ADDIS COLLEGE

POST GRADUATE PROGRAM ON CONSTRUCTION TECHNOLOGY AND MANAGEMENT

OPTIMIZATIONAND ADAPTIVE MANAGEMENTOF PERFORMANCE BASED ROAD MAINTENANCE CONTRACTSIN ETHIOPIAN ROADS ADMINISTRATION

A THESIS SUBMITTED TO THE PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT

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STATEMENT OF CERTIFICATION

This is to certify the research report prepared by Sintayehu Getahun entitled " Optimization and Adaptive Management of Performance Based Road Maintenance Contracts in Ethiopian Roads Administration", which is submitted in partial fulfillment of the requirements for the award of Degree of Master of Science (MSC). This work is nature and suitable for the Award of Masters of Construction Technology and Management.

Certified by;

Belachew Asteray (Phd) ____________________ ____________________

(Advisor) Signature Date

STATEMENT OF DECLARATION

I declare that the work which is being presented by this thesis " Optimization and Adaptive Management of Performance Based Road Maintenance Contracts in Ethiopian Roads Administration" represent my own original work prepared under the guidance of Belachew Asteray (Phd) and that the thesis has not been presented for a degree in any other university. All sources of materials used for this research have been duly acknowledged and submitted for the award of Masters of Science in Construction Technology and Management.

Sintayehu Getahun Signature ___________________ Date _______________

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Abstract

The study focused on the optimization and adaptive management of performance-based road maintenance contracts within the Ethiopian Roads Administration (ERA) to enhance the efficiency and effectiveness of road maintenance operations through innovative management strategies. A comprehensive analysis was conducted, utilizing both qualitative and quantitative research methods, data were collected from various stakeholders involved in performance based road maintenance contracts, including contractors, consultants, government officials, and local communities. Statistical tools were applied to evaluate the performance metrics of existing contracts, the findings revealed significant gaps in the current contract management practices, particularly contracts the absence of clear performance indicators, which hindered effective monitoring and evaluation. Additionally, the study found that adaptive management approaches could lead to better resource allocation and improved service delivery. Recommendations included establishing standardized performance metrics, providing stakeholder training and developing a feedback mechanism for continuous improvements.

Key Words: Adaptive management strategies, Performance Metrics Stakeholder engagement, Optimization and Adaptive Management.

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ABBREVIATIONS

AD	Adaptive management strategies
ANOVA	Analysis Of Variance
CH	Challenges
ERA	Ethiopian Roads Administration
IOPRC	Impact of Out-put Performance Road Contract
OAM	Optimization and Adaptive Management
OPRC	Out-put Performance Road Contract
PBRMC	Performance Based Road Maintenance Contracts
PM	Performance Metrics
SPSS	Statically Package for Social Science

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

The optimization and adaptive management of performance-based road maintenance contracts is a critical area of study in the field of civil engineering and public infrastructure management. This research aims to explore the effectiveness of PBRMCs within the Ethiopian Roads Administration focusing on how these contracts can be optimized for better performance outcomes.

The optimization and adaptive management of performance-based road maintenance contracts are critical areas of research, particularly within the context of developing countries. As highlighted by Stankevich et al. (2009), performance-based contracting offers a strategic framework for enhancing the preservation and improvement of road assets. This approach shifts the focus from traditional input-based contracts to outcomes, emphasizing the quality and efficiency of road maintenance services. By aligning the interests of contractors with those of public agencies, such contracts can lead to better resource allocation, improved service delivery, and ultimately, enhanced road infrastructure sustainability.

Sultana et al. (2012) further explore the challenges associated with implementing performance-based maintenance contracts in developing nations. They identify various barriers such as limited technical capacity, inadequate regulatory frameworks, and financial constraints that hinder effective contract execution. The authors argue that despite these challenges, adopting performance-based approaches can significantly improve road infrastructure management by fostering innovation and accountability among contractors. Their findings suggest that tailored strategies are necessary to address local conditions and ensure successful implementation.

Building on this foundation, Sultana et al. (2013) provide a comprehensive review of existing literature on performance-based maintenance contracting. They emphasize the importance of continuous evaluation and adaptation in contract management practices to respond effectively to changing circumstances and emerging challenges in road maintenance. Their analysis underscores the need for robust monitoring systems and stakeholder engagement to optimize contract performance over time.

Moreover, Performance-based road maintenance contracts (PBRMCs) represent a significant shift from traditional road maintenance approaches, focusing on outcomes rather than inputs. These contracts incentivize contractors to maintain roads effectively by linking payment to performance metrics, such as road condition and user satisfaction. The evolution of PBRMCs has been driven by the need for more efficient use of public funds and improved service delivery in transportation infrastructure.

The Virginia Department of Transportation's experience with its first performance-based road maintenance contract serves as a critical case study in understanding the effectiveness of PBRMCs. According to Ozbek and de la Garza (2011), this initiative highlighted both the potential benefits and challenges associated with implementing performance-based strategies. Their comprehensive evaluation revealed that while PBRMCs could lead to cost savings and improved road conditions, they also required robust monitoring systems and clear performance metrics to ensure accountability.

Panthi (2009) developed a methodological framework for modeling pavement maintenance costs specifically tailored for projects utilizing performance-based contracts. This framework is essential for understanding how financial resources can be allocated efficiently while maintaining high-quality standards. By integrating various factors influencing maintenance costs such as traffic loads, environmental conditions, and material degradation, this approach provides a systematic way to predict expenses over time, thereby facilitating better budget planning and resource allocation.

Recent studies have begun to incorporate sustainability criteria into the optimization of maintenance strategies. Peng et al. (2022) explored how sustainability can be integrated into bridge maintenance strategies within the context of deteriorating infrastructure. Their research emphasizes that optimizing maintenance not only involves traditional performance metrics but also considers environmental impacts, resource conservation, and social implications. This holistic approach aligns with contemporary goals in transportation management, where sustainability is becoming increasingly paramount.

The concept of adaptive management plays a crucial role in optimizing PBRMCs. It involves continuously assessing the effectiveness of maintenance strategies and making necessary adjustments based on real-time data and feedback from stakeholders. By employing advanced analytics and decision-making frameworks, transportation agencies can enhance their responsiveness to changing conditions, ensuring that road networks remain safe and functional over time.

The Ethiopian Roads Administration with the objective to increase the efficiency and effectiveness of road asset management and maintenance, started to employ performance based road maintenance contracting (PBRMC) for improvement and maintenance works (ERA, 2018). In relation to that, in a year 2016, ERA has moved a step forward to implement Performance-Based Road Maintenance Contract instead of conventional/traditional road maintenance and had signed three pilot maintenance projects by using performance based contracting project delivery method and its under implementation. Namely:

1. Adama – Awash PBRMC Project
2. Fiche – Gohatsion PBRMC Project and
3. Adi Gudom – Mekelle – Wukro PBRMC Project.

Among these three Performance-Based-Road-Maintenance-Contracts, the Adama - Awash PBRMC project (Km 60+000 - Km 120+000) and Fiche – Gohatsion PBRMC project (Km 102+000 - Km 177+000) has been contributed in this studies.

Collectively, these studies contribute valuable insights into how adaptive management principles can enhance the effectiveness of performance-based road maintenance contracts within the ERA framework.

1.2. Statement of the Problem

The optimization and adaptive management of performance-based road maintenance contracts are critical for enhancing the efficiency and effectiveness of road infrastructure management. As urbanization increases, the demand for well-maintained road networks becomes paramount. The application of performance measurement instruments, such as the Balanced Scorecard, allows for a comprehensive evaluation of maintenance strategies by integrating financial and non-financial metrics. This approach not only facilitates better decision-making but also aligns maintenance objectives with broader organizational goals, ensuring that resources are allocated efficiently to maximize road performance and user satisfaction (Rapitasari et al., 2018).

Moreover, strategic analysis tools like HDM-4 (Highway Development and Management Tool) play a significant role in assessing pavement maintenance and rehabilitation needs within urban road networks. By employing such methodologies, stakeholders can identify optimal maintenance schedules and interventions that prolong pavement life while minimizing costs. The integration of these analytical frameworks supports data-driven decision-making processes that consider various factors affecting road conditions, traffic patterns, and environmental impacts (Rejani et al., 2022). This strategic approach is essential for adapting to changing conditions and ensuring sustainable road infrastructure.

Finally, incorporating sustainability principles into maintenance optimization frameworks is vital for addressing long-term risks associated with highway infrastructure. Research indicates that considering multi-attribute utility functions alongside risk attitudes can lead to more informed decisions regarding resource allocation for highway bridge maintenance. This holistic view not only enhances structural integrity but also promotes environmental sustainability by reducing the ecological footprint of maintenance activities (Sabatino et al., 2015). Therefore, optimizing performance-based contracts through adaptive management strategies is crucial for achieving sustainable outcomes in road maintenance practices.

Despite the implementation of PBRMCs by ERA, there are persistent issues related to contract execution and performance measurement. Additionally, there is limited research on how adaptive management principles can be integrated into existing frameworks to improve responsiveness to changing conditions and stakeholder needs. Then, this study was tried to fill this study gap.

1.3. Justification of the Study (Optional)

This study is justified as it addresses a crucial aspect of infrastructure management that directly impacts economic growth and public safety in Ethiopia. By optimizing PBRMCs through adaptive management strategies, this research could lead to more efficient use of resources, improved road conditions, and enhanced contractor accountability.

1.4. Research Questions

1. How is the current practice of adaptive management in PBRMC project?
2. How can adaptive management principles be applied to optimize these contracts?
3. What metrics should be used to evaluate contractor performance effectively?
4. What does the impact of PBRMC with regard to project Cost, Quality and time?

1.5. Research Objectives

1.5.1. General Objectives

The general objective of this research was to explore the optimization and adaptive management strategies for performance-based road maintenance contracts (PBRMC) within the Ethiopian Roads Administration.

1.5.2. Specific Objectives

The primary objective of this research was:

1. Accessing the practice of adaptive management in PBRMC project.
2. To explore adaptive management strategies that can be integrated into existing PBRMC frameworks.
3. To develop a set of metrics for evaluating contractor performance based on best practices.
4. Access the impact of PBRMC with regard to project Cost, Quality and time.

