheme 3.2) through lifecycle evaluations are necessary to ensure that resiliency is preserved after implementation. Bocchini et al. (2014) and Hsu & Mostafavi (2024) support the findings by noting that monitoring is required throughout the life of an infrastructure to maintain an adaptive capacity. Nevertheless, the participants observed a lack of local data and the lack of context-specific benchmarks, unlike the wide usage of data analytics in developed countries. As a result, despite the theoretical frameworks promoting the measurable resilience, the present results demonstrate the practical constraints of the South African ability to conduct longitudinal assessment. However, the introduction of quantifiable resilience indicators is an essential development in project management accountability.

6.3.4 Discussion of Theme 4: Technological Tools and Innovation

The results under Theme 4 highlight the importance of technology, including GIS, BIM, and predictive analytics, in promoting climate resilience in PM practices. These innovations support the simulation of hazards, early warning, and scenario planning, which is consistent with the technological and systemic aspects of the Systems Resilience Theory (see section 2.2.1). The focus on climate modelling (Subtheme 4.1) and local innovation at the level of R&D (Subtheme 4.2) is based on the arguments of Argyroudis et al. (2022) and Jiang et al. (2023), who concluded that digital technologies could be used to increase the adaptive capacity and optimise resource distribution. Besides, academia-industry research collaborations are consistent with Shafei et al. (2024), who recommend co-produced resilience knowledge. Nonetheless, the participants noted technological differences between regions, which is similar to Pretorius et al. (2023), who observe resource limitations in underdeveloped settings. Thus, although digitalisation is, in theory, an agent of resilience, in practice, it is subject to investment in capacity and data infrastructure. This observation proves the fact that climate resilience is a driver of the digitalisation of project management.

6.3.5 Discussion of Theme 5: Stakeholder Collaboration and Governance

Theme 5 in the study focuses on the inclusive stakeholder collaboration and multi-level governance as the basis of resilience integration. This is quite consistent with the Systems Resilience Theory, which recognises interdependence and coordinated governance as

essential to systemic stability (Francis & Bekera, 2014). It is reflected in the inclusive coordination (Subtheme 5.1) and policy and institutional support (Subtheme 5.2), which Erkul et al. (2020) and Johnston et al. (2024) find to be more effective in increasing community trust and compliance in participatory governance. Likewise, Osei-Kyei et al. (2022) discovered that cross-sectoral collaboration enhances project delivery and institutional learning. Nevertheless, the problem of governance fragmentation in South Africa is still a barrier to implementation, which substantiates Clark et al. (2022) that ineffective institutional connections are barriers to resilience outcomes. In theory, these findings support the Adaptive Management Theory because constant feedback from stakeholders and adaptive decision-making allow successful integration of resilience. The results, therefore, contribute to a comprehensive perspective on governance—one that will change PM from procedural compliance to participatory leadership.

6.3.6 Discussion of Theme 6: Human Capacity and Skills Development

The results under theme six state that human capacity is the key to climate-resilient project management. As the preconditions of adaptive decision-making and innovation, special knowledge (Subtheme 6.1) and lifelong learning (Subtheme 6.2) were highlighted. Such results are reflected in Section 2.4.2.2, which emphasises that resilience-oriented PM needs multidisciplinary and climate-literate specialists (Tetteh et al., 2025; Osei-Kyei et al., 2022). In addition, Adebowale & Agumba (2023) confirm this by associating the lack of skills in South Africa with the poor integration of climate. Theoretically, the findings are reminiscent of Adaptive Management Theory, in which learning and capacity building are viewed as a cyclical process that is necessary to adapt a system (Williams & Brown, 2014). Although the participants mentioned that there was a lack of institutional support in training, they were aware of the necessity of competence building in the long term. Thus, human capital turns out to be not only an enabling factor of technical resilience but also a cultural underpinning of adaptive project management change.

6.3.7 Discussion of Theme 7: Procurement and Cost Management Flexibility

Theme 7 results show that the concept of climate resilience redefines financial planning and procurement through its focus on flexibility instead of strict compliance. Subtheme 7.1, adaptive procurement, promotes innovative materials and quality-based selection and Subtheme 7.2, long-term financial planning, incorporates lifecycle costs and adaptation funds. These findings support the principle of resource allocation and financial flexibility

presented in Section 2.4.2.2, according to which Osei-Kyei et al. (2022) and Jiang et al. (2023) state that resilience requires flexible budgeting. In addition, Lotfi et al. (2022) discovered that resilient projects are expensive in the short term but save money in the long term due to their durability and maintenance. The results of the study in South Africa also support the Systems Resilience Theory, which focuses on sustainability rather than efficiency in the short term (Francis & Bekera, 2014). However, the inflexibility of budgets in government procurement systems was mentioned as an obstacle to flexible funding. Therefore, resilience integration requires a change of focus on cost management to lifecycle sustainability rather than immediate efficiency, which is a vital area of reform of South African infrastructure governance.

6.3.8 Discussion of Theme 8: Community and Cultural Considerations

The results in Theme 8 indicate that climate-resilient infrastructure needs to be compatible with local social and cultural environments to become sustainable and legitimate. Subtheme 8.1 is social inclusion, whereas Subtheme 8.2 is equity and benefit-sharing. This is in line with Section 2.3.1-2.3.3 that defines resilience as a socio-technical system that includes communities, institutions, and technology (Osei-Kyei et al., 2022). It is supported by the empirical literature: Eisenhauer et al. (2024) and Ziervogel et al. (2022) who verify that inclusive engagement promotes adaptive governance and sustainability of the project. Nevertheless, community consultation is not a consistently used practice, which is reflected by the results of Pretorius et al. (2023) that social engagement in Africa does not always have organised structures. In theory, this result would be in line with Adaptive Management and Systems Resilience, both of which focus on stakeholder involvement to learn and provide feedback. Therefore, incorporating local culture in PM improves legitimacy, stability, and long-term custodianship of infrastructural assets.

6.3.9 Discussion of Theme 9: Policy, Standards, and Regulatory Alignment

Lastly, Theme 9 recognises policy consistency and standardisation of regulations as the key to instilling resilience in infrastructure governance. The compliance audit focus of Subtheme 9.1 and the adaptive legislation focus of Subtheme 9.2 align with the institutional aspect of the Systems Resilience Theory, which emphasises the alignment of policies to achieve system stability (Linkov et al., 2022). This is reflected by empirical research by Curt & Tacnet (2018) and Majlingova & Kadar (2025), who concluded that fragmented regulations undermine implementation. The results also mirror the literature-

based appeal to unified professional standards (Adebowale & Agumba, 2023). Nevertheless, the institutional inertia tends to slow down the adaptive policy change despite the acknowledgement of the regulatory significance in South Africa. The results thus affirm the fact that good governance is the key to resilience integration, yet also suggest that in the absence of coherent standards, resilience is just a dream. Essentially, policy alignment is shifting resilience from a project-level program to a national mandate.

