PROJECT ID:

"An investigation into the quality performance of road projects in Kigali, Rwanda"

A THESIS

Submitted by

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Under the Guidance of

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Submitted in partial fulfillment of the requirements for the award of

MASTER OF SCIENCE DEGREE

IN

HIGHWAY ENGINEERING AND MANAGEMENT

JULY 2025

COLLEGE OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING

P.O. Box: 3900 Kigali, Rwanda.

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DECLARATION

I, **UWINTWALI Jean de Montfort**, with Reg. No **220017074**, from University of Rwanda College of Science and Technology, School of Engineering; Department of Civil, Environmental and Geomatics Engineering, following studies of Master of Science in Highway Engineering and Management Programme, hereby declare that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institution.

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CERTIFICATION

This study has been submitted with approval from the University supervisor (Main supervisor).

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ABSTRACT

This study “an investigation into the quality performance of road projects in Kigali, Rwanda” focused on determining the factors influencing road quality, examining critical criteria for road quality performance measurement, and recommending effective strategies for improving road project quality. A mixed-methods approach was employed, combining quantitative data from structured questionnaires with qualitative insights from field observations, interviews, and document reviews. The study involved 94 respondents, including engineers, contractors, consultants, project managers, and road users, and covered four strategically selected road projects across Kigali’s districts. Regarding findings the study has revealed that there was a strong consensus among Project Managers, Road Engineers/Contractors/Consultants, and Government officials in Kigali regarding both the factors influencing road quality performance and the critical criteria for its measurement, as well as effective improvement strategies. Across all project phases (initiation, procurement, execution, monitoring, closure), factors such as project design quality, contractor qualification and experience, skilled labor, compliance with specifications, and regulatory enforcement were consistently rated as highly influential. Similarly, road geometry, pavement integrity, drainage, and smoothness were universally prioritized as key measurement criteria. For improvement strategies, use qualified and skilled contractors, comply with design specifications and standards, use certified materials, and strengthen project planning and design were top-ranked. Crucially, ANOVA results consistently showed no statistically significant differences in perception among the professional groups for nearly all factors, criteria, and strategies (all p-values ≥ 0.05). This indicates a remarkable, shared understanding and alignment among stakeholders on road quality aspects in Kigali, providing a solid foundation for collaborative initiatives. Minor, non-significant variations in mean scores suggest subtle differences in emphasis, but overall agreement is high.

Keywords:

Road quality, Road quality performance, project lifecycle, quality assurance, project management, factors influencing quality, quality measurement criteria, improvement strategies.

ACKNOWLEDGEMENTS

First and foremost, I am profoundly grateful to the Almighty God for granting me the strength, wisdom, and perseverance that enabled me to successfully complete this study.

I extend my sincere appreciation to the Government of Rwanda and the University of Rwanda for providing me with the invaluable opportunity to pursue my master's program, which has greatly enhanced my academic and professional growth.

I am deeply indebted to my supervisor, Associate Professor Oluwaseun Sunday Dosumu, whose unwavering guidance, insightful feedback, and expert knowledge were instrumental throughout the process of developing and completing this thesis.

I would also like to acknowledge all the lecturers in the master's program for their dedication and the comprehensive knowledge imparted to me during my academic journey.

My heartfelt thanks go to the professionals working in the road infrastructure sector, specifically those from the Rwanda Transport Development Agency (RTDA), the City of Kigali office, and the various road construction and supervision firms who generously shared their time and expertise during data collection. Their contributions provided essential insights into the quality performance of road projects, which significantly enriched this research.

Finally, I am thankful to my colleagues and friends, Eng. BYIRINGIRO Emmanuel, Eng. TUYIZERE Fiacre and Mr. HABIMANA Benoit, whose support and encouragement played a vital role in the successful completion of this thesis.

DEDICATION

This dissertation is dedicated to my beloved family, whose constant support, prayers, and encouragement have been my source of strength throughout this academic journey.

I also dedicate this dissertation to all professionals working tirelessly to improve the quality of road infrastructure in Rwanda, whose efforts continue to enhance economic growth and the well-being of our communities.

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LIST OF ABBREVIATIONS

RTDA: Rwanda Transport Development Agency

CoK: City of Kigali

BIM: Building Information Modeling

HDM-4: Highway Development and Management Model Version 4

M&E: Monitoring and Evaluation

SPSS: Statistical Package for the Social Sciences

CHAPTER ONE: INTRODUCTION

1.1.Research background

The significance of infrastructure for economic growth and the welfare of a country has become a burning issue over the past three decades (Mehr & Khalid, 2024). The construction industry serves as a key driver of economic development, with governments allocating substantial resources to large-scale infrastructure projects such as roads, bridges, airports, railways. Among these, road infrastructure holds a critical role in enhancing accessibility and facilitating the free movement of goods and people within and across borders. As noted by Banerjee (2020), road infrastructure is essential for fostering economic growth and improving the standard of living for citizens.

National road projects involve significant capital investment by government agencies, contractors, and other stakeholders. For instance, India presents a notable case of making remarkable strides in the infrastructure sector over the past two decades, especially since economic liberalization (Tata Projects Integrated Annual Report, 2023 - 2024). Rapid urbanization has stimulated an increased demand for urban infrastructure, prompting the central and state governments to launch a series of high-cost projects. This trend is particularly evident in sectors such as transportation, affordable housing, and civic utilities (Halder, 2021).

According to the Athanasios and Dimitra (2018) the success of road project depends not only on investment but also on how effectively it meets performance benchmarks related to scope, time, cost, and quality and it is considered successful when it meets its technical requirements, adheres to its schedule, and maintains quality and safety standards within the agreed budget. Yet, due to the dynamic and unpredictable nature of the construction industry, predicting project success has become increasingly challenging (Joseph, 2021). One of the central roles of road project management is to ensure such success, which underscores the need to understand the factors influencing road project performance, especially quality. While numerous studies have evaluated various aspects of road quality, few have addressed quality in an integrated manner throughout the entire project lifecycle (Minde & Ghadge, 2018). It is important to assess different dimensions of quality such as the quality of concept, design, construction, conformance, and performance. Projects often fail to meet expectations across all performance indicators: time, cost, and quality. Among these, poor road construction quality is a universal challenge that varies in intensity across

projects and geographies (Minde & Ghadge, 2018). Improving the quality of road is closely linked to implementing robust quality management practices throughout the project life cycle (Minde & Ghadge, 2018).

In roadway construction, quality is especially vital. It influences how well road pavements withstand traffic loads and environmental conditions. Quality serves as a critical tool for both clients and construction professionals in achieving durable and serviceable roads. The performance of road pavements depends heavily on their structural design, materials, construction process, and the quality control measures in place (Minde & Ghadge, 2018). Regular monitoring and evaluation systems enable stakeholders to track the progress of road projects, ensuring milestones are met and corrective measures can be implemented promptly, which helps maintain or improve the road quality. The combination of effective monitoring and robust legal frameworks is crucial for ensuring high-quality road infrastructure (Noah et al., 2020).

1.2.Problem statement of the research

Rwanda's capital, Kigali, is undergoing rapid urban growth and economic development, driven in part by extensive infrastructure expansion. However, this expansion in road construction and rehabilitation has not consistently translated into sustained quality performance. According to Pandey (2025) impending global urban population growth is expected to be accompanied by substantial infrastructure expansion. The construction industry, as one of the largest sectors of employment, plays a central role in this expansion and serves as a key indicator of a nation's development.

Noah et al. (2024) conducted a study on contractor's perception of success factors for implementing public road construction projects, researchers pointed out that the road projects failures oscillated between cost and schedule overruns and highlighted that the institutional and managerial challenges affecting the implementation of public road construction projects. However, researchers did not deeply tackle on the road quality which is a vital dimension in assessing the road performance and ensuring its success and sustainability. There were no technical quality parameters such as surface smoothness, pavement materials not included. No indications of how road construction quality performance can be measured.

Mutamuliza Eularie and Vishwanatha (2016) conducted research on infrastructure development in Rwanda: challenges and socio-economic prospects where highlighted that

the road quality specifically in Kigali remains one of the key challenge to the economic development and identified factors for infrastructure development such an ineffective project execution and weak management systems, but the research did not tackle on the quality of those infrastructures and deeply show the impact on the road quality performance.

A study in Nyarugenge district was previously conducted by Gamariel & David (2021) which was about role of monitoring and evaluation and the performance of projects in Rwanda where primarily focused on regular and timely monitoring and evaluation of the road project contributed to the performance of the road construction project, but researchers did not pay attention on the actual quality of road. Crucially that research lacked a comprehensive assessment of quality performance metrics, including user satisfaction, environmental sustainability, and long-term maintenance which directly affect the road quality. It also failed to conduct a comparative analysis with other districts like Gasabo and Kicukiro of the Kigali City as researchers only limited to Nyarugenge district, which could offer broader insights into the determinants of successful road construction projects.

A study conducted by Clement BYIRINGIRO (2021) analyzed the causes of time and cost overruns through the road construction projects life cycle in Kigali, where he mentioned that time and cost management over the project execution period define the road construction project success and proposed the adoption of Lean Design and Construction (LDC) in the road construction life cycle in Rwanda to overcome delays and cost overruns. However, he failed to investigate on quality performance and propose strategies to improving the quality performance of road projects in Kigali.

There is another study conducted by Assaad et al. (2020) in which the researchers state that cost and schedule overruns are always regarded as paramount in the project controls area, impacting road performance. However, the researchers did not mention quality, which also affects road performance. During this research, a proposed model framework was introduced to improve road project performance in terms of cost and schedule/time, but it did not include quality, despite its importance as a variable for road performance. Assaad also noted the continued absence of an integrated framework for estimating the overall performance of road construction projects. This knowledge gap is particularly critical given the increasing complexity and uncertainty in the contemporary construction environment.

Moreover, concerns reported by the Office of the Auditor General in 2022–2023 exposed critical quality assurance lapses. These included unresolved disputes between the Rwanda

Transport Development Agency (RTDA) and the Rwanda Standards Board (RSB), which led to five major roads being left untested, raising alarming questions about the structural safety and compliance of newly constructed infrastructure leading to their overall road quality performance.

Given the above identified research gap and all those concerns, the quality issues in road projects warrant thorough investigation of the quality performance of road projects in Kigali, Rwanda, thus, this research project aims to contribute to enhancing the safety, durability, and overall performance of the road infrastructure in Kigali, Rwanda. Ultimately, improving road quality performance will enhance the quality of life for residents and support economic development in the region.

1.3.Research objectives

1.3.1. Main objective

The objective of this research was to investigate the quality performance of road projects in Kigali, Rwanda, to ensure the continued sustainability of infrastructure development in Rwanda.

1.3.2. Specific objectives

The specific objectives of this research were to:

1. Determine the factors influencing the quality performance of road projects in Kigali.
2. Examine the critical criteria for measuring the quality performance of road projects.
3. Assess the quality performance of road projects in Kigali against examined criteria.
4. Recommend effective strategies/methods for improving the quality performance of road projects.

1.4.Research questions

1. What factors can influence the quality of road projects?
2. What critical criteria can be based on to measure the quality of road projects?
3. How can quality performance of road projects be assessed?
4. How can quality performance of road projects be improved? Or which methods/strategies can be used to improve the quality performance of the road projects?

1.5.Research matrix

The following research matrix is helpful to systematically align research questions, objectives, methods with their source of data.

Research Questions	**Research Objectives**	**Research Methods**	**Data Sources**
1. What factors can influence the quality of road projects?	1. Determine the factors influencing the quality of road projects.	- Literature review - Interviews with stakeholders - Questionnaire survey - Review of quality-related documentation	- Academic journals - Stakeholder interviews (engineers, officials) - Project archives and quality reports - Questionnaire responses
2. What critical criteria can be used to measure the quality of road projects?	2. Examine critical criteria for measuring the quality performance of road projects.	- Literature review on quality standards and evaluation frameworks - Semi-structured interviews with technical experts and practitioners	- Industry guidelines and policy documents - Academic research on infrastructure quality - Inputs from engineers, consultants, and project supervisors/managers from questionnaire
3. How can the quality performance of road projects be assessed?	3. Assess the quality performance of road projects.	- Case studies of selected roads in Gasabo, Kicukiro, and Nyarugenge - Performance data analysis - Statistical and content analysis	- Road project reports - Field observations - Stakeholder feedback - Project evaluation data

4. How can the quality performance of road projects be improved?	4. Recommend effective strategies/methods for improving the quality performance of road projects.	- Thematic analysis from interviews - Comparative analysis from case studies - Synthesis of findings into strategies	- Stakeholder interviews - Case study findings - Best practice models from literature and field insights

1.6.Scope of the study

This research aimed at assessing the quality performance of road projects as a vital contributor to economic efficiency, social wellbeing, environmental sustainability, and institutional integrity. The study focused on road projects completed within the last five years (2020-2024) in the three districts of Kigali: Gasabo, Nyarugenge, and Kicukiro which are the only districts in the city and represent varied topographical, urbanization, and traffic characteristics. The five-year timeframe ensures the availability of complete documentation, reflects current construction standards, and aligns with key national strategies such as NST1 (2017–2024), the City of Kigali Master Plan 2020, and the Strategic Transport Master Plan for Rwanda. Ongoing projects are excluded to avoid relying on incomplete or evolving data, ensuring the analysis is based only on fully implemented and operational roads. The assessment focused on four strategically selected roads: ALU Campus–Musave Cell Access Road (1.629 km) in gasabo district, Rugenge–Muhima Hospital–Nyabugogo Access Road (3.21 km) in nyarugenge district, Sonatubes–Gahanga–Akagera Road (13.8 km) in kicukiro district, Kabeza–Airport–Itunda–Busanza Road(2.71Km) in Kicukiro district, was also considered as a fourth case for comparative purposes.

These roads provide geographical representation across all districts and serve diverse functions: supporting education, health services, and major transport flows. Their strategic and economic importance, variation in length and complexity, and completion within the target timeframe make them suitable case studies for comparative quality assessment.

The research did not involve pavement or direct material testing, due to time, resource, and technical limitations. Instead, it relied on existing project documents, including supervision reports and contractor evaluations, supplemented by qualitative data collected through field observations, interviews, and questionnaires. This approach enables the evaluation of a

broader range of projects based on already monitored performance indicators without requiring intrusive field testing.

Respondents included a diverse group of stakeholders. These include government officials from institutions like RTDA and the City of Kigali, who are responsible for road infrastructure oversight, as well as project managers, engineers, and consultants, who can provide technical insights. Contractors and other technical professionals/engineers contributed perspectives on technical assessment and challenges, while road users offered satisfaction feedback on the practical performance of the roads in terms of safety, durability, and comfort.

1.7.Significance of the study

To conduct this research titled "An investigation into the quality performance of road projects in Kigali, Rwanda" is very essential not only for understanding the current quality performance of road projects in Kigali but also for fostering long-term improvements in infrastructure quality. Understanding the factors that affect road project quality is essential for identifying weaknesses in the current processes. By investigating these influences such as project management practices, stakeholder engagement, and material quality. In this case different stakeholders can gain insights into areas needing improvement. This was helpful in suggesting better strategies for future projects, ensuring that they meet community and regulatory standards.

Establishing clear criteria for measuring quality performance is crucial for accountability and continuous improvement. Thus, by identifying specific metrics like adherence to specifications, and user satisfaction, this research provided a framework for assessing the quality performance of road projects which enabled researchers and other stakeholders to assess current projects effectively and make informed decisions about future developments.

A careful assessment of existing road projects in Kigali conducted and highlighted successes and areas for improvement. By assessing quality performance against identified criteria, the investigation revealed patterns or trends affecting project outcomes. This assessment provided a vital for understanding the current state of road infrastructure and ensuring that future projects align with best practices and community needs.

The goal of this research was to enhance the quality performance of road projects in Kigali, therefore, by analyzing the findings from the previous objectives, the study came up with

proposing actionable recommendations and strategies for improvement. These strategies could enhance stakeholder engagement in innovative construction techniques.

CHAPTER TWO: LITERATURE REVIEW

This chapter presents a comprehensive review of literature concerning the quality performance of road projects. It synthesizes existing knowledge, identifies key theoretical perspectives, and highlights research gaps that this study aims to address. The review is structured around the core objectives of this research focusing on: factors influencing road project quality, criteria for measuring quality performance, assessment of road quality performance and strategies/methods for road quality improvement. Drawing upon a range of academic sources, industry reports, and empirical studies, this chapter provides a robust theoretical foundation for understanding the complexities of ensuring high-quality road infrastructure.

2.1.Introduction to road infrastructure

Road infrastructure plays a pivotal role in socio-economic development, fundamentally facilitating mobility, trade, and access to essential services. The quality of road projects significantly influences their durability, safety, and long-term maintenance costs. In the context of road construction, quality refers to the degree to which project deliverables meet specified technical standards, satisfy user expectations, and align with broader sustainability goals (Athanasios & Dimitra, 2018).

Infrastructure development has long been recognized as a primary catalyst for economic growth and societal well-being. Over the past three decades, road infrastructure has gained prominence due to its pivotal role in national and regional connectivity (Mehr & Khalid, 2024). Banerjee (2020) further emphasizes that robust road networks are fundamental in promoting internal and international trade, enabling access to critical social services like healthcare and education, and ultimately improving the standard of living for citizens. Roads form the backbone of transportation systems, essential for bridging rural and urban divides, thereby supporting inclusive development and fostering regional integration.

Quality stands as one of the core performance benchmarks of any road project. Athanasios and Dimitra (2018) assert that for road infrastructure to be deemed successful, it must fulfill not only its technical specifications but also meet stringent criteria related to time, cost, and safety standards. The inherent quality of a road project directly affects road safety, influences overall user satisfaction, and determines the long-term maintenance burden placed on governments and public agencies. Thus, ensuring the quality of road infrastructure is not merely a technical necessity but a developmental imperative, crucial for sustained economic progress and improved societal welfare.

2.2.Theoretical frameworks for road quality management

The concept of quality in road infrastructure development is complex and multi-dimensional, influenced by a range of theoretical approaches. These frameworks are essential for understanding the principles that underpin quality performance in road construction and provide structured ways to evaluate and improve it.

2.2.1 Total quality management

Total Quality Management (TQM) is a comprehensive management philosophy that promotes continuous improvement, stakeholder satisfaction, and collaborative participation across all organizational levels. In the context of road infrastructure, TQM offers a strategic approach to quality management by integrating quality considerations at every phase of the project life cycle, from initial planning and design through construction and post-construction maintenance (Minde & Ghadge, 2018).

Minde and Ghadge (2018) emphasize that the consistent application of TQM principles throughout the entire project process is critical for enhancing road quality outcomes. TQM's proactive focus on the prevention of defects, rather than reactive correction, aligns well with the long-term demands of durable and sustainable road infrastructure. This preventative approach ensures that quality is built into the process from the outset, minimizing rework and costly rectifications. Similarly, Athanasios and Dimitra (2018) highlight that successful infrastructure projects depend not only on financial inputs but also on systematic performance against established quality indicators, such as compliance with design standards, adherence to timelines, and ensuring functional usability. The TQM framework thus serves as a valuable theoretical lens for assessing how an organization-wide commitment to quality can address persistent challenges like substandard road construction, poor durability, and inadequate post-construction evaluation. Key TQM principles applicable to road projects include:

1. **Customer focus:** Prioritizing and meeting the needs of road users for durability, safety, and usability.
2. **Continuous improvement:** Fostering an environment of ongoing enhancement in materials, construction techniques, and supervision methods.
3. **Employee involvement:** Actively engaging all personnel, from engineers and contractors to laborers, in quality assurance processes.

4. **Process approach:** Integrating quality considerations systematically into each phase: planning, design, construction, and maintenance.
5. **Evidence-based decision making:** Utilizing performance data, supervision reports, and audit findings to inform and improve practices.

2.2.2 ISO 9001 quality management systems

The ISO 9001 standard offers a globally recognized framework for quality management systems, emphasizing a process-oriented approach, customer focus, strong leadership, and a commitment to continual improvement. For road construction projects, ISO 9001 promotes systematic quality control procedures, comprehensive documentation practices, and regular internal and external audits (RTDA, 2022). Organizations that adopt ISO 9001 frameworks demonstrate a commitment to accountability, adherence to regulatory standards, and establish a structured pathway for identifying and resolving quality issues.

In the context of road projects, ISO 9001 principles serve as benchmarks for assessing institutional compliance and enhancing construction governance. By mandating documented processes for design, procurement, construction, and inspection, ISO 9001 ensures a consistent approach to quality delivery. This systematic framework helps in minimizing variations, identifying non-conformities early, and fostering a culture of quality consciousness throughout the project team (Kerzner, 2022).

Table 2. 1: ISO 9001 quality management systems

ISO 9001 component	**Role in road construction quality management**
Process orientation	Emphasizes structured workflows for design, construction, and audits
Customer focus	Ensures roads are built to meet end-user expectations and safety
Leadership	Encourages accountability from road authorities and contractors
Risk management	Promotes anticipation and mitigation of potential quality risks
Continuous review	Supports regular evaluation and updating of road construction standards

2.2.3 Lean construction

Clement Byiringiro (2021) suggests the adoption of Lean Design and Construction (LDC) in the road construction lifecycle in Rwanda specifically to overcome delays and cost overruns. While Byiringiro's primary focus was on time and cost efficiency, the inherent

lean principles of reducing defects and emphasizing “getting it right the first time” directly contribute to improved quality performance. By streamlining processes, reducing variations in construction activities, and fostering a culture of continuous flow, lean construction can lead to more consistent, higher-quality outcomes, and enhanced durability in road projects. Key LDC principles applied to road construction include:

1. **Value maximization:** Focusing on delivering roads that provide optimal value to users and stakeholders, ensuring functional and durable infrastructure.
2. **Waste reduction:** Systematically eliminating non-value-adding activities such as rework due to defects, unnecessary delays, and excess material inventory.
3. **Continuous flow:** Promoting smooth and uninterrupted coordination among contractors, suppliers, and supervisors to optimize workflow.
4. **Pull planning:** Ensuring that construction activities are driven by real-time demand and readiness, rather than a rigid push system, enhancing efficiency and quality control.
5. **Integrated project teams:** Encouraging close collaboration among all project participants for better coordination and problem-solving, fostering a shared commitment to quality.
6. **Continuous improvement:** Supporting a culture of learning and adaptation throughout construction processes, where lessons from each project feed into future enhancements.

2.2.4 Project management body of knowledge

The Project Management Body of Knowledge (PMBOK) Guide, developed by the Project Management Institute (PMI), provides a standardized and globally recognized framework for project management. This comprehensive framework includes a dedicated knowledge area for project quality management, outlining processes such as planning quality management, performing quality assurance, and controlling quality (Kerzner, 2022). Joseph (2021) notes the dynamic and unpredictable nature of the road construction industry, which makes achieving consistent project success challenging. This unpredictability underscores the critical need for structured project management, as advocated by PMBOK.