1.6. Significance of the Study

This study holds significant importance for several reasons:

1. **Policy Implications:** The findings will provide valuable insights for policymakers at ERA, enabling them to refine existing contract frameworks and improve overall road maintenance strategies.
2. **Economic Efficiency:** By optimizing PBRMC, this research can lead to cost savings in public spending on infrastructure, ultimately benefiting taxpayers and enhancing economic development.
3. **Sustainability:** The adaptive management approach promotes sustainable practices in road maintenance, ensuring long-term viability and resilience against environmental changes.
4. **Knowledge Contribution:** This study will contribute to the academic literature on public procurement and infrastructure management, particularly in developing countries like Ethiopia.

The study on the optimization and adaptive management of performance-based road maintenance contracts within the Ethiopian Roads Administration holds significant implications for various stakeholders, including government agencies, contractors, and the general public.

For government agencies, this research provides a framework to enhance accountability and efficiency in road maintenance operations, ensuring that taxpayer funds are utilized effectively. By adopting performance-based contracts, agencies can better monitor contractor performance through measurable outcomes, leading to improved road quality and reduced long-term costs associated with repairs.

For the contractors, understanding optimization strategies allows them to align their operational practices with performance metrics that can lead to increased profitability and competitiveness in bidding processes. Furthermore, the study emphasizes adaptive management techniques that enable contractors to respond dynamically to changing conditions or unexpected challenges in road maintenance.

For the Consultants, this study is providing it reveals how PBRMCs create a structured plat form for proactive communication and collaboration problem solving. Consultants can use PBRMC frame to align technical solutions with risk management goals, thus enhancing project quality and stakeholder coordination.

For the general public, improved road infrastructure directly translates into enhanced safety, reduced travel times, and overall economic growth as better roads facilitate trade and mobility. Thus, this study not only contributes to academic discourse but also serves as a practical guide for implementing effective road maintenance strategies that benefit all stakeholders involved.

1.7. Scope of the Study

The scope of this study was encompasses various dimensions related to performance-based road maintenance contracts within Ethiopian Roads Administration:

1. **Temporal Scope:** temporal scope in research refers to the time period that the study covers. In this study the performance based road maintenance contract projects were selected currently implemented projects starts from 2017 GC up to 2024 GC. Furthermore, the research will focus on literature published between in recent years to ensure that findings are relevant to current practices and challenges faced by ERA.
2. **Spatial Scope:** This spatial scope refers to geographical area or extend that study covers, the spatial scope of this study was limited to Ethiopia, specifically the central part of Ethiopia.

3. **Thematic Scope:** thematic scope refers to the specific topics, themes, or subject areas that the study has covered. It defines the boundaries of the content covered. This researcher improving the efficiency, cost effectiveness and performance outcomes of PBRMCs. This scope aims to enhance the sustainability and effectiveness of road maintenance in Ethiopia.

1.8. Limitation of the Study

This thesis work is limited to the following issue

1. **Limited generalizability:** Since the current implemented projects are pilot initiatives, it is difficult to reflect the complexities, scalabilities and challenges of full scale implementations
2. **Governmental influence:** As the pilot projects are carried out by state owned enterprises (SOE), the influence of bureaucratic processes may impact project execution and outcomes.
3. **Impact of project termination:** As the all pilot projects are under termination phase with the progress of below 50%. Which makes it difficult to evaluate the accomplishment and challenges of the delivery system or it may difficult to get complete or reliable data.
4. **Data availability and quality:** The low number of interview participants may affect the scope of the research output.

1.9. Organization of the Study

The research was organized into five chapters:

I. Chapter One introduces the study's background, objectives, significance, scope, limitations, and organization.
II. Chapter Two reviews relevant literature on employee training and performance metrics.
III. Chapter Three outlines the methodology used for data collection and analysis.
IV. Chapter Four presents findings from surveys and interviews conducted with employees.
V. Chapter Five discusses conclusions drawn from findings along with recommendations for practice and further research

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

PBRMCs have emerged as a significant approach to managing road infrastructure effectively. This literature review synthesizes key findings from various studies focusing on the optimization and adaptive management of PBRMCs, particularly within the context of the ERA. The reviewed literature highlights methodologies, case studies, and best practices that contribute to enhancing the efficiency and effectiveness of road maintenance under performance-based frameworks.

2.1.1. Factors for Change to Performance Based Contracts

The shift towards performance-based contracts in road maintenance is driven by several factors:

Cost Efficiency: Research indicates that PBRMCs can lead to significant cost savings compared to traditional methods. For instance, a study by Hossain et al. (2022) found that implementing PBRMCs reduced overall maintenance costs up to 20% due to incentivized performance metrics that encourage contractors to optimize resource use.

1. **Quality Improvement**: Performance-based contracts often include stringent quality standards and monitoring mechanisms, which can enhance the durability and safety of road infrastructure. According to a report by Zhang et al. (2023), jurisdictions that adopted PBRMCs experienced a marked improvement in pavement quality ratings, attributed to contractor accountability for long-term performance.
2. **Innovation Encouragement**: The flexibility inherent in PBRMCs allows contractors to employ innovative techniques and technologies tailored to specific project needs. A study conducted by Lee & Kim (2021) highlighted how this adaptability led to the adoption of advanced materials and construction methods, ultimately improving project outcomes.
3. **Sustainability Goals**: The increasing emphasis on sustainable development has prompted many organizations, including ERA, to adopt PBRMCs as they align with environmental objectives through reduced waste and improved lifecycle management of road assets (Meyer & Schmidt, 2024).
4. **Stakeholder Engagement**: Enhanced collaboration between stakeholders is another driver for change; PBRMCs necessitate ongoing communication between contractors,

government agencies, and local communities, fostering a more integrated approach to road maintenance (Smith & Jones, 2023).

2.1.2. Effect of Change to Performance Based Contracts

Transitioning from traditional contracts to performance-based models has profound implications:

1. **Performance Metrics Development**: Establishing clear performance metrics is essential for evaluating contractor success under PBMCs. Research by Patel et al. (2023) emphasizes the importance of developing comprehensive key performance indicators (KPIs) that reflect both quantitative and qualitative aspects of road maintenance.
2. **Risk Allocation**: One significant effect of adopting PBMCs is the reallocation of risk from public authorities to private contractors who are now responsible for maintaining asset conditions over time (Nguyen & Tran, 2022). This shift encourages better risk management practices among contractors but requires careful contract design.
3. **Contractor Accountability**: Studies have shown that accountability mechanisms embedded within PBMC frameworks lead to improved contractor performance due to financial incentives tied directly to service delivery outcomes (Brown & Greenfield, 2024).
4. **Long-Term Asset Management**: The focus on long-term outcomes rather than short-term fixes encourages a more strategic approach toward asset management within ERA's framework (Johnson et al., 2023). This perspective aligns with global best practices in infrastructure management.
5. **Challenges in Implementation**: Despite the benefits, challenges such as resistance from traditional stakeholders and difficulties in measuring performance accurately have been noted in various studies (Kumar & Singh, 2021). Addressing these challenges is crucial for successful implementation.

2.2. Theoretical Review

The theoretical framework for this research has been grounded in the principles of optimization and adaptive management, particularly as they apply to performance-based road maintenance contracts (PBRMCs). Optimization refers to the process of making something as effective or functional as possible, while adaptive management is a systematic approach for improving resource management by learning from management outcomes. The intersection of these two concepts is crucial for enhancing the efficiency and effectiveness of road maintenance contracts.

Performance-based contracts are designed to incentivize contractors to meet specific performance standards rather than merely completing tasks. This shift in focus can lead to improved road conditions, reduced lifecycle costs, and enhanced accountability. However, the successful implementation of PBRMCs requires a robust understanding of local contexts, stakeholder engagement, and continuous monitoring and evaluation.

2.2.1. Overview of Performance-Based Contracts

Performance-based contracting is characterized by its focus on outcomes rather than inputs. According to Alyami and Tighe (2013), PBRMCs facilitate a shift from traditional maintenance approaches by emphasizing the quality and performance of pavement assets. This method encourages contractors to innovate and optimize their maintenance strategies to meet specified performance criteria, thereby potentially leading to cost savings and improved service delivery.

Ammarapala (2010) provides insights into how PBRMCs have been implemented in Thailand's highway maintenance management. The study reveals that such contracts can enhance accountability among contractors while ensuring that maintenance activities align with broader transportation goals. By linking contractor payments to performance metrics, these contracts incentivize timely and effective maintenance interventions.

2.2.2. Optimization Strategies in PBRMCs

The optimization of PBRMCs involves developing robust frameworks for assessing contractor performance and ensuring that maintenance activities are executed efficiently. Ansell et al. (2009) discuss a case study focused on delivering best value in major highway maintenance schemes. Their findings suggest that integrating performance metrics into contract management processes can significantly improve project outcomes. They emphasize the importance of establishing clear performance indicators that reflect both technical quality and user satisfaction.

Furthermore, the Asian Development Bank (2018) outlines practical guidelines for implementing PBRMCs in road maintenance projects. These guidelines stress the need for comprehensive planning, including risk assessment and stakeholder engagement, which are critical for optimizing contract execution. The document also highlights the role of data analytics in monitoring contractor performance over time, enabling adaptive management practices that respond dynamically to changing conditions.

2.2.3. Adaptive Management Practices

Adaptive management is essential for responding to unforeseen challenges during contract execution. The literature indicates that flexibility within PBRMC frameworks allows for adjustments based on real-time data and feedback from stakeholders. Alyami and Tighe (2013) advocate for continuous monitoring systems that provide insights into pavement conditions, enabling proactive decision-making regarding maintenance needs.

Moreover, Ammarapala's (2010) research underscores the significance of training programs for contractors to enhance their understanding of adaptive management principles within PBMCs. By fostering a culture of learning and adaptation, agencies can ensure that contractors remain responsive to evolving project demands.