6.3.10 Integrative Discussion and Theoretical Convergence based on RQ2

The synthesis of all nine themes suggests that integrating climate resilience has a significant impact on risk management, frameworks, measurement systems, technology application, stakeholder governance, human capacity, procurement, social engagement, and policy alignment. These findings collectively support the Systems Resilience Theory, as they demonstrate that resilience integration is systemic, cross-cutting, and interdependent throughout the project lifecycle. Moreover, the Adaptive Management Theory, which emphasises learning, feedback and flexibility, is affirmed by the dynamic and iterative adaptations in Themes 1, 2, 4 and 6. The findings further operationalise the Rethinking Project Management (RPM) paradigm by showing that resilience changes PM from a linear execution to an adaptive system thinking. The overlap of these theories, therefore, supports the theoretical framework that was developed in Chapter 2 and proves that resilient project management requires not just technical adaptations but institutional and cultural development.

6.3.11 Concluding the discussion of findings of Research Question 2

The research question “What are the most important project management practices that have been most significantly influenced by climate resilience integration in critical infrastructure projects in South Africa?” has been addressed in detail. The research confirms that resilience integration redefines fundamental PM practices in nine thematic areas, which include adaptive risk management, agile methodologies, measurable sustainability, technological innovation, inclusive governance, human capacity building, flexible procurement, socio-cultural inclusion, and policy alignment. These results are largely in line with the global literature and are well-grounded in Systems Resilience Theory, Adaptive Management Theory, and Rethinking Project Management frameworks. The South African evidence, however, contributes to the new information on the contextual issues, the lack of skills, the disintegration of governance, and the absence of

data, which do not allow for full implementation. It follows that even though theory and international experience indicate the transformative nature of resilience integration, this research demonstrates that its success in South Africa depends on institutional change, capacity building, and systemic change towards adaptive governance.

6.4 Discussion of Findings for Research Question 3

6.4.1 Discussion of Theme 1: Policy and Governance Alignment

The results under Theme 1 indicate that the establishment of climate resilience in the management of infrastructure projects is built on coherent policy frameworks and effective governance structures. Contributors underscored that access to modernised laws, multi-level coordination, and definite standards of implementation are crucial to achieving accountability and harmonisation. This is in line with Systems Resilience Theory (see Section 2.2.1) that notes that resilience is a system-wide property that needs interdependent governance elements to maintain infrastructure functionality in the event of disruptions (Fiksel, 2006; Francis & Bekera, 2014). Likewise, Pretorius et al (2023) note that developed countries base their resilience integration on effective governance systems, whereas fragmented regulatory systems in South Africa are seen as a limitation.

Using a bottom-up approach, the subthemes of updating and enforcing legislative frameworks and multi-level coordination are related to the conceptual argument in Section 2.3.3, where institutional coherence is identified as a key facilitator of climate-resilient infrastructure. Scholars such as Curt & Tacnet (2018) and Majlingova & Kadar (2025) affirm that without revised legislation and vertical alignment of policies, resilience strategies only remain rhetoric. The present results, therefore, confirm the rest of the world and also expand on them by making sense of governance integration in the South African intergovernmental environment. To sum up, Theme 1 demonstrates that resiliency project management cannot be effective in policy voids; it needs to have a well-developed, coordinated, and enforceable governance system that puts principles of resilience into project delivery tools.

6.4.2 Discussion of Theme 2: Stakeholder Engagement and Collaboration

Theme 2 reveals that diversity and multi-stakeholder engagement are at the core of an effective resilience framework. Participants indicate that community engagement and a cross-disciplinary type of collaboration are important when it comes to relevance and

ownership among infrastructure end-users. This finding supports the idea of Adaptive Management Theory (see Section 2.2.2), where learning is shared between interconnected participants to navigate uncertainty (Williams & Brown, 2014; Roux et al., 2025). The definition of climate-resilient infrastructure provided in Section 2.3.2 also emphasises that participation in decision-making is fundamental to resilience design (Shafei et al., 2024).

The results also agree with those of Erkul et al. (2020) and Eisenhauer et al. (2024), who state that participation here increases adaptive capacity through the integration of expert and local knowledge. On the other hand, Curt & Tacnet (2018) noticed that poor collaboration in developing environments often leads to technical inefficiency and low project sustainability. The findings of the current study, therefore, both corroborate and historicise these scholars' claims that participatory approaches in South Africa have had to contend with power imbalances and within-sector silos. Ultimately, it suggests that effective climate-resilient project management partnerships are those in which a technical contribution is well balanced by community experience.

6.4.3 Discussion of Theme 3: Capacity Building and Knowledge Sharing

The findings under Theme 3 highlight that developing skills and sharing knowledge are essential for putting climate resilience into action in project management practice. Participants have acknowledged that professional training, lifelong learning, and research publication are the means that open the gap between theory and practice, thus they are in line with the adaptive learning cycle referred to in Adaptive Management Theory (see Section 2.2.2). Moreover, Bradford et al. (2023) and Foxcroft & McGeoch (2011) state that organisational learning via repetitive training significantly improves the ability to respond to changing climate challenges.

The subthemes 3.1 of training and education on resilient design, as well as the dissemination of research and best practices, also confirm the argument of Svejvig & Andersen (2015) in Project Management Theory (see Section 2.2.3). Participants advocate for dynamic, non-deterministic project approaches, which are rooted in continuous professional development. In the same vein, Mapepeta (2015) and Lakmeharantner et al. (2020) pinpoint the lack of skills as the main factor impeding the resilience of the South African built environment. The results recognise that technical competence and institutional learning are two interrelated factors that drive the adaptive

management process. In short, Theme 3 is in line with the literature, which sees resilience as a capability that is acquired and developed through continuous education; thus, project management is being transformed from a mere static control to an adaptive knowledge-based practice.

6.4.4 Discussion of Theme 4: Institutional Accountability and Compliance

The findings under Theme 4 demonstrate that monitoring, ethical conduct, and institutional accountability are critical for ensuring credibility and transparency in resilience implementation. Participants stressed that monitoring and enforcement mechanisms, coupled with professional ethics, safeguard quality and compliance throughout project lifecycles. This finding aligns with the Systems Resilience Theory view that feedback loops and accountability are vital to maintaining functional integrity across interconnected systems (Francis & Bekera, 2014).

The results under Theme 4 indicate that the aspects of monitoring, ethics, and institutional accountability are the main determinants, which result in the creation of openness and trust in resilience implementation; ultimately, they are the prerequisites for successful resilience integration. Participants argued that mechanisms for enforcement and control, alongside professional ethical principles, constitute the arsenal that upholds the quality and compliance with regulations throughout the lifecycle of projects. This observation is consistent with the Systems Resilience Theory view, where Francis & Bekera (2014) argue that feedback systems and accountability are crucial to the operational integrity of the system.