The PMBOK framework provides a practical and widely accepted theoretical basis for understanding how quality is systematically planned, implemented, and monitored throughout a road project’s lifecycle. It aligns with the need to assess different dimensions of quality, including the quality of concept, design, construction, conformance, and performance (Minde & Ghadge, 2018). By defining clear processes within its various

knowledge areas and process groups, PMBOK ensures that quality considerations are integrated from initiation to closure. Key PMBOK knowledge areas and their relevance to road construction quality include:

1. **Integration management:** Ensuring all project aspects, including quality, are coordinated and managed holistically from project charter development to integrated change control.
2. **Scope management:** Clearly defining and controlling the project scope to prevent scope creep, which can compromise quality if not managed effectively.
3. **Schedule (time) management:** Planning and controlling the project schedule to ensure timely completion, as delays can lead to rushed work and quality compromises.
4. **Cost management:** Planning, estimating, and controlling costs to ensure the project is completed within budget, without sacrificing quality for cost-cutting.
5. **Quality management:** Specifically planning for quality, performing quality assurance activities (e.g., audits, process analysis), and controlling quality (e.g., inspections, testing) throughout the project.
6. **Resource management:** Ensuring the right human, material, and equipment resources are available and managed effectively to support quality work.
7. **Communications management:** Facilitating effective information exchange among stakeholders to ensure everyone is aware of quality requirements and issues.
8. **Risk management:** Identifying, analyzing, and responding to risks that could impact project quality, such as unforeseen ground conditions or material supply issues.
9. **Procurement management:** Managing the acquisition of goods and services from outside the project team, ensuring suppliers meet quality standards.
10. **Stakeholder management:** Engaging and managing stakeholders' expectations to ensure their needs and concerns regarding quality are addressed.

These theoretical frameworks collectively offer a robust foundation for analyzing and improving road project quality performance. They guide the identification of critical success factors, facilitate systematic performance monitoring, and support evidence-based decision-making for sustainable infrastructure development.

2.3.The road infrastructure project life cycle

The development of road infrastructure follows a structured engineering life cycle, where each phase builds systematically upon the previous one to ensure that the road is efficiently

planned, accurately designed, properly constructed, and sustainably maintained. This sequential process is essential to achieving roads that meet expected performance levels and safety standards throughout their service life (World Bank, 2023). According to RTDA (2022) and Banerjee (2020), adopting a life cycle approach in road infrastructure projects enhances project quality, minimizes risks, and promotes long-term value for stakeholders.

2.3.1. Project initiation and feasibility study phase

The first phase, Project initiation and feasibility study lays the groundwork for road infrastructure development. The primary focus is to assess the necessity, practicality, and potential impacts of the proposed road project. Key activities in this phase include identifying transportation needs, analyzing projected traffic volumes, and conducting comprehensive feasibility studies encompassing technical, financial, and environmental aspects (World Bank, 2023). Environmental and Social Impact Assessments (ESIA) are also crucial to evaluate the project's sustainability and social acceptability (RTDA, 2022). Stakeholder consultations, preliminary route alignment studies, and budget estimations help build a realistic project concept. The phase concludes with key outputs such as a project brief, feasibility report, initial governmental approvals, and funding proposals aimed at mobilizing financial resources.

2.3.2. Planning and design phase

Following the feasibility analysis, the planning and design phase transforms conceptual ideas into detailed implementation blueprints. This stage involves extensive engineering design processes, including determining the road’s geometric alignment, pavement structure, and drainage systems (Banerjee, 2020 & AASHTO, 2018). Geotechnical investigations ensure the suitability of the subgrade, while utility relocation and land acquisition plans secure the project’s right-of-way. In addition, obtaining permits and preparing tender documents are essential steps in ensuring regulatory compliance. Construction planning, including developing project schedules and methods, is finalized during this phase. The primary outputs include approved design drawings, detailed technical specifications, bills of quantities (BOQ), and finalized tender documentation.

2.3.3. Procurement phase

The procurement phase focuses on selecting qualified contractors and consultants capable of delivering the project efficiently and to standard. Guided by public procurement regulations, such as the Rwanda Public Procurement Authority (RPPA) guidelines, this phase includes advertising tenders, evaluating submitted bids, awarding contracts, and

finalizing agreements through contract signing. The successful completion of this stage results in signed construction contracts and mobilization plans that detail how contractors will organize personnel, equipment, and materials to commence the project.

2.3.4. Execution/construction phase

The construction phase marks the physical realization of the project, where all planning and design efforts are translated into tangible infrastructure. Activities typically include site clearance, earthworks, sub-base and base construction, pavement surfacing, and the installation of drainage systems and culverts (Assaad, 2020). This phase also involves placing road furniture such as guardrails, signage, and road markings. Quality assurance plays a pivotal role during construction, with regular inspections and testing of compaction levels, pavement thickness, and surface smoothness. Environmental and social management measures are implemented to mitigate negative impacts, and progress is closely monitored to align with project schedules. Upon completion of each section, test results and performance data are compiled to validate construction quality.

2.3.5. Testing, commissioning, and handover phase

After the completion of construction works, the testing, commissioning, and handover phase ensures the road meets required quality and safety standards before being opened for public use. Final inspections are conducted to identify and resolve any defects, while independent quality assurance audits verify compliance with design and regulatory requirements (Mutamuliza & Vishwanatha, 2016). Environmental and social safeguard measures are also reviewed to confirm compliance. Upon successful testing, the contractor hands over the project to the implementing agency, accompanied by essential documentation such as completion certificates and as-built drawings. This phase closes in the formal opening of the road to traffic.

2.3.6. Operation and maintenance (O&M) phase

The operation and maintenance phase ensures the long-term safety, functionality, and sustainability of the road infrastructure. During this phase, routine maintenance activities such as pothole patching, drainage cleaning, and minor repairs are carried out alongside periodic maintenance interventions like resurfacing and resealing (World Bank, 2023). Regular safety audits are performed to address emerging hazards, while user satisfaction surveys and road performance monitoring provide feedback on service quality. Maintenance

records and performance reports guide decision-making regarding potential renovations or upgrades, ensuring that the road continues to serve its intended purpose efficiently throughout its design life (Rwanda Maintenance Management System, 2022).

2.4.Types of project contracts in road construction

The choice of contract type in road construction projects plays a critical role in defining the relationship between clients, contractors, and other stakeholders. Contract selection is often influenced by factors such as project complexity, financing arrangements, allocation of risk, and the desired speed of project delivery (World Bank, 2023). In Rwanda and similar developing contexts, several contract models are widely applied to meet diverse project requirements and policy objectives (RTDA, 2022).

2.4.1 Lump sum contracts (fixed price contracts)

Lump sum contracts, also known as fixed price agreements, are among the most straightforward forms of contracting in road works. Under this arrangement, the contractor commits to completing the entire project for a predetermined total cost, regardless of the actual expenses incurred during execution (Kerzner, 2022). This type of contract demands a well-defined project scope and design documentation from the outset to avoid ambiguities. The main advantage of lump sum contracts is that they provide budget predictability for public agencies such as the Rwanda Transport Development Agency (RTDA) and local district authorities, as cost overruns become the responsibility of the contractor (RTDA, 2022). Furthermore, administrative overhead during implementation is reduced, since payments are based on progress milestones rather than unit quantities. However, a key limitation lies in the contract's inflexibility: any change in project scope can lead to disputes or costly contract amendments. Contractors often mitigate risks by incorporating contingency margins into their bids, potentially increasing project costs upfront. In Kigali, such contracts are prevalent in small-to-medium road rehabilitation and upgrading projects, where the project scope is relatively clear.

2.4.2 Unit price contracts (bill of quantities contracts)

Unit price contracts operate on a different principle, where payments are made according to measured quantities of work completed, multiplied by pre-agreed unit rates for each item of work. This structure is particularly useful in road construction activities with inherent uncertainties regarding work volumes, such as extensive earthworks, rock excavation, or

complex drainage installations, where variations in ground conditions can significantly impact the actual quantities required (World Bank, 2023).

The primary advantage of unit price contracts is their flexibility, which allows for more accurate payments that directly reflect the actual scope of work completed on site. This adaptability is beneficial when precise quantities cannot be determined during the design phase. However, this flexibility also introduces potential cost uncertainty for the client, particularly if initial site investigations are poor, leading to significant quantity overruns. To mitigate this, rigorous on-site measurements, meticulous record-keeping, and effective supervision are essential to control costs, prevent disputes over payments, and ensure that only verified quantities of quality work are compensated. This model is common in Kigali's Road widening works and subsoil-dependent projects, where precise quantities can only be determined accurately during the construction phase.

2.4.3 Design-Build (DB) contracts

The Design-Build contract model integrates both the design and construction responsibilities within a single contractual entity. This approach encourages innovation, faster project delivery, and more streamlined communication, as the design and construction teams work collaboratively (Banerjee, 2020).

Design-build arrangements reduce the time lag between design completion and construction start, offering advantages in projects where timelines are critical. Moreover, the contractor assumes responsibility for design errors, reducing the client's risk exposure. However, the success of such contracts depends on the competence of the contractor. Additionally, public sector clients may have limited control over detailed design aspects, potentially leading to deviations from initial expectations. Some elements of the design-build approach have been piloted in Rwanda's Kigali urban road upgrading projects, showcasing its potential for fast-tracked infrastructure works.

2.4.4 Engineering, procurement, and construction (EPC) contracts

EPC contracts, often referred to as turnkey contracts, require the contractor to undertake all project components from detailed engineering and procurement to construction and commissioning (Kerzner, 2022). This contract type is well-suited for large and complex infrastructure projects, where a single point of responsibility simplifies coordination and delivery.

EPC contracts facilitate faster project execution through parallel processes but place substantial risks and responsibilities on the contractor. For the client, this arrangement

minimizes involvement during execution but may reduce their ability to influence project decisions. In East Africa, EPC contracts are commonly applied in regional trunk roads or major public-private partnership (PPP) infrastructure projects, though their use in Rwanda remains limited to a few strategic investments.

2.4.5 Performance-based maintenance contracts (PBMC) / output-based contracts

Performance-based maintenance contracts represent a modern shift toward quality-focused road maintenance. Instead of paying contractors for the quantity of work performed, these contracts compensate them based on how well the road performs over a given period (Osei-Kyei & Chan, 2021). Contractors are incentivized to deliver long-lasting, high-quality works to minimize their maintenance liabilities.

The advantages of PBMCs include improved road durability, reduced oversight requirements for the client, and better long-term outcomes. However, these contracts are technically demanding as they require robust monitoring systems and clearly defined performance indicators. In African contexts, such contracts have been applied successfully in World Bank-funded Road maintenance programs, with Rwanda piloting similar initiatives for its critical road corridors (World Bank, 2023).

2.4.6 Public-private partnership (PPP) concession contracts

PPP concession models are used when the private sector finances, constructs, and operates road infrastructure over an agreed concession period. In return, the private partner recovers their investment through mechanisms such as road tolls or availability payments (Yescombe, 2020).

PPP contracts enable governments to leverage private capital, transferring financial and operational risks to the private sector. However, such arrangements are complex to structure, requiring sophisticated legal frameworks and long-term regulatory oversight (World Bank, 2023). While Rwanda has explored PPP frameworks, practical application remains limited, with neighboring countries like Kenya and Uganda already implementing toll road concessions.

2.5.Factors influencing the quality performance of road projects

Numerous authors have identified various factors that significantly influence the quality of road construction projects. These factors span across project planning, execution, and oversight, forming a complex interplay that ultimately determines the durability, safety, and serviceability of the final infrastructure.

2.5.1 Design and planning standards

The initial stages of a road project, particularly design and planning, are crucial for ensuring quality. Oyemogun, Fadeyi, and Aina (2020) emphasize the importance of robust design specifications and adherence to standards as critical criteria for highway construction quality. Inadequate geological surveys, poor alignment design, and insufficient drainage plans can lead to premature road deterioration. Minde and Ghadge (2018) implicitly support this by highlighting the importance of structural design and material quality. The quality of concept and design is a fundamental dimension of overall project quality, as poor initial planning can create inherent flaws that are difficult and costly to rectify later.

2.5.1.2 Geometric design compliance

The geometric design, encompassing horizontal and vertical alignment, cross-section, and sight distances, directly impacts road safety and operational efficiency. Compliance with established design manuals (AASHTO, 201 & RTDA, 2021) is crucial. Poor alignment design can create hazardous curves, insufficient sight distances, and inadequate super-elevation, significantly increasing accident risks and reducing user comfort (Nicholas J. Garber & Lester A. Hoel, 2009). These elements are fundamental for safe and smooth traffic flow.

2.5.1.3 Drainage design effectiveness

An effective drainage system is indispensable for road longevity, as water is a primary cause of pavement deterioration. Poorly designed drainage plans, including inadequate culverts, insufficient side drains, or improper cross-slopes, lead to water infiltration into pavement layers, weakening the subgrade and accelerating distresses like potholes and rutting (Austroads, 202; RTDA, 2022). A robust design must meticulously account for anticipated rainfall intensity and runoff volumes to prevent water-related damage and ensure structural integrity.

2.5.1.4 Pavement design suitability

The design of the pavement structure, including the type, thickness, and composition of each layer (subgrade, subbase, base, and surface course), must be suitable for the projected traffic loads and environmental conditions. Minde and Ghadge (2018) stress that the structural design dictates how well the pavement withstands traffic. An unsuitable pavement design,

whether due to underestimation of traffic volumes, incorrect material specifications, or inadequate consideration of environmental factors, will inevitably lead to early structural failure and a significantly reduced service life (Assaad, 2020).

2.5.2 Material quality and management

The quality of materials used in road construction is a direct determinant of the pavement's performance and durability. Minde and Ghadge (2018) explicitly state that the performance of road pavements depends heavily on the quality control measures in place, directly linking it to material quality. Substandard aggregates, asphalt, or concrete mixtures can significantly compromise the structural integrity and lifespan of roads. Seninde (2020) in a study on factors affecting road quality in Uganda, likely touches upon material quality as a key influencing factor. Effective material management, including proper storage, handling, and testing, is therefore paramount.

2.5.2.1 Quality of raw materials (Aggregates, Binders, Cement)

The fundamental quality of raw materials, such as aggregates (crushed stone, gravel), asphalt binders, and cement, directly dictates the strength, stability, and durability of the final pavement. Substandard or contaminated aggregates can lead to poor compaction, reduced load-bearing capacity, and increased susceptibility to cracking and rutting (Oyemogun, Fadeyi, & Aina, 2020). Similarly, inferior asphalt or concrete mixtures compromise the structural integrity and lifespan of roads, as they may not achieve the required strength or flexibility (Morake & Meng, 2020).

2.5.2.2 Material testing and certification

Rigorous material testing and certification are paramount to ensuring that all components meet specified engineering properties and national standards. This involves systematic laboratory testing of samples from quarries and production plants, as well as on-site verification of delivered materials. A lack of consistent testing, reliance on uncertified suppliers, or insufficient verification introduces significant risks of quality compromise, as the actual properties of the materials may deviate from design assumptions, leading to unforeseen failures (RTDA, 2022).

2.5.2.3 Storage and handling practices

Even high-quality materials can degrade if not properly stored and handled. Improper storage can lead to contamination (aggregates mixed with soil), moisture absorption (affecting cement or asphalt binders), or segregation of aggregate sizes. Inadequate handling during transportation and on-site can damage materials or alter their properties, thereby undermining the final construction quality and the pavement's long-term performance (Love, Sing, & Wang, 2019). This highlights the importance of proper logistics and site management.

2.5.3 Construction practices and workmanship

The execution phase, involving actual construction practices and workmanship, profoundly impacts road quality. Damoah, Ayakwah, and Twum (2022) investigate key factors influencing road construction quality in Ghana, which would certainly include on-site construction practices. Poor compaction, inadequate layering, incorrect mixing ratios, and insufficient curing can lead to structural weaknesses and early failure. Otim and Alinaitwe (2013) also examined factors affecting pavement road construction projects in Uganda, with workmanship being a significant aspect. The supervision and skills of the labor force are critical; a lack of skilled labor or inadequate supervision can result in deviations from specifications and reduced quality.

2.5.3.1 Compaction quality

Achieving optimal compaction for each pavement layer (subgrade, subbase, base, and asphalt/concrete) is critical for structural integrity and durability. Poor compaction leads to insufficient density, increased voids, and reduced load-bearing capacity, making the pavement susceptible to early settlement, rutting, and cracking under traffic loads (Otim & Alinaitwe, 2013). This is a common and often immediate cause of premature road failure.

2.5.3.2 Layering and mixing accuracy

The precise layering sequence and accurate mixing ratios of materials (e.g., asphalt concrete mix design, cement-stabilized base) are fundamental to the pavement's structural performance. Deviations from specified layer thicknesses can lead to inadequate structural support, while incorrect mixing proportions can compromise material strength and

workability. These inaccuracies directly affect the pavement's ability to perform as designed and can lead to rapid deterioration (Assaad, 2020).

2.5.3.3 Curing practices

For concrete pavements or cement-stabilized layers, proper curing is essential to achieve the designed strength and durability. Inadequate curing (e.g., insufficient moisture, premature drying) can lead to surface cracking, reduced compressive strength, and increased permeability, making the pavement vulnerable to environmental degradation and traffic wear, thereby shortening its lifespan (FHWA, 2020).

2.5.3.4 Adherence to construction methodologies

Strict adherence to approved construction methodologies and best practices is crucial for consistent quality. This includes proper preparation of the subgrade, accurate placement of materials, correct joint construction, and appropriate use of construction equipment. Any shortcuts, deviations from established procedures, or lack of skilled application can introduce defects that compromise the road's structural integrity and functional performance (Damoah, Ayakwah, & Twum, 2022).

2.5.4 Project management and supervision

Effective project management and rigorous supervision are consistently identified as critical for quality outcomes. Mutamuliza Eularie and Vishwanatha (2016) highlighted ineffective project execution and weak management systems as challenges to infrastructure development in Rwanda, which directly impacts road quality. Byaruhanga and Basheka (2017) explored the role of contractor monitoring in the performance of road infrastructure projects in Uganda, underscoring the importance of oversight. Joseph (2021) notes the challenge of predicting project success due to the dynamic construction industry, reinforcing the need for strong management. Consistent monitoring, clear communication channels, and proactive problem-solving by project managers and supervisors are essential to ensure adherence to quality standards.

2.5.4.1 Project planning and scheduling

Comprehensive project planning and realistic scheduling are vital for efficient resource allocation, timely execution, and integrated quality control. Poor planning can lead to delays, resource bottlenecks, and rushed work, which often result in compromises on

quality. A well-structured plan ensures that all quality control activities are integrated into the project timeline, preventing reactive measures (Kerzner, 2022).

2.5.4.2 Risk management

Proactive identification, assessment, and mitigation of risks (e.g., unforeseen geological conditions, material supply chain disruptions, adverse weather, political interference) are essential for maintaining quality. Unmanaged risks can lead to significant project disruptions, forcing compromises in materials, methods, or timelines that negatively impact quality and increase costs (Joseph, 2021).

2.5.4.3 Communication and coordination

Effective communication channels and seamless coordination among all project stakeholders: client, contractor, consultant, suppliers, and regulatory bodies are crucial for quality delivery. Miscommunication, lack of information sharing, or poor coordination can lead to misunderstandings, rework, and significant deviations from quality standards (PMBOK Guide, 2022). Integrated project teams, as advocated by Lean Construction, can significantly improve this aspect (Byiringiro, 2021).

2.5.4.4 Site supervision quality

The quality of on-site supervision is paramount for ensuring that construction activities conform to design specifications and quality standards. Competent, experienced, and vigilant supervisors can identify and rectify defects early, prevent the use of substandard materials, and ensure proper construction practices. A lack of adequate or qualified site supervision is a frequently cited cause of quality issues and project failures (Otim & Alinaitwe, 2013; Byaruhanga & Basheka, 2017).

2.5.5 Monitoring, evaluation, and regulatory frameworks

Regular monitoring and evaluation systems are crucial for tracking progress and ensuring quality. Noah et al. (2020) emphasize that the combination of effective monitoring and robust legal frameworks is crucial for ensuring high-quality road infrastructure. Gamariel and David (2021), in their study on the role of monitoring and evaluation in project performance in Nyarugenge district, highlight the contribution of regular and timely M&E to road construction project performance. The Office of the Auditor General’s concerns in Rwanda (2022-2023) regarding quality assurance lapses and untested roads further highlight

the critical role of independent oversight and regulatory compliance in ensuring quality. Wamalwa and Herbert (2018) also discuss the impact of devolved road construction management processes on public building project quality, which has implications for road projects and their regulatory oversight.

2.5.5.1 Regular site inspections and audits

Consistent and systematic site inspections and quality audits throughout the construction process are vital for verifying compliance with specifications, identifying deviations, and assessing workmanship. Independent audits, as highlighted by the Office of the Auditor General's concerns in Rwanda (2022-2023) regarding untested roads, add an essential layer of unbiased verification and accountability, ensuring that quality standards are met objectively (Gamariel & David, 2021).

2.5.5.2 Performance monitoring systems

Implementing comprehensive performance monitoring systems allows for continuous tracking of key quality indicators, material usage, and construction progress. Such systems can provide real-time data to identify trends, predict potential issues, and enable timely corrective actions to uphold quality standards throughout the project lifecycle (RTDA, 2022). This proactive approach minimizes the risk of major quality failures.

2.5.5.3 Enforcement of regulations and standards

The mere existence of robust regulations and technical standards is insufficient without effective enforcement. Regulatory bodies must possess the necessary capacity, resources, and autonomy to conduct regular inspections, impose penalties for non-compliance, and ensure adherence to construction codes, safety standards, and environmental regulations. Weak enforcement can lead to contractors cutting corners, using substandard practices, and ultimately compromising road quality and durability (Wamalwa & Herbert, 2018).

2.5.6 Financial constraints and budget management

While not always directly linked to quality in isolation, financial constraints can indirectly influence quality performance. Under-budgeting or inadequate allocation of funds for quality control measures, skilled labor, or high-quality materials can compromise project outcomes. Clement Byiringiro (2021) addressed time and cost overruns, which are often symptoms of financial mismanagement or unrealistic budgeting. While his study did not

directly investigate quality performance, the relationship between cost and quality is often inverse if cost-cutting leads to compromises in materials or workmanship. Assaad et al. (2020) also acknowledged the paramount impact of cost and schedule overruns on road performance, implying an indirect link to quality, even though they did not explicitly include quality as a variable in their proposed framework.

2.5.6.1 Adequacy of project funding

Insufficient initial funding or unexpected budget cuts during the project lifecycle can severely impact a project's ability to procure high-quality materials, engage adequately skilled labor, or implement necessary quality control measures. Inadequate funding often forces project teams to make compromises that directly undermine quality and long-term durability (Andrić et.al, 2019).

2.5.6.2 Budget allocation for quality control

Even with sufficient overall funding, if the budget is not adequately allocated to critical quality control and assurance activities (e.g., comprehensive material testing, independent supervision, investment in advanced equipment), quality can suffer. Prioritizing cost-cutting in these essential areas can lead to undetected defects and premature failures, ultimately increasing lifecycle costs (Byiringiro, 2021).

2.5.6.3 Cost overruns and their impact

Unforeseen cost overruns can lead to a domino effect, where project managers are forced to make rapid decisions to stay within budget, often at the expense of quality. This can manifest as using cheaper, inferior materials, reducing construction time (leading to rushed work and poor workmanship), or cutting back on essential quality checks. Assaad et al. (2020) acknowledge the paramount impact of cost and schedule overruns on road performance, implying a critical indirect link to quality, as financial pressures can force compromises that erode quality.