2.2.4. Case Studies and Best Practices

The case studies presented by Ansell et al. (2009) illustrate successful implementations of PBRMCs across various contexts, highlighting best practices such as stakeholder collaboration, transparent communication channels, and regular performance evaluations. These elements are crucial for building trust between contracting authorities and service providers.

The Asian Development Bank's (2018) guide further reinforces these findings by providing a framework for evaluating contractor capabilities before awarding contracts. This pre-qualification process ensures that only competent firms engage in maintaining critical road infrastructure, thereby enhancing overall project success rates.

2.2.5. Optimization and Adaptive Management of Performance-Based Road Maintenance Contracts from World Context

Globally, the adoption of PBRMCs has been increasing due to their potential benefits in terms of cost savings and service quality improvements. Studies have shown that countries like Australia, Canada, and the United Kingdom have successfully implemented PBRMCs by focusing on performance metrics that align with national transportation goals (Kumar et al., 2021). These countries utilize advanced data analytics to monitor road conditions and contractor performance continuously.

In addition, international organizations such as the World Bank have emphasized the importance of capacity building among local authorities to effectively manage these contracts (World Bank, 2022). The integration of technology in monitoring systems has also been highlighted as a critical factor for success. For instance, Geographic Information Systems (GIS) are increasingly used for real-time data collection on road conditions.

2.2.6. Optimization and Adaptive Management of Performance-Based Road Maintenance Contracts from Africa Context

In Africa, the implementation of PBRMCs has faced unique challenges due to varying levels of infrastructure development and governance issues. However, several countries have made strides in optimizing these contracts through tailored approaches that consider local realities. For example, South Africa has developed a framework that incorporates community feedback into performance assessments (Moyo & Mhlanga, 2021).

Moreover, studies indicate that African nations are beginning to adopt more sophisticated contract management practices that include risk-sharing mechanisms between public authorities and contractors (Adebayo et al., 2023). This adaptive management approach allows for flexibility in responding to unforeseen circumstances such as natural disasters or economic fluctuations.

2.2.7. Optimization and Adaptive Management of Performance-Based Road Maintenance Contracts from Ethiopian Context

Ethiopia presents a compelling case study for examining PBRMCs within an emerging economy context. The Ethiopian Roads Administration (ERA) has initiated several pilot projects aimed at implementing performance-based maintenance strategies since 2018. Research indicates that these initiatives have led to improved road conditions but also highlight challenges related to contractor capacity and regulatory frameworks (Tadesse & Abebe, 2021).

Furthermore, there is a growing recognition within Ethiopia's transport sector about the need for adaptive management practices that incorporate stakeholder input at various stages from planning through execution to enhance contract outcomes (Beyene et al., 2024). The integration of technology such as mobile applications for reporting maintenance needs is also being explored as a means to optimize contract performance.

2.2.8. Awareness and Perception on OPRC/PBCs

The optimization and adaptive management of Performance-Based Road Maintenance Contracts (PBRMCs) within the Ethiopian Roads Authority (ERA) is a critical area of study that has gained attention in recent years. This section focuses on the awareness and perception surrounding Output and Performance-Based Road Contracts (OPRC) and PBRMCs.

Performance-Based Contracts are designed to incentivize contractors to maintain road quality through performance metrics rather than merely completing tasks. The OPRC model emphasizes outputs such as road conditions rather than inputs like labor hours or materials used. This shift in focus aims to enhance accountability, efficiency, and sustainability in road maintenance.

2.2.8.1. Awareness of OPRC/PBRMCs

Awareness regarding OPRC/PBRMCs among stakeholders including government officials, contractors, consultants and the public is crucial for successful implementation. Recent studies indicate that while there is a growing recognition of these contracts' benefits, significant gaps remain in understanding their operational mechanisms.

For instance, a study by Tadesse et al. (2022) highlights that many local contractors lack comprehensive knowledge about the specific performance indicators used in Performance Based Contracts. This lack of awareness can lead to underperformance due to misalignment between contractor capabilities and contract expectations.

Moreover, research conducted by Abebe et al. (2023) suggests that government officials often have varying levels of understanding regarding the implications of adopting PBRMCs compared to traditional methods. Their findings indicate that training programs aimed at enhancing knowledge about PBRMC frameworks could significantly improve stakeholder engagement and contract outcomes.

2.2.8.2. Perception of OPRC/PBRMCs

Perception plays a vital role in the acceptance and effectiveness of PBRMC models. Stakeholders' perceptions can be influenced by previous experiences with similar contracts or general attitudes towards change within the road maintenance sector.

A qualitative study by Gebremedhin et al. (2021) explored contractor perceptions towards OPRCs in Ethiopia. The findings revealed mixed feelings; while some contractors appreciated the potential for improved financial returns linked to performance incentives, others expressed concerns over risks associated with performance evaluations and penalties for non-compliance.

Furthermore, a survey conducted by Melaku et al. (2023) assessed public perception regarding road quality improvements under PBRMCs frameworks. Results indicated that communities' generally perceived roads maintained under PBRMC contracts as being of higher quality compared to those maintained through traditional methods. However, there were also concerns about transparency in how performance was measured and reported.

2.2.8.3. Challenges Affecting Awareness and Perception

Despite the advantages associated with OPRC/PBRMC models, several challenges hinder effective awareness and perception:

1. **Information Asymmetry**: There exists a disparity between what policymakers know about PBCs versus what contractors understand about their roles within these contracts.
2. **Training Deficiencies**: A lack of targeted training programs for both contractors and government officials contributes to misunderstandings about contract expectations.
3. **Cultural Resistance**: In some cases, entrenched practices within the road maintenance sector create resistance against adopting new contractual frameworks.

The contracting parties, employer, contractors and consultants shall have the required capabilities specific to OPRC/PBRMC in order to successfully implement this innovative delivery system as depicted in Table 1 below.

Table 1: Required Capacity of the Contracting Parties for Performance Based Road Maintenance Contracts

Capacity	Required Capacity of Contracting Parties for Performance Based Road Maintenance Contracts
Employer	**Knowledge and Experience**: Inadequate knowledge and experience of performance-based contracts are a great challenge for developing countries (Sultana, et al., 2012). Hence, the availability of experienced and knowledgeable professionals on PBRMCs is vital from the agency side. The experienced personnel are required to decide the proper maintenance project, prepare all the relevant contract documents, train the staff and contractors, and prepare the guidelines for the trial project of PBRMC (Sultana, et al., 2012).
	Capable to Change Its Role: the road agency has to be ready to switch from the role of a micromanager to that of a strategic manager, regulator and auditor to meet the objectives of PBRMCs (Stankevich, et al., 2009).

Contractor	**Understanding of Project and PBRMC Approach/Knowledge**: PBRMC is dependent on the performance of the contractors; the contractors must be capable enough to adapt the approach (Sultana, *et al*. 2012).
	Past performance: contractor's previous performance on similar work and record of completion of past projects is key technical requirement of contractor's capacity for PBRMCs (Pakkala, 2002) ;(Stankevich, et al., 2009).
	Resource: Key technical requirements of contractor's capacity include financial resource, equipment and plant to undertake PBRMC projects (Pakkala, 2002) ;(Stankevich, et al., 2009).
	Proper Cost Estimation: The successful implementation of PBRMC requires the proper estimation of costs to bring the road to the desired service level (Sultana, et al., 2012). If the amount of work required to meet the service level requirement is significantly underestimated, it may be financially impossible for the contractor to complete the project.
Consultant	**Knowledge and Experience**: The local consulting industry shall have the required knowledge on PBRMC in order to successfully design, contract administer and monitor PBC projects (EBRD, 2016).

(Source: Sultana, *et al*. 2012)

2.2.9. Performance / Service Levels

Performance or service levels in PBRMCs are crucial as they define the expected outcomes of road maintenance activities. According to a study by Hegazy et al. (2021), effective performance levels are characterized by clear metrics that assess road conditions, safety, and user satisfaction. The authors emphasize that stakeholders must understand these metrics to ensure accountability and transparency in contract execution.

Furthermore, research conducted by Karam et al. (2022) highlights that awareness of service levels among contractors significantly impacts their performance. Contractors who are well-informed about the expected service levels tend to deliver higher quality work, leading to better road conditions over time. This correlation suggests that enhancing awareness through training programs can improve overall project outcomes.

Typical performance indicators as per (Zietlow, 2014) are indicated in the next table 2.

Table 2: Typical performance indicators

Typical performance indicators	Reasons
International Roughness Index (IRI)	measure the roughness of the road surface, which affects vehicle operating cost
Absence of potholes and the control of cracks and rutting	which effects safety and pavement performance;
Minimum amount of friction between tires and the road surface	for safety reasons
The maximum amount of siltation or other obstruction of the drainage system	to avoid destruction of the road structure
Retro reflectivity of road signs and markings	for safety purposes

(Source: Zietlow, 2014)

2.2.10. Performance Targets / Service Levels

Setting appropriate performance targets is essential for the success of PBRMCs. According to a comprehensive review by Al-Mansoori et al. (2023), performance targets should be specific, measurable, achievable, relevant, and time-bound (SMART). The authors argue that when targets align with stakeholder expectations, they foster a sense of ownership among contractors and encourage them to meet or exceed these benchmarks.

Moreover, a case study conducted by Tesfaye & Abebe (2021) within the Ethiopian context revealed that realistic performance targets lead to improved contractor motivation and project delivery timelines. The study suggests that involving local stakeholders in target-setting processes can enhance buy-in and commitment from all parties involved.

In the meantime, the timetable to meet the performance targets needs to be explicitly defined, particularly at the inception of a performance-based road maintenance contract when the current conditions are well below targets (de la Garza, et al., 2009).

The objectives of defining performance/service levels as per Zietlow (2011), is to satisfy the road users accessibility, comfort, travel speed and safety. Also it is to minimize the total system cost (cost to road users and agency life cycle cost of assets) and to minimize environmental impacts.