Literature also infers that resilience redefines traditional risk and quality management in terms of probabilistic analysis and continuous monitoring (Linkov et al., 2022; Lonsdale et al., 2024). Moreso, the call for institutional transparency in the outcomes replicates Adaptive Management Theory's emphasis on reflexivity and iterative evaluation (Williams & Brown, 2014). While Curt & Tacnet (2018) stated that institutional inertia would weaken compliance in developing countries, the present results show that strengthening professional ethics and independent control mechanisms would overcome such constraints in South Africa. Conclusively, Theme 4 shows institutional accountability not only imposing compliance but also fostering ethical responsibility as a normative pillar of resilient project management.

6.4.5 Discussion of Theme 5: Socio-Political Integration and Community Awareness

Theme 5 reveals that political will and public awareness are important in institutionalising resilience in infrastructure management. Subtheme 5.1 of political prioritisation and social awareness provides that successful integration cannot be possible without the commitment of the leadership and without civic awareness. This observation is consistent with Systems Resilience Theory, which acknowledges the fact that political and social systems co-define the adaptive capacity of infrastructure networks (Fiksel, 2006; Linkov et al., 2022). It is also consistent with the conceptualisation found in Section 2.3.1, in which critical infrastructure is perceived as a socio-technical system, which relies on policy legitimacy and social acceptance.

In line with the results of Ziervogel et al. (2022) and Clark et al. (2022), the results depict that such efforts become unsuccessful when policy priorities are intermittent or the general populace is not aware of the program. In contrast, robust leadership commitment, which is underlined by Atli & Krystallis (2025), leads to improved coherence in the policy and expedites the funding approvals. The findings are, however, helpful in extending the literature by showing that in South Africa, social awareness projects must overturn apathy by establishing a prolonged educational campaign and localised interaction. To sum up, Theme 5 strengthens the idea supported by the rest of the themes that the socio-political legitimacy enhances the sustainability of resilience plans by aligning the intent of governance with the behaviour of the community.

6.4.6 Discussion of Theme 6: Financial and Resource Sustainability

According to the results of Theme 6, financial innovation and resource optimisation are the key to instilling resilience in project management. The participants emphasised the necessity of climate finance systems and cost-benefit analysis to support resilience investments and make them economically viable. This substantiates the arguments in Section 2.4.3.1, in which Curt & Tacnet (2018) and Forino et al. (2015) emphasise that the scalability of resilience programs depends on the funding models. In addition, the results are consistent with the focus of the Adaptive Management Theory on resource allocation through feedback, in which financial planning changes according to the changing risk situation (Sharma & Gupta, 2024).

The findings are also consistent with Osei-Kyei et al. (2022) and Tetteh et al. (2025), who claim that flexible budgeting and evidence-based investment can increase infrastructure

flexibility. Nonetheless, the present research takes a slightly different path by demonstrating that financial sustainability in South Africa does not only entail financial innovation but also transparency in governance to guarantee equal distribution of resources. In theory, the theme supports Systems Resilience Theory, since it incorporates financial resilience into the overall adaptive capacity of the infrastructure system. Therefore, Theme 6 shows that resilience is impossible to attain without incorporating the principles of sustainability in funding, procurement, and lifecycle cost management.

6.4.7 Discussion of Theme 7: Continuous Improvement and Adaptive Management

Theme 7 offers evidence that resilience frameworks need to be developed because of continuous learning and adaptive feedback. The participants emphasised dynamic criteria and feedback loops as the conditions of institutional learning and project refinement. This result directly operationalises Adaptive Management Theory (see Section 2.2.2) that focuses on the iterative decision-making and learning-by-doing in complex and uncertain environments (Williams & Brown, 2014; Roux et al., 2025). The incorporation of the feedback mechanism is also in line with the agile and non-deterministic principles that are promoted in the Project Management Theory (Svejvig & Andersen, 2015; Padalkar & Gopinath, 2016).

Empirical research, including Pedde et al. (2025) and McNaught (2024), supports the fact that organisations with iterative learning have a greater resilience maturity. The results of this research build on these observations by demonstrating that institutionalisation of learning between government and professional boundaries is achieved through the incorporation of feedback at every stage of the project. Overall, the integration of theory and practice, which is the core of Theme 7, is where adaptive management is not just a guiding principle, but a practical process that is integrated into project delivery cycles.

6.4.8 Integrative Discussion and Theoretical Convergence based on RQ3

The seven themes together offer a consistent and context-driven approach to the incorporation of climate resilience into the management of projects in the built environment in South Africa. The results are consistent with the theoretical insights described in Sections 2.2.1-2.2.3, in which Systems Resilience Theory describes interdependent governance, Adaptive Management Theory focuses on iterative learning, and Project Management Theory promotes flexible and collaborative approaches. Collectively, these

theories offer the conceptual base on which the elements of the framework, which are policy alignment, collaboration, capacity building, accountability, socio-political integration, financial innovation, and adaptive management, are organised.

In comparison, the suggested framework is aligned with the current models of internationalisation (Curt & Tacnet, 2018; Forino et al., 2015) and is also sensitive to the contextual constraints of South Africa, incorporating socio-political, educational, and financial aspects. It also addresses the empirical and theoretical gaps as pointed out in Section 2.6, in which the lack of localised resilience frameworks was found to be a significant weakness. The framework therefore does not only support the global discourse but localises it, proving that resilience integration needs to be socially inclusive, institutionally based and financially feasible.

6.4.9 Concluding the discussion of findings on Research Question 3 (RQ3)

Finally, the results of Research Question 3, which is, what framework can be created to improve the consideration of climate resilience in the project management of critical infrastructure in the South African built environment industry? have been thoroughly discussed in seven interconnected themes. All the themes are aligned with the theoretical and conceptual background that was laid out in Chapter 2, and they all form a holistic and adaptive model that is applicable in South Africa in terms of its governance, socio-political, and economic environment. A combination of Systems Resilience, Adaptive Management, and Project Management Theories gives the framework both an explanatory and practical foundation. Thus, the study adds a contextually applicable multi-dimensional framework that leads to the development of the theory and practice of climate-resilient project management in developing economies.

6.5 Chapter Summary

The general finding is that the introduction of climate resilience in project management in the South African critical infrastructure sector is a paradigm shift opportunity and a systemic challenge. The study proves that the integration of resilience reinvents conventional project management by instilling flexibility, learning, inclusivity, and sustainability throughout the entire project life cycle. Based on the Systems Resilience Theory, Adaptive Management Theory, and Project Management Theory, the results show that successful resilience implementation needs interconnected advancements in governance coherence, financial innovation, human capacity development, collaboration

among stakeholders, and learning through continuous feedback. Nevertheless, institutional fragmentation, lack of technical capacity and short-term fiscal interests are still major obstacles to complete realisation. It is thus concluded in the study that the attainment of climate resilient infrastructure in South Africa lies in the transition of compliance-based management to adaptive governance, where policy, practice and learning are aligned to maintain performance in the face of climatic uncertainty. Ultimately, the chapter highlights that resilience is not a specific technical intervention but a comprehensive management paradigm that has the capacity to enhance systemic adaptability, accountability and sustainability in the built environment.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

In this chapter, the findings of the study are synthesised to place them in the context of the wider scholarly discourse and practical implications for the South African built environment. It starts with the summary of the objectives of the study, the context of the research, and the methodology used before pointing out how the findings will fill the gaps in the existing knowledge. The chapter then illustrates how the research has contributed to the existing discussions on climate-resilient infrastructure and successful project management, both in theory and practice. Lastly, the chapter ends with practitioner, policymakers and future research recommendations, thus closing the gap between empirical evidence, theory and action plans on improving resilience in critical infrastructure projects.