2.6.Critical criteria for measuring the quality performance of road projects

Measuring road project quality requires a comprehensive set of criteria that go beyond mere physical attributes. Authors have proposed various dimensions to assess quality effectively, moving beyond simplistic notions to embrace a more holistic understanding of a road’s performance and value to its users and the environment.

2.6.1 Adherence to specifications and standards

This is a fundamental criterion for quality. Minde and Ghadge (2018) implicitly refer to this when discussing structural design, materials, and construction process quality control measures. Quality is achieved when the constructed road meets the technical requirements outlined in project specifications, national standards, and relevant codes of practice. This includes adherence to material properties, pavement thickness, layer compaction, and geometric design. Non-compliance often leads to structural deficiencies and premature failure.

2.6.1.1 Material properties compliance

This criterion assesses whether the physical and chemical properties of all materials used (aggregates, asphalt, cement, steel) conform to the specified standards and design requirements. Non-compliance, such as incorrect aggregate gradation, insufficient binder content, or impurities, directly impacts the strength, stability, durability, and long-term performance of the pavement layers (Oyemogun, Fadeyi, & Aina, 2020).

2.6.1.2 Pavement thickness and compaction

Verification of pavement layer thicknesses (subgrade, subbase, base, wearing course) and their achieved compaction densities against design specifications is crucial. Deviations from specified thicknesses can lead to inadequate structural capacity, while insufficient compaction results in voids and reduced load-bearing ability, making the pavement susceptible to premature rutting and cracking under traffic loads (Assaad, 2020).

2.6.1.3 Geometric design compliance

This sub-criterion evaluates whether the constructed road’s horizontal and vertical alignments, cross-slopes (camber/superelevation), and lane widths precisely match the approved geometric design. Non-compliance can compromise safety (e.g., insufficient sight distance on curves), affect ride comfort, and lead to drainage issues, even if the pavement structure itself is sound (Banerjee, 2020; Nicholas J. Garber & Lester A. Hoel, 2009).

2.6.2 Durability and longevity

A high-quality road is expected to be durable and have a long service life, withstanding anticipated traffic loads and environmental conditions. Joseph (2021) and Minde and Ghadge (2018) both allude to this, with the latter stating that quality serves as a critical tool for achieving durable and serviceable roads. This criterion often involves assessing the road's ability to resist cracking, rutting, potholes, and other forms of distress over time. Long-term performance data, including maintenance records, can be used to gauge durability.

2.6.2.1 Resistance to cracking and rutting

This measures the pavement's ability to resist common forms of structural distress such as fatigue cracking (often appearing as alligator cracking), transverse cracking, and rutting (permanent deformation in wheel paths). High resistance indicates good structural integrity, appropriate material selection, and effective construction, leading to a longer service life (FHWA, 2020).

2.6.2.2 Resistance to environmental degradation

This assesses how well the road withstands environmental factors like temperature fluctuations, moisture infiltration, freeze-thaw cycles, and UV radiation, which can cause raveling, stripping of asphalt, or material degradation over time. Effective drainage, proper material selection, and appropriate surface treatments are key to this resistance (World Bank, 2019).

2.6.2.3 Expected service life and lifecycle performance

This criterion evaluates whether the road is on track to meet or exceed its anticipated design life (e.g., 10, 15, or 20 years) before requiring major rehabilitation. It is a long-term indicator of initial quality and the effectiveness of maintenance strategies, reflecting the overall economic value of the asset over its lifespan (Osei-Kyei & Chan, 2021).

2.6.3 User satisfaction and safety

The ultimate beneficiaries of road infrastructure are the users, and their satisfaction is a crucial, though often overlooked, measure of quality. This includes factors ride comfort, smoothness, safety features (proper signage, clear markings, adequate lighting), and

accessibility. Noah et al. (2020) emphasizes high-quality road infrastructure, which inherently includes safety. Most authors mentioned in this study did not investigate into user satisfaction metrics, it's a critical component of assessing overall road quality performance.

2.6.3.1 Ride comfort and smoothness

This assesses the physical comfort experienced by road users, primarily influenced by the road's surface evenness and smoothness. High roughness, often quantified by the International Roughness Index (IRI), leads to discomfort, increased vehicle operating costs, and reduced perceived quality. A smooth ride is a direct indicator of good pavement surface quality (ASTM D6433, 2018 & World Bank, 2019).

2.6.3.2 Presence and quality of safety features

This evaluates the adequacy and condition of safety features such as proper signage (visibility, clarity, placement), clear road markings (lane lines, stop lines, pedestrian crossings), functional street lighting, and the presence and integrity of guardrails, barriers, and reflective studs (cat's eyes). These elements are critical for accident prevention, safe navigation, and overall user confidence (Noah et al., 2020).

2.6.3.3 Accessibility for all users

This criterion assesses the provision and quality of infrastructure for non-motorized users, including sidewalks (adequate width, good condition, continuity), clearly marked pedestrian crossings (with appropriate ramps), and dedicated bicycle lanes (where applicable and needed). It also specifically considers the accessibility features for persons with disabilities, such as well-designed and compliant curb ramps, ensuring inclusivity (Gamariel & David, 2021).

2.6.4 Environmental sustainability

With increasing global awareness of environmental impacts, the quality of road projects also encompasses their environmental footprint. This includes criteria such as the use of sustainable materials, minimization of environmental pollution during road construction, proper waste management, and impact on local ecosystems. This is a growing area in infrastructure quality assessment. Halder (2021) discusses the impact of urbanization on energy use and emissions, which broadly relates to the environmental considerations in infrastructure development.

2.6.4.1 Sustainable material use and resource efficiency

This assesses the extent to which environmentally friendly and locally sourced materials are utilized, including recycled aggregates, warm-mix asphalt, or other low-carbon alternatives, thereby minimizing the environmental impact of material extraction and production. It also considers resource efficiency in water and energy consumption during construction (Halder, 2021).

2.6.4.2 Pollution control during construction and operation

This evaluates the effectiveness of measures to minimize air pollution (dust, vehicle emissions), water pollution (runoff, sediment control), and noise pollution during both the construction and operational phases. Proper waste management and disposal practices are also critical to ensure compliance with environmental regulations (Banerjee, 2020).

2.6.4.3 Impact on local ecosystems and climate resilience

This criterion assesses the project's efforts to minimize disruption to local ecosystems, including protection of sensitive habitats, proper waste management, and rehabilitation of disturbed areas post-construction. It also considers the road's resilience to climate-related events, such as extreme rainfall, flooding, and temperature variations, which is particularly relevant in contexts like Kigali (World Bank, 2023).

2.6.5 Maintenance requirements and cost-effectiveness

A high-quality road should require minimal maintenance over its design life, leading to lower lifecycle costs. Conversely, a poorly constructed road will incur significant maintenance expenses, undermining its economic viability. This criterion links directly to the durability and longevity of the road and its initial quality.

2.6.5.1 Frequency of required maintenance

This assesses how often routine or periodic maintenance (e.g., patching, crack sealing, resurfacing) is needed. A high-quality road should inherently require less frequent and less extensive maintenance, indicating good initial construction quality and robust design. Conversely, frequent maintenance needs signal underlying quality deficiencies (Osei-Kyei & Chan, 2021).

2.6.5.2 Lifecycle cost analysis

This criterion involves evaluating the total cost of the road over its entire service life, including initial construction, routine maintenance, major rehabilitation, and eventual disposal. A high-quality road is expected to have a lower lifecycle cost due to reduced maintenance needs and extended service life, representing better value for money (Yescombe, 2020).

2.6.5.3 Maintenance accessibility and efficiency

This assesses how easily and efficiently maintenance activities can be performed. Factors include clear access to drainage structures, availability of space for maintenance crews, and the design of features that facilitate repair and upkeep. A design that simplifies future maintenance contributes significantly to long-term cost-effectiveness and sustained quality (World Bank, 2023).

2.7.Assessment of quality performance in road projects

Quality performance assessment in road construction refers to the systematic evaluation of whether the constructed road meets predefined technical, safety, and functional standards (Kerzner, 2022). This process ensures that road infrastructure delivers its intended serviceability, durability, and safety over its design life. Quality assessment spans the entire project life cycle from planning and design to construction and maintenance, and involves a combination of technical inspections, material testing, and performance monitoring (RTDA, 2022). Quality assessment in road construction involves both technical evaluation and stakeholder perception analysis, offering a comprehensive understanding of whether the delivered infrastructure meets intended performance standards (Athanasios & Dimitra, 2018)

2.7.1 Technical-based assessment methods

The technical dimension of road project quality is often evaluated through a range of standardized engineering tests and inspections. According to Assaad (2020), the following technical parameters are commonly assessed:

1. **Pavement structural integrity:** This involves checking layer thickness, compaction, and material composition to ensure durability under traffic loads.

2. **Surface condition:** Smoothness, rutting, potholes, and cracking are visual and mechanical indicators of pavement quality, measurable through tools such as the International Roughness Index (IRI) and pavement deflectometers.
3. **Drainage effectiveness:** Proper drainage systems are essential to road longevity. Evaluation includes inspecting side drains, culverts, and surface water management.
4. **Carriageway width and road geometry:** Compliance with geometric design standards, including alignment, lane width, and gradient, contributes to operational safety and user satisfaction (Banerjee, 2020).
5. **Safety features and road furniture:** The presence and quality of guardrails, signage, lighting, pedestrian crossings, and road markings are checked to ensure conformance with safety standards.

2.7.1.1 Pavement structural integrity

Pavement structural integrity refers to the ability of a pavement to support imposed traffic loads over time without excessive deformation, cracking, or failure. A pavement with high structural integrity ensures durability, riding comfort, and road safety, minimizing maintenance costs and extending the road's service life (Assaad, 2020).

The structural performance of a pavement is fundamentally dependent on the quality of its constituent materials, the thickness of each layer, the degree of compaction achieved during construction, and the effectiveness of its drainage design (Nicholas & Lester, 2009).

Table 2. 2: Key functions of pavement structural integrity

Function	**Explanation**
Load distribution	Distributes traffic loads from vehicles to the subgrade to avoid failure.
Crack resistance	Prevents structural cracking due to stress, fatigue, or temperature variation.
Moisture protection	Protects underlying layers from water infiltration, which causes weakening.
Durability under repeated loads	Maintains performance under repeated loading from heavy and light vehicles.
Support for surface integrity	Provides a strong foundation that prevents surface deformation or potholes.

Below is a figure illustrating the **layered structure of a typical flexible pavement** and how each layer contributes to structural integrity. Each layer plays a role in preventing pavement failures such as rutting, fatigue cracking, and deflection under dynamic loads.

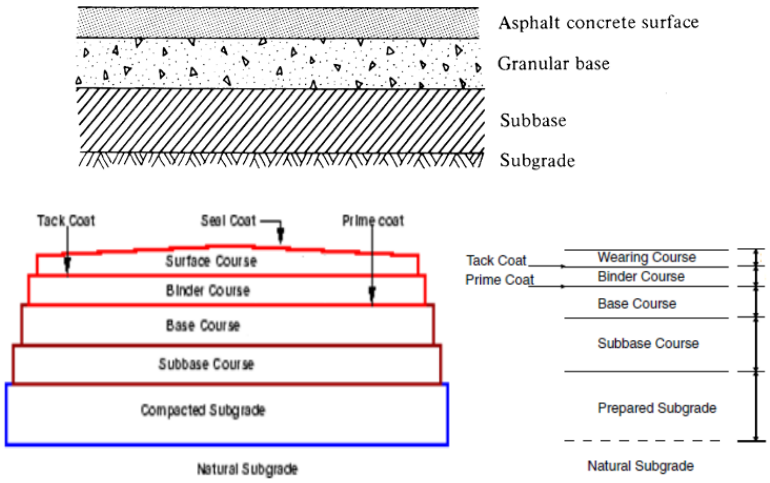

Figure 2. 1: Typical pavement layered structure

(Nicholas J. Garber& Lester A. Hoel, 2009)

Table 2. 3: Performance indicators for pavement structural integrity

Indicator	**Measurement technique**	**Purpose**
Pavement layer thickness	Core sampling / Ground Penetrating Radar (GPR)	Verify construction compliance and structural design.
California Bearing Ratio (CBR)	Penetration test on subgrade/base	Evaluate strength and load-bearing capacity.
Falling Weight Deflectometer (FWD)	Dynamic load deflection measurement	Assess in-situ structural capacity.
Pavement Condition Index (PCI)	Surface distress survey (0–100 scale)	Indirectly reflects subsurface structural performance.
Elastic Modulus	Lab test on pavement cores	Measures stiffness of materials.

Table 2. 4: Causes of loss of structural integrity

Factor	**Impact**
Inadequate compaction	Causes early settlement, rutting, and surface cracks.
Poor quality materials	Reduces load-bearing capacity of layers.
Water infiltration	Weakens base and subgrade, leads to potholes.
Overloading	Induces fatigue cracking and deformation.
Poor maintenance	Allows minor failures to evolve into full structural damage.

Table 2. 5: Visual representation: Failure due to poor integrity

Failure type	Visual description
Alligator Cracking	Interconnected cracks indicating fatigue in base/subgrade due to repetitive loading.
Rutting	Depressions in wheel paths due to deformation in subgrade or compaction failure.
Potholes	Cavities on the surface caused by water infiltration and base failure.

***Source**: FHWA (Federal Highway Administration). (2020).* Pavement Structural Design Manual. *U.S. Department of Transportation.*

Assessing and maintaining the structural integrity of pavements is essential for road durability, cost-effective maintenance, and user safety. Monitoring tools such as the Falling Weight Deflectometer (FWD) and CBR tests provide quantifiable insights into the pavement's ability to carry expected loads. In Rwanda, as elsewhere, ensuring structural integrity remains a top priority in road infrastructure projects especially in urban areas like Kigali with increasing vehicular demand.

2.7.1.2 Surface condition

The surface condition of a road refers to the physical state and appearance of the pavement layer exposed to traffic. It is a critical indicator of road quality as it directly affects ride comfort, vehicle operating costs, traffic safety, and long-term maintenance needs (Assaad, 2020). A deteriorated surface can lead to reduced serviceability, increased accident risk, and faster degradation of the road structure. Therefore, regular monitoring of surface condition is essential for maintenance planning, quality assurance, and overall road asset management (World Bank, 2019).

Common surface distresses

Surface condition is typically evaluated by identifying visible distresses that indicate functional or structural failures.

Table 2. 6: Common surface distresses and their causes

Surface distress	Description	Possible causes	Impact
Cracking	Longitudinal, transverse, or alligator cracks	Poor subgrade, aging, thermal stress	Water infiltration, reduced durability
Potholes	Bowl-shaped depressions with exposed base	Water damage, traffic load, aging	Safety hazard, vehicle damage
Rutting	Surface depression along wheel paths	Asphalt instability, compaction defects	Uneven ride, water pooling
Raveling	Loss of aggregate from surface	Binder aging, poor mix design	Surface erosion, slipperiness

Polishing	Smooth shiny surface due to traffic	Aggregate wear	Reduced skid resistance
Bleeding	Excess binder rising to surface	Over-asphalting, high temperatures	Slippery surface, poor texture

(Source: FHWA, 2020 and Assaad, 2020)

Surface condition rating systems

To standardize assessments, road agencies use rating systems to classify the severity of surface deterioration. One widely used method is the Pavement Condition Index (PCI), which provides a score between 0 (failed) and 100 (excellent) based on visual inspection. Below is a clear and well-structured table of the Pavement Condition Index (PCI) Rating Scale, which is commonly used to assess road surface condition based on visual inspections.

Table 2. 7: Pavement Condition Index (PCI) rating scale

PCI Score Range	**Condition Category**	**Description**
85 – 100	Excellent	Pavement is newly constructed or in near-perfect condition; no visible distress.
70 – 84	Very Good	Minor surface defects; no structural problems.
55 – 69	Good	Slight to moderate distresses (e.g., light cracking); still functionally sound.
40 – 54	Fair	Moderate surface defects; potential early signs of structural deterioration.
25 – 39	Poor	Significant distresses present; pavement needs rehabilitation.
10 – 24	Very Poor	Major structural failures; ride quality severely compromised.
0 – 9	Failed	Completely failed pavement; reconstruction required.

Notes:

1. PCI is a numerical index between **0 (worst)** and **100 (best)**.
2. PCI is typically calculated after assessing types, severities, and quantities of surface distresses (e.g., cracking, potholes, rutting).
3. It supports maintenance decision-making and budget prioritization.

(Source: ASTM D6433, 2018)

Field inspectors assess surface distresses and input their severity and extent into a PCI formula to compute an overall condition score.

Functional assessment metrics

In addition to visual inspection, **several functional indicators** are used to quantify surface condition:

Table 2. 8: Functional surface condition metrics

Indicator	Unit	Purpose
International Roughness Index (IRI)	m/km	Measures road smoothness using accelerometers or laser profilers
Skid Resistance (SCRIM value)	–	Indicates surface friction for vehicle safety
Surface Texture Depth	mm	Evaluates macro-texture for water drainage and skid resistance
Deflection (using FWD)	mm	Indicates structural support beneath the surface

(Source: World Bank, 2019)

Table 2. 9: IRI Threshold for Rwandan Pavement Condition

Type of Road	IRI Value	Road Condition
Paved Road	IRI <4 m/Km	Good Condition
	IRI >4m/km	Bad Condition
Unpaved	IRI <8 m/Km	Good Condition
	IRI > 8 m/km	Bad Condition

It is recommended that the following IRI thresholds be adopted similar to categories used in the US:

1) very good,
2) good,
3) fair,
4) poor,
5) and very poor

2.7.1.3 Drainage effectiveness

Drainage effectiveness is a critical component in evaluating road quality, as it directly influences the structural integrity, longevity, and safety of road infrastructure. Proper drainage ensures that surface water and groundwater are efficiently diverted away from the pavement structure, minimizing water infiltration that could otherwise weaken subgrade materials and cause premature pavement failure. Poor drainage is one of the leading causes of road deterioration, contributing to issues such as potholes, rutting, erosion, and cracking (Austroads, 202 & RTDA, 2022).

Effective drainage systems typically include a combination of components:

1. **Surface drains:** Such as side ditches, curbs, and gutters, designed to collect and convey runoff from the road surface and adjacent areas.
2. **Subsurface drains:** Including perforated pipes (e.g., underdrains, French drains) and granular drainage layers, designed to intercept and remove groundwater or water that has infiltrated the pavement structure.
3. **Cross-drainage structures:** Such as culverts and bridges, designed to allow water to flow across or under the road embankment without causing damage.
4. **Erosion control measures:** Techniques to prevent soil erosion around drainage exits and along embankments.

Their performance is assessed based on their capacity to manage runoff during peak rainfall events, the adequacy of the road's cross-slope and longitudinal gradient for shedding water, and the design life and maintenance condition of drainage components. Inadequate or poorly maintained drainage can lead to water ponding on the road surface, reduced skid resistance, and unsafe driving conditions, especially during heavy rains, increasing the risk of accidents (World Bank, 2023). In road quality assessments, drainage inspections involve checking outlet functionality, ensuring proper slope alignment, identifying blockages or sediment accumulation, and evaluating the presence of erosion around drainage exits. These inspections are often combined with environmental compliance audits to ensure that stormwater discharge does not adversely affect surrounding ecosystems.

2.7.1.4 Carriageway width and road geometry

Among the key physical and design attributes that influence road quality performance, carriageway width and road geometry are crucial for ensuring operational efficiency, road safety, structural durability, and user satisfaction. These features directly affect the traffic-carrying capacity, ride comfort, accident risk, and overall service level of a road network (Banerjee, 2020).

Evaluating the compliance of these elements with design standards forms an integral part of road quality assessments during both construction and operational phases.

2.7.1.4.1 Carriageway Width

The carriageway width refers to the total width of the paved portion of the road intended for vehicular movement. It may consist of one or more lanes and typically does not include shoulders or sidewalks. The required width depends on the road classification, projected traffic volume, design speed, and the presence of non-motorized traffic.

Insufficient or non-standard carriageway width can lead to several adverse outcomes:

1. **Vehicle encroachment:** Vehicles may encroach into opposing lanes, increasing the risk of head-on collisions.
2. **Traffic congestion:** Reduced capacity leads to bottlenecks and slower traffic flow.
3. **Side shoulder failures:** Increased use of shoulders for maneuvering can lead to their rapid deterioration.
4. **Safety risks:** Particularly for larger vehicles or in areas with mixed traffic, narrow widths can create significant safety hazards.

According to the Rwandan Road Design Manual (RTDA, 2021), carriageway width must meet the specifications outlined by functional road classes.

Table 2. 10: Standard carriageway widths by road type in Rwanda

Road Type	**Number of Lanes**	**Standard Width (m)**	**Remarks**
Urban primary arterial	4	14.0 (3.5 m/lane)	May include median or turning lane
Urban secondary road	2	7.0	Standard 2-lane road
Rural collector road	1–2	6.0–7.0	Based on expected volume and terrain
Access roads	1	3.5–5.0	Narrow carriageway for low-traffic conditions

(Source: RTDA, 2021)

2.7.1.4.2 Road Geometry

Road geometry refers to the alignment and shape of the road in both horizontal and vertical dimensions. It encompasses the horizontal curvature, vertical grades, sight distances, and cross slopes (superelevation). Good geometry is essential for safe, comfortable, and efficient vehicular movement (AASHTO, 2018).

Key components of road geometry include:

1. **Horizontal Alignment:** This describes the curvature of the road in plan view. Sharp or poorly designed curves (e.g., inadequate radius) can reduce driver visibility, increase lateral forces on vehicles, and significantly increase crash risk.

2. **Vertical Alignment:** This defines the road profile in elevation, including crests (summits) and sags (valleys). Poor gradient design can affect vehicle braking performance, acceleration capabilities, and the effectiveness of water drainage.
3. **Cross Slope (Camber):** This is the sideways slope of the pavement surface, typically 2% for paved roads, designed to drain water efficiently from the carriageway, preventing ponding and enhancing skid resistance.
4. **Superelevation:** This is the banking of a horizontal curve, where the outer edge of the pavement is raised relative to the inner edge. It is crucial for offsetting centrifugal forces on vehicles navigating sharp curves, ensuring stability and safety.

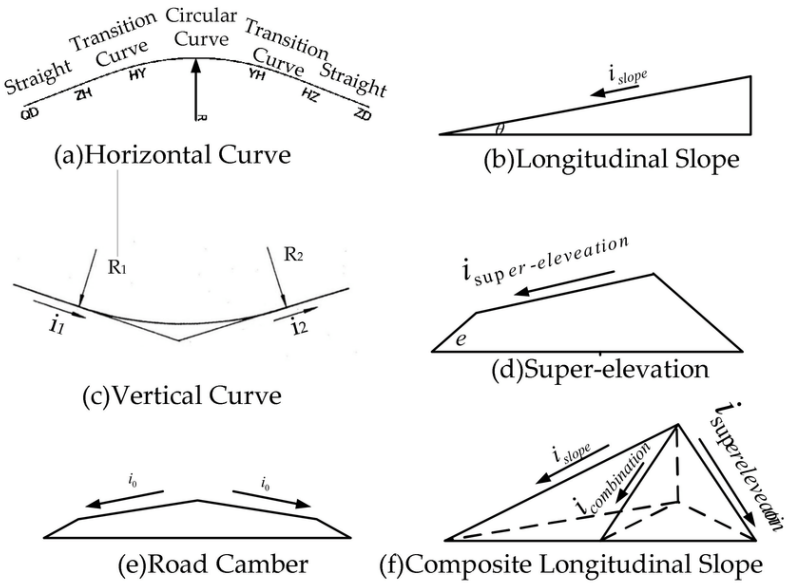

Figure 2. 2: Elements of road geometry

The functional importance of proper road geometry in road quality is multifaceted:

1. **Enhances drainage and pavement longevity:** Correct cross slopes and longitudinal gradients facilitate rapid water runoff, protecting the pavement from water damage.
2. **Ensures driver visibility and vehicle control**: Well-designed curves and vertical alignments provide adequate sight distances, allowing drivers to react safely to changing conditions.
3. **Reduces accident rates:** Proper geometry minimizes hazardous conditions, especially at intersections and curves, contributing directly to road safety.