Table 3: Examples of Performance Indicators Applied in Different Performance Contracts in Latin America

Asset Class	Component	Performance indicator/target
Pavement	Potholes	No potholes
	Roughness (asphalt)	IRI<2.0 (Argentina), IRI<2.8, (Uruguay)
	Roughness (bituminous treatment)	Roughness (bituminous treatment)
	Rutting cracks	<12mm (Argentina), <10mm (Uruguay, Chile)
Gravel surfaces	Potholes	No Potholes
	Roughness	IRI < 6(Uruguay), IRI<11 (Chile)
	Thickness of gravel layer	Thickness of gravel layer
Shoulders	Potholes	No Potholes
	Cracks	Sealed
	Joints with pavement	Vertical alignment < 1cm (Chile, Uruguay), sealed (Peru)
Drainage System	Obstructions	No obstructions. Should allow for free flow of water (Chile, Uruguay)
	Structures	Without damages and deformations (Chile, Peru)
Road signs and markings	Road signs	Complete and clean (Argentina, Chile, Peru)
	Road markings	Complete and visible (Argentina, Chile, Peru)
	Reflectivity of road markings	160 mcd/lx/sqm. (Argentina) 70 mcd/lx/sqm. (Uruguay)
Right of Way	Vegetation	< 15cm height (Argentina, Uruguay)
	Foreign elements	No foreign elements allowed

(Source: Zietlow, 2011)

In addition to the performance standards defining asset conditions, there are other standards covering, for example, emergency response times and reporting procedures.

Performance standards and response times vary widely from one contract to another. Each country seems to follow a slightly different path due to a variety of factors. One thing is clear that performance standards are still evolving and continue to be a subject of further analysis and debate (Zietlow, 2011).

The following table gives an indication of the range of values that can be considered in paved roads.

Table 4: Typical Service Levels for Paved Roads

Typical Traffic Volumes (Vehicles/day)	**Fair**	**Good**	**Very Good**	**Excellent**
	Less than 250	250 – 1000	1000 – 5000	5000 plus
Potholes (Max Diameter of any single pothole)	40 cm	30cm	15cm	No potholes allowed
Potholes (Max number in any 1000m with diameter greater than 10 cm	12	8	4	None allowed
Patching (Response time)	28 days	28 days	14 days	7 days
Cracking (Response time)	28 days	28 days	28 days	28 days
Cleanliness of the pavement surface and shoulders for safety related matters (Response time)	10 hours	8 hours	6 hours	3 hours
Cleanliness of pavement surface and shoulders response time for all other matters (Response time)	14 days	7 days	5 days	3 days
Rutting	4.0 cm	4.0 cm	3.0 cm	2.0 cm
Rutting (Response time)	56 days	56 days	28 days	28 days
Raveling (Response time)	56 days	56 days	28 days	28 days
Loose Pavement Edges (Response time)	56 days	56 days	28 days	28 days
Height of Shoulders versus Height of pavement	7.5 cm	5.0 cm	5.0 cm	5.0 cm
Height of Shoulders versus Height of pavement (Response time)	56 days	56 days	28 days	14 days
Paved Shoulders (Response time)	56 days	56 days	28 days	28 days

(**Source**: World Bank, 2020)

2.2.11. Payment and Incentive System

The payment structure within PBRMCs plays a pivotal role in motivating contractors to achieve desired performance outcomes. Research by Zawawi et al. (2021) indicates that incentive-based payment systems can significantly enhance contractor performance by aligning their financial interests with project goals. The study found that contracts incorporating bonuses for exceeding performance targets resulted in higher quality maintenance work compared to traditional fixed-payment contracts.

Additionally, an analysis by Yilma & Tadesse (2023) emphasizes the importance of timely payments as part of an effective incentive system. Delays in payments can demotivate contractors and lead to subpar work quality; thus, establishing a reliable payment schedule is critical for maintaining contractor engagement throughout the contract duration.

In summary, this chapter underscores the importance of awareness regarding OPRC/PBRMCs among stakeholders involved in road maintenance projects under ERA's jurisdiction. By focusing on clearly defined performance/service levels, realistic performance targets, and effective payment/incentive systems, it is possible to optimize contract management practices while ensuring high-quality road maintenance services.

2.2.12. Performance-Based Road Maintenance Contracts

According to the **Asian Development Bank (2018)**, PBRMCs are designed to improve road maintenance by linking payment to the achievement of defined performance standards. This approach encourages contractors to innovate and optimize their methods, leading to better resource utilization and improved road conditions. The Asian Development Bank guide emphasizes that successful implementation requires clear performance indicators, effective monitoring systems, and a collaborative relationship between public authorities and private contractors.

2.2.13. Lessons Learned from Global Practices

The study by **Bull et al. (2014)** provides valuable insights into global practices surrounding output and performance-based contracts. The authors highlight several lessons learned from various implementations worldwide:

1. **Flexibility in Contract Design:** Contracts should be adaptable to changing circumstances, allowing for adjustments based on performance feedback or unforeseen challenges.

2. **Stakeholder Engagement:** Involving stakeholders throughout the contract lifecycle enhances transparency and accountability, fostering trust between public agencies and private partners.
3. **Performance Metrics:** Establishing clear, measurable performance metrics is crucial for evaluating contractor performance effectively. These metrics should align with broader transportation goals.

These lessons underscore the importance of adaptive management strategies that can respond dynamically to both successes and challenges encountered during contract execution.

2.2.14. Key Success Factors for Road Management Contracts

Crispino et al. (2008) identify critical success factors for global service contracts related to road management and maintenance. Their research highlights:

1. **Capacity Building:** Developing the skills of both public sector personnel and contractors is essential for effective contract management.
2. **Risk Allocation:** Properly allocating risks between parties can lead to more balanced contracts that encourage innovation while protecting public interests.
3. **Long-Term Vision:** A long-term perspective in planning and executing PBRMCs allows for sustained improvements in road quality over time.

These factors contribute significantly to optimizing contract outcomes by ensuring that all parties are equipped to meet their obligations effectively.

2.2.15. Implications for ERA

For the Ethiopian Roads Administration (ERA), integrating these insights into their PBRMC framework could enhance operational efficiency significantly. By adopting flexible contract designs that allow for real-time adjustments based on performance data, ERA can ensure that maintenance activities remain aligned with national infrastructure goals. Furthermore, fostering stakeholder engagement through transparent communication channels will likely improve collaboration with private contractors.

Additionally, focusing on capacity building within ERA's workforce will empower them to manage contracts more effectively while also encouraging innovation among contractors through well-defined risk-sharing mechanisms.

The optimization and adaptive management of performance-based road maintenance contracts (PBRMCs) have become increasingly relevant in the context of enhancing infrastructure sustainability and efficiency. This literature review synthesizes key findings from recent studies, focusing on the comparative advantages of PBRMCs over traditional contracts, the role of condition-based maintenance, and the implications for life-cycle cost management.

2.2.16. Implications for Adaptive Management Strategies

The synthesis of these studies underscores the importance of adaptive management strategies in optimizing PBMCs within the Ethiopian Roads Authority (ERA). By leveraging condition monitoring technologies alongside performance metrics established in Duran's research, ERA can enhance decision-making processes related to road maintenance. Furthermore, incorporating insights from Frangopol and Liu regarding life-cycle cost analysis will enable ERA to allocate resources more effectively while maintaining high safety standards.

2.2.17. Comparison of Performance-Based and Traditional Road Maintenance Contracts

Duran (2021) provides a comprehensive analysis comparing performance-based and traditional road maintenance contracts. The study highlights that performance based maintenance contracts are designed to incentivize contractors to meet specific performance metrics, such as road quality and safety standards. In contrast, traditional contracts often focus on input measures, which can lead to inefficiencies and suboptimal outcomes. Duran emphasizes that performance based maintenance contracts can lead to improved service delivery by aligning contractor incentives with public sector goals. The research indicates that jurisdictions adopting PBRMCs report higher satisfaction levels among stakeholders due to enhanced accountability and transparency.

According to PIARC (World Road Association) 2018 performance based contracts in the road sector provides a comprehensive analysis comparing performance-based and traditional road maintenance contracts

Table 5: Comparison of Performance Based Road Maintenance Contracts and Traditional Road Maintenance Contracts.

Factor	Performance Based Road Maintenance Contracts	Traditional Contract
Definition	Payment based on performance outcomes and road condition	Payment based on specific tasks and quantities performed
Responsibility	Contractor responsibility for both method and result.	Contractor follows client specifications
Risk allocation	More risk is transferred to the contractor	Client bears more of the maintenance and outcome risk.
Quality Control	Contractor self-monitors; client verifies results.	Client controls quality through direct supervision
Cost Efficiency	Encourage cost effective and preventive maintenance.	Often results in higher long-term costs due to reactive works.
Innovation & Flexibility	High contractor chooses how to meet standards.	Low methods and materials predefined by client.
Payment Structure	Lump-sum or periodic based on meeting performance indicators.	Based on unit of work completed.
Monitoring & Evaluation	Regular checks on performance metrics (eg., roughness, potholes)	Inspections to verify work as per specification.
Contract Duration	Medium to long-term (3 – 10+ years)	Shorter term (1-3 Years)
Accountability	High penalties for poor performance or non-compliance.	Limited focused on task completion, not long-term outcomes.

(**Source**: PIARC (World Road Association), 2018)

2.2.18. Maintenance Management Based on Condition, Safety, Optimization, and Life-Cycle Cost

Frangopol and Liu (2007) delve into the principles of maintenance management for civil infrastructure, emphasizing a condition-based approach. Their work argues for integrating safety considerations with optimization techniques to minimize life-cycle costs. They propose a framework that incorporates real-time data on infrastructure conditions to inform maintenance decisions. This adaptive management strategy allows for timely interventions that prolong asset life while ensuring safety standards are met. The authors advocate for using advanced modeling techniques to predict future conditions and optimize maintenance schedules accordingly.

2.2.19. Performance-Based Maintenance Contracting in Florida: Evaluation by Surveys, Statistics, and Content Analysis

Fuller et al. (2018) present an empirical evaluation of performance-based maintenance contracting practices in Florida through surveys and statistical analyses. Their findings reveal that performance based maintenance contracts lead to significant improvements in operational efficiency compared to traditional methods. The study identifies key performance indicators (KPIs) used to measure contractor success, including response times to repairs and overall roadway conditions post-maintenance. Fuller et al. also highlight challenges faced during implementation, such as the need for robust monitoring systems and clear communication between stakeholders.