7.2 Overview of the Study and Its Importance

The research, entitled 'Influence of the Implementation of Climate-Resilient Critical Infrastructure on Effective Project Management Practices - South African Context,' explores how the integration of climate resilience alters project management practices in the South African built environment. Climate change is getting increasingly severe, revealing the constraints of conventional infrastructure strategies and requiring systems capable of responding to uncertainty and shocks (Hallegatte et al., 2020; Nhamo et al., 2025). As a result, this research aimed at comprehending the role of climate-resilient infrastructure in managerial choices, resource distribution, and governance procedures of key areas of transport, water, and energy. It will fill the gap between resilience planning and project implementation by connecting theory and practice. In the end, the research topic is important in that it provides a channel through which the infrastructure systems in South Africa can be transformed into a position of vulnerability to adaptive strength.

This study is significant because it can be used in project management and sustainability discourse. Although international organisations encourage the development of resilient infrastructure, South Africa continues to fail in translating these concepts into practice due to the lack of financial resources and institutional disintegration (Halkos & Gkampoura, 2021; Pretorius et al., 2023). The results of this study highlight the importance of the fact that resilience does not only needs technological innovation but also managerial agility, policy coherence, and collaborative governance. Therefore, it offers an evidence-based model of how resilience principles can be incorporated into the national infrastructure

plans. This study helps to enhance the capacity of institutions in the long run and facilitate sustainable infrastructure governance in climate-prone economies.

7.3 Research Context and Its Significance.

The South African built environment is working in a situation of growing climatic uncertainty, where extreme weather patterns are constantly pointing out the weaknesses of the national infrastructure systems. With these climatic disturbances increasing, resilience should be incorporated in project management as a necessity and not an option. The lack of infrastructure in South Africa, fiscal and fragmented governance, makes it even harder to implement climate-resilient systems (Ngepah et al., 2022; Dorsouman, 2024). Thus, the research into the role of climate-resilient critical infrastructure in the context of project management practices is timely and necessary to national sustainability. Ultimately, the research fills an acute developmental gap- the connection between resilience and project management to enhance the adaptive capacity of South Africa. This orientation makes the study a critical input to the climate adaptation debate in the developing economies.

Moreover, the study has great practical importance, as it determines how the principles of climate resilience can be used to make infrastructure projects more efficient, adaptive, and accountable. The study offers practical information on how projects can be resilient to future uncertainties by analysing resilience in terms of financial, technical, and governance aspects (Linkov et al., 2022). Its results guide policymakers, engineers and project managers on the need to incorporate systemic learning and adaptive frameworks in the delivery of infrastructure. This way, the study will fill the gap between the global theory and local practice, and the development of infrastructure in South Africa will be in line with the imperatives of sustainability and resilience. Ultimately, the research is important since it will enable the nation to shift towards reactive recovery efforts to proactive resilience-building, protecting infrastructure and livelihoods against a shifting climate.

7.4. Existing Knowledge and Knowledge Gaps

Recent literature has established that the incorporation of climate resilience into critical infrastructure can improve the long-term sustainability of the project and project success due to decreases in the susceptibility of the infrastructure to extreme weather events (Linkov et al., 2022; Sharma & Gupta, 2024). Adaptive project management, flexible

planning, and collaboration with stakeholders are highlighted by global research to be important enablers of resilience (Atli & Krystallis, 2025). However, such results are mostly based on the developed economies, in which financial resources, governing frameworks, and data platforms are more sophisticated (Curt & Tacnet, 2018). As opposed to this, developing countries such as South Africa have institutional, technical and financial constraints that make it difficult to implement climate-resilient infrastructure fully. Thus, despite the available theoretical knowledge in the world, their applicability in the local context in the South African built environment is under-researched. The research will serve the purpose of making resilience concepts global, as applied in the context of South Africa's infrastructural and project management realities.

The empirical literature reveals that resilience integration changes the practices of project management through the need to have flexible leadership, adaptable financial planning, and increased stakeholder interactions (Piperca & Floricel, 2023; Osei-Kyei et al., 2022). However, South African project managers tend to have no standardised frameworks, tools, and capacity-building programs to put resilience into practice (Pretorius et al., 2023). The latency, therefore, consists in the creation of context-specific models that can be adjusted to local constraints and advance adaptive management practices. Filling this gap will facilitate a workable framework that facilitates the connection between climate resilience and the management effectiveness of project management in South Africa's critical infrastructure projects, and thus closes the theory-implementation gap.

7.5 Research Questions Answered

Research Question 1: How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices within the South African context?

Results showed incorporation of resilience characteristics at all project lifecycle stages is a way of altering management practices by facilitating flexibility, inclusiveness of stakeholders, and proactive risk management. The inclusion of resilience in the inception, design, and implementation phases created more flexibility and lifecycle sustainability, as suggested by Systems Resilience Theory, which considers resilience as a cross-phase property (Francis & Bekera, 2014; Linkov et al., 2022). In addition, the Adaptive Management Theory justified the importance of the iterative learning process and the ability to make flexible decisions (Williams & Brown, 2014). Institutional barriers and

financial constraints prevent uniformity on a national level, but through resilience integration, project management is redefined as a learning-based and dynamic field. Thus, the implementation of resilience is a paradigm shift to shift to adaptive governance in management of South African infrastructure and not linear control.

Research Question 2: What are the key project management practices most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?

It was discovered that resilience incorporation essentially changes nine major domains of project management: risk management, methods, performance measurement, technology utilisation, governance, capacity building, procurement, community involvement, and policy alignment. These results proved that risk and cost management now demand anticipatory planning and lifecycle strategies (Lotfi et al., 2022). Also, the stakeholder collaboration and agile frameworks became the top facilitators of adaptive decision-making, which fits the Systems Resilience and Adaptive Management Theories (Fiksel, 2006; Svejvig & Andersen, 2015). Despite contextual constraints (i.e. limited data and lack of skills), integration of resilience enhances project management maturity and creates a systemic, feedback-based approach to infrastructure governance.

Research Question 3: What framework can be developed to enhance the integration of climate resilience considerations into the project management of critical infrastructure in the South African built environment industry?