Table 2. 11: Typical geometric design parameters (urban roads)

Parameter	Standard value	Acceptable tolerance	Impact on quality
Horizontal curve radius	≥ 60–300 m (based on speed)	±10%	Affects turning safety and sight distance
Longitudinal gradient	0.5% – 7%	±1%	Impacts water flow and vehicle traction
Cross slope (camber)	2%	±0.5%	Controls surface drainage and skid resistance
Superelevation	2%–6%	Varies by design speed	Required for sharp curves

(Source: AASHTO, 2018; RTDA, 2021)

Table 2. 12: Key performance metrics for road geometry

Indicator	Function	Ideal Value
Actual vs. Design Width	Check construction compliance	100% match preferred
Sight distance compliance	Ensure driver visibility at curves/hills	≥ Stopping Distance
Gradient regularity	Ensure smooth vertical alignment	≤ 7%
Water drainage path	Avoid standing water	Slopes ≥ 2% required

(Source: AASHTO, 2018; RTDA, 2021)

Carriageway width and road geometry are vital design and construction components that must comply with national and international standards. Their proper implementation ensures safety, functional efficiency, and durability of road infrastructure. Assessing these features during and after construction is essential in determining the overall quality performance of road projects.

2.7.1.5 Safety features and road furniture

Safety features and road furniture are critical components in road design and construction that enhance the safety, comfort, and efficiency of road use. While often considered secondary to pavement quality or drainage systems, these elements directly impact user experience, accident reduction, and overall traffic management.

Key safety features and road furniture include:

1. **Guardrails and crash barriers**: These are installed along sharp curves, bridges, steep embankments, or medians to prevent vehicles from leaving the roadway or entering opposing lanes (FHWA, 2020).
2. **Pedestrian crossings (zebra crossings**): These improve pedestrian safety at intersections and high-traffic zones by alerting drivers and giving right-of-way to pedestrians.
3. **Speed bumps and rumble strips**: These serve as traffic calming measures, particularly in residential areas or near schools, to reduce vehicle speeds and enhance safety.
1. **Traffic signs and signals:** Regulatory, warning, and guide signs help to control traffic flow and inform road users of potential hazards. These also include speed limits, directional signs, stop signs, and warnings that guide driver behavior.
4. **Road lighting:** Streetlights ensure visibility at night, reducing accident rates and improving pedestrian safety.
5. **Road markings:** Lane lines, stop lines, and edge lines provide visual guidance and improve lane discipline.
6. **Crash cushions and impact attenuators:** Devices placed in high-risk collision zones to absorb impact energy and reduce injury.
7. **Bollards and delineator posts:** Used to channel traffic or protect pedestrian zones, especially in urban or commercial areas.
8. **Street nameplates and directional signs:** Essential for navigation and wayfinding within urban road networks.
9. **Benches, bins, and shelters (in urban settings):** These enhance roadside user comfort particularly in pedestrian or bus stop zones.
10. **Reflective studs (cat's eyes):** Embedded on lane lines or edges to improve visibility, especially during poor lighting or weather conditions.

2.7.2 Field observations and visual inspections

Direct field observations and visual inspections by trained professionals are essential for assessing visible defects, road construction practices, and overall conformity to design. The proposed research methodology includes field observations, validating this as a crucial assessment method. This method allows for a qualitative assessment of workmanship, adherence to safety standards, and identification of surface defects that might not be captured by instrumental measurements. These inspections are typically conducted during

construction, post-construction, and periodically during operation and maintenance phases (RTDA Report, 2023)

2.7.3 Stakeholder feedback and surveys

Gathering feedback from various stakeholders, including direct road users, contractors, consulting engineers, and government officials, provides invaluable insights into perceived quality and operational challenges that might not be evident through purely technical assessments. The proposed methodology's use of interviews and questionnaires for this purpose aligns with established practices (Gamariel & David, 2021). This qualitative and perception-based data can uncover critical issues related to ride comfort, safety concerns from a user's perspective, the effectiveness of project management processes, and areas for improvement that quantitative technical data might miss. Gamariel and David (2021) specifically also highlighted the historical lack of comprehensive assessment of quality performance metrics, including user satisfaction, emphasizing the critical need for integrating stakeholder feedback to obtain a holistic view of road quality performance. User satisfaction surveys, for instance, can reveal how well the road meets its functional purpose from the perspective of those who use it daily, providing a human-centered dimension to quality assessment.

2.7.4 Case studies and comparative analysis

In-depth case studies of selected road projects allow for a comprehensive assessment of quality performance within specific contexts, providing rich, detailed insights that complement broader survey data. This research design's use of case studies in Gasabo, Kicukiro, and Nyarugenge districts aligns with this methodology. Case studies enable a deep dive into the unique challenges, successes, and influencing factors pertinent to individual projects (Yin, 2018). Furthermore, a comparative analysis of these case studies can reveal common challenges across projects, identify best practices that could be replicated, and highlight the influence of varying geographical, environmental, or project-specific factors on quality outcomes. This comparative approach facilitates the identification of patterns and anomalies in quality performance, offering valuable lessons for future road infrastructure development (Banerjee, 2020).

Assessing the quality performance of road projects is a multifaceted process that combines rigorous engineering inspections, objective technical measurements, valuable stakeholder feedback, and long-term performance monitoring. It is vital not only for ensuring the

structural soundness and usability of roads but also for promoting accountability, optimizing maintenance costs, enhancing public trust, and guiding future improvements in construction practices and policy. The use of integrated, data-driven approaches provides a more holistic view of road performance and helps guide future improvements in construction practices and policy.

2.8.Effective strategies for improving the quality performance of road projects

Improving road quality is a continuous endeavor that requires strategic interventions across multiple stakeholders.

2.8.1 Robust quality assurance and control systems

Implementing and enforcing stringent quality assurance (QA) and quality control (QC) systems throughout the project lifecycle is paramount. Minde and Ghadge (2018) directly link improving road quality to implementing robust quality management practices. This includes comprehensive material testing, regular on-site inspections, adherence to construction methodologies, and independent quality audits. The concerns raised by the Office of the Auditor General (2022-2023) about unresolved disputes between RTDA and RSB and untested roads underscore the critical need for effective QA/QC.

2.8.1.1 Comprehensive material testing and verification

This involves systematic testing of all construction materials (aggregates, asphalt, cement, steel) at various stages from source to delivery and placement to ensure they meet specified engineering properties and national standards. Regular verification prevents the use of substandard materials, which is a common cause of premature road failure (RTDA, 2022).

2.8.1.2 Regular on-site inspections and compliance checks

Consistent and documented on-site inspections by qualified personnel are crucial to ensure that construction methodologies, compaction efforts, layering sequences, and overall workmanship adhere strictly to design specifications and approved standards. These checks provide real-time feedback and allow for immediate correction of deviations (Otim & Alinaitwe, 2013).

2.8.1.3 Independent quality audits

Conducting independent quality audits, ideally by third-party entities, provides an unbiased assessment of project quality and compliance. The concerns raised by the Office of the Auditor General in Rwanda (2022-2023) about unresolved disputes between RTDA and RSB and the issue of untested roads underscore the critical need for effective and independent QA/QC mechanisms to ensure accountability and verify quality objectively (Gamariel & David, 2021).

2.8.2 Enhanced project planning and design

Investing in thorough geotechnical investigations, detailed engineering designs, and comprehensive project planning can mitigate many quality issues before road construction begins. Early identification and resolution of potential design flaws and site-specific challenges contribute significantly to overall road project quality. This aligns with the importance of design mentioned by Oyemogun, Fadeyi, and Aina (2020).

2.8.2.1 Advanced geotechnical and hydrological surveys

Conducting in-depth geotechnical investigations to fully understand soil conditions, and comprehensive hydrological surveys to assess water flow patterns and drainage requirements, can prevent unforeseen challenges during construction and operation. Early identification and resolution of potential design flaws and site-specific challenges contribute significantly to overall road project quality and reduce future maintenance burdens (Banerjee, 2020; Hendrickson, 2020).

2.8.2.2 Optimized geometric and pavement design

Ensuring that geometric designs are optimized for safety, traffic flow, and future growth, and that pavement designs are precisely tailored to anticipated traffic loads and environmental conditions, is crucial. This aligns with the importance of robust design specifications mentioned by Oyemogun, Fadeyi, and Aina (2020), ensuring the road is fit for purpose and durable.

2.8.2.3 Integrated quality management planning

Developing a detailed quality management plan during the planning phase that outlines specific quality objectives, responsibilities, procedures, and metrics for each project stage.

This proactive planning ensures that quality is not an afterthought but an integral part of project execution (Kerzner, 2022).

2.8.3 Skilled workforce and capacity building

The availability of a skilled workforce, from engineers and project managers to construction laborers, is crucial for quality execution. Training and capacity-building programs can enhance the technical capabilities of personnel involved in road construction. This addresses aspects of workmanship and effective project execution (Mutamuliza Eularie & Vishwanatha, 2016).

2.8.3.1 Professional training and development

Implementing continuous training and professional development programs can enhance the technical capabilities, knowledge of best practices, and awareness of quality standards among all personnel involved in road construction. This addresses aspects of workmanship and effective project execution, as highlighted by Mutamuliza Eularie and Vishwanatha (2016).

2.8.3.2 Certification and licensing

Establishing and enforcing robust certification and licensing requirements for key technical roles (e.g., specialized equipment operators, quality control technicians, site engineers) ensures a baseline level of competence and accountability within the workforce.

2.8.3.3 Retention of experienced personnel

Strategies to retain experienced and skilled personnel within road agencies and contracting firms are vital, as their accumulated knowledge and expertise are invaluable for maintaining consistent quality and mentoring new talent.

2.8.4 Effective contract management and procurement

Well-defined contracts that clearly outline quality requirements, performance specifications, and accountability mechanisms are essential. Fair and transparent procurement processes that prioritize quality alongside cost can prevent the selection of contractors who might compromise quality for lower bids. Byaruhanga and Basheka (2017)

discuss contractor monitoring, highlighting the importance of managing contractors effectively to ensure performance.

2.8.4.1 Clear contractual quality clauses

Ensuring that contracts include explicit and measurable quality clauses, performance indicators, and penalties for non-compliance. This creates a legal framework that holds contractors accountable for delivering specified quality levels (World Bank, 2023).

2.8.4.2 Transparent and merit-based procurement

Implementing transparent and merit-based procurement processes that emphasize technical competence, past performance, and quality proposals, rather than solely focusing on the lowest bid. This helps in selecting qualified contractors who are committed to quality (RTDA, 2022).

2.8.4.3 Robust contractor monitoring and performance evaluation

Establishing systematic mechanisms for monitoring contractor performance throughout the project lifecycle, including regular assessments against key performance indicators (KPIs) related to quality. Byaruhanga and Basheka (2017) discuss contractor monitoring, highlighting the importance of actively managing contractors to ensure adherence to quality and performance standards.

2.8.5 Adoption of advanced technologies and innovation

Utilizing modern road construction technologies, such as advanced pavement materials, intelligent compaction equipment, and Geographic Information Systems (GIS) for monitoring, can significantly enhance road quality and efficiency. Byiringiro (2021) proposed Lean Design and Construction (LDC), an innovative approach, to overcome project challenges. Embracing such innovations can lead to more durable and sustainable road infrastructure.

2.8.5.1 Use of advanced pavement materials

Adopting innovative pavement materials such as polymer-modified asphalt, perpetual pavements, or self-healing concrete can lead to significantly more durable and resilient roads that require less frequent maintenance (FHWA, 2020).

2.8.5.2 Intelligent compaction and automated equipment

Implementing intelligent compaction (IC) equipment with GPS and real-time feedback systems ensures optimal compaction density and uniformity, directly impacting pavement longevity. Automated grading and paving equipment can enhance precision and reduce human error (Byiringiro, 2021).

2.8.5.3 Digital planning and monitoring tools

Leveraging digital tools like Building Information Modeling (BIM) for design and coordination, Geographic Information Systems (GIS) for asset management and condition monitoring, and drones for site surveys and progress tracking can improve planning accuracy, oversight, and data-driven decision-making (Halder, 2021). Byiringiro (2021) proposed Lean Design and Construction (LDC), an innovative approach, to overcome project challenges, often facilitated by digital tools.

2.8.6 Strong regulatory and legal frameworks

Clear, enforceable regulations and strong legal frameworks are vital for holding stakeholders accountable for quality standards. Noah et al. (2020) explicitly state that robust legal frameworks are crucial for high-quality road infrastructure. The issues highlighted by the Office of the Auditor General regarding disputes and untested roads underscore the need for consistent enforcement of quality standards and regulations.

2.8.6.1 Clear and updated technical standards

Ensuring that national road design and construction standards (RTDA manuals) are comprehensive, clear, and regularly updated to reflect best practices and new technologies. These standards provide the fundamental benchmarks for quality (RTDA, 2022).

2.8.6.2 Effective enforcement mechanisms

Establishing robust mechanisms for the enforcement of these standards and regulations, including regular inspections, independent audits, and appropriate penalties for non-compliance. Noah et al. (2020) explicitly state that robust legal frameworks are crucial for high-quality road infrastructure. The issues highlighted by the Office of the Auditor General (2022-2023) regarding disputes and untested roads underscore the critical need for

consistent and impartial enforcement of quality standards and regulations to deter substandard practices.

2.8.6.3 Legal accountability for defects

Implementing legal provisions that hold contractors and consultants accountable for defects or failures resulting from poor quality work for a defined warranty period, thereby incentivizing higher initial quality.

This research aims to providing an integrated and context-specific investigation into the quality performance of road projects in Kigali, Rwanda, developing effective methods for improvement based on a comprehensive assessment of influencing factors and measurement criteria.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1.Introduction

This chapter outlines the methodology employed in this study was designed, detailing the research design, study area, population, sampling techniques, data collection instruments, and methods of data analysis. It shows approach used to answer the research questions or test the hypotheses, allow other researchers to replicate the study or assess the validity and reliability of the findings and show that the research process is systematic, rigorous, and appropriate for the objectives of the study.

3.2.Research design

According to Robson and McCartan (2016) research design is a structured plan to conduct a study, outlining how to collect, analyze, and interpret data. It serves as a blueprint for the research process, ensuring that the study addresses the research questions effectively and systematically

The study has adopted descriptive research design because it enabled the researcher to describe and assess the current practices, perceptions, and challenges in the quality performance of road construction projects without altering existing conditions. This was appropriate as the goal was to collect factual data from a specific population to present an accurate picture of the status of selected road projects regarding to their quality performance.

This study employed a mixed-methods approach, combining both quantitative data from structured questionnaires and qualitative data from field observations and document reviews. This approach allowed for a comprehensive analysis of road quality performance from both statistical and experiential perspectives. Quantitative data was gathered through structured questionnaires administered to road sector professionals, including those from the Rwanda Transport Development Agency (RTDA), Kigali City, and selected road contractors. This provided measurable insights into the key performance factors of road projects. Qualitative data was collected through field observations and the review of secondary documents, allowing for a deeper understanding of on-site practices, project management processes, and quality control mechanisms. Therefore, the qualitative and quantitative data collected were used to evaluate the performance of road projects and identify recurring quality issues.

The selected research design aligns with the study's objectives by enabling a systematic analysis of quality-related factors, measurement criteria, and performance outcomes. It also

facilitates the identification of practical recommendations for improving road projects quality in Kigali.

3.3.Study area description

This study aimed to investigate the quality performance of selected road projects within three districts of Kigali: Gasabo, Nyarugenge, and Kicukiro. In each district one road project constructed between 2020 and 2024 was selected as case study.

This study has focused on Kigali City, Rwanda's political and economic hub, specifically the districts of Gasabo, Nyarugenge, and Kicukiro. Those roads were:

1. ALU Campus–Musave Cell Access Road (1.629 km) in Gasabo district
2. Rugenge–Muhima Hospital–Nyabugogo Access Road (3.21 km) in Nyarugenge district
3. Kabeza–Airport–Itunda–Busanza Road(2.71Km) in Kicukiro district, was also considered as a fourth case for comparative purposes.
4. Sonatubes–Gahanga–Akagera Road (13.8 km) in Kicukiro district

These projects were chosen based on their relevance to urban and peri-urban mobility, visibility, and variation in road length, usage, and quality indicators.

3.4.Population and sampling strategy

Determining an appropriate sampling strategy and sample size is essential for ensuring that the study findings are both reliable and applicable to the target population. This study employed a mixed sampling strategy to accommodate the different categories of respondents involved in road construction projects in Kigali.

3.4.1. Target population

The target population for this study comprised key stakeholders directly involved in the planning, execution, supervision, and usage of road infrastructure within Kigali City. This diversity was essential for capturing a holistic understanding of road project quality performance from both government institutions (Kigali City office and RTDA) and user perspectives.

Specifically, the population was categorized into two main groups:

1. **Technical professionals:** This group included individuals with direct technical knowledge and decision-making authority in road infrastructure. The total population for this group was identified as **73 individuals**, distributed as follows:
    - Technical professionals from Kigali City: 25 individuals.
    - Technical professionals from RTDA: 45 individuals.
    - Contractors (Representatives from companies involved in the selected road projects): 3 individuals.
2. **Road users:** This group comprised individuals who regularly interact with the selected road projects, providing insights into real-world experience regarding road conditions, usability, and safety.

The **total target population for the study was 113 individuals** (73 Technical professionals + 40 Road users).

Table 3. 1: Targeted population of the study

Category of targeted respondents	**Description**	**Population (N)**
Kigali City/district Staff	Technical professionals for the road project from Kigali City (Road engineers, project managers)	25
Rwanda Transport Development Agency (RTDA)	Technical professionals for the road project from RTDA (Road engineers, project managers)	45
Contractors	Representatives from road construction companies involved in the selected road projects.	3
Subtotal population	Only technical professionals	**73**
Road users (Population=Sample)	Road users randomly sampled from four selected road projects	**40**
Total target population	73 technical professionals and 40 road users	**113**

3.4.2. Sampling techniques

To ensure comprehensive and representative data collection, the study employed a combination of non-probability and probability sampling techniques:

3.4.2.1. Non-probability sampling

Purposive sampling was applied for the selection of **technical professionals** and for gathering qualitative insights non-probability sampling was applied for qualitative aspects of the study. According to Creswell (2014), this approach allows for the selection of participants based on specific characteristics rather than randomization. Purposive sampling was used to identify individuals with relevant expertise, including engineers, project managers, supervisors, procurement officers, and monitoring and evaluation specialists affiliated with RTDA, Kigali City, and construction firms responsible for the selected road projects.

Patton (2015) in qualitative research & evaluation methods defines purposive sampling as a non-probabilistic technique where participants are selected based on specific characteristics or criteria relevant to the research question and allows researchers to focus on individuals or groups who have specific knowledge or experiences that are critical for the study.

3.4.2.2. Probability sampling

For the selection of **road users**, a stratified random sampling approach was employed. Groves et al. (2011) define probability sampling as a sampling technique in which every unit in the population has a known, non-zero probability of being selected. This is fundamental for making statistical inferences about a population, for this study the stratified sampling was used where the population divided into subgroups (strata) based on characteristics like age or location, and samples were drawn from each stratum. This stratified sampling guarantees that all important categories (e.g., gender, age, district) are proportionally or equally represented in the sample, reduces variability within each subgroup (stratum), improving statistical precision and reducing sampling error and allows researchers to either maintain natural proportions or oversample smaller groups for better analysis

In this method, the population was divided into subgroups (strata) based on characteristics relevant to road usage. For road users, stratification was based on:

1. **Road segment:** Ensuring representation from each of the four selected road projects.
2. **Transport mode:** Ensuring balanced representation of diverse transport modes (public transport, private car, motorcycle, bicycle, and pedestrian).

This stratified approach guaranteed that all important categories of road users were proportionally or equally represented in the sample, reducing variability within each subgroup and improving statistical precision. This allowed for comparative analysis across road segments and user types, providing a balanced representation of end-user perspectives.

3.4.3. Sample size determination

To ensure that the findings of this study are both statistically valid and practically feasible, the sample size was determined using the Yamane (1967) formula for the technical professionals, and a fixed number for road users to ensure balanced representation across the case studies.

The Yamane (1967) formula for sample size calculation is:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = Sample size

N= Population size

e = Level of precision (margin of error), the margin error of 0.05 for 95% confidence level was used for this study.

1. **Calculation of sample size for targeted technical professionals:**
   - Population (N) = 73
   - Margin of error (e) = 0.05

The sample size(n) for technical professionals = $\frac{N}{1+N(e)2} = \frac{73}{1+73(0.05)2} = 61.733 \approx$ **62** (sample size for technical professionals was approximately **62).**

Thus, the calculated sample size for technical professionals was approximately 62. Out of this calculated sample size, a total of **54 technical professionals ultimately participated** in the study.

2. **Sample size for road users:** For road users, a specific sample of **40 individuals** was targeted to ensure a diverse yet balanced representation across the four selected road projects and different transport modes. This distribution was as follows:

Table 3. 2: Distribution of Road users per each road

Road project name	Public transport	Private car	Motorcycle	Bicycle	Pedestrian	Total
ALU Campus–Musave Cell road (Gasabo)	2	2	2	2	2	10
Rugenge–Muhima hospital–Nyabugogo access road (Nyarugenge)	2	2	2	2	2	10
Sonatubes–Gahanga–Akagera road (Kicukiro)	2	2	2	2	2	10
Kabeza–Airport–Itunda–Busanza Road (Kicukiro)	2	2	2	2	2	10
Total	**8**	**8**	**8**	**8**	**8**	**40**

This stratified approach ensured equal representation (2 respondents per category per road) and provided insights into the road quality experiences of both motorized and non-motorized users across the specific case studies.

Therefore, the total targeted sample size of the study was 102, among them only **94 respondents participated (**comprising **54 technical professionals** and **40 road users)**. This rigorous approach ensured that the selected sample accurately reflects the broader population while also enabling focused insight into quality performance issues in urban road projects.

3.5.Sources of data

This study relied on both primary and secondary data sources to ensure comprehensive and triangulated insights.

1. **Primary data** were obtained directly from respondents through structured questionnaires, interviews and field observations. These sources provided current, firsthand insights into road quality, project performance, and user experience.
2. **Secondary data** were collected through desk review of project documents such as contracts, technical specifications, design reports, monitoring reports, and quality control documentation. These provided critical contextual and background information to validate and enrich the primary data. Combining these two sources enabled the study to bridge perceptual data with factual, documented evidence, enhancing both reliability and interpretability.