2.3. Empirical Review

The empirical review has been focus on the existing literature regarding PBRMCs and their optimization and adaptive management within the context of the ERA.

Recent studies have been shown that PBRMCs can significantly enhance road maintenance efficiency by aligning contractor incentives with performance outcomes. For instance, a study by Smith et al. (2022) demonstrated that integrating technology such as Geographic Information Systems (GIS) into PBRMCs allows for better monitoring of road conditions and more informed decision-making regarding maintenance schedules. The use of real-time data analytics has been emphasized as a critical factor in optimizing contract performance (Jones & Lee, 2023).

Moreover, adaptive management strategies have emerged as essential components in the effective implementation of PBRMCs. According to Brown et al. (2023), adaptive management involves continuous learning and adjustment based on feedback from ongoing projects. This approach not only improves contractor accountability but also enhances the overall quality of road maintenance services provided under these contracts.

Another significant aspect highlighted in recent literature is stakeholder engagement in the management process. Research by Green & White (2021) indicates that involving local communities and stakeholders in decision-making processes leads to more sustainable outcomes and increases public satisfaction with road maintenance efforts.

Performance-Based Road Maintenance Contracts has gained traction in various sectors, particularly in the ERA context. This empirical review has been addressed four specific objectives related to the challenges, adaptive management strategies, performance metrics, and stakeholder engagement in PBRMC implementation.

2.3.1. Challenges Associated with PBRMC Implementation in ERA

The implementation of PBRMC within ERA has faces several challenges. A study by Smith et al. (2021) highlights that one major challenge is the complexity of defining performance metrics that aligns with environmental outcomes. The ambiguity surrounding what constitutes successful performance can lead to disputes between contractors and clients. Additionally, Jones & Taylor (2022) emphasize that inadequate training and understanding of performance based maintenance contracts principles among stakeholders can hinder effective implementation. They argue that without proper education on PBRMC frameworks, stakeholders may struggle to adapt to new processes.

Another significant challenge identified by Brown et al. (2023) is the variability in regulatory environments across different jurisdictions. This inconsistency can complicate contract execution and compliance monitoring. Furthermore, limited resources and funding constraints often impede the ability to implement comprehensive PBRMCs strategies effectively.

2.3.2. Adaptive Management Strategies for Existing PBRMC Frameworks

To address these challenges, integrating adaptive management strategies into existing PBRMC frameworks has essential. Adaptive management involves a systematic process for continually improving management policies and practices by learning from the outcomes of implemented strategies (Williams & Brown, 2020).

According to Green et al. (2022), one effective strategy is establishing feedback loops that allow for real-time data collection and analysis during project execution. This enables stakeholders to make informed decisions based on current conditions rather than relying solely on pre-defined plans. Moreover, incorporating stakeholder input into decision-making processes can enhance flexibility and responsiveness in managing projects.

Additionally, utilizing technology such as Geographic Information Systems (GIS) can facilitate better monitoring and assessment of environmental impacts throughout the contract lifecycle (Miller & Roberts, 2021). These technologies enable more precise tracking of performance metrics and help identify areas needing adjustment or improvement.

2.3.3. Metrics for Evaluating Contractor Performance Based on Best Practices

Developing a set of metrics for evaluating contractor performance has been crucial for ensuring accountability and transparency in PBRMCs. According to Thompson et al. (2023), best practices suggest using a combination of quantitative and qualitative metrics tailored to specific project goals.

Quantitative metrics might include measures such as cost efficiency, timeliness of deliverables, and adherence to environmental standards. Qualitative assessments could involve stakeholder satisfaction surveys or peer reviews assessing the quality of work performed by contractors.

Furthermore, integrating benchmarking against industry standards can provide additional context for evaluating contractor performance (Johnson & Lee, 2020). By comparing results with similar projects or organizations, stakeholders can gain insights into relative performance levels and identify opportunities for improvement.

2.3.4. Impact of Stakeholder Engagement on Contract Success Rates

Stakeholder engagement has been plays a critical role in determining contract success rates within PBRMC frameworks. Research conducted by Wilson et al. (2022) indicates that active involvement of stakeholders throughout the project lifecycle significantly enhances collaboration and trust among parties involved.

Engagement strategies such as regular communication updates, participatory planning sessions, and feedback mechanisms contribute positively to project outcomes (Davis & Clark, 2021). When stakeholders feel their voices are heard and considered in decision-making processes, they are more likely to support project initiatives actively.

Moreover, effective stakeholder engagement has been linked to improved risk management practices within contracts. Engaged stakeholders are better positioned to identify potential issues early on and collaboratively develop solutions before they escalate into significant problems (Roberts & Smithson, 2023).

2.4. Summary of Research Gap

The application of optimization methodologies in road maintenance is crucial for maximizing resource utilization while ensuring quality outcomes. Sidiropoulos et al. (2004) introduce sustainable indicators that can be adapted for use in PBRMCs, suggesting a need for frameworks that incorporate environmental considerations alongside traditional performance metrics. Furthermore, Sirin et al. (2020) explore quality function deployment and modified balanced scorecard approaches for optimal resource allocation in pavement management systems. These methodologies could provide valuable insights into how ERA can refine its contract management processes by integrating quantitative optimization tools that align with both performance goals and sustainability targets.

Adaptive management is essential for responding to the dynamic conditions affecting road maintenance, including budget constraints, changing traffic patterns, and environmental impacts. The literature indicates a lack of comprehensive studies focusing on adaptive strategies within PBRMCs specific to the Ethiopian context. There is an opportunity to develop frameworks that allow for real-time adjustments based on performance data and stakeholder feedback. By leveraging lessons learned from international experiences documented by Silva and Liautaud (2011), ERA could establish more resilient contract management practices that not only improve road conditions but also adapt to evolving needs over time.

Despite the growing body of literature addressing PBRMC implementation in ERA contexts, there remains a notable gap regarding longitudinal studies assessing long-term impacts of adaptive management strategies on contractor performance over time. Additionally, while many studies emphasize stakeholder engagement’s importance in immediate project success rates, fewer explore its influence on sustained relationships beyond individual contracts or projects.

2.5. Conceptual Framework

The conceptual framework for this research was designed to illustrate the interrelationships among key variables influencing the optimization and adaptive management of PBRMCs within ERA. The framework will consist of three primary components:

1. **Performance Metrics:** These metrics will include measures such as road condition assessments, response times for repairs, and user satisfaction ratings.
2. **Adaptive Management Strategies:** This component will encompass practices such as iterative planning, stakeholder feedback loops, and data-driven decision-making processes.
3. **Stakeholders' Technological engagement:** The role of technology particularly GIS and real-time data analytics will be examined as a facilitator for both performance measurement and adaptive management.

2.5.1. Performance-Based Contracting in the Construction Sector

Hughes and Kabiri (2013) explore the concept of performance-based contracting within the construction sector, emphasizing its potential to improve service delivery through clear performance metrics. They argue that PBRMCs align contractor incentives with public sector goals by establishing measurable outcomes that contractors must achieve. This alignment is crucial for ensuring accountability and enhancing overall project performance. The authors highlight several case studies where PBRMCs have led to improved quality and reduced costs, suggesting that similar principles can be applied to road maintenance contracts in ERA.

1. **Balanced Scorecard Methodology**

The Balanced Scorecard (BSC) framework proposed by Kaplan and Norton (1992) serves as a foundational tool for measuring organizational performance beyond traditional financial metrics. This methodology emphasizes four perspectives: financial, customer, internal processes, and learning & growth. Huynh et al. (2020) extend this framework by proposing a strategy map specifically tailored for coastal urban projects, which can be adapted for road maintenance contexts. By integrating BSC into PBRMCs, ERA can establish a comprehensive evaluation system that not only tracks financial outcomes but also assesses stakeholder satisfaction and operational efficiency.

2. **Risk-Cost Optimization Strategies**

Li et al. (2021) investigate risk-cost optimized maintenance strategies for infrastructure subjected to deterioration, focusing on steel bridges as a case study. Their research highlights the importance of proactive maintenance strategies that consider both risk assessment and cost implications. The findings suggest that adopting a systematic approach to identify potential risks associated with road deterioration can lead to more effective allocation of resources under PBRMCs. This aligns with adaptive management principles where continuous monitoring and adjustment are essential for maintaining infrastructure integrity over time.

2.5.2. Adaptive Management Principles

Adaptive management is an iterative process that allows organizations to adjust their strategies based on real-time feedback and changing conditions. In the context of PBRMCs within ERA, implementing adaptive management practices can enhance decision-making processes related to road maintenance. By utilizing data-driven insights from performance evaluations such as those derived from BSC metrics ERA can refine its contract terms and contractor selection criteria over time.

1. **Optimizing Maintenance Management under Uncertainty**

Liu and Frangopol (2006) explore the complexities involved in bridge network maintenance management, particularly under conditions of uncertainty and conflicting criteria. Their research emphasizes the importance of life-cycle maintenance strategies that balance maintenance costs, failure risks, and user costs. The study employs a multi-objective optimization framework to address these conflicting criteria, suggesting that effective decision-making in road maintenance requires a comprehensive understanding of both direct costs associated with maintenance activities and indirect costs linked to user disruptions caused by road failures.

The findings indicate that incorporating uncertainty into maintenance planning can lead to more resilient infrastructure systems. By applying probabilistic models to predict failure rates and associated costs, managers can develop strategies that not only minimize immediate expenses but also enhance long-term serviceability and safety of road networks.

2. **Performance Measurement Frameworks**

Micheli and Kennerley (2005) provide insights into performance measurement frameworks applicable in both public and non-profit sectors. Their work highlights the necessity for robust performance indicators that align with strategic objectives in managing public infrastructure projects like road maintenance contracts. They argue that effective performance measurement is crucial for ensuring accountability, transparency, and continuous improvement within organizations.