A seven-pillar framework was created, which focuses on policy alignment, collaboration of the multi-stakeholders, capacity building, institutional accountability, socio-political integration, financial sustainability and adaptive management. This is the framework that integrates the Systems Resilience, Adaptive Management, and Project Management Theories into a localised framework in South Africa (Francis & Bekera, 2014; Williams & Brown, 2014; Padalkar & Gopinath, 2016). The results support the idea that the success of resilience integration is determined by the coherence of institutions, participatory governance, and a learning process. Ultimately, the framework offers a context-specifically-based framework in which one can introduce climate resilience into national systems of delivering infrastructure, thereby guaranteeing long-term flexibility and socio-economic sustainability.

7.6 Research Methodology and Approach

The research design applied in this study was an exploratory study that aimed at examining the impacts of implementing climate-resilient critical infrastructure on the practice of effective project management within the context of South Africa. The reason the exploratory design was selected was because the subject is still new and understudied and specifically in developing nations, where resilience and project management integration are low (Pretorius et al., 2023; Saunders & Lewis, 2018). This research design gave the freedom to delve into the lived experiences and perceptions of participants and discover new ideas about the influence of resilience considerations on the outcomes of infrastructure projects. Accordingly, the exploratory design enabled the determination of patterns and themes fundamental in interpreting the sophisticated interactions of resilience and management efficiency in the real world. As such, this design provided the basis of producing context-related frameworks that were applicable to the South African infrastructure.

An interpretivism philosophy formed the basis of the study as it assumes there is no objective reality of the truth (Creswell & Creswell, 2017). The interpretivist philosophy was appropriate since it enabled the researcher to understand the subjective meanings that professionals attach to their experiences when engaging in climate-resilient infrastructure projects. The philosophy was also very appropriate because it allowed the researcher to access the realities beyond the superficial observations on the problem to uncover underlying frameworks-including governance systems and resource limitations-that influence ways of delivering climate-sensitive infrastructures. The lens of the interpretivist, therefore, provided a connection between the practical experiences of project management and the theoretical explanations about the resilience performance. Finally, interpretivism contributed to the analytical adequacy of the study and the contextual precision of findings interpretation.

To enable theoretical implications to appear out of the collected data rather than being restricted by the already existing models, an inductive approach to research was adopted (Saunders and Lewis, 2018). This approach was in line with the objective of the study which was to come up with a new project management framework that would respond to the demands of the climate-resilient infrastructure in South Africa. Inductive reasoning enabled the capacity to generalise practical experience of professionals to convert it into

conceptual patterns to manage effectively through resilience. As a result, this method made the study more original as it produced empirically based theory to improve practice.

The narrative inquiry strategy was to explore the question of how and why associated with the integration of climate resilience into the project management practices (Yin, 2018). This narrative inquiry strategy specialised in the narratives, lived experiences, and thoughts of professionals working on climate-resilient infrastructure projects. The storytelling enabled the participants to make sense of their professional actions, decisions, and learning experiences, which enabled the researcher to learn how resilience integration is practiced and perceived in practice. This strategy also facilitated the in-depth analysis of real-life projects and provided broad contextual information with diversity of various stakeholders including project managers, engineers and even contractors. Therefore, the narrative inquiry strategy was very instrumental in the explanation of practical implications that were core in facilitating climate-resilient project management in South Africa.

The semi-structured interviews with 13 purposively sampled professionals involved in climate-resilient infrastructure projects were used to collect data. This data collection method was flexible and enabled a depth but focused on the research objectives (Saunders & Lewis, 2018). Interviews helped the participants to talk about their experiences openly, thus exposing new practices and major challenges to be faced in the process of project implementation. The data were subjected to thematic analysis using the six-step framework of Braun & Clarke (2021) and considered and interpreted meaningful themes associated with resilience and project performance. Atlas.ti software was utilised to code and organise the interview data systematically, ensuring a structured and transparent analytic process. As a result, thematic analysis was used to guarantee a stringent interpretation of qualitative evidence and correspondence with the exploratory aim of the study.

Credibility, dependability, confirmability, and transferability criteria of Lincoln and Guba (2004) were strictly followed to ensure that the study is trustworthy. Member checking, pilot testing, and audit trail helped to reinforce credibility and dependability, whereas in-depth contextual description helped to increase transferability. The researcher maintained reflexive journaling and kept an audit trail throughout the research process to enhance confirmability. The subjects were informed of their rights and made well-informed consent before participating in the study, preserving confidentiality and making voluntary decisions

(Kwame & Petrucka, 2024). All these quality control measures had given the findings authentic and ethical findings. In conclusion, such a methodological design allowed the research to produce valid and practical knowledge regarding the variables of climate-resilient infrastructure application in affecting the project management success in the South African context.

7.7 Summary of Findings

The research shows that the incorporation of climate-resilient characteristics into the South African critical infrastructure can greatly facilitate the effectiveness of project management by fostering flexibility, future-oriented thinking, and teamwork. By integrating resilience considerations into the project planning and design early, future vulnerabilities can be reduced by identifying potential risks ahead of time and resource allocation, as well as making decisions promptly. As a result, the projects become long-term, sustainable and efficient in their operation, which proves that resilience integration in the early stage is a strategic feature but not an optional one. These results indicate that climate-ready infrastructure is based on proactive planning.

Economic and financial aspects are also very important in resilience adoption. Although the upfront costs of resilient infrastructure can be greater, the participants reported that the lifecycle savings, lowered maintenance, and minimised disaster recovery costs can be justified by the investment. Nevertheless, lack of financial resources and underestimation of resilience are issues of concern, and financial policies and cost-benefit modelling can help to institutionalise resilience funding. Therefore, economic foresight and technical design can reinforce the sustainability and viability of the infrastructure projects in South Africa.

Governance, institutional accountability, and policy alignment were found to be the key factors in effective integration of resilience. Consistent legislation, uniform compliance systems and multi-level governmental alignment will improve consistency and professional responsibility of the project. Simultaneously, the development of human capacity, lifelong learning, and interaction with the stakeholders guarantee that technical skills, local knowledge, and social consent form the context of the project results. These results were obtained based on the narrative descriptions of 13 professionals who told their stories and reflected on them in the form of semi-structured interviews, which were analysed thematically with the help of Atlas.ti. Taken together, these results show that climate resilience converts project management into a holistic, adaptive, and future-

oriented practice, balancing the technical, economic, and social aspects of the development of the infrastructure in South Africa.

7.8 Contribution to the Current Scholarly Debate of The Phenomenon

Introduction of climate-resistance attributes in the South African critical-infrastructure projects developments promotes academic discourse on the adaptive management of projects and systemic resilience. This study validates Systems Resilience Theory and proves that incorporating resilience in project lifecycles increases adaptability, sustainability, and risk management (Francis & Bekera, 2014; Linkov et al., 2022). Empirical data indicate that incorporation at an early stage and refinement of the design stage not only predict the risks related to climate but also translate theoretical flexibility into practical management activities. The results, however, display endemic institutional loopholes and disjointed politics that limit complete theoretical implementation, and that need to be addressed with context-specific operational designs. These revelations are broadening the discussions in the global arena because they show the feasible constraints of the resilience theory in emerging economies.