3.6.Research instruments

Research instruments are the tools that researchers use to collect, measure, and analyze data relevant to their study objectives. Creswell (2014) defines research instruments as structured tools such as questionnaires, checklists, and interview guides used to obtain valid and reliable data from research participants. The proper selection of instruments is essential for ensuring the accuracy, reliability, and relevance of the data collected. In this study, a combination of primary and secondary data collection instruments was used to gather both quantitative and qualitative data necessary for assessing the quality performance of road projects in Kigali.

3.6.1. Structured questionnaire

A structured questionnaire was the primary tool for collecting quantitative data, this questionnaire was developed based on the research objectives and the factors identified from the literature review to obtain respondents' perceptions and experiences regarding road quality performance. The questionnaire was focusing on the following;

1. Demographic information: Captured participants' background, such as age, gender, qualification, years of experience, district of work, and institutional affiliation.

2. Project background: Focused on the specific road project, contractor involved, and implementation context.

3. Factors affecting road quality: Included Likert-scale statements assessing the extent to which various technical, managerial, financial, and environmental factors influence road performance.

4. Road quality measurement: Assessed perceptions of quality dimensions such as durability, surface condition, drainage, safety features, and maintenance practices.

Responses were collected using SurveyCTO, a digital survey platform, ensuring real-time data entry and accuracy. Where necessary, paper-based forms were used and later digitized. The use of structured, closed-ended questions allowed for efficient quantitative analysis while open-ended items gave respondents the opportunity to elaborate on key points

3.6.2. Field assessment form and road project documents review

The field assessment form was used to objectively assess the physical condition of selected road projects in Kigali and interviewing road users in line with the road quality performance. That assessment form was designed to ensure consistency in data collection during selected road project assessment and it provided a practical assessment of actual road quality, validating the responses gathered from the questionnaire. To continue supplementing primary data, other secondary data were collected through a road project documents/reports review by focusing on road project design specifications and contracts and timeline for the road project completion.

3.6.3. Reliability and validity of research instrument

To ensure reliability, instruments were piloted and refined to maintain consistency across respondents. Validity was ensured through triangulation of multiple data sources, enhancing the credibility of the findings. As noted by Patton (2015), triangulation strengthens the interpretability and accuracy of research by cross-verifying data.

The consistency and reliability of the collected data specifically for reliability of factors influencing road quality performance, a Cronbach's Alpha reliability test was performed on the grouped items associated with each project management phase. This statistical measure assesses the internal consistency of items within a factor group, indicating how closely related the items are when measuring a particular construct.

Table 3. 3: Cronbach's Alpha reliability test for road project phases

Factor group	**Cronbach's Alpha**	**Interpretation**
Design/planning phase	0.872	Good internal consistency
Procurement phase	0.842	Good internal consistency
Execution/construction phase	0.890	Very good internal consistency
Monitoring and control phase	0.813	Good internal consistency
Project closure phase	0.796	Acceptable to good internal consistency

The Cronbach's Alpha coefficients for all the five project phases range from 0.796 to 0.890, which indicates a high level of internal consistency across the questionnaire items related to quality performance. Specifically:

1. The Execution/construction phase yielded the highest reliability ($\alpha = 0.890$), suggesting that responses to items in this category were very consistent and strongly correlated.
2. The Design/planning and procurement phases also demonstrated strong internal reliability ($\alpha = 0.872$ and $\alpha = 0.842$, respectively), confirming that the items effectively captured the key aspects of quality performance during these stages.
3. The Monitoring and control phase showed good reliability ($\alpha = 0.813$), while the project closure phase ($\alpha = 0.796$) showed slightly lower but still acceptable internal consistency.

These results affirm that the survey instrument used in the study is statistically reliable for measuring the factors influencing the quality performance of road projects across the different project lifecycle phases in Kigali.

3.7.Data collection methods

Data collection methods refer to the systematic processes through which researchers gather relevant information from primary and secondary sources to answer the research questions. Creswell (2014) defines data collection as the series of interrelated activities used to gather information for answering a research problem. Proper data collection methods ensure that the gathered data is reliable, valid, and relevant to the study objectives. The choice of data collection methods depends on the research design, the nature of the inquiry, and the types of data required. Given the mixed-methods approach of this study, both quantitative and qualitative data collection techniques were employed to ensure comprehensive coverage of road quality performance in Kigali. This included the use of structured questionnaires, field assessment forms, key informant interviews, and document reviews. The combination of these methods allowed for triangulation of data sources, enhanced validity, and a deeper understanding of both numerical patterns and contextual insights related to road construction practices.

3.8.Method of data analysis and presentation

Data analysis refers to the systematic process of organizing, transforming, and interpreting collected data to draw meaningful conclusions. According to Creswell (2014), data analysis is the process of reducing accumulated data into a manageable size, developing summaries, identifying patterns, and applying statistical techniques to derive meaningful insights. Effective data analysis helps to answer the research questions and achieve the study objectives.

This study applied both quantitative and qualitative analysis techniques, aligning with its descriptive research design and mixed-methods approach. The results were then systematically presented using visual and descriptive tools for clarity.

This study utilized a combination of using both Statistical Package for the Social Science (SPSS) and Microsoft Excel: descriptive statistics such as frequencies to identify trends and relationships among variables.

Meanwhile, qualitative data derived from field observations, interviews, and document reviews were analyzed through thematic content analysis, allowing for the identification of key patterns, themes, and insights. The results were then presented using tables, and narrative summaries to ensure clarity, precision, and ease of interpretation for both technical and non-technical audiences.

The study employed both quantitative and qualitative data analysis techniques in line with its mixed-methods design:

1. Quantitative analysis: Data from structured questionnaires were analyzed using SPSS and Microsoft Excel. Descriptive statistics were used to summarize the characteristics of respondents and their perceptions of road quality.
2. Qualitative Analysis: Open-ended responses and field observation notes were analyzed using thematic analysis. Key themes such as quality control practices, and user concerns were identified, coded, and synthesized.
3. Data Presentation: Findings were presented using tables and narrative summaries to enhance readability and facilitate interpretation. Comparisons across roads, districts, and stakeholder categories were highlighted where relevant.

This combination of methods allowed for a robust interpretation of data and supported the generation of practical, evidence-based recommendations.

CHAPTER FOUR: PRESENTATION OF FINDINGS

4.1.Introduction

This chapter presents the key findings of the study assessing the quality performance of selected road projects in Kigali. The data, collected from field observations, structured interviews, and user surveys, are systematically analyzed to uncover the technical and management factors influencing road quality. The chapter begins with a summary of respondent demographics, followed by a detailed presentation and interpretation of quality indicators across four road sections. These include design compliance, construction practices, road safety features, maintenance efforts, and user satisfaction.

Findings are organized thematically and supported by descriptive statistics, tables, and visual illustrations. The results reflect both the professional assessments of engineers and project supervisors as well as the lived experiences of road users, offering a comprehensive perspective on the current state of road infrastructure quality in Kigali.

4.2.Presentation and analysis of findings

This part offers a thorough analysis of findings from the study on the quality performance of selected road projects in Kigali, based on field observations, technical assessments, key informant interviews, and user feedback from four road sections: African Leadership University-Musave, Kabeza-Airport-Itunda-Busanza, Rugenge-Muhima Hospital-Nyabugogo, and Sonatube-Gahanga-Akagera. The results are organized thematically, emphasizing the physical, technical, institutional, and environmental factors that influence road performance.

4.2.1 Demographic characteristics of respondents

Understanding the demographic characteristics of respondents is essential to contextualize the findings of this study. A total of 94 respondents (54 professionals and 40 road users) participated in the research. These were strategically selected to represent both technical professionals involved in the implementation and supervision of road projects, as well as regular users of road infrastructure in Kigali.

Out of the total, 54 respondents (57%) were technical professionals, including civil engineers, site supervisors, project managers, infrastructure planners, both from and CoK and RTDA. These individuals provided expert insights into design standards, construction quality, supervision practices, and post-construction performance. Their years of experience

in the road sector ranged from 3 to over 15 years, with the majority (over 70%) having more than five years of professional experience in road construction or management. The remaining 40 respondents (43%) were regular road users, comprising pedestrians, motorcyclists, private car drivers, public transport users and operators, and cyclists. Their perspectives were critical in assessing road usability, accessibility, safety, and overall satisfaction with the road infrastructure across various sections of Kigali.

This blend of technical and non-technical respondents allowed the study to capture both objective assessments of road project performance and subjective user experiences, contributing to a more holistic and credible analysis of road quality in the Kigali city. This demographic profile underscores the study's strength in gathering multi-stakeholder views and provides a solid foundation for analyzing the performance of road infrastructure across different segments of Kigali.

a. Demographics of technical professionals

This part provides a breakdown of the professional backgrounds of the technical respondents involved in the study. The aim is to understand the diversity and distribution of expertise among those directly engaged in the planning, execution, and supervision of road infrastructure in Kigali. By capturing inputs from a cross-section of stakeholders including public sector engineers, agency-level experts, and private contractors the study ensures a balanced representation of institutional roles and technical experience. It was drawn from three main categories: Kigali City office, Rwanda Transport Development Agency (RTDA), contractors and road users.

Respondents were as follow:

1. **14 respondents (26%)** were staff from Kigali City office including engineers and technicians involved in supervision/monitoring and maintenance of road projects.
2. **12 respondents (22%)** were from the Rwanda Transport Development Agency (RTDA), providing input on national standards, compliance, and policy alignment.
3. **18 respondents (33%)** were from private contracting companies, including project managers, resident engineers, and site supervisors. These respondents offered practical insights into construction methodologies, challenges in execution, and contractor as well as client interactions.

Additionally, the views of **road users** were included as a comparative group to contrast professional perceptions with public experience.

Table 4. 1: Demographic information for road project professionals

Variables name	Category of respondents	Frequency	Percentage
Gender	Male	37	68.52
	Female	17	31.48
	Total	**54**	**100.00**
Age range	35–44	27	50.00
	25–34	22	40.74
	45–54	4	7.41
	Under 25	1	1.85
	Total	**54**	**100.00**
Highest qualification	Bachelor's degree (A0)	29	53.70
	Master's degree	21	38.89
	PhD	3	5.56
	Advanced diploma (A1)	1	1.85
	Total	**54**	**100.00**
Institution	Kigali city office/Kigali City Hall	21	38.89
	Road construction/supervision firm	18	33.33
	RTDA	15	27.78
	Total	**54**	**100.00**
Profession	Road civil engineer	29	53.70
	Consultant	12	22.22
	None	8	14.81
	Project manager	5	9.26
	Total	**54**	**100.00**
Work experience	6–10 years	29	53.70
	1–5 years	19	35.19
	More than 10 years	5	9.26
	Less than 1 year	1	1.85
	Total	**54**	**100.00**

Source: Primary Data

The engineering workforce engaged in road projects in Kigali is predominantly male, with 68.52% of respondents identifying as male. Females represent 31.48%, indicating a moderate level of gender inclusion but still highlighting a gender gap in the road infrastructure sector.

A significant majority (90.74%) of respondents are between 25 and 44 years old, suggesting that the workforce is composed of early- to mid-career professionals. Only a small fraction is above 45 or below 25, indicating that highly experienced veterans or very young entrants are less represented in the current road project workforce.

The workforce is highly educated, with over 92% of respondents holding at least a bachelor's degree. Notably, 38.89% hold a master's degree and 5.56% have PhDs, suggesting strong academic preparation, which is crucial for managing complex infrastructure projects. This also reflects the professionalization of the road construction sector in Rwanda.

Respondents were evenly distributed across key institutions involved in road projects: Kigali City office (38.89%), private firms (33.33%), and RTDA (27.78%). This balance enhances the representativeness of the study, ensuring that perspectives from both public sector and private contractors were included.

Most participants (53.70%) are road civil engineers, followed by consultants (22.22%) and project managers (9.26%). A small portion (14.81%) the rest of the respondents, which might include administrative, or support staff indirectly involved. The dominance of engineers confirms that technical expertise was prioritized in respondent selection.

b. Demographic information for road users

The study engaged a total of 40 road users across four selected roads in Kigali to assess their demographic characteristics and road usage patterns. This component of the research aimed to complement technical perspectives by capturing the lived experiences and perceptions of everyday road users. The findings offer valuable insights into the diversity of user profiles including their modes of transport, frequency of use, and interaction with road infrastructure thereby enriching the analysis of road project quality and its real-world impact on urban mobility in Kigali.

Table 4. 2: Demographic information for road users

Variables	Category of respondents	Frequency	Percentage
Gender	Male	28	70.00
	Female	12	30.00
	Total	**40**	**100.00**
Age range	35–44	14	35.00
	25–34	16	40.00
	45–54	4	10.00
	Under 25	6	15.00
	Total	**40**	**100.00**
Highest qualification	Master's degree	2	5.00
	Bachelor's degree (A0)	4	10.00
	Advanced diploma (A1)	4	10.00
	Secondary Level	13	32.50
	Primary Level	14	35.00
	None	3	7.50
	Total	**40**	**100.00**
Road used	African Leadership University-Musave	10	25.00
	Kabeza-Airport-Itunda-Busanza	10	25.00
	Sonatube-Gahanga-Akagera	10	25.00
	Rugenge-Muhima Hospital-Nyabugogo	10	25.00
	Total	**40**	**100.00**
Means of transport	Public transport	8	20.00
	Private car	8	20.00
	Motor	8	20.00
	Bicycle	8	20.00
	Walking	8	20.00
	Total	**40**	**100.00**
Frequency of road use (per week)	Daily	36	90.00
	3–5 times	4	10.00
	1–2 times	0	-
	Rarely	0	-
	Total	**40**	**100.00**

Source: Primary Data

The demographic data for the 40 road users surveyed reveals a profile of highly engaged and diverse individuals. The sample was predominantly male (70%) and largely comprised individuals in their economically active years (75% aged 25-44), indicating frequent commuters. Educational backgrounds were varied, with the majority having primary (35%) or secondary (32.5%) level qualifications. Crucially, respondents were evenly distributed across the four selected road projects and across five different means of transport (20% each for public transport, private car, motor, bicycle, and walking). An overwhelming 90% reported daily road use, confirming their status as regular and experienced users whose feedback is highly relevant to the study of road quality performance. In summary, the demographic data indicates that the surveyed road users are a diverse group in terms of education, balanced by transport type, and are highly frequent users of Kigali's roads. The majority are male, aged 25–44, and rely on these roads for their daily activities, underscoring the relevance and practical value of their feedback in evaluating road infrastructure performance.

4.2.2 Findings related to factors influencing road project quality

This section presents the findings related to the first research objective **"To determine the factors influencing the quality performance of road projects in Kigali"** This presents perceptions of engineers, infrastructure supervisors, and staff from CoK and RTDA and private contracting companies regarding factors influencing the quality of road projects. Respondents were asked to rate their level of agreement with each factor using a 5-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. The results reflect a general consensus toward agreement and strong agreement on the listed factors. The analysis relied on mean scores to determine the perceived importance of each factor.

Table 4. 3: Mean scores of factors influencing road quality performance

Variable (Factors influencing road quality performance)	**Maximum mean score**	**Ranking**
Project design quality	4.91	1
Contractor qualification and experience	4.89	2
Transparent tendering	4.85	3
Availability of funds	4.81	4
Quality management plan	4.74	5
Equipment and machinery availability	4.74	6
Project contract type	4.65	7

Timely procurement of materials	4.61	8
Use of substandard materials	4.57	9
Stakeholders' involvement	4.46	10
Environmental conditions	4.44	11
Use of outdated road construction technologies	4.41	12
Appropriateness of site selection	4.30	13
Changes in project scope	4.28	14

This consolidated ranking provides a clearer hierarchy of the factors perceived to influence road quality performance, focusing on the strongest agreement for each unique factor as follow:

1. **Top-rated factors (Mean ≥4.8):**

The analysis reveals that project design quality (mean 4.91) is perceived as the most critical factor, underscoring the fundamental importance of robust initial planning and technical design. Closely following are contractor qualification and experience (mean 4.89), emphasizing the paramount role of competent implementers. Transparent tendering (mean 4.85) is also highly valued, highlighting the need for fair selection processes to ensure quality. Lastly, availability of funds (mean 4.81) is recognized as an essential enabler, preventing quality compromises due to financial constraints.

2. **Moderately influential factors (Mean 4.6−4.7):**

Following the top-rated factors, quality management plan and equipment and machinery availability (both with a mean of 4.74) are equally emphasized, indicating strong agreement on the necessity of systematic quality processes and appropriate tools for efficient and precise construction. Additionally, the project contract type (mean 4.65) and timely procurement of materials (mean 4.61) are recognized as crucial, highlighting the importance of supportive contractual frameworks and efficient supply chain management to prevent delays and maintain material quality.

Lower-rated factors (Mean 4.2−4.5):

While ranked lower than the primary drivers, the use of substandard materials (mean 4.57) remains a significant concern, indicating its strong recognized impact on quality when it occurs. Stakeholders 'involvement (mean 4.46), environmental conditions (mean 4.44), and the use of outdated road construction technologies (mean 4.41) are considered important contextual influences, highlighting the need for collaboration, ecological consideration, and modern practices. Lastly, the appropriateness of site selection (mean 4.30) and changes in

project scope (mean 4.28), though still perceived above the “Agree” threshold, are seen as relatively less impactful compared to the highest-ranked factors, suggesting their influence on overall quality might be considered more manageable or less frequent.

In conclusion, the analysis of perceived factors influencing road quality performance in Kigali reveals a clear hierarchy of importance: Robust project design quality, highly qualified and experienced contractors, transparent tendering processes, and adequate funding are consistently identified as the most critical drivers. While systematic quality management, availability of appropriate equipment, supportive contract types, and timely material procurement are also deemed highly influential, factors such as the use of substandard materials, stakeholder involvement, environmental conditions, site selection, and scope changes, though still relevant, are perceived to have a comparatively lower, albeit still significant, impact. This hierarchy underscores that foundational planning, competent execution, and sound financial and procedural frameworks are considered paramount for ensuring high-quality road infrastructure.

The below table summarizes the perceived influence of various factors on road quality performance across different professional groups (Project Managers, Road Engineers/Contractors/Consultants, and Government Officials), based on ANOVA analysis. Mean scores are on a 1-5 Likert scale (1=Strongly Disagree, 5=Strongly Agree). Rankings are determined within each column (1=highest mean). The Significance decision is based on a p-value threshold of $\alpha=0.05$ and the F-statistic measures differences between group means. For the interpretation the P-value assesses the probability of observed differences occurring by chance: P-value < 0.05 signifies a statistically significant difference among professional groups, requiring post-hoc tests to identify specific group variations and P-value ≥ 0.05 indicates no statistically significant difference, suggesting similar perceptions across groups.

Factor	**Project Manager mean and (Ranking)**	**R.Eng/Contr/ Cons mean and (Ranking)**	**Govt. Official mean and (Ranking)**	**Overall mean and (Ranking)**	**P-value (Sig.Value)**	**Significance decision (α=0.05)**
Factors for project initiation, planning and design phase						
Project design quality	4.889 (1)	4.939 (1)	4.875 (1)	4.907 (1)	0.844	NSS
Availability of funds	4.778 (2)	4.788 (2)	4.875 (1)	4.796 (2)	0.927	NSS
Quality management plan	4.667 (3)	4.848 (3)	4.875 (1)	4.796 (2)	0.586	NSS
Stakeholders' involvement	4.556 (4)	4.424 (4)	4.250 (5)	4.444 (4)	0.636	NSS
Environmental conditions (planning)	4.444 (5)	4.424 (4)	4.250 (5)	4.407 (5)	0.899	NSS

Appropriateness of site selection	4.222 (6)	4.424 (4)	4.000 (7)	4.278 (6)	0.649	NSS
Changes in project scope	4.111 (7)	4.000 (7)	4.625 (4)	4.185 (7)	0.269	NSS
Factors for procurement & pre-construction						
Contractor qualification	4.778 (1)	4.939 (1)	4.875 (1)	4.870 (1)	0.705	NSS
Equipment and machinery availability	4.778 (1)	4.939 (1)	4.500 (6)	4.796 (2)	0.392	NSS
Timely procurement of materials	4.556 (3)	4.576 (3)	4.750 (5)	4.593 (3)	0.848	NSS
Project contract type	4.667 (2)	4.576 (3)	4.500 (6)	4.593 (3)	0.921	NSS
Transparent tendering	4.444 (4)	4.515 (5)	4.875 (1)	4.556 (5)	0.293	NSS
Use of standard materials	4.444 (5)	3.788 (6)	4.875 (1)	4.296 (6)	0.106	NSS
Use of updated road construction technologies	3.889 (6)	3.727 (7)	4.875 (1)	4.074 (7)	0.075	NSS
Factors for execution/construction phase						
Skilled and experienced	4.889 (1)	4.879 (1)	4.875 (1)	4.889 (1)	0.994	NSS

contractor and labor						
Compliance with project specifications	4.889 (1)	4.848 (2)	5.000 (1)	4.889 (1)	0.693	NSS
Adherence to project schedule	4.333 (3)	4.303 (3)	4.625 (3)	4.370 (3)	0.594	NSS
Environmental conditions (execution)	4.444 (2)	4.242 (4)	4.000 (5)	4.296 (4)	0.642	NSS
Proper site supervision	3.889 (4)	3.364 (5)	4.750 (2)	3.963 (5)	0.115	NSS
Traffic management during road construction	3.444 (5)	3.152 (6)	3.875 (4)	3.444 (6)	0.465	NSS
Factors for project monitoring and control phase						
Regulatory enforcement by authorities	4.778 (1)	4.788 (1)	5.000 (1)	4.852 (1)	0.586	NSS
Regular monitoring and evaluation during road construction	4.778 (1)	4.788 (1)	4.875 (2)	4.815 (2)	0.927	NSS
Factors for project closure phase						

Post-road construction quality audits	4.444 (2)	4.515 (1)	4.750 (1)	4.537 (1)	0.676	NSS
Maintenance readiness plan	4.444 (2)	4.576 (1)	4.625 (2)	4.537 (1)	0.751	NSS
Stakeholder acceptance and handover	4.556 (1)	4.667 (1)	3.875 (4)	4.481 (3)	0.141	NSS
Documenting quality success and failures	4.333 (4)	4.364 (4)	4.750 (1)	4.444 (4)	0.358	NSS

Note: NSS= Not Statistically Significant

Factors for project initiation, planning and design phase: In the initial phase of road projects, there's a high agreement among all professional groups on the core planning elements: Project design quality (Overall Mean: 4.907), availability of funds (Overall Mean: 4.796), and quality management plan (Overall Mean: 4.796) are consistently ranked highest, universally recognized as foundational for achieving quality outcomes. Project Managers, road engineers/contractors/consultants, and government officials all place project design quality as their top factor. While stakeholders' involvement (Overall Mean: 4.444), environmental conditions (Overall Mean: 4.407), appropriateness of site selection (Overall Mean: 4.278), and changes in project scope (Overall Mean: 4.185) receive comparatively lower overall mean scores, they are still generally agreed upon as influential. Notably, changes in project scope are ranked lowest by project managers, road engineers /contractors /consultants, but higher by government officials, potentially reflecting a more acute awareness of its administrative implications from the government perspective. All p-values in this phase are high (ranging from 0.269 to 0.927), confirming no statistically significant differences in perception among the groups, thus reinforcing the strong consensus on these initial project elements

Factors for procurement & pre-construction: This phase emphasizes competence and resources as crucial prerequisites for quality. contractor qualification (Overall Mean: 4.870) and equipment and machinery availability (Overall Mean: 4.796) are the top-ranked factors, with all groups consistently ranking contractor qualification and experience as their top factor. While not statistically significant, interesting variations exist for use of standard materials (Overall Mean: 4.296) and use of updated road construction technologies (Overall Mean: 4.074). Government officials rank these as their top factors (mean 4.875), considerably higher than road Engineers/Contractors/Consultants (3.788 and 3.727 respectively). This suggests a greater concern from the government/oversight perspective regarding these issues, possibly due to their broader impact on public trust and long-term infrastructure. All p-values in this phase (ranging from 0.075 to 0.921) indicate no statistically significant differences, implying that despite perceptual leanings, the groups are not statistically distinct in their views.