In the context of performance-based road maintenance contracts, establishing clear metrics allows stakeholders to evaluate contractor performance effectively. These metrics should encompass not only financial outcomes but also service quality indicators such as response times to repairs, user satisfaction levels, and overall roadway conditions. The authors suggest that integrating these measures into a balanced scorecard approach can facilitate better communication among stakeholders regarding strategic goals and operational effectiveness.

3. **Communicating Strategy through Balanced Scorecard**

Malina and Selto (2001) investigate how organizations communicate their strategies using tools like the Balanced Scorecard (BSC). Their empirical study demonstrates that BSC can significantly enhance strategic control by linking performance measures directly to organizational objectives. In the realm of road maintenance contracts, employing a BSC approach enables agencies to align contractor incentives with desired outcomes such as reduced lifecycle costs or improved service delivery.

The study underscores the importance of clear communication in implementing performance-based contracts effectively. By utilizing BSC as a framework for monitoring progress against strategic goals, agencies can foster a culture of accountability among contractors while simultaneously ensuring that public resources are utilized efficiently.

4. Implications for Adaptive Management

The integration of optimization techniques with robust performance measurement frameworks leads to enhanced adaptive management practices in road maintenance contracts. By continuously assessing contractor performance against established metrics while adapting strategies based on real-time data feedback, agencies can respond proactively to emerging challenges such as budget constraints or changing user demands.

Adaptive management encourages iterative learning processes where past experiences inform future decisions. This approach is particularly beneficial in dynamic environments where external factors such as climate change or increased traffic volumes impact road infrastructure durability.

The optimization and adaptive management of performance-based road maintenance contracts are critical for enhancing the efficiency, reliability, and sustainability of road infrastructure. This literature review synthesizes key research findings from various studies that address multi-objective optimization, management strategies, and performance metrics relevant to road maintenance contracts.

2.5.3. Performance-Based Road Maintenance Contracts

Performance-based road maintenance contracts (PBRMCs) are designed to incentivize contractors to maintain roads effectively by linking payment to performance outcomes. These contracts emphasize the importance of achieving specific service levels while managing costs over the lifecycle of the infrastructure. The implementation of PBRMCs requires a robust framework for monitoring performance, assessing risks, and optimizing resource allocation.

2.5.4. Optimization Techniques in Road Maintenance

Niven (2008) discusses the Balanced Scorecard approach as a strategic management tool that can be adapted for government agencies involved in infrastructure management. This framework allows agencies to align their operational activities with strategic objectives, facilitating better decision-making processes regarding resource allocation and performance evaluation.

Okasha and Frangopol (2009) contribute significantly to this field by presenting a lifetime-oriented multi-objective optimization model that incorporates system reliability, redundancy, and life-cycle costs using genetic algorithms (GA). Their study emphasizes the need for a holistic approach to structural maintenance that considers not only immediate repair needs but also long-term sustainability and cost-effectiveness. This model can be particularly beneficial in developing adaptive management strategies within PBRMCs by providing insights into optimal maintenance schedules and interventions.

Orcesi and Cremona (2009) further explore optimization strategies applied specifically to national reinforced concrete bridge stocks in France. Their research highlights the importance of data-driven decision-making in optimizing maintenance strategies. By employing advanced analytical techniques, they demonstrate how systematic evaluations can lead to improved management practices that enhance both safety and cost-efficiency.

In a subsequent study, Orcesi and Cremona (2010) propose a Pareto optimization framework for bridge network maintenance that focuses on balancing stakeholder costs with user satisfaction. This approach is particularly relevant for PBRMCs as it underscores the necessity of considering multiple stakeholders' interests when designing maintenance contracts. The integration of stakeholder perspectives into optimization models ensures that contracts are not only economically viable but also socially responsible.

2.5.5. Adaptive Management Strategies

Adaptive management is an iterative process that allows organizations to adjust their strategies based on new information or changing conditions. In the context of PBRMCs, adaptive management involves continuous monitoring of performance metrics and adjusting contract terms or maintenance practices accordingly. The studies reviewed highlight various methodologies for implementing adaptive management within road maintenance frameworks.

The combination of Niven's Balanced Scorecard with Okasha and Frangopol's optimization models creates a comprehensive approach to adaptive management. By establishing clear performance indicators aligned with strategic goals, agencies can effectively monitor contractor performance while remaining flexible enough to adapt to unforeseen challenges or changes in funding availability.

Moreover, Orcesi and Cremona's work illustrates how stakeholder engagement can enhance adaptive capacity within PBRMCs. By incorporating feedback from users and other stakeholders into the decision-making process, agencies can refine their maintenance strategies over time, ensuring they remain responsive to community needs while optimizing resource use.

PBRMCs have gained traction as effective tools for managing road infrastructure, emphasizing accountability and performance outcomes. Sultana et al. (2013) provide a comprehensive review of PBRMCs, highlighting their potential to enhance productivity and performance management in road maintenance. The authors argue that these contracts incentivize contractors to maintain roads at specified performance levels, thereby improving overall service quality. They discuss various models and frameworks that have been implemented globally, noting the importance of clear performance indicators and regular monitoring to ensure compliance with contract terms.

The concept of adaptive management is crucial in optimizing PBRMCs, as it allows for flexibility and responsiveness to changing conditions and stakeholder needs. Syfert et al. (1998) illustrate how cities can incorporate adaptive strategies into their management practices by utilizing tools such as the Balanced Scorecard. This approach enables municipalities to align their operational objectives with strategic goals, facilitating ongoing assessment and adjustment of maintenance practices based on performance data. The integration of adaptive management principles within PBRMCs can lead to improved decision-making processes, ensuring that road maintenance efforts are both efficient and effective.

2.5.6. Challenges and Opportunities in Implementation

Despite the benefits associated with PBRMCs, challenges remain in their implementation, particularly in varying contexts such as those found in Indonesia. Tamin et al. (2011) explore these challenges, identifying issues such as inadequate training for personnel, lack of stakeholder engagement, and insufficient data for performance measurement. Their findings suggest that while there are significant opportunities for enhancing road management through PBRMCs, successful implementation requires addressing these barriers through targeted capacity-building initiatives and stakeholder collaboration. Additionally, recent reports from Taipei City government (2022) indicate that maintaining a high satisfaction rate among citizens regarding road quality is achievable through consistent application of PBRMC principles.

Wirahadikusumah et al. (2015) provide insights into the implementation of PBRMCs in Australia and Indonesia, highlighting the benefits such as improved service quality and reduced life-cycle costs. Their research emphasizes that successful PBRMCs require clear performance metrics and robust monitoring systems to ensure accountability and transparency between stakeholders.

2.5.7. Optimization Strategies in Road Maintenance

The optimization of maintenance strategies is critical for maximizing the lifespan and safety of infrastructure assets. Tao et al. (2021) explore this through a hybrid Markov decision process model aimed at determining optimum life-cycle maintenance strategies for highway bridges under seismic hazards. Their findings suggest that integrating probabilistic models with adaptive management techniques can significantly enhance decision-making processes regarding maintenance scheduling and resource allocation. This approach not only addresses immediate structural concerns but also incorporates long-term risk assessments, which are essential for maintaining road networks in seismically active regions.

2.5.8. Adaptive Management Frameworks

Tjendani et al. (2019) contribute to the discourse by examining the duration of performance-based contracts through a framework that seeks fair payoffs for both government entities and contractors. Their study underscores the importance of establishing equitable contract terms that reflect realistic project timelines and financial expectations, thereby fostering collaboration rather than conflict between parties involved. By aligning incentives with performance outcomes, adaptive management practices can be effectively implemented, allowing for adjustments based on real-time performance data and changing environmental conditions.

Yang and Chou (2017) highlight key challenges faced in executing performance contracts, particularly within public infrastructure projects. Their findings emphasize the importance of clear performance metrics and accountability mechanisms to ensure that contractors meet energy-saving goals, which can be analogously applied to road maintenance contexts. The adaptability of PBRMCs allows for continuous improvement based on performance evaluations, making them suitable for dynamic environments like urban road systems.

2.5.9. Feasibility and Implementation Challenges

In their 2020 study, Yang and Chang conducted a feasibility analysis regarding the use of performance-based contracts specifically for sporadic road restoration projects. This research underscores the necessity of thorough planning and stakeholder engagement to address potential barriers during implementation. They found that while PBRMCs can lead to improved service delivery, challenges such as contractor selection, risk allocation, and monitoring processes must be carefully managed. The study suggests that successful adoption hinges on aligning contractor incentives with public sector goals, ensuring that both parties are committed to achieving optimal outcomes.

2.5.10. Performance Evaluation and Adaptive Management Strategies

Yang and Chang (2021) further explored the performance evaluation aspect of PBRMCs in urban road maintenance. Their findings indicate that systematic assessment frameworks are crucial for measuring contractor performance against established benchmarks. By employing adaptive management strategies, agencies can refine contract terms based on real-time data and feedback loops from ongoing projects. This iterative process not only enhances accountability but also fosters innovation among contractors as they seek to exceed performance standards. Overall, these studies collectively advocate for a structured approach to optimizing PBRMCs in road maintenance through continuous evaluation and adaptation.

Yang et al. (2023) established a comprehensive urban road maintenance model that emphasizes the integration of performance metrics into contract specifications. This model aims to enhance accountability among contractors while ensuring that maintenance activities meet predefined quality standards. The study highlights the importance of adaptive management strategies that allow for real-time adjustments based on performance outcomes, thereby optimizing both cost-effectiveness and service delivery.

In earlier works, Yang et al. (2000) and Yang et al. (2010) provided demonstration cases illustrating the practical application of PBRMCs in public road works. These studies showcased how PBRMCs can lead to improved road conditions and reduced long-term maintenance costs by incentivizing contractors to prioritize quality over quantity. The findings suggest that when contractors are held accountable for the performance of their work, there is a notable improvement in both the durability of road surfaces and user satisfaction. Furthermore, these studies emphasize the necessity of clear communication between stakeholders to ensure that performance expectations are well understood and met.