Additionally, the research adds to the literature on the topic of Adaptive Management Theory by demonstrating that iterative learning, feedback, and stakeholder involvement can convert deterministic project processes into responsive systems (Williams & Brown, 2014). Such theory-based arguments as resilience as socially constructed, and community-integrative justify stakeholder collaboration and inclusive decision-making (Eisenhauer et al., 2024). However, the lack of resources and expertise points to the fact that theory should be adapted to the local realities, which, in turn, enhances the applicability of the adaptive management models to the emerging economies.

Also, the study contributes to the modern project management theory by showing how the integration of resilience changes procurement, financial planning, and technological innovation. Systems Resilience Theory and the idea of Rethinking Project Management are supported by adaptive budgeting and the lifecycle-focused approach to cost management (Svejvig & Andersen, 2015; Lotfi et al., 2022). Empirical evidence indicates that resilience-oriented projects have a long-term economic and operational payoff despite initial expenditures, which seem to be problematic against conventional efficiency-oriented approaches. The theoretical contributions are supported by the insights gained through the narratives of participants, as they are based on lived experiences and not solely on the evidence of the documents. The study, therefore, contributes to the academic

discourse since it suggests that resilience-centred project management necessitates an integrated approach to governance, finance, technology, and human capital, especially in the context of developing countries where institutional and socio-economic factors are predominant.

7.9 Implications and Recommendations

7.9.1 Practical Implications

The results of the study prove that the introduction of climate-resilient aspects to critical infrastructure projects radically changes the project management practices in South Africa. The projects can be more adaptive, sustainable, and have long-term performance through the implementation of resilience throughout the lifecycle stages, which explains the necessity of proactive planning, iterative design, and agile decision-making. In addition, financial and economic aspects indicate that initial investments in resilient materials and design are cost-effective in terms of lifecycle costs, but short-term financial concerns tend to hinder this implementation. Equally, governance, policy and institutional alignment are essential since disjointed regulations and inconsistent enforcement limit resilience integration.

The results also point out that effective resilience-based project management is enabled by human capital and technical capacity, which necessitates the ongoing professional growth, technical training, and availability of localised climate data. Resilience outcomes are also supported by stakeholder collaboration and inclusive communication practices through the promotion of contextual adaptation, social legitimacy and collective learning. All these findings support the view that adaptive, participatory, and system-oriented management practices, which are compatible with Systems Resilience, Adaptive Management, and Project Management theories, are critical in maintaining critical infrastructure in the face of climate uncertainty.

7.9.2 Recommendations for Practitioners and Stakeholders

- To be able to predict and react to climate risks, project managers are encouraged to institutionalise resilience integration at early stages using iterative design and agile approaches.
- The legislators and regulators should reconcile laws, create binding standards, and coordinate at multiple levels to enhance governance coherence.

- The focus should be on the continuous professional development programs and capacity-building initiatives to prepare the personnel with technical competencies informed by climate.
- The stakeholder engagement must be participatory, inclusive and culturally sensitive, with the inclusion of the local knowledge and the development of the sense of ownership of the infrastructure outcomes by the communities.
- Financial planning must embrace the lifecycle cost assessment, flexible budgeting and climate finance mechanisms to strike a balance between immediate spending and long-term savings and resilience benefits.

7.9.3 Recommendations for Future Research

Research on the longitudinal effects of climate-resilient infrastructure projects in South Africa should be conducted in the future to understand the sustainability and institutionalisation of resilience practices. Comparative studies in multiple areas with various types of infrastructure may help determine best practices, benchmark adaptive capacity, and determine socio-economic impacts. Also, the study of the interaction between the governance structures, community involvement, and technological advancement could contribute to more contextually specific models of resilience. Longitudinal narrative strategy might also be used in the future to trace changing practitioner experiences over time, as a continuation of the cross-sectional basis of this study.

7.10 Conclusion

In conclusion, the study established that the incorporation of climate resilience attributes in South African critical infrastructure projects contributes considerably to effective, sustainable, and adaptable project management. With the integration of principles of resilience throughout project lifecycles, project stakeholders attain proactive risk management, effective resource allocation and dynamism in decision making despite fiscal and institutional limits. The study highlights the importance of a holistic strategy when it comes to effective resilience integration, which includes alignment of governance, development of human capacity, financial foresight, as well as engagement of stakeholders. Furthermore, the established seven-pillar framework provides a contextualised framework for operationalising resilience in the domain of national infrastructure planning. Ultimately, this research will play a role in advancing adaptive

project management practices empirically and theoretically by providing an avenue for future research about climate-resilient infrastructure in developing economies.

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APPENDICES

Appendix 1: Interview Schedule

Introduction

Thank you for taking the time to speak with me today. My research focuses on understanding how incorporating climate resilience into critical infrastructure projects affects the management of these projects. Your experience and insights in this area will be invaluable to this study.

Section 1: Participant's background

1. Could you please describe your current role and experience with critical infrastructure projects?
2. What is your understanding of "climate-resilient critical infrastructure"?
3. In your experience, how often are climate change considerations explicitly integrated into the planning and execution of infrastructure projects?

Section 2: Project management effectiveness:

4. What specific project management practices need to change to best suit climate-resilient critical infrastructure implementation?
5. What would be the benefits of incorporating climate resilience into critical infrastructure projects?
6. Are there any challenges or resistance that arise when trying to incorporate climate-resilient features into the critical infrastructure projects?
7. Are current traditional project management methods sufficient for addressing climate-resilient projects? If not, what modifications can be made for these methods?
8. At which project lifecycle stage is it most crucial to incorporate climate resilience features into a project, and why?
9. If you were to propose a project management framework, that addresses climate-resilience, what key elements would you include in relation to tools, processes, roles, responsibilities, in relation to risk, cost, schedule and procurement management?

Section 3: Measurements of resilience and sustainability:

10. What standardised indicators or benchmarks are essential in measuring the resilience & sustainability of critical infrastructure projects, and why are they suitable?

Section 4: Alternative project management method:

11. Could agile and adaptive project management methodology benefit climate-resilient critical infrastructure projects, and why?
12. Are there any other types, besides the ones mentioned above, of project management that you could incorporate into climate-resilient infrastructure projects to improve project outcomes?

Section 5: Policy, regulations & standards

13. What is the role of national and local governments in the political context regarding stakeholder engagement in ensuring the sustainability and resilience of infrastructure projects?
14. How do socio-political (local & national) factors affect the success of sustainability & climate-resilient infrastructure projects?
15. At the project level, what is the importance of stakeholder participation (incl. engineering professional teams, contractors, private clients, supply chains, etc) in ensuring project sustainability and resilience?
16. What initiatives could be made to improve the participation of councils and professional and regulatory bodies (e.g. CIDB, ECSA, SACPCMP, PMP, SAICE, etc, other professional bodies) and the way that such are currently being implemented?
17. What other aspects would you consider, besides what you have mentioned, to be key considerations to ensure that climate-resilient critical infrastructure project success?