Factors for execution/construction phase: During the construction phase, skilled and experienced contractor and labor (Overall Mean: 4.889) and compliance with project specifications (Overall Mean: 4.889) are universally perceived as the most critical factors, achieving the highest overall mean scores and top rankings across all groups. This underscores the importance of human capital and adherence to standards during implementation. Factors such as proper site supervision (Overall Mean: 3.963) and traffic management during road construction (Overall Mean: 3.444) receive the lowest overall mean scores. However, Government officials rate proper site supervision (4.750) significantly higher than other groups, indicating a greater concern from an oversight perspective regarding supervision effectiveness. All p-values in this phase are high (ranging from 0.115 to 0.994), indicating no statistically significant differences among the groups, suggesting general agreement on the impact of these execution-related factors despite some mean score variations.

Factors for project monitoring and control phase: This phase shows strong agreement on the importance of oversight. Regulatory enforcement by authorities (Overall Mean: 4.852) and Regular monitoring and evaluation during road construction (Overall Mean: 4.815) are highly rated, signifying a strong consensus on the importance of continuous oversight and regulatory action. Government officials particularly emphasize regulatory enforcement by authorities with a perfect 5.00 mean score. Both factors show high p-values (0.586 and 0.927), indicating no statistically significant differences in perception

among the groups, which reinforces the shared belief in the necessity of robust monitoring and enforcement mechanisms.

Factors for project closure phase: In the project closure phase, the focus is on post-construction quality and long-term upkeep. Post-road construction quality audits (Overall Mean: 4.537) and maintenance readiness plan (Overall Mean: 4.537) are the top-ranked factors. While stakeholder acceptance and handover (Overall Mean: 4.481) is also rated, Government officials rate it lower (3.875) compared to other groups, a non-significant difference that might suggest a different administrative perspective on its direct influence. All p-values in this phase (ranging from 0.141 to 0.751) indicate no statistically significant differences among the groups for any factor, suggesting a consensus on the importance of these closure-related activities.

4.2.3 Findings related to critical criteria for measuring road quality performance

This section presents the findings corresponding to the second research objective "to examine the critical criteria used in assessing the quality performance of road projects in Kigali" where respondents were asked to rate various quality assessment indicators based on their relevance and effectiveness in evaluating road infrastructure. Each criterion was rated on a five-point Likert scale, and the results are analyzed through their mean scores. The table below shows the mean scores for 13 critical variables used to assess road quality performance, grouped according to their function.

Table 4. 4 Mean scores for road quality measurement criteria

Criterion	Mean score	Ranking
Carriageway width compliance with standards	4.87	1
Pavement thickness and layer composition	4.85	2
Road geometry and alignment safety	4.85	2
Drainage systems performance	4.83	4
Smoothness of the road	4.81	5
Roadside safety features (guardrails, barriers...)	4.76	6
User satisfaction	4.65	7
Road signage and markings	4.61	8
Frequency of maintenance needs	4.57	9
Long-term performance (over 5 years)	4.56	10
Availability of pedestrian and cyclist facilities	4.54	11
Lighting and visibility features	4.54	11
Traffic controls and calming measures	4.46	13

The findings indicate that respondents placed a high degree of importance on nearly all listed quality assessment criteria, as all variables scored above 4.4 on average.

1. **Top-rated criteria (Mean ≥ 4.8):**

The most critical indicators for evaluating road quality were carriageway width compliance (4.87), pavement layer composition (4.85), and road geometry and alignment safety (4.85), highlighting their importance in ensuring structural integrity and operational safety. Additionally, drainage system performance (4.83) and road smoothness (4.81) emerged as key indicators, reflecting stakeholder emphasis on road durability and driving comfort.

2. **Moderately rated criteria (Mean 4.6–4.79):**

Roadside safety features (4.76) and user satisfaction (4.65) highlight a strong focus on both safety infrastructure and the overall experience of road users. Meanwhile, road signage and markings (4.61) and maintenance frequency (4.57) underscore the importance of functional usability and ongoing upkeep in road quality assessment

3. **Lower-rated (But still relevant) Criteria (Mean 4.4–4.55):**

Pedestrian and cyclist facilities (4.54), lighting and visibility features (4.54), and long-term performance (4.56) received slightly lower ratings, possibly reflecting inconsistent prioritization across different road projects. Traffic calming measures (4.46) ranked lowest, suggesting they may be underemphasized in current road design and implementation practices.

Therefore, the assessment of road quality criteria highlights a strong emphasis on structural integrity and operational safety, with top-rated indicators including carriageway width, pavement layers, and road alignment. Moderately rated factors like safety features and maintenance reflect concerns for user experience and functionality. Lower-rated yet important aspects such as pedestrian facilities, lighting, and traffic calming suggest these elements may be underprioritized, pointing to opportunities for more inclusive and balanced road project planning.

This table summarizes whether there are statistically significant differences in the perceived importance of various critical criteria for measuring road quality performance among different professional groups: Project Managers, Road Engineers/Contractors/Consultants, and Government Officials. Rankings are determined within each column (1=highest mean). The Significance decision is based on a p-value threshold of α=0.05 and the F-statistic measures differences between group means. Fo the interpretation the P-value assesses the probability of observed differences occurring by chance: P-value < 0.05 signifies a statistically significant difference among professional groups, requiring post-hoc tests to identify specific group variations and P-value ≥ 0.05 indicates no statistically significant difference, suggesting similar perceptions across groups.

Criterion	**Project Manager mean and (Rank)**	**Road Engineer / Contractor / & Consultants mean and (Rank)**	**Government official mean and (Rank)**	**Overall mean and (Rank)**	**F-statistic**	**P-value (Sig.Value)**	**Significance decision (α=0.05)**
Smoothness of the road	4.889 (2)	4.697 (4)	4.750 (2)	4.778 (4)	0.297	0.744	NSS
Drainage systems performance	4.778 (3)	4.879 (1)	5.000 (1)	4.870 (3)	0.490	0.617	NSS
Carriage way width compliance with standards	4.944 (1)	4.879 (1)	4.750 (2)	4.889 (2)	0.370	0.693	NSS
Pavement thickness and layer composition	4.889 (2)	4.788 (3)	5.000 (1)	4.870 (3)	0.490	0.617	NSS
Availability of pedestrian and	4.667 (4)	4.636 (5)	4.125 (6)	4.519 (9)	1.350	0.269	NSS

cyclist facilities							
Road signage and markings	4.667 (4)	4.636 (5)	4.625 (3)	4.648 (6)	0.007	0.993	NSS
Traffic controls and calming measures	4.556 (5)	4.576 (6)	4.000 (7)	4.444 (11)	1.140	0.327	NSS
Road geometry and alignment safety	4.944 (1)	4.879 (1)	5.000 (1)	4.926 (1)	0.370	0.693	NSS
Roadside safety features (guardrails, barriers …)	4.778 (3)	4.848 (2)	4.625 (3)	4.778 (4)	0.297	0.744	NSS
Frequency of maintenance needs	4.667 (4)	4.576 (6)	4.375 (5)	4.556 (8)	0.395	0.676	NSS
Lighting and visibility features	4.556 (5)	4.576 (6)	4.250 (6)	4.481 (10)	0.590	0.561	NSS
Long-term performance (over 5 years)	4.444 (6)	4.424 (7)	5.000 (1)	4.593 (7)	2.290	0.115	NSS
User satisfaction	4.556 (5)	4.576 (6)	5.000 (1)	4.667 (5)	1.140	0.327	NSS

Note: NSS= Not Statistically Significant

The above table shows that professionals demonstrated a high consensus on core criteria related to fundamental structural integrity and design. This includes factors such as Road geometry and alignment safety (Overall Mean: 4.926), Pavement thickness and layer composition (Overall Mean: 4.870), Drainage systems performance (Overall Mean:

4.870), and Carriageway width compliance with standards (Overall Mean: 4.889). These criteria consistently received very high mean scores across all professional groups, and their p-values confirm that there are no statistically significant differences in how these professionals prioritize these essential engineering aspects.

Furthermore, there was strong agreement on functional and safety aspects of road quality. Criteria like Smoothness of the road (Overall Mean: 4.778), Roadside safety features (Overall Mean: 4.778), Road signage and markings (Overall Mean: 4.648), Lighting and visibility features (Overall Mean: 4.481), and traffic controls and calming measures (Overall Mean: 4.444) also exhibited high mean scores and no statistically significant differences across groups. This indicates a shared understanding of the importance of both operational performance and user safety for road users.

User satisfaction and long-term performance were also highly valued, user satisfaction (Overall Mean: 4.667) and long-term performance (over 5 years) (Overall Mean: 4.593) showed no significant differences in perception among the professional groups. Notably, Government Officials consistently assigned a perfect 5.00 mean score to several key criteria, including drainage systems performance, pavement thickness and layer composition, road geometry and alignment safety, user satisfaction, and long-term performance. This reinforces their strong emphasis on these aspects, even though the overall ANOVA did not find these specific inter-group differences to be statistically significant. Finally, criteria related to maintenance needs and accessibility also demonstrated general agreement. Frequency of maintenance needs (Overall Mean: 4.556) and Availability of pedestrian and cyclist facilities (Overall Mean: 4.519) showed no statistically significant differences in perception, indicating a shared understanding of their importance as measurement criteria for road quality.

4.2.4 Findings related to strategies for improving the quality performance of road projects

This section addresses the third research objective "to identify and analyze effective strategies for improving the quality performance of road projects in Kigali" where respondents rated several proposed strategies on a 5-point Likert scale according to their perceived importance and effectiveness.

Table 4. 5: Strategies to improve road quality performance

Rank	Strategy	Mean score	Ranking
1	Use qualified and skilled contractors and labors	4.97	1
2	Regularly verify compliance with design specifications and standards	4.92	2
3	Use certified and high-quality materials complying with standards	4.90	3
4	Strengthen project planning and design	4.87	4
5	Promote timely maintenance and monitoring	4.82	5
5	Enhance community and stakeholder engagement	4.82	5
7	Improve procurement and contracting practices	4.74	7
7	Conduct independent third-party supervision and audits	4.74	7
7	Encourage the use of modern road construction technologies	4.74	7
10	Clarify roles and responsibilities of stakeholders in quality management	4.67	10

The findings show very strong agreement among respondents on the importance of the proposed strategies, with all mean scores above 4.6 and most exceeding 4.8:

1. **Top-ranked strategies (Mean ≥ 4.9):**

The most effective strategies for improving road quality were identified as the use of qualified and skilled contractors (mean 4.97), regular verification of compliance (mean 4.92), and the use of certified quality materials (mean 4.90), collectively emphasizing the critical roles of human expertise, rigorous oversight, and material integrity.

2. **Moderately high strategies (Mean 4.8–4.89):**

Strong project planning (4.87) and both timely maintenance and stakeholder engagement (4.82) were seen as key to sustainability and inclusiveness.

3. **Other important strategies (Mean 4.6–4.79):**

Further strategies highlighting the need for procedural enhancements include improvements in procurement, auditing, and technology adoption (all with a mean of

4.74). While rated comparatively lower, clarification of stakeholder roles (mean 4.67) still indicates a recognized need for better coordination and accountability in quality management.

In conclusion, the study reveals a strong consensus among respondents on effective strategies for enhancing road quality. The paramount strategies involve ensuring qualified contractors, rigorous compliance verification, and the use of certified materials, complemented by robust project planning, timely maintenance, and active stakeholder engagement. Additionally, improvements in procurement, auditing, and technology adoption are deemed crucial, alongside a recognized need for clearer stakeholder roles, all contributing to a holistic approach for sustainable road quality improvement.

In addition to the predefined strategies, respondents were invited to suggest other strategies they believe could improve the quality performance of road projects in Kigali. These open-ended responses provide deeper insights into field-based challenges and innovative solutions. As shown in the table below, while a significant portion of respondents (35.19%) had no additional suggestions, others highlighted critical areas such as the need for improved drainage, periodic maintenance, quality assurance, digital planning tools, training, and the adoption of sustainable and modern construction practices. These diverse recommendations underscore the value of multi-dimensional approaches tailored to specific operational and environmental contex.

This table summarizes whether there are statistically significant differences in the perceived importance of various recommended strategies for improving road quality performance among different professional groups: Project Managers, Road Engineers/Contractors/Consultants, and Government Officials. Rankings are determined within each column (1=highest mean). The Significance decision is based on a p-value threshold of $\alpha=0.05$ and the F-statistic measures differences between group means. Fo the interpretation the P-value assesses the probability of observed differences occurring by chance: P-value < 0.05 signifies a statistically significant difference among professional groups, requiring post-hoc tests to identify specific group variations and P-value ≥ 0.05 indicates no statistically significant difference, suggesting similar perceptions across groups.

Strategy	**Project Manager mean and ranking**	**Road Engineer / Contractor / &Consultant mean and ranking**	**Government official mean and ranking**	**Overall mean and ranking**	**F-statistic**	**P-value (Sig.Value)**	**Significance decision (α=0.05)**
Use qualified and skilled contractors and labours	4.889 (1)	4.939 (1)	4.875 (1)	4.907 (1)	0.170	0.844	NSS
Strengthen project planning and design	4.889 (1)	4.879 (2)	4.875 (1)	4.889 (2)	0.006	0.994	NSS
Use certified and high-quality materials	4.889 (1)	4.879 (2)	4.875 (1)	4.889 (2)	0.006	0.994	NSS
Verify compliance with design specifications and standards	4.889 (1)	4.879 (2)	4.875 (1)	4.889 (2)	0.006	0.994	NSS

Promote timely maintenance and monitoring	4.778 (2)	4.879 (2)	4.875 (1)	4.852 (5)	0.297	0.744	NSS
Conduct independent third-party supervision and audits	4.778 (2)	4.788 (4)	4.875 (1)	4.815 (6)	0.076	0.927	NSS
Use modern road construction technologies	4.778 (2)	4.788 (4)	4.750 (4)	4.778 (7)	0.009	0.991	NSS
Improve procurement and contracting practices	4.667 (3)	4.788 (4)	4.125 (5)	4.611 (8)	1.579	0.216	NSS
Enhance community and stakeholder engagement	4.778 (2)	4.848 (3)	4.625 (4)	4.778 (7)	0.297	0.744	NSS
Clarify roles and responsibilities of stakeholders	4.556 (4)	4.576 (6)	4.000 (6)	4.444 (9)	1.140	0.327	NSS
Other strategies suggested by respondent	0.556 (5)	0.576 (7)	0.500 (7)	0.556 (10)	0.134	0.875	NSS

Note: NSS= Not Statistically Significant

The above table showed that strategies such as use qualified and skilled contractors and labors (Overall Mean: 4.907), strengthen project planning and design (Overall Mean:

4.889), use certified and high-quality materials (Overall Mean: 4.889), and verify compliance with design specifications and standards (Overall Mean: 4.889) consistently received very high mean scores across all groups. The p-values for these strategies (e.g., 0.844, 0.994) confirm that there are no statistically significant differences in how these professionals prioritize these fundamental improvement approaches.

Furthermore, strategies like promote timely maintenance and monitoring (Overall Mean: 4.852) and conduct independent third-party supervision and audits (Overall Mean: 4.815) also show high mean scores and no statistically significant differences across groups. This indicates a shared understanding of the importance of continuous oversight and proactive maintenance for sustained road quality. A consensus also exists on procedural and modern approaches, improve procurement and contracting practices (Overall Mean: 4.611) and use modern road construction technologies (Overall Mean: 4.778) show no statistically significant differences in perception. Even for improve procurement and contracting practices, where government officials have a slightly lower mean (4.125) compared to other groups, the difference is not statistically significant (p-value 0.216). This suggests a general agreement on the need for efficient processes and technological adoption.

There is also a shared value for engagement and clarity, enhance community and stakeholder engagement (Overall Mean: 4.778) and clarify roles and responsibilities of stakeholders (Overall Mean: 4.444) demonstrate no statistically significant differences in perception. This highlights a shared recognition of the importance of collaborative governance and clear communication in quality management.

Finally, regarding “Other strategies”, the analysis of other strategies suggested by respondents (Overall Mean: 0.556) indicates that approximately 55.6% of all respondents provided an additional strategy. The p-value of 0.875 confirms that there is no statistically significant difference in the proportion of respondents from each professional group who offered additional suggestions. This implies that the willingness to contribute beyond the provided list of strategies is consistent across project managers, road Engineers /Contractors/Consultants, and Government officials.

Table 4. 6: Other recommended strategies by respondents to improve the road quality performance

Other strategies improving the road quality performance	**Frequency**	**Percent**
No others	19	35.19
Digital Planning and Management Tools	1	1.85
Building the drainage	1	1.85
Construct and cover the drainage	1	1.85
Continuous improvement	2	3.70
Conventional earthwork equipment	1	1.85
Culvert maintenances	1	1.85
Cutting glass near road	1	1.85
Drainage system	1	1.85
Effective communication	1	1.85
Evaluation	1	1.85
Implementation of Building Information Modeling (BIM) for better planning and coordination.	1	1.85
Increasing transparency	1	1.85
Limited use of geosynthetics and reinforcements	1	1.85
Monitoring & Evaluation	1	1.85
Performing periodic maintenance in drainage structures	1	1.85
Planting	1	1.85
Quality assurance	2	3.70
Quality planning	1	1.85
Reflectors not only on barriers	1	1.85
Regular maintenance	1	1.85
Regular training programs for workers and supervisors.	2	3.70
Regularly maintenance	2	3.70
Repair covers for water drainage	1	1.85
Risk management	1	1.85
Shaping green	1	1.85
Source high-quality construction materials	1	1.85
Sustainability & innovation	1	1.85

Traffic control	1	1.85
Training	1	1.85
Use of checklists and documentation to track compliance.	1	1.85
Use of prefabrication and modular construction	1	1.85
Total	**54**	**99.94**

Source: Primary Data

In addition to the established strategies, respondents offered a variety of supplementary approaches to improve the quality performance of road projects. Although 35.19% of participants had no further suggestions, the remaining responses, each accounting for 1.85% to 3.70% were contextually relevant and thoughtful. A significant portion of the feedback emphasized drainage-related improvements, such as constructing, covering, and regularly maintaining drainage systems, underscoring the critical role of water management in road longevity and safety. Other responses focused on preventive and routine maintenance measures like culvert cleaning, greening initiatives, and the installation of reflectors, highlighting the importance of sustainability and user safety. Capacity-building initiatives were also prominent, with recommendations for training programs, quality assurance systems, the use of planning tools and documentation, and checklist-driven compliance mechanisms, all pointing toward strengthening institutional and workforce capacity.

Moreover, several respondents advocated for the adoption of modern technologies, including Building Information Modeling (BIM), digital planning systems, prefabrication, modular construction techniques, and geosynthetics, suggesting a forward-looking orientation toward innovative and efficient project execution. Governance-related recommendations also emerged, focusing on improving transparency, communication, monitoring and evaluation, and integrating sustainability and risk management into project delivery. Together, these additional strategies reflect a comprehensive understanding among stakeholders of the multifaceted factors that influence road quality. The suggestions highlight the value of combining technical excellence, innovation, skilled human resources, robust management practices, and continuous maintenance to achieve long-term performance and sustainability in road infrastructure.

4.2.5 Road project quality field assessment findings

This part outlines general details of the road projects included in the field observations for assessing road quality performance. The assessment focused on four key asphalt-paved road sections located across the three districts of Kigali; Gasabo, Kicukiro, and Nyarugenge. All the roads were observed in their completed state, allowing for a comprehensive evaluation of their structural quality, safety features, drainage systems, and overall user experience. The contractors involved include NPD Ltd, which handled three of the projects, and China Road and Bridge Corporation (CRBC), responsible for the Sonatube–Gahanga–Akagera road. These data details set the context for subsequent findings and comparisons across the observed road sections.

4.2.6.1 Selected road general information

Table 4. 7: Selected Road project general information

Road Name	**District**	**Contractor**	**Consultant**	**Road Type**	**Stage of Work**
African Leadership University-Musave	Gasabo	NPD Ltd	Prisma Ltd	Asphalt	Completed
Kabeza - Airport- Itunda – Busanza	Kicukiro	NPD Ltd	Prisma Ltd	Asphalt	Completed
Rugenge-Muhima Hospital-Nyabugogo access roads	Nyarugenge	NPD Ltd	Prisma Ltd	Asphalt	Completed
Sonatube-Gahanga-Akagera	Kicukiro	CRBC (China Road and Bridge Corporation)	Tecos Ltd	Asphalt	Completed

Source: Primary Data

As part of the fieldwork, the research team conducted detailed observational assessments of four completed road projects in Kigali City to complement data gathered through surveys and interviews. The assessed roads included the African Leadership University-Musave Road in Gasabo district; Kabeza-Airport-Itunda-Busanza and Sonatube-Gahanga-Akagera roads in Kicukiro district; and the Rugenge-Muhima Hospital-Nyabugogo access roads in Nyarugenge district. All segments were asphalt-paved and completed at the time of observation. Three of the four roads were executed by NPD Ltd (in Gasabo, Kicukiro, and Nyarugenge) and Prisma Ltd as the consultancy firm, while the Sonatube-Gahanga-Akagera road was constructed by CRBC (China Road and Bridge Corporation) and Tecos Ltd as the consult. The observations provided valuable insights into actual construction outcomes, allowing for an assessment of design compliance, construction quality, material use, safety provisions, and operational effectiveness. These findings, combined with stakeholder feedback and expert interviews, contributed to a comprehensive understanding of road quality performance in Kigali.

The following is the table summarizing the overall field observations per each assessed road project:

Table 4. 8: Overall Road quality field assessment

Road project name	**Field observations**	**Recommendations for improvements**
ALU-Musave	The road section is generally in good condition, with satisfactory structural integrity and a high level of user satisfaction. Minor issues exist in specific areas, including slope stability and drainage maintenance. The overall quality performance rating is estimated at **80.7%**.	Reinforce erosion-prone zones with retaining walls; improve signage visibility; remove sediment from drains; redesign curb ramps to enhance accessibility for people with disabilities.
Kabeza-Airport-Itunda-Busanza	This road performs acceptably overall, particularly in street lighting and pavement alignment. However, significant shortcomings include poor sidewalk condition, lack of culverts and reflectors, and	Rehabilitate sidewalks; maintain and upgrade drainage infrastructure; install culverts and reflectors to improve nighttime visibility and water management.

	subpar drainage maintenance. The road received a quality score of **75%**.	
Rugenge-Muhima Hospital-Nyabugogo Access Road	This nearly completed road demonstrates strong performance in drainage and surface smoothness. Some safety features and accessibility elements are still being finalized. The current quality score is **79%**.	Complete road markings and signage installation; install reflectors; improve pedestrian walkways and curb ramps; address uneven shoulder conditions to enhance safety and durability.
Sonatube-Gahanga-Akagera	The corridor is operationally sound, with robust pavement, clear signage, and effective drainage. Minor issues such as sediment in drainage near Gahanga and limited accessibility infrastructure were noted. Overall rating: **82%**.	Regularly maintain drainage systems (especially near Gahanga); mark vehicle stops lines at pedestrian crossings; upgrade curb ramps for wheelchair accessibility to promote inclusive design.