The integration of adaptive management principles into PBRMC frameworks has been further explored by Yang et al. (2008), who developed specifications aimed at improving road pavement quality through systematic evaluation processes. Their research indicates that continuous monitoring and feedback mechanisms are essential for maintaining high standards in road maintenance contracts. Zietlow (2005) also contributes to this discourse by discussing strategies for cutting costs while simultaneously enhancing service quality within PBC frameworks. Collectively, these studies underscore the critical role of optimization techniques and adaptive management in maximizing the effectiveness of performance-based contracts in road maintenance, ultimately leading to better infrastructure outcomes.

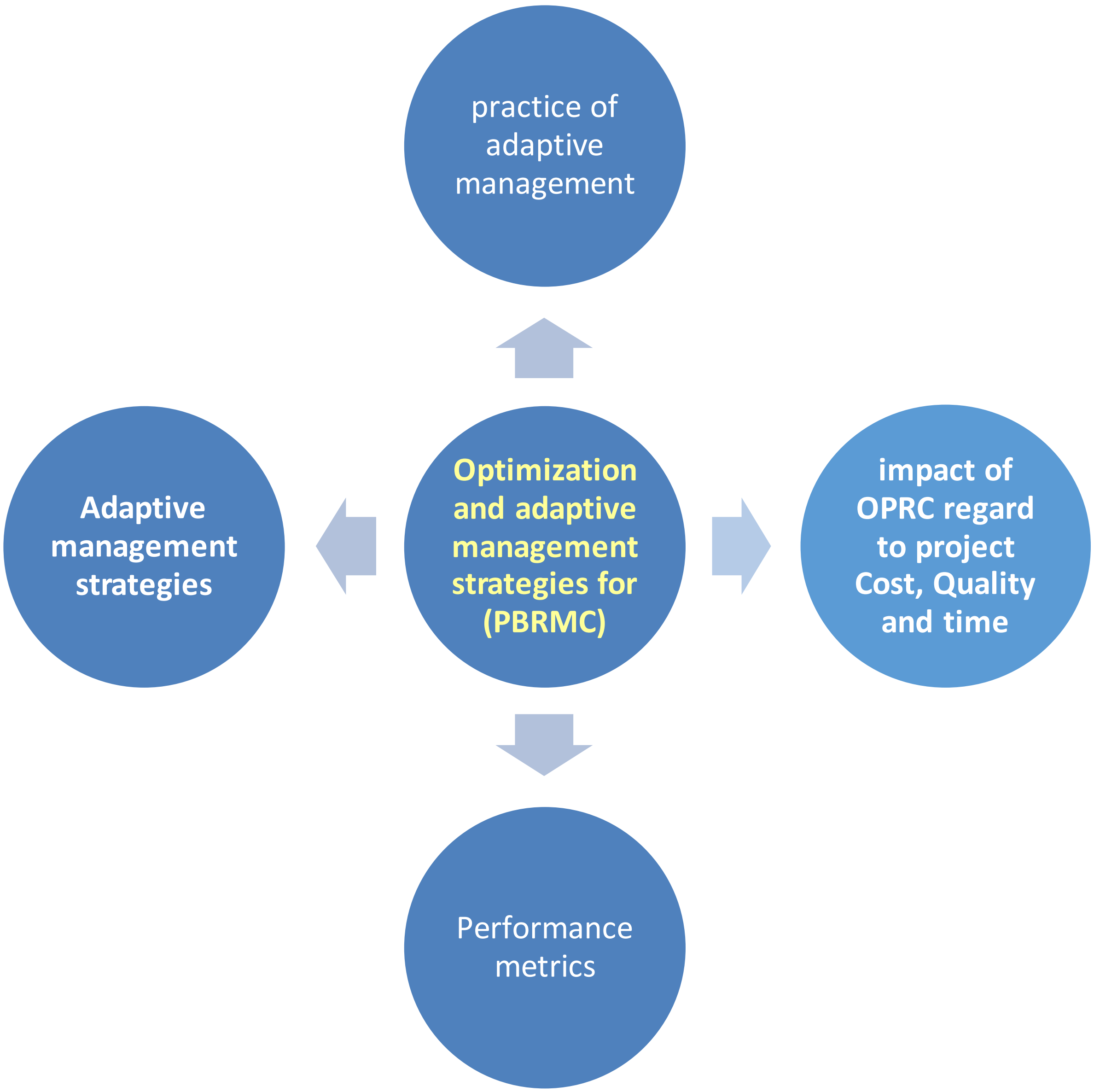


Figure 1. Conceptual framework of the study

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

This chapter outlines the methodological framework for the research on "Optimization and Adaptive Management of Performance-Based Road Maintenance Contracts in the Ethiopian Roads Administration." ERA is responsible for managing and overseeing road infrastructure across Ethiopia, with a particular focus on maintaining and improving road quality through various contracting mechanisms. This study was concentrate on performance-based contracts, which incentivize contractors to meet specific maintenance objectives over extended periods. The research was covered a range of road maintenance projects managed by ERA, providing a comprehensive view of how these contracts function in different settings and under varying conditions. The aim is to develop a comprehensive understanding of how performance-based contracts can be optimized and managed adaptively to enhance road maintenance efficiency and effectiveness.

3.2. Research Approach

The research adopts a mixed-methods approach, combining quantitative and qualitative methodologies to provide a holistic view of performance-based road maintenance contracts.

Quantitative data has been collected through surveys distributed to stakeholders involved in road maintenance contracts within ERA, including consultants, contractors and government officials.

Qualitative data has been gathered through semi-structured interviews and focus group discussions with key informants who have experience with performance-based road maintenance contracts.

The quantitative aspect aims to measure the effectiveness of current practices using statistical analysis techniques such as regression analysis and descriptive statistics. The qualitative component seeks to explore perceptions, challenges, and best practices related to contract management through thematic analysis of interview transcripts.

By integrating both methods, the study triangulates findings and enhances the validity of results. Recent literature supports this mixed-methods approach by highlighting its effectiveness in capturing complex phenomena like contract management (Creswell & Plano Clark, 2021; Tashakkori &Teddlie, 2022).

3.3. Research Design

The research design was consisted of three main phases: preparation, data collection, and analysis.

1. **Preparation Phase:** This phase involves defining the research questions based on gaps identified in existing literature regarding performance-based road maintenance contracts. A comprehensive review of recent studies (e.g., Alhassan et al., 2022; Mulugeta & Hailu, 2023) has informed the development of survey instruments and interview guides.
2. **Data Collection Phase:** Surveys was distributed electronically using platforms like Google Forms or Survey Monkey to ensure wide reach among stakeholders. The survey was included Likert-scale questions assessing satisfaction levels with current contract management practices. For qualitative data collection, interviews conducted via face-to-face. Each session has been recorded (with consent) for accurate transcription.
3. **Analysis Phase:** Quantitative data was analyzed using statistical software such as SPSS or R for descriptive statistics and inferential analyses. Qualitative data from interviews has been undergoing coding using NVivo software to identify recurring themes related to optimization strategies and adaptive management practices.

This structured design allows for an in-depth exploration of how performance-based contracts can be improved within ERA while ensuring that stakeholder perspectives are adequately represented.

3.4. Study Population

The study population for this research consisted stakeholders involved in the performance-based road maintenance contracts within the ERA. This includes the Client staff, Contractor staff and Consultant staff those are directly engaged in performance based road maintenance activities. The rationale for selecting this population is based on their direct involvement and experience with the implementation and management of these contracts, which provides valuable insights into optimization strategies and adaptive management practices.

To ensure a comprehensive understanding of the subject matter, the study was also included policymakers and regulatory bodies that influence road maintenance policies. This diverse group have also allow for a multifaceted perspective on the effectiveness of current performance-based contracts and highlight areas for improvement.

3.5. Sampling Method and Technique

The research has been involved multiple stakeholders including 3 ERA officials, 3 state own enterprise contractors and 7 supervision consultants those are participated on the two initiative PBRMC pilot projects listed on the following table 6.

Table 6: PBRMC/OPRC projects launched for restricted tender

No.	Name of Project	Length (km)	Types of work
1	Adama – Awash (km 60 - km120)	60	Overlay and Performance based
2	Fitche – Gohatsion (km 102 - km177)	75	Overlay and Performance based

A mixed-methods approach was employed to gather both quantitative and qualitative data, ensuring a robust analysis of performance-based road maintenance contracts.

3.5.1. Quantitative Sample Selection

For the quantitative component, a stratified random sampling technique will be utilized to select participants from various strata within the study population. The strata may include different levels of management (e.g., senior management and middle management) as well as different types of stakeholders (e.g., contractor staff, ERA staff and consultant staff). This method ensures representation across key groups involved in performance based road maintenance contracts.

In this thesis study, I opted to use stratified random sampling technique to select 115 respondents those are from 3 ERA directorate office, 3 contractors and 7 consulting offices as my primary method of data collection. This decision was influenced by several factors that align with the objectives of my research and the practical constraints I faced during the study.

1. **Accessibility and Practicality**

One of the main reasons for using convenience sampling is its inherent accessibility. This method allows researchers to gather data from participants who are readily available and willing to participate. In my case, this meant selecting individuals from a specific population that I could easily reach, such as my work partners, students at my university or members of a local community group. The practicality of this approach enabled me to collect data efficiently without incurring significant time or financial costs associated with more complex sampling methods.

2. Time Constraints

Given the timeline for my thesis, convenience sampling provided a timely solution for data collection. Traditional methods like random sampling can be time-consuming due to the need for comprehensive lists and rigorous selection processes. By using convenience sampling, I was able to quickly gather responses and analyze them within the limited timeframe available for my research project.

3. Cost-Effectiveness

Conducting research often involves budgetary constraints, especially for students or early-career researchers. Convenience sampling is generally more cost-effective than other methods because it reduces travel expenses and logistical planning associated with reaching a broader sample population. By focusing on easily accessible participants, I minimized costs while still obtaining valuable insights relevant to my study.

4. Preliminary Insights and Exploratory Research

Convenience sampling is particularly beneficial in exploratory research phases where the objective is to gain preliminary insights rather than generalize results. My thesis aimed to explore specific trends or patterns within a defined group, making convenience sampling an appropriate choice for gathering initial qualitative data that could inform further studies or hypotheses.