Conclusion

Thank you very much for sharing your valuable insights. Your contributions will be greatly appreciated in this research.

Do you have any questions you would like to ask me regarding this research or anything else?

Appendix 2: Consistency Table

Research Question	Themes and Subthemes (from Results Section)	Interview Guide Questions	Key Literature (from Chapter 2)	Summary of Key Empirical Results
RQ1: How does the introduction of climate-resilient features in critical infrastructure projects impact the use of effective project management practices in the South African context?	Theme 1: Integration of Climate Resilience Across Project Lifecycle Stages Subtheme 1.1: Early-stage Incorporation for Long-term Adaptability Subtheme 1.2: Continuous Design Refinement and Agile Responsiveness	Q1: How are climate-resilient features introduced across project stages? Q2: At what stage is climate adaptation first considered in your projects? Q3: How do you ensure flexibility and learning across project stages?	Francis and Bekera (2014); Fiksel (2006); Linkov et al. (2022); Williams and Brown (2014); Sharma and Gupta (2024)	Early integration enhances adaptive capacity, enabling proactive climate risk anticipation and flexible design refinement throughout project cycles.
	Theme 2: Financial and Economic Dimensions of Resilience Integration Subtheme 2.1: Long-term Cost Efficiency and Lifecycle Savings Subtheme 2.2: Budget Constraints and Undervaluation of Resilience	Q4: How does budgeting incorporate resilience measures? Q5: What are the major financial challenges when integrating resilience?	Mayar et al. (2024); Lotfi et al. (2022); Seidu et al. (2025); Curt and Tacnet (2018)	Upfront resilience investments increase long-term cost efficiency, but limited fiscal flexibility and undervaluation of resilience hinder implementation.
	Theme 3: Governance, Policy, and Institutional Alignment Subtheme 3.1: Legislative and Contractual Drivers Subtheme 3.2: Institutional Gaps and Lack of Standardisation	Q6: What role do governance and policy frameworks play in resilience integration? Q7: How do institutional structures support or hinder resilience practices?	Padalkar and Gopinath (2016); Osei-Kyei et al. (2022); Majlingova and Kadar (2025); Pretorius et al. (2023)	Governance coherence promotes resilience integration, but fragmented institutional policies and weak enforcement limit adaptive project management.
	Theme 4: Human Capital, Knowledge, and Technical Capacity Subtheme 4.1: Specialised Skills and Continuous Learning Subtheme 4.2: Climate Data	Q8: What technical skills or training are needed to manage climate-resilient projects? Q9: How accessible is climate-related data for	Roux et al. (2025); Bradford et al. (2023); Adebawale and Agumba (2023); Hsu and Mostafavi (2024)	Capacity building and data-driven learning improve resilience but are constrained by limited technical expertise and poor data systems.

	Integration and Information Sharing	decision-making?		
	Theme 5: Stakeholder Collaboration and Communication Subtheme 5.1: Inclusive Engagement and Local Knowledge Subtheme 5.2: Interdisciplinary Coordination	Q10: How are stakeholders involved in resilience planning? Q11: What forms of collaboration exist among teams and communities?	Watson, & Ahn, . (2022).; Williams and Brown (2014); Svejvig and Andersen (2015); Johnston et al. (2024); Clark et al. (2022)	Collaborative and participatory engagement enhances social legitimacy but remains challenged by fragmented coordination and unclear communication channels.
RQ2: What are the key project management practices most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa?	Theme 1: Risk Management Integration for Climate Adaptation Subtheme 1.1: Proactive Risk Identification Subtheme 1.2: Responsive Planning	Q12: How has risk management changed due to climate-resilient practices? Q13: How are climate risks identified and mitigated in your projects?	Fiksel (2006); Francis and Bekera (2014); Linkov et al. (2022); Singapore et al. (2023)	Risk management has evolved into a dynamic, anticipatory process integrating climate-related risk forecasting and flexible planning.
	Theme 2: Evolving Frameworks and Methodologies Subtheme 2.1: Hybrid and Agile PM Models Subtheme 2.2: Systems Thinking Integration	Q14: Which project management methodologies are used for resilience-based projects? Q15: How has climate resilience changed project methodologies?	Svejvig and Andersen (2015); Dong et al. (2024); Osei-Kyei et al. (2022); Padalkar and Gopinath (2016)	Shift from linear to hybrid and agile models; systems thinking adopted to integrate flexibility and responsiveness across project stages.
	Theme 3: Sustainability and Resilience Measurement Practices Subtheme 3.1: Quantifiable Metrics Subtheme 3.2: Lifecycle Resilience Audits	Q16: How is resilience measured and monitored in your projects? Q17: Are there performance indicators for resilience integration?	Watson, & Ahn,(2022).; Linkov et al. (2022); Bocchini et al. (2014); Hsu and Mostafavi (2024)	Quantitative metrics and lifecycle audits improve accountability but remain limited by lack of local data and standard benchmarks.
	Theme 4: Technological Tools and Innovation Subtheme 4.1: Digital Modelling and Simulation Subtheme 4.2: R&D and Local Innovation	Q1–Q3 follow-ups (depending on technology questions in interview)	Argyroudis et al. (2022); Jiang et al. (2023); Shafei et al. (2024); Pretorius et al. (2023)	GIS, BIM, and predictive analytics enhance adaptation planning, though regional technological gaps hinder consistent application.
	Theme 5–9: (Governance,	Q4–Q17, depending on	Osei-Kyei et al. (2022);	Governance coherence, skills