4.3. Comparative analysis on the road quality assessment

This part presents a comparative analysis of how road quality is perceived and evaluated by two key stakeholder groups: technical professionals and regular road users. The analysis is based on responses from 94 participants, comprising 54 road engineers and infrastructure experts, and 40 daily road users including pedestrians, drivers, cyclists, and public transport users. While engineers emphasized technical compliance with design specifications such as carriageway width, pavement structure, drainage systems, and camber slopes, road users focused more on functional aspects that affect daily mobility, comfort, and safety. Key differences emerged in perceptions related to lane uniformity, pavement conditions, signage visibility, and the presence (or lack) of traffic-calming measures near sensitive locations.

The analysis further examines the actual physical conditions of four road sections: ALU–Musave**,** Kabeza–Airport-Itunda-Busanza**,** Rugenge–Muhima Hospital–Nyabugogo**,** and Sonatube–Gahanga-Akagera to assess their alignment with standard specifications. While most roads generally adhered to design norms, field observations revealed

inconsistencies in shoulder quality, lane dimensions, signage clarity, and the implementation of safety features. This dual-perspective approach highlights the importance of integrating both technical assessments and user experience in evaluating the overall performance of urban road infrastructure.

Table 4. 9: Comparative analysis on road quality performance

Assessment item	**Road name**	**Technical professionals' view**	**Regular road users' view**	**Observed features / issues**
Respondents' composition	All roads	54 engineers/infrastructure professionals focused on compliance with standards	40 road users (pedestrians, drivers, cyclists, etc.) emphasizing usability, comfort, and safety	Road users' feedback enriched by daily experience
Carriageway width	ALU-Musave Sonatube-Gahanga-Akagera	Widths matched 7m design	Adequate for driving comfort	Fully compliant with design
	Rugenge-Muhima Hospital-Nyabugogo access	Slightly exceeded at 7.6m; deemed acceptable	No major complaints	Slight deviation from standard (7m), may need construction oversight
	Kabeza-Airport-Itunda-Busanza	Noted width variation; concerned about inconsistency	Reported maneuvering difficulty due to lane variation (2.7m–3.5m)	Variation impacts uniformity and driving comfort

Shoulder width and condition	ALU-Musave Sonatube-Gahanga-Akagera	Fully compliant, structurally sound	Considered safe and supportive	Met specifications
	Kabeza-Airport-Itunda-Busanza	One-sided shoulders, poor condition	Reported safety risks for non-motorized users	Partial implementation; non-compliance noted
	Rugenge-Muhima Hospital-Nyabugogo access	Narrow and inadequate	Concerned about lack of emergency maneuver space	Potential safety hazard
Pavement surface quality	All roads	Rated as structurally sound	Complaints of uneven patches, narrow shoulders, reduced comfort	Surface defects and reduced ride quality, especially on Kabeza-Itunda and Rugenge-Muhima
Drainage & camber slope	All roads	Adequate camber slopes and drainage structures confirmed	Reported pooling and sediment, especially in Gahanga and Rugenge	Sonatube-Gahanga and Rugenge-Muhima had effective slope/channeling
Road markings & signage	ALU-Musave and Sonatube-Gahanga-Akagera	Proper visibility and placement met standards	Confirmed clarity of markings	Safe navigation supported

	Kabeza-Airport-Itunda-Busanza	Met basic standards, but fading signs noted	Reported poor visibility, confusion under weather/traffic conditions	Needs repainting, especially around Kabeza
	Rugenge-Muhima Hospital-Nyabugogo access	Markings incomplete or missing near Nyabugogo	Cited as risky area for drivers and pedestrians	Markings missing in high-traffic zones
Traffic-calming measures	Sonatube-Gahanga-Akagera	Included functioning rumble strips	Appreciated for safety enhancement	Effective speed reduction near sensitive zones
	ALU-Musave, Rugenge-Muhima Hospital-Nyabugogo access, Sonatube-Gahanga-Akagera	Absence justified per original design	Reported need for humps/strips, especially near hospitals, markets, and schools	Lacked calming features; example: Muhima Hospital area
Road alignment & maneuverability	ALU-Musave, Kabeza-Airport-Itunda-Busanza, Sonatube-Gahanga-Akagera	Well aligned, facilitated smooth driving	Confirmed smooth flow and safe turns	Functional design noted

	Rugenge-Muhima Hospital-Nyabugogo access,	Adequate but flagged issues near Muhima Hospital	Reported tight curvature or poor visibility in some segments	Localized realignment may be needed

The comparative analysis between technical professionals and regular road users reveals significant differences in how road quality is perceived and evaluated. While engineers primarily focused on structural conformity to design standards such as proper carriageway width, camber slopes, and drainage where road users emphasized daily usability, safety, and comfort. For instance, engineers confirmed that roads like ALU-Musave and Sonatube-Gahanga-Akagera met the 7-meter design width, while Rugenge-Muhima Hospital-Nyabugogo access road slightly exceeded it without compromising performance. However, concerns raised about inconsistent lane widths on Kabeza-Airport-Itunda-Busanza, which impacted maneuverability. Similarly, while technical respondents rated pavements and shoulders as structurally sound, users reported surface defects, narrow or one-sided shoulders, and limited pedestrian space, especially on Kabeza–Airport-Itunda-Busanza and Rugenge-Muhima Hospital-Nyabugogo access road. In drainage, engineers viewed the infrastructure as adequate, yet users identified recurring issues like water pooling and sediment buildup, particularly during rains in Gahanga and Rugenge.

Further evaluation of the four studied roads: ALU-Musave, Kabeza-Airport-Itunda-Busanza, Rugenge-Muhima Hospital-Nyabugogo access road, and Sonatube-Gahanga-Akagera showed varying performance across several parameters. Sonatube-Gahanga-Akagera and ALU-Musave generally adhered to design standards in markings and alignment, supporting smooth traffic flow. However, road markings in Kabeza-Airport-Itunda-Busanza, Rugenge-Muhima Hospital-Nyabugogo access road were often faded or missing, especially near high-traffic areas like Nyabugogo, posing safety risks. Traffic-calming features like rumble strips were only present on Sonatube-Gahanga-Akagera, while other roads lacked such measures despite their importance near hospitals and schools. Although camber slopes on all roads were technically acceptable, only Sonatube-Gahanga-Akagera and Rugenge-Muhima Hospital-Nyabugogo access road had well-functioning surface drainage systems. Overall, while engineers assessed compliance and structural soundness, the perspectives of regular users exposed critical

gaps affecting real-world safety and functionality, underscoring the need to integrate user experience into road quality assessments.

The overall conclusion on this comparative analysis, Sonatube-Gahanga-Akagera emerges as the best-performing road segment in terms of alignment, width, and safety features. ALU-Musave also ranks highly, though it lacks traffic-calming infrastructure. Kabeza-Itunda and Rugenge-Muhima Hospital-Nyabugogo present areas for improvement, particularly regarding road markings and shoulder adequacy. These differences highlight the importance of consistent design enforcement, routine audits, and the integration of user safety features across all urban road projects in Kigali.

As a summary, this comprehensive analysis focused on factors influencing road project quality, critical performance criteria, effective improvement strategies, and field assessments of specific road sections in Kigali. Data was primarily collected from experienced professionals using a 5-point Likert scale.

Respondents demonstrated a strong consensus on the importance of various factors influencing the road quality throughout the road project lifecycle:

1. Initiation, planning, and design: project design quality (over 98% agreement), availability of funds (over 94% agreement), and stakeholders' involvement (over 98% agreement) are considered paramount. A clear quality management plan and consideration of environmental conditions are also highly valued.
2. Procurement & pre-construction: Contractor qualification and experience (over 98% agreement), transparent tendering (over 96% agreement), equipment and machinery availability, and timely procurement of materials (both over 96% agreement) are deemed crucial. While the impact of outdated technologies and substandard materials drew some mixed opinions, their negative effects are widely acknowledged.
3. Execution/construction phase: The presence of skilled and experienced contractors and labor (over 98% agreement) and strict compliance with project specifications (100% agreement) are pivotal. Proper site supervision (100% agreement) and effective traffic management during construction (over 95% agreement) are also highly valued.
4. Monitoring and control: Regular monitoring and evaluation (over 96% agreement) and strong regulatory enforcement by authorities (over 94%

agreement) received overwhelming support, highlighting their critical role in maintaining quality.

5. Project closure: Post- Road construction quality audits (over 96% agreement), stakeholder acceptance and handover (over 90% agreement), and documenting quality successes and failures (over 90% agreement) are seen as essential for long-term sustainability.

Respondents emphasized both structural integrity and user experience in defining assessment criteria of the road quality performance:

1. Structural integrity & design: Highly rated criteria include road geometry and alignment safety (over 96% strongly agreed/agreed), pavement thickness and layer composition (over 96%), drainage system performance (over 96%), carriageway width compliance (over 99%), and road surface smoothness (over 94%).
2. Safety & user experience: Roadside safety features (over 98%), road signage and markings (over 90%), and user satisfaction (over 96%) were also recognized as highly important.

There was a strong consensus on actionable strategies, with an overall mean recommendation score of 4.818, indicating high perceived importance across all respondents, irrespective of academic qualification or profession.

1. Top strategies: The use of qualified and skilled contractors and labor (over 99% agreement), regular verification of compliance with design specifications (over 99% agreement), and strengthening project planning and design (over 99% agreement) emerged as most critical.
2. Other highly rated strategies: Promoting timely maintenance and monitoring (over 99%), enhancing community and stakeholder engagement (over 99%), using certified and high-quality materials (over 99%), improving procurement and contracting practices (over 99%), encouraging modern construction technologies (over 99%), and conducting independent third-party supervision and audits (over 99%) were also strongly endorsed.
3. Additional suggestions: Respondents also highlighted the need for improved drainage systems, periodic maintenance, quality assurance systems, adoption of digital planning tools (e.g., BIM), training programs, and emphasis on transparency and risk management.

Field assessments of four completed road sections in Kigali revealed varying road quality performance:

1. **Overall performance:** While basic pedestrian and safety infrastructure was present, consistent weaknesses were identified. The Sonatube-Gahanga-Akagera Road generally scored highest in safety and accessibility.
2. **Common areas for improvement:** Across projects, consistent issues included substandard design and construction of accessible curb ramps, limited coverage and visibility of signage and barriers, and the need for enhanced protective features like reflectors and guardrails. Specific roads also showed poor sidewalk conditions (Kabeza-Airport-Itunda-Busanza) and significant safety concerns due to a lack of protection features (Rugenge-Muhima Hospital-Nyabugogo).

Thus, the analysis collectively underscores the critical importance of robust design and planning as the primary drivers of road quality performance in Kigali. While a general consensus exists among professionals on what constitutes quality and how to achieve it, there are tangible areas, particularly in accessibility features and protective infrastructure, where significant improvements are needed across existing road projects. A multi-faceted approach combining strong technical foundations, transparent processes, skilled human capital, and continuous monitoring, alongside a focus on user-centric safety, is essential for sustainable road infrastructure development in Kigali.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Based on the findings from the comprehensive analysis of road project quality in Kigali, the following conclusions are drawn, leading to actionable recommendations:

5.1. Conclusions

The study provides a robust understanding of the factors influencing road project quality, critical performance criteria, and effective improvement strategies from the perspective of key stakeholders in Kigali.

This study set out to investigate the quality performance of road projects in Kigali, Rwanda, with a focus on determining key influencing factors, examining critical measurement criteria, and recommending effective strategies for road quality improvement. The findings revealed that quality performance is shaped by a combination of technical, managerial, environmental, and institutional factors across all phases of the project lifecycle: from planning and design to execution, monitoring, and closure. High emphasis was placed on the use of qualified personnel, compliance with standards, proper design and material selection, and continuous supervision. Key performance indicators such as road geometry, drainage systems, surface smoothness, and user satisfaction were identified as essential in evaluating road quality. Furthermore, a range of strategic methods including the use of certified materials, regular audits, stakeholder engagement, and modern technologies were widely endorsed as effective for enhancing quality. The strong agreement among diverse stakeholder groups underscores the collective understanding of what constitutes quality in road construction and how it can be achieved. These insights are expected to guide future infrastructure planning and implementation in Kigali and contribute to the broader goal of sustainable and high-performing road networks in Rwanda.

5.2. Recommendations

Based on the conclusions, the following recommendations are proposed to enhance the quality performance of road projects in Kigali:

1. **Prioritize and invest in design and planning:**

    - **Recommendation:** Allocate increased resources and expertise to the project initiation, planning, and design phases. Ensure detailed feasibility study, detailed technical drawings, comprehensive site analyses, and robust quality management plans are developed and rigorously reviewed before construction commences.

    - **Rationale:** As the most significant predictor of quality, a strong foundation in design reduces costly errors and quality compromises during later stages.

2. **Strengthen contractor and labor capacity & oversight:**

    - **Recommendation:** Implement strict qualification criteria for contractors and subcontractors, emphasizing proven experience and skilled labor. Invest in continuous training programs for construction personnel, including supervisors and site workers.

    - **Rationale:** Skilled human capital and competent oversight are critical for ensuring compliance with specifications and high-quality execution.

3. **Enhance procurement and transparency:**

    - **Recommendation:** Further improve procurement processes to ensure transparent tendering, timely acquisition of certified, high-quality materials, and appropriate contract types that clearly define responsibilities and risk-sharing.

    - **Rationale:** Transparent and efficient procurement reduces opportunities for corruption, ensures material quality, and prevents delays that can compromise road project standards.

4. **Improve safety and accessibility infrastructure:**

    - **Recommendation:** Mandate and rigorously enforce standards for the design and construction of accessible curb ramps, ensuring they meet universal design principles for persons with disabilities. Increase the coverage, visibility, and quality of road signage, markings, guardrails, and reflectors across all new and existing road projects.

    - **Rationale:** These areas were consistently identified as weaknesses in field assessments and are crucial for enhancing user safety and inclusiveness.

5. **Reinforce monitoring, evaluation, and regulatory enforcement:**

    - **Recommendation:** Establish robust, independent third-party supervision and audit mechanisms throughout the project lifecycle. Empower regulatory authorities with sufficient resources and autonomy to conduct regular inspections and enforce compliance with construction codes and standards.

    - **Rationale:** Continuous monitoring and effective enforcement are vital for early detection of issues, ensuring accountability, and upholding quality standards.

6. **Foster stakeholder engagement and continuous learning:**

    - **Recommendation:** Promote enhanced community and stakeholder engagement throughout all project phases, from planning to closure. Institutionalize processes for documenting both quality successes and failures, fostering a culture of continuous improvement through lessons learned.

    - **Rationale:** Inclusive planning leads to better project outcomes, and systematic learning from past projects drives future quality enhancements.

7. **Embrace modern technologies and sustainable practices:**

    - **Recommendation:** Encourage the adoption of modern road construction technologies such as HDM-4, BIM, digital planning tools, advanced materials, modular construction, high tech equipment in road construction and integrate sustainable practices, particularly robust drainage systems and environmental mitigation measures.

    - **Rationale:** Modern technologies can improve efficiency and precision, while sustainable practices enhance road longevity and resilience to environmental challenges like heavy rainfall and soil erosion.

By implementing these conclusions and recommendations through a multi-faceted and integrated approach, Kigali can significantly elevate the quality performance, durability, and user satisfaction of its road infrastructure projects, contributing to sustainable urban development.

REFERENCES

1. Mehr, U.N. & Khalid, F. (2024). Impact of infrastructure on economic growth: A comparative analysis of developed and developing countries. Journal of Asian Development Studies, 13(1).
2. Banerjee, A., Duflo, E., & Qian, N. (2020). On the road: Access to transportation infrastructure and economic growth in China. Journal of Development Economics, 145, 102442.
3. Halder, S., & Sharma, G. (2021). Impact of urbanization on per capita energy use and emissions in India. International Journal of Energy Sector Management.
4. Athanasios, L. & Dimitra V. (2018). Success criteria and critical success factors in project success. International journal of real estate and land planning, vol.1 (2018).
5. Joseph, A. (2021). Construction Project Management: Understanding Factors Influencing Road Quality Performance. Harvard Business Review, 76(2), 45-58.
6. Minde, R. R., & Ghadge, A. N. (2018). Analyzing the factors influencing quality throughout the lifecycle of a road project. Paper presented at the 3rd International Conference on Construction, Real Estate, Infrastructure, and Project Management (ICCRIP 2018), Pune, India.
7. Noah Mwelu & Peter R. Davis & Yongjian Ke & Susan Watundu. (2020). Compliance mediating role within road construction regulatory framework.Journal of Public Procurement, Emerald Group Publishing Limited, vol. 20(3), pages 209-233, April.
8. Pandey, B., Brelsford, C., & Seto, K. C. (2025). Rising infrastructure inequalities accompany urbanization and economic development. Nature Communications, 16(1), Article 1193.
9. Mutamuliza, E., & Vishwanatha. (2016). Infrastructure development in Rwanda: Challenges and socio-economic prospects. International Journal of Research in Social Sciences, 6(5), 257–269.
10. Mbonimana, G. & Indekwe, D. (2021) Role of Monitoring and Evaluation and the Performance of Projects in Rwanda. A Case of Road Construction Project in Nyarugenge District. Social Science Learning Education Journal.

11. Byirirngiro, C. (2021). Causes of time and cost overruns through the road construction projects life cycle in Kigali: University of Rwanda Digital Repository.

12. Assaad, R. H., El-Adaway, I., & Abotaleb, I. (2020,). Predicting Project Performance in the Construction Industry: A critical review of modeling techniques and the need for integrated frameworks. ResearchGate.

13. Office of the Auditor General. (2022-2023). Annual audit report for the year ended 30 June 2023: Rwanda Parliament Accounts Committee (PAC) hearing.

14. RTDA (Rwanda Transport Development Agency). (2022). Road Construction and Contracting Guidelines.

15. Kerzner, H. (2022). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley.

16. Seninde, M. (2020). Factors affecting the quality of road construction projects in Uganda: A case study of KCCA. [Master's dissertation, Makerere University]. Makerere University Institutional Repository.

17. Oyemogun, T. A., Fadeyi, O. S., & Aina, A. A. (2020). Assessment of quality criteria in highway construction in Nigeria. Journal of Construction Engineering and Management, 146(6), 04020052.

18. Morake, N. E., & Meng, Q. (2020). Assessment of factors affecting quality in road construction projects in Botswana. Engineering, Construction and Architectural Management, 27(10), 2737–2757.

19. Love, P., Sing, C., & Wang, X. (2019). Procurement in Infrastructure Projects: Managing Risk and Uncertainty. Journal of Financial Management of Property and Construction.

20. Damoah, I. S., Ayakwah, A., & Twum, K. (2022). Key factors influencing the quality of road construction projects in Ghana. International Journal of Construction Management, 22(6), 995–1006.

21. Otim, G. & Alinaitwe, H. (2013). Factors Affecting the Performance of Pavement Road Construction Projects in Uganda. In Journal of Construction in Developing Countries.

22. Federal Highway Administration (FHWA). (2020). Pavement Condition and Surface Evaluation Guidelines. U.S. Department of Transportation.

23. Byaruhanga, A. and Basheka, B.C. (2017) Contractor Monitoring and Performance of Road Infrastructure Projects in Uganda: A Management Model. Journal of Building Construction and Planning Research, 5, 30-44.

24. Wamalwa, C. W. Mukoche & Herbert, D. (2018). Impact of Devolved Construction Management Process on Quality of Public Building Projects in Kenya; A Case of Busia County, Kenya: International Journal of Development Research.

25. Andrić, J. M., Mahamadu, A.-M., Wang, J., Zou, P. X. W., & Zhong, R. (2019). The cost performance and causes of overruns in infrastructure development projects in Asia. *Journal of Civil Engineering and Management*, *25*(3),203-214. https://doi.org/10.3846/jcem.2019.8646

26. World Bank. (2023). Procurement and Contracting in Transport Infrastructure.

27. Osei-Kyei, R., & Chan, A. (2021). Performance-Based Contracting in Emerging Markets. International Journal of Project Management.

28. ASTM D6433-18 – Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys.

29. Yescombe, E. (2020). Public-Private Partnerships: Principles of Policy and Finance.

30. Nicholas J. Garber& Lester A. Hoel. (2009). Traffic and Highway Engineering.4th Edition. University of Colombia

31. Yin, R. K. (2018). Case Study Research Design and Methods (6th Ed.). Thousand Oaks, CA: Sage Publishing.

32. Hendrickson, C. (2020). Project Management for Construction. Prentice Hall.

33. Banerjee, S. (2020). Infrastructure Design and Project Delivery Models. Routledge.

34. Robson, C. and McCartan, K. (2016) Real World Research. 4th Edition, Wiley.

35. Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approach (4th ed.). SAGE Publications.

36. Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (4th ed.). SAGE Publications.

37. Groves, R. M., Fowler Jr, F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2011). Survey methodology (2nd ed.). Wiley.

38. Yamane, Y. (1967). Mathematical Formulae for Sample Size Determination

APPENDIX

Appendix A: Research Questionnaire

Centre of Postgraduate Studies

Department of Civil, Environmental and Geomatics Engineering

Faculty of Environmental Sciences, School of Engineering

College of Science and Technology

University of Rwanda

Date: ……./……/ 2025

Request to participate in responding to Research questionnaire

Dear Respondent,

I am a postgraduate student in Masters of Highway Engineering and Management (HEM) at University of Rwanda, conducting research titled **"An Investigation into the Quality Performance of Road Projects in Kigali, Rwanda."** This study aims to assess the quality performance of road projects in Kigali to support the ongoing sustainability of infrastructure development in Rwanda.

I am humbly requesting your participation in this survey which is highly appreciated. Completing the questionnaire will take short time of minutes (10-15 minutes). All responses will be used exclusively for academic purposes and will remain strictly confidential.

Thank you for your time and contribution to this study.

Yours faithfully,

UWINTWALI Jean de Montfort

ujfort3ir443@gmail.com ,

Tel: +250788927649

Research project title: "An Investigation into the quality performance of road projects in Kigali, Rwanda."