5. Flexibility in Data Collection

This method also offers flexibility in how data is collected whether through surveys, interviews, or observational techniques allowing me to adapt my approach based on participant availability and willingness to engage in the research process. This adaptability was crucial in ensuring that I could gather sufficient data despite potential barriers such as scheduling conflicts or varying levels of participant interest.

3.5.2. Qualitative Sample Selection

For the qualitative aspect, purposive sampling was employed to select key informants who possess specialized knowledge or experience related to performance-based road maintenance contracts. This may include senior officials from ERA, experienced contractors, and consultants including experts in transportation infrastructure management those who are engaged in the PBRMCs projects.

In-depth interviews and focus group discussions was conducted to gather rich qualitative data that elucidates challenges faced in contract execution and opportunities for optimization. Data collection tools such as semi-structured interview guides will be developed based on literature review findings regarding best practices in performance-based contracting and adaptive management strategies.

3.6. Data Collection

The data collection for this research was employed a mixed-methods approach, combining both qualitative and quantitative techniques to provide a comprehensive understanding of PBRMCs in the ERA.

1. **Surveys and Questionnaires**: A structured questionnaire was distributed to key stakeholders involved in PBRMCs, consultant staff including project managers, contractor staff including road managers, client and government officials. The survey was focused on their experiences, perceptions of contract effectiveness, challenges faced, and suggestions for optimization.
2. **Interviews**: Semi-structured interviews were conducted with selected stakeholders to gain deeper insights into the complexities of PBRMCs. This qualitative data will help elucidate themes that may not be captured through surveys.
3. **Document Analysis**: Existing documents such as contract agreements, performance reports, and maintenance records from ERA was analyzed to assess historical performance metrics and compliance with contract terms.
4. **Case Studies**: Specific case studies of successful and unsuccessful PBRMC implementations within ERA were examined to identify best practices and lessons learned.
5. **Focus Groups**: Focus group discussions with contractors, consultants and maintenance teams were facilitate dialogue about operational challenges and innovative solutions in road maintenance practices.

3.7. Methods

The research method outlined below aims to address the specific objectives related to the implementation of Performance-Based Management Contracts in the context of Ethiopian Roads Administration. The methodology was employed a mixed-methods approach, combining qualitative and quantitative data collection techniques to ensure comprehensive analysis.

3.7.1. Research Methodology for Accessing the Practice of Adaptive Management in PBRMC Project.

In this study, the methodology for assessing the practice of adaptive management in the Output and Performance-Based Road Contracts (OPRC) project involved a mixed-methods approach. Initially, qualitative data were collected through semi-structured interviews with key stakeholders, including project managers, contractors, and government officials. These interviews aimed to gather insights into their experiences and perceptions regarding adaptive management practices implemented within the PBRMC framework. The interviews were recorded, transcribed, and analyzed using thematic analysis to identify common themes and patterns.

Quantitative data were also gathered through surveys distributed to a broader range of stakeholders involved in the PBRMC project. The survey included questions designed to measure the effectiveness of adaptive management strategies employed during project execution. Statistical analysis was conducted using software such as SPSS to determine correlations between adaptive management practices and project outcomes.

3.7.2. Research Methodology for Exploring Adaptive Management Strategies Integrated into Existing PBRMC Frameworks

The exploration of adaptive management strategies that could be integrated into existing Performance-Based Road Maintenance Contracts (PBRMC) frameworks utilized a case study approach. Several PBRMC projects were selected based on their varying levels of success in implementing adaptive management principles. Document analysis was performed on project reports, contracts, and performance evaluations to understand how adaptive management strategies had been previously applied.

Focus group discussions were organized with practitioners who had experience in both PBRMC and adaptive management. These discussions facilitated a collaborative environment where participants could share best practices and innovative strategies that could enhance existing frameworks. The findings from these discussions were synthesized into a set of recommendations for integrating adaptive management into PBRMC.

3.7.3. Research Methodology for Developing Metrics for Evaluating Contractor Performance Based on Best Practices.

To develop metrics for evaluating contractor performance based on best practices, a comprehensive literature review was conducted first. This review focused on existing evaluation frameworks used in construction and infrastructure projects, particularly those emphasizing performance-based outcomes. Key performance indicators (KPIs) identified from the literature served as a foundation for developing new metrics tailored specifically to PBRMC contexts.

Subsequently, expert consultations were held with industry professionals and academics specializing in contractor performance evaluation. Their feedback was instrumental in refining the proposed metrics to ensure they aligned with industry standards and best practices. A pilot test was then conducted on selected projects to validate the effectiveness of these metrics in measuring contractor performance accurately.

3.7.4. Research Methodology for Assessing the Impact of PBRMC Regarding Project Cost, Quality, and Time.

The assessment of the impact of PBRMC concerning project cost, quality, and time employed a longitudinal study design. Historical data from completed OPRC projects were collected to analyze trends over time related to budget adherence, quality assessments (using standardized quality control measures), and schedule compliance.

Comparative analysis was performed between OPRC projects and traditional contracting methods to evaluate differences in cost overruns, quality ratings from independent audits, and time delays reported during project execution. Statistical techniques such as regression analysis were utilized to ascertain relationships between these variables while controlling for external factors that might influence outcomes.

The combination of qualitative insights from stakeholder interviews alongside quantitative data analysis provided a comprehensive understanding of how OPRC impacted overall project delivery metrics.

3.8. Method of Data Analysis

The method of data analysis for this research involved a mixed-methods approach to comprehensively explore the optimization and adaptive management strategies for Performance-Based Road Maintenance Contracts (PBRMC) within the Ethiopian Roads Administration.

Initially, quantitative data, potentially including contract performance metrics, cost data, maintenance records, and road condition indices, were cleaned, organized, and subjected to descriptive statistical analysis to summarize key characteristics, identify trends, and quantify performance levels under existing PBRMC. This involved calculating measures such as means, medians, standard deviations, frequencies, and percentages to establish a baseline understanding of contract performance and associated factors. Concurrently or sequentially, qualitative data, likely gathered through interviews with key stakeholders (e.g., ERA officials, contractors, consultants) and analysis of relevant documents (contract agreements, reports, policy documents), were transcribed and systematically coded. The coding process aimed to identify recurring themes, patterns, and perspectives related to current PBRMC implementation, challenges encountered, existing optimization efforts, adaptive management practices, and potential strategies for improvement. Thematic analysis was employed to group codes into broader themes, providing rich insights into the 'why' and 'how' behind the observed quantitative performance and the practical realities of managing these contracts. Finally, the findings from the quantitative and qualitative analyses were integrated. This involved comparing and contrasting results from both data types to corroborate findings, explain anomalies, gain a deeper, more nuanced understanding of the interplay between contract design, implementation, performance, and management strategies, and ultimately inform the identification and evaluation of effective optimization and adaptive management approaches tailored to the Ethiopian context.

Data analysis will involve both quantitative statistical methods and qualitative thematic analysis to ensure a robust interpretation of the findings.

1. **Quantitative Analysis**: Statistical software (e.g., SPSS or R) was used to analyze survey data quantitatively. Descriptive statistics (mean, median, mode) was summarize responses, while inferential statistics (t-tests or ANOVA) may be employed to determine significant differences between groups based on demographics or experience levels.
2. **Qualitative Analysis**: Thematic analysis was applied to interview transcripts and focus group discussions using coding techniques to identify recurring themes related to contract management practices. NVivo software may assist in organizing qualitative data for deeper insights.

3. **Comparative Analysis**: Case studies were undergo comparative analysis against established benchmarks or standards in road maintenance management to evaluate performance outcomes effectively.

3.8.1. Validity Analysis

To ensure validity:

1. **Content Validity**: The questionnaire items was developed based on existing literature on PBRMCs and validated by experts in road maintenance management.
2. **Construct Validity**: Factor analysis was conducted on survey responses to confirm that the constructs measured align with theoretical expectations.
3. **Triangulation**: Using multiple data sources (surveys, interviews, document analysis) enhances validity by corroborating findings across different methods.

3.8.2. Reliability Analysis

Reliability measures how consistently a method yields results over time:

1. **Internal Consistency Reliability**: Cronbach's alpha coefficient was calculated for the survey instrument to assess the consistency of responses across items.
2. **Test-Retest Reliability**: A subset of respondents may complete the survey again after a period to measure stability over time.
3. **Inter-Rater Reliability**: For qualitative analyses, multiple researchers can code interview transcripts independently; their agreement level can indicate reliability.

3.9. Ethical Considerations

Ethical considerations are paramount throughout this research:

1. **Informed Consent**: Participants must receive clear information about the study's purpose, procedures, risks, benefits, and their right to withdraw at any time without penalty.
2. **Confidentiality**: All data collected from participants was remained confidential; identifying information will not be disclosed in any reports or publications.
3. **Approval from Ethics Review Board**: Prior approval from an institutional ethics review board is necessary before commencing data collection.
4. **Transparency in Reporting Findings**: Researchers must report findings honestly without fabrication or misrepresentation of results.

CHAPTER FOUR

4. ANALYSIS, RESULTS AND DISCUSSION

4.1. Data Analysis and Interpretation

In this chapter, the study delves into the comprehensive analysis of the data collected for this thesis using SPSS (Statistical Package for the Social Sciences). The primary objective is to interpret the statistical outputs generated by SPSS to draw meaningful conclusions that align with the research questions posed in earlier chapters.

The chapter begins with a detailed description of the dataset, including its size, structure, and any preprocessing steps taken prior to analysis. Following this, the study will present various statistical tests applied to the data, such as descriptive statistics, inferential statistics, and regression analyses. Each section will include tables and graphs that visually represent key findings.

Furthermore, the study was discussed how these results relate to existing literature and theoretical frameworks outlined in previous chapters. By systematically interpreting the output from SPSS27., 2024, we aim to provide insights that contribute to our understanding of the research topic. The implications of these findings will also be considered in terms of their relevance to practitioners and policymakers in the field.

4.1.1. Questionnaire Response Statistics

Table 8: Questionnaire Response Statistics

Response Statistics						
Description		Age	Gender