	Human Capacity, Procurement, Social Integration, and Policy)	institutional or social dimension	Ziervogel et al. (2022); Majlingova and Kadar (2025); Adebowale and Agumba (2023)	development, and policy alignment improve systemic resilience but need stronger institutional frameworks.
RQ3: What institutional and policy mechanisms can enhance the implementation of climate-resilient project management in South Africa?	Theme 1: Policy and Governance Alignment Subtheme 1.1: Legislative Frameworks Subtheme 1.2: Multi-level Coordination	Q6, Q7, Q10	Francis and Bekera (2014); Curt and Tacnet (2018); Majlingova and Kadar (2025); Pretorius et al. (2023)	Coordinated governance and clear standards are essential for institutionalising resilience within infrastructure policy frameworks.
	Theme 2: Stakeholder Engagement and Collaboration Subtheme 2.1: Community Participation Subtheme 2.2: Cross-sectoral Cooperation	Q10, Q11	Williams and Brown (2014); Shafei et al. (2024); Eisenhauer et al. (2024); Erkul et al. (2020)	Inclusive, multi-stakeholder collaboration enhances project ownership and adaptive capacity but faces sectoral silos.
	Theme 3: Capacity Building and Knowledge Sharing Subtheme 3.1: Training and Education Subtheme 3.2: Knowledge Dissemination	Q8, Q9, Q13	Bradford et al. (2023); Foxcroft and McGeoch (2011); Svejvig and Andersen (2015)	Institutional learning and continuous professional development bridge theory–practice gaps in resilience integration.
	Theme 4: Institutional Accountability and Compliance	Q14, Q15	Linkov et al. (2022); Lonsdale et al. (2024); Curt and Tacnet (2018)	Accountability, ethics, and feedback systems are fundamental to credible, transparent resilience implementation.
	Theme 5: Socio-Political Integration and Awareness	Q16, Q17	Fiksel (2006); Ziervogel et al. (2022); Clark et al. (2022); Atli and Krystallis (2025)	Political commitment and community awareness are central to sustaining resilience policies and project legitimacy.
	Theme 6: Financial and Resource Sustainability	Q4, Q5	Curt and Tacnet (2018); Osei-Kyei et al. (2022); Sharma and Gupta (2024)	Resilience financing needs flexible budgeting and transparent governance for sustainable implementation.

	Theme 7: Continuous Improvement and Adaptive Management	Q3, Q13, Q15	Williams and Brown (2014); Roux et al. (2025); Pedde et al. (2025)	Adaptive learning cycles enable project refinement and institutionalisation of resilience in PM frameworks.
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Appendix 3: Master Table of Themes, Sub-Themes, and Codes

Research Question	Theme	Sub-theme	Generated Codes
RQ1: How does the implementation of climate-resilient features in critical infrastructure projects influence the application of effective project management practices? (24 Codes)	1. Integration of Climate Resilience in Project Lifecycle Stages	1.1 Early-stage incorporation for long-term adaptability	Early-Stage Planning; Long-Term Adaptability
		1.2 Continuous design refinement and agile adaptation	Design Refinement; Agile Adaptation
	2. Financial and Economic Implications of Climate-Resilient Implementation	2.1 Long-term cost efficiency and lifecycle savings	Cost Efficiency; Lifecycle Savings
		2.2 Budget constraints and undervaluation of resilience	Budget Constraints; Resilience Undervaluation
	3. Governance; Policy; and Regulatory Alignment	3.1 Legislative and contractual drivers for climate resilience	Legislative Drivers; Contractual Drivers
		3.2 Institutional gaps and lack of standardisation	Institutional Gaps; Lack of Standardisation
	4. Human Capital; Knowledge; and Technical Capacity	4.1 Need for specialised skills and continuous professional development	Specialised Skills; Professional Development
		4.2 Information availability and climate data integration	Data Availability; Climate Data Integration
	5. Stakeholder Collaboration and Communication Practices	5.1 Inclusive engagement and local knowledge integration	Inclusive Engagement; Local Knowledge
		5.2 Interdisciplinary coordination and team collaboration	Interdisciplinary Coordination; Team Collaboration
RQ2: What are the key project management practices that are most significantly impacted by the integration of climate resilience in critical infrastructure projects in South Africa? (36 Codes)	1. Risk Management Integration for Climate Adaptation	1.1 Enhanced Climate Risk Identification and Mitigation	Risk Identification; Climate Risk Mitigation
		1.2 Flexibility in Risk Response and Monitoring	Flexible Response; Risk Monitoring

	2. Evolving Frameworks and Methodologies	2.1 Hybrid Project Management Approaches	Hybrid PM; Methodologies Evolution
		2.2 Systems Thinking and Integration Across Phases	Systems Thinking; Cross-Phase Integration
	3. Sustainability and Resilience Measurement Practices	3.1 Standardised Indicators and Benchmarks	Standardised Indicators; Resilience Benchmarks
		3.2 Lifecycle and Performance Evaluation	Lifecycle Evaluation; Performance Assessment
	4. Technological Tools and Innovation	4.1 Use of Climate Modelling and Data Analytics Tools	Climate Modelling; Data Analytics
		4.2 Research and Development for Contextual Adaptation	R&D; Contextual Adaptation
	5. Stakeholder Collaboration and Governance	5.1 Inclusive Multi-Stakeholder Coordination	Multi-Stakeholder Coordination; Inclusive Governance
		5.2 Policy and Institutional Support	Policy Support; Institutional Support
	6. Human Capacity and Skills Development	6.1 Specialised Climate Expertise and Training	Climate Expertise; Specialised Training
		6.2 Continuous Professional Development and Knowledge Transfer	Knowledge Transfer; Continuous PD
	7. Procurement and Cost Management Flexibility	7.1 Adaptive Procurement Strategies	Adaptive Procurement; Procurement Strategies
		7.2 Long-Term Financial Planning and Maintenance Funding	Financial Planning; Maintenance Funding
	8. Community and Cultural Considerations	8.1 Social Engagement and Inclusion	Social Engagement; Community Inclusion
		8.2 Equity and Local Benefits	Equity; Local Benefits
	9. Policy; Standards; and Regulatory Alignment	9.1 Standardisation and Compliance Audits	Compliance Audits; Standardisation
		9.2 Legislative and Institutional Frameworks	Legislative Frameworks; Institutional Alignment

RQ3: What framework can be developed to enhance the integration of climate resilience considerations into the project management of critical infrastructure in the South African built environment industry? (30 Codes)	1. Policy and Governance Alignment	1.1 Updating and enforcing legislative frameworks	Legislative Frameworks Update; Enforcement
		1.2 multi-level government coordination	Multi-Level Coordination; Government Alignment
	2. Stakeholder Engagement and Collaboration	2.1 Inclusive participation of local communities	Community Participation; Inclusive Engagement
		2.2 Interdisciplinary collaboration and partnerships	Interdisciplinary Partnerships; Collaboration
	3. Capacity Building and Knowledge Sharing	3.1 Training and education on resilient design	Resilient Design Training; Education
		3.2 Dissemination of research and best practices	Research Dissemination; Best Practices
	4. Institutional Accountability and Compliance	4.1 Monitoring and enforcement mechanisms	Monitoring Mechanisms; Enforcement
		4.2 Professional and ethical accountability	Ethical Accountability; Professional Standards
	5. Socio-Political Integration and Community Awareness	5.1 Political will and policy prioritisation	Political Will; Policy Prioritisation
		5.2 Social awareness and behavioural change	Social Awareness; Behavioural Change
	6. Financial and Resource Sustainability	6.1 Climate finance and funding mechanisms	Climate Finance; Funding Mechanisms
		6.2 Cost–benefit modelling for resilience investment	Cost-Benefit Modelling; Resilience Investment
	7. Continuous Improvement and Adaptive Management	7.1 Dynamic standards and iterative learning	Dynamic Standards; Iterative Learning
		7.2 Integrating feedback loops into project lifecycles	Feedback Loops; Lifecycle Integration