Research questionnaire
Section A: Demographic information

Instruction: Kindly read carefully the following questions and **tick (√)** for your selected correct answer among the provided possibles answers for each question

1. **What is your gender?**
   - □ Male
   - □ Female
2. **What is your age range?**
   - □ Under 25
   - □ 25–34
   - □ 35–44
   - □ 45–54
   - □ 55 and above
3. **Specify your highest academic qualification:**
   - □ Phd
   - □ Master's degree
   - □ Bachelor's degree/A0
   - □ Advanced diploma/A1
   - □ Other, please specify, if any: _____
4. **What is your institution/company?**
   - □ RTDA
   - □ Kigali City
   - □ Road construction firm/supervision firm
   - □ Other, please specify, if any: _____
5. **What is your current profession/position/title?**
   - □ Road/Civil engineer
   - □ Contractor
   - □ Consultant
   - □ Project Manager
   - □ Academia/Researcher
   - □ Government official, please specify the position: _____
6. **What is your working experience?**
   - □ Less than 1 year

- 1–5 years
- 6–10 years
- More than 10 years

7. **Which district are you primarily associated with in road projects implementation**?
   - Gasabo
   - Nyarugenge
   - Kicukiro
   - None
   - Other, please specify: _____
8. **Which professional body are you registered with?**
   - Institution of Engineers Rwanda (IER)
   - Rwanda Institute of Architects (RIA)
   - Project Management Professional (PMP)
   - Rwanda Institute of Quantity Surveyors (RIQS)
   - None
   - Other, please specify_____
9. **Among the following road projects in Kigali city, which one were you involved in?**
   - African Leadership University Campus–Musave Cell access road
   - Rugenge- Muhima Hospital-Nyabugogo access roads
   - Kabeza-Airport-Itunda-Busanza
   - Sonatubes-Gahanga-Road
   - None
   - Other, please specify, if any: _____
10. **What was your specific role during the involvement in that road project?**
    - Project Manager
    - Road engineer/Civil engineer
    - Contractor
    - Consultant
    - Road construction workers
    - Government official, please specify the position: _____
    - Other (if any), please specify: _____

Section B: Questions related to the objectives of the study

B1. Specific objective: To determine the factors influencing the quality performance of road projects in Kigali

Instruction: Please rate the following factors influencing quality performance of the road projects by indicating your level of agreement, from 1 to 5 (5= Strongly Agree, 4= Agree, 3 = Neutral, 2= Disagree, 1= Strongly Disagree)

Factors influencing road quality performance	1	2	3	4	5
Factors for project initiation, planning and design phase					
1. Project design quality					
2. Availability of funds					
3. Stakeholders' involvement					
4. Appropriateness of site selection					
5. Changes in project scope					
6. Environmental conditions (rainfall, soil erosion)					
7. Quality management plan					
Others, please specify: _____					
Factors for procurement & pre-construction					
1. Contractor qualification					
2. Transparent tendering					
3. Project contract type					
4. Use of substandard materials					
5. Equipment and machinery availability					
6. Use of outdated road construction technologies					
7. Timely procurement of materials					
Others, please specify: _____					
Factors for execution/construction phase					
1. Skilled and experienced contractor and labor					
2. Compliance with project specifications					
3. Lack of proper site supervision					
4. Traffic management during road construction					
5. Adherence to project schedule					
6. Environmental conditions (rainfall, soil erosion)					
Others, please specify: _____					
Factors for project monitoring and control phase					
1. Regular monitoring and evaluation during road construction					
2. Regulatory enforcement by authorities					
Others, please specify:					
Factors for project closure phase					
1. Post-road construction quality audits					
2. Stakeholder acceptance and handover					
3. Documenting quality success and failures					
4. Maintenance readiness plan					
Others, please specify: _____					

B2. Specific objective: To examine the critical criteria for measuring the quality performance of road projects

Instruction: Among the following statements are emphasizing on the criteria for measuring road quality performance, rank them according to your level of agreement from 1 to 5 (5= Strongly Agree, 4= Agree, 3 = Neutral, 2= Disagree, 1= Strongly Disagree)

Criteria for measuring road quality performance	1	2	3	4	5
1. Smoothness of the road					
2. Drainage systems performance					
3. Carriageway width compliance with standards					
4. Pavement thickness and layer composition					
5. Availability of pedestrian and cyclist facilities					
6. Road signage and markings					
7. Traffic controls and calming measures					
8. Road geometry and alignment safety					
9. Roadside safety features (guardrails, barriers…)					
10. Frequency of maintenance needs					
11. Lighting and visibility features					
12. Long-term performance (over 5 years)					
13. User satisfaction					
Others, please specify: _____					

B3. Specific objective: To recommend effective strategies/methods for improving the quality performance of road projects.

Based on your experience of being involved in road projects implementation in Kigali, rank the following recommended effective strategies/methods to improve the quality performance of road projects in Kigali for future use.

Instruction: Please rank strategies/methods to improve the quality performance of road projects in Kigali, by indicating your level of agreement, from 1 to 5 (5= Strongly Agree, 4= Agree, 3 = Neutral, 2= Disagree, 1= Strongly Disagree)

Effective strategies/methods for improving the quality performance of road projects.	1	2	3	4	5
1. Strengthen project planning and design					
2. Use certified and high-quality materials complying with standards					
3. Use qualified and skilled contractors and labors					
4. Improve procurement and contracting practices					
5. Conduct independent third-party supervision and audits					
6. Regularly verify compliance with design specifications and standards					
7. Promote timely maintenance and monitoring					
8. Clarify roles and responsibilities of stakeholders in quality management					
9. Enhance community and stakeholder engagement					
10. Encourage the use of modern road construction technologies					
Others, please specify: _____					

Thank you for your valuable time and contribution to this research!

Appendix B: Used road quality field assessment form

Research project title: An Investigation into the Quality Performance of Road Projects in Kigali, Rwanda.

……

A. General Information

Road project name:

District:

Contractor:

Date of assessment:

Inspector/Assessor name:

Road type: Asphalt / Gravel / Other: _____

Stage of work: Completed / Ongoing / Maintenance

Note on scoring (score 1-5) for B to F criteria: This is how each criterion is ranked from 1to5 (1= Strongly Disagree, 2= Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

B. Pavement surface quality

Criteria	**Yes/No**	**Score (1–5)**	**Comments**
Pavement smoothness: are potholes and cracks available on the road surface?			
Pavement smoothness: is the road surface even or bumpy?			
Is pavement edge properly finished and stable?			
Does the road surface have depressions and/or loss pavement materials?			

C. Drainage and Water Management

Criteria	Yes/No	Score (1–5)	Comments
Are the side drains properly constructed?			
Presence of signs of waterlogging or erosion			
Culverts present and functional			
Drains are regularly cleaned			
Shoulders and side drains are present and functional			
Drainage structures match design plans			

D. Road Alignment, markings, and width

Criteria	Yes/No	Score (1–5)	Comments
Carriageway width matches design specification			
Shoulders width matches with design specification			
Road markings are visible and correct			
Humps ahead or rumble strips available			
Camber has a proper slope			
Road alignment facilitates safe driving			

E. Safety and accessibility features

Criteria	Yes/No	Score (1–5)	Comments
Sidewalks present and usable			
Pedestrian crossings marked			
Signage properly placed and visible			
Guardrails, reflectors and barriers are in place			
Adequate street lighting available			
Bicycle lanes (if applicable)			
Curbs ramps for people with disabilities			
Trimming of vegetation ensured			

F. Maintenance and sustainability considerations

Criteria	Yes/No	Score (1–5)	Comments
Regular maintenance observed (patching, resurfacing)			
Evidence of repairs since completion			
Construction waste cleared			
Environmentally friendly practices used			

G. User satisfaction

Question	Response (Circle one)
How do you rate the smoothness of this road?	Poor / Fair / Good / Very Good / Excellent
Are drainage and flooding issues a concern here?	Yes / No
Do you feel safe using this road?	Yes / No
Are pedestrian facilities adequate?	Yes / No

H. Overall observations and recommendations

……
……
……
……

I. Signature of road quality assessor

Signature:

Date:

Appendix C: Responses from respondents

Pavement surface quality assessment

Criteria	Yes/No	Score	Comments
African Leadership University-Musave			
Pavement smoothness: (The potholes and cracks availability on the road surface)	No	4	No potholes or cracks; surface smoothness is good
Pavement smoothness: (The road surface bumpy)	No	4	The surface is even under normal conditions
Pavement edge properly finished and stable	Yes	4	The pavement edge is in good condition
The road surface has depressions and/or loss pavement materials	Yes	3	Minor defects present
Kabeza - Airport- Itunda – Busanza			
Pavement smoothness: (The potholes and cracks availability on the road surface)	Yes	4	The road is in good condition; no major potholes or cracks.
Pavement smoothness: (The road surface bumpy)	No	4	The surface is even under normal conditions
Pavement edge properly finished and stable	Yes	4	Stable and confined at both edges
The road surface has depressions and/or loss pavement materials	Yes	2	There are visible defects and some surface degradation.
Rugenge- Muhima Hospital-Nyabugogo access roads			
Pavement smoothness: (The potholes and cracks availability on the road surface)	Yes	4	The surface is mostly smooth with no visible cracks or potholes.
Pavement smoothness: (The road surface bumpy)	No	4	The surface is generally even under normal conditions.

Pavement edge properly finished and stable	Yes	4	Pavement edges are stable and well-confined.
The road surface has depressions and/or loss pavement materials	Yes	4	No significant surface defects were observed.
Sonatube-Gahanga-Akagera			
Pavement smoothness: (The potholes and cracks availability on the road surface)	Yes	4	Only minor cracks observed, the surface is in good condition.
Pavement smoothness: (The road surface bumpy)	No	4	A few uneven areas are present, mostly due to previously repaired pavement areas through patching.
Pavement edge properly finished and stable	Yes	4	Pavement edges are well-constructed and stable throughout.
The road surface has depressions and/or loss pavement materials	no	3	Some minor surface defects were noted but do not hinder traffic flow.

Source: Primary Data

Drainage and water management assessment

Criteria	**Yes/No**	**Score**	**Comments**
African Leadership University-Musave			
The side drains properly constructed	yes	4	Well-constructed on both sides
Presence of signs of waterlogging or erosion	No	4	Minor debris only; drainage structure supports flow
Culverts present and functional	Yes	4	Correct size as per design
Drains are regularly cleaned	Yes	4	Some sediments present; cleaning can be improved
Shoulders and side drains are present and functional	Yes	4	Sediments present; recommend removal for functionality

Drainage structures match design plans	yes	4	1m width and 1m depth, as per specification
Kabeza - Airport- Itunda – Busanza/KIP			
The side drains properly constructed	Yes	3	Some drain covers are damaged
Presence of signs of waterlogging or erosion	No	3	Sediments are present in some drains; however, near the airport section, drains are clean
Culverts present and functional	No	4	Culverts are not present
Drains are regularly cleaned	Yes	4	Some sediment observed; regular cleaning is recommended.
Shoulders and side drains are present and functional	Yes	4	Sediment was found in some drains, though the airport section is clean.
Drainage structures match design plans	Yes	4	Drainage structures conform to design specifications.
Rugenge- Muhima Hospital-Nyabugogo access roads			
The side drains properly constructed	Yes	4	Side drains are well-built but require covering in some sections.
Presence of signs of waterlogging or erosion	Yes	4	Drainage channels are clean and free from erosion or stagnation.
Culverts present and functional	Yes	4	Culverts are in good condition and serve their intended purpose.
Drains are regularly cleaned	Yes	4	Regular cleaning is evident; minor sediment accumulation observed.
Shoulders and side drains are present and functional	Yes	4	Functional overall, but sediment removal is recommended.
Drainage structures match design plans	Yes	4	Drainage structures conform to the intended specifications.
Sonatube-Gahanga-Akagera			
The side drains properly constructed	Yes	4	Side drains are generally in good condition and well-aligned.

Presence of signs of waterlogging or erosion	Yes	4	At Gahanga , sediment buildup was observed in drainage channels, suggesting the need for routine cleaning.
Culverts present and functional	Yes	4	Culverts are in place and operational, but periodic maintenance is recommended.
Drains are regularly cleaned	Yes	4	Drains appear functional but require consistent maintenance to prevent blockage.
Shoulders and side drains are present and functional	Yes	4	Sidewalks and drains are in working condition; sediment removal is advised for optimal function.
Drainage structures match design plans	Yes	4	Structures meet standard specifications (1m depth × 1m width).

Source: Primary Data

Geometric and functional road design elements assessment

Criteria	**Yes/No**	**Score**	**Comments**
African Leadership University-Musave			
Carriageway width matches design specification	Yes	5	It is 7m in width (3.5m each side)
Shoulders width matches with design specification	Yes	5	
Road markings are visible and correct	Yes	4	Markings visible
Humps ahead or rumble strips available	No	5	No humps ahead in that area
Camber has a proper slope	Yes	5	
Road alignment facilitates safe driving	Yes	4	Supports safe maneuvering
Kabeza - Airport- Itunda – Busanza			

Carriageway width matches design specification	Yes	4	Varies across the section: some lanes are 2.7 m, others 3.5 m.
Shoulders width matches with design specification	Yes	4	Shoulder exists on one side but is in poor condition
Road markings are visible and correct	Yes	3	Markings are not clearly visible, especially near the Kabeza section
Humps ahead or rumble strips available	No	5	No humps or rumble strips in this section
Camber has a proper slope	Yes	5	Proper slope is provided
Road alignment facilitates safe driving	Yes	4	Alignment supports safe driving and maneuverability.
Rugenge- Muhima Hospital-Nyabugogo access road			
Carriageway width matches design specification	No	4	Slight deviation from design (7.6m instead of 7m), but functional.
Shoulders width matches with design specification	Yes	3	Shoulder exists only on one side and not wide enough
Road markings are visible and correct	Yes	4	Markings are mostly present but absent on the roadway to Nyabugogo market and car park.
Humps ahead or rumble strips available	No	5	No humps present
Camber has a proper slope	Yes	5	Camber slopes correctly toward one side for effective drainage.
Road alignment facilitates safe driving	Yes	3	Road alignment supports safety, though some areas (near Muhima Hospital) need attention.
Sonatube-Gahanga-Akagera			
Carriageway width matches design specification	Yes	4	The road has a 7-meter wide at one direction, consistent with the intended design.

Shoulders width matches with design specification	Yes	4	Shoulders are available on both sides and meet the required specifications.
Road markings are visible and correct	Yes	4	Road markings are clear and visible across most sections.
Humps ahead or rumble strips available	Yes	4	Rumble strips are available and functioning effectively.
Camber has a proper slope	Yes	5	Camber slopes correctly to both sides, promoting efficient water runoff.
Road alignment facilitates safe driving	Yes	4	The alignment facilitates smooth and safe vehicle maneuvering.

Source: Primary Data

Safety and accessibility features assessment

Criteria	**Yes/No**	**Score**	**Comments**
African Leadership University-Musave			
Sidewalks present and usable	Yes	4	
Pedestrian crossings marked	Yes	4	
Signage properly placed and visible	Yes	3	Requires renovation for clearer visibility
Guardrails, reflectors and barriers are in place	Yes	3	Only reflectors are installed
Adequate street lighting available	Yes	5	Very good
Bicycle lanes (if applicable)	No	5	Not needed for this road section
Curbs ramps for people with disabilities	Yes	3	Not properly designed for accessibility
Trimming of vegetation ensured	Yes	3	Few plants present; no trimming needed
Kabeza - Airport- Itunda – Busanza			
Sidewalks present and usable	Yes	3	Sidewalk exists on one side but is in poor condition
Pedestrian crossings marked	Yes	4	Well-marked; approximately 3 meters wide.

Signage properly placed and visible	Yes	4	Signage is properly installed and visible.
Guardrails, reflectors and barriers are in place	Yes	3	Not installed in all required areas; no reflectors.
Adequate street lighting available	Yes	5	Street lighting is excellent.
Bicycle lanes (if applicable)	No	5	Not available but needed for this section.
Curbs ramps for people with disabilities	Yes	3	Not properly designed for accessibility
Trimming of vegetation ensured	Yes	3	Vegetation is not sufficiently trimmed.
Rugenge- Muhima Hospital-Nyabugogo access road			
Sidewalks present and usable	Yes	3	Present only on one side; condition needs improvement.
Pedestrian crossings marked	Yes	4	Crossings are clearly marked and visible.
Signage properly placed and visible	Yes	4	Most signage is in place.
Guardrails, reflectors and barriers are in place	Yes	2	Barriers are installed, but reflectors are missing.
Adequate street lighting available	Yes	4	Lighting is functional on one part of the road.
Bicycle lanes (if applicable)	No	5	Not applicable for this road section.
Curbs ramps for people with disabilities	Yes	3	Ramps are insufficient and not well-designed.
Trimming of vegetation ensured	No	5	No vegetation present; trimming not applicable.
Sonatube-Gahanga-Akagera			
Sidewalks present and usable	Yes	4	Sidewalks are present on both sides and are generally in good condition.
Pedestrian crossings marked	Yes	4	Crosswalks are visible, but some lack vehicle stop lines for improved pedestrian safety.

Signage properly placed and visible	Yes	4	Traffic signage is appropriately placed and easily visible.
Guardrails, reflectors and barriers are in place	Yes	4	Guardrails are present and in good condition; reflectors also installed where required.
Adequate street lighting available	Yes	5	Street lighting is excellent and ensures nighttime visibility.
Bicycle lanes (if applicable)	No	5	Not applicable for this section; bicycle lanes are not required.
Curbs ramps for people with disabilities	Yes	3	Ramps exist but are not adequately designed for wheelchair users.
Trimming of vegetation ensured	Yes	4	Landscaping and greening are well-maintained along the road.

Source: Primary Data

Road maintenance and sustainability considerations

Criteria	**Yes/No**	**Score**	**Comments**
African Leadership University-Musave			
Regular maintenance observed (patching, resurfacing)	Yes	4	Some repairs done but not clearly visible
Evidence of repairs since completion	Yes	3	Few repairs observed near ALU entrance
Construction waste cleared	Yes	5	No construction waste observed
Environmentally friendly practices used	Yes	4	No roadside dustbins present, but general cleanliness is good
Kabeza - Airport- Itunda – Busanza road			
Regular maintenance observed (patching, resurfacing)	No	3	Some drainage structures are not well-maintained
Evidence of repairs since completion	No	4	No visible evidence of repairs since completion
Construction waste cleared	Yes	4	Construction waste has been removed.

Environmentally friendly practices used	Yes	3	No waste bins are available; general cleanliness is acceptable.
Rugenge- Muhima Hospital-Nyabugogo access road			
Regular maintenance observed (patching, resurfacing)	Yes	4	Maintenance work evident, e.g., near Muhima Hospital gate.
Evidence of repairs since completion	Yes	4	Recent repairs noted, especially in front of Muhima hospital gate.
Construction waste cleared	Yes	5	No construction waste observed; area is clean.
Environmentally friendly practices used	No	4	No visible greens or dustbins, but general cleanliness is acceptable.
Sonatube-Gahanga-Akagera road			
Regular maintenance observed (patching, resurfacing)	Yes	4	Maintenance activities such as patching and resurfacing were observed.
Evidence of repairs since completion	Yes	4	Some minor repairs have been carried out.
Construction waste cleared	Yes	4	No construction debris was observed; the area is clean.
Environmentally friendly practices used	Yes	4	Presence of plantations and dustbins along the road promotes environmental hygiene.

Source: Primary Data

User satisfaction assessment

Road user satisfaction assessment

Question	**Response (Circle one)**
African Leadership University-Musave Road	
How do you rate the smoothness of this road?	Very Good
Are drainage and flooding issues a concern here?	No
Do you feel safe using this road?	Yes
Are pedestrian facilities adequate?	Yes
Kabeza - Airport- Itunda – Busanza road	
How do you rate the smoothness of this road?	Good
Are drainage and flooding issues a concern here?	No
Do you feel safe using this road?	Yes
Are pedestrian facilities adequate?	Yes
Rugenge- Muhima Hospital-Nyabugogo access road	
How do you rate the smoothness of this road?	Very Good
Are drainage and flooding issues a concern here?	No
Do you feel safe using this road?	Yes
Are pedestrian facilities adequate?	Yes
Sonatube-Gahanga-Akagera road	
How do you rate the smoothness of this road?	Very Good
Are drainage and flooding issues a concern here?	No
Do you feel safe using this road?	Yes
Are pedestrian facilities adequate?	Yes

Source: Primary Data

Appendix D: Used interview questionnaire for road user

Instruction: Please respond to the following questions based on your experience using the road.

1. How often do you use this road per week?
   - **Daily**
   - **3–5 times**
   - **1–2 times**
   - **Rarely**
2. Which means of transport do you use?
   - **Public transport**
   - **Private car**
   - **Motor**
   - **Bicycle**
   - **Walking**
3. Do you face traffic congestion on this road?
   - **Yes**
   - **No**
4. Do you feel safe using this road?
   - **Yes**
   - **No**
5. Are pedestrian facilities adequate?
   - **Yes**
   - **No**
6. Is the road lighting conditions adequate at night?
   - **Yes**
   - **No**
   - **Partially**
7. Do you think the road designer consider all categories of users?
   - **Yes**
   - **No**
   - **Not Sure**
8. Are public transport stops/shelters along this road sufficient and usable?
   - **Yes**
   - **No**

- **Not Applicable**

9. Have you experienced any accidents or near-misses on this road?
   - **Yes**
   - **No**
10. Are drainage and flooding issues a concern here?
    - **Yes**
    - **No**
11. Would you recommend any specific improvement for this road?

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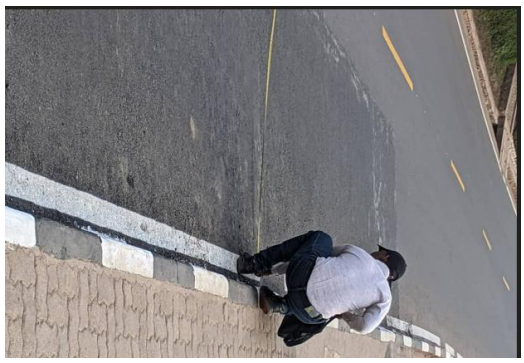
Thank you very much for participating in this interview!

Appendix E: Field photos during road quality performance assessment

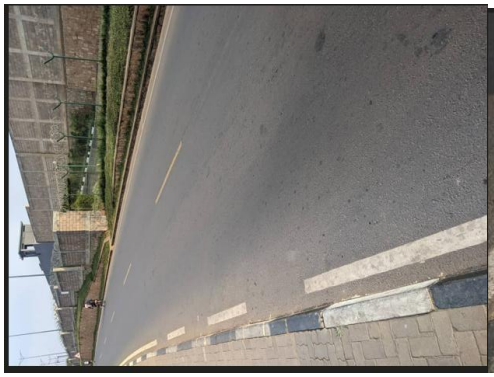
At Rugenge- Muhima Hospital-Nyabugogo access road



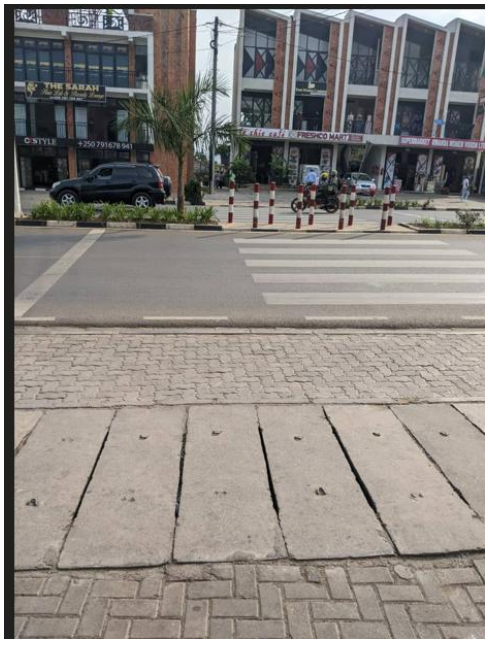
At African Leadership University Campus–Musave Cell access road

At Kabeza-Airport-Itunda-Busanza road

STOP



At Sonatubes-Gahanga-Road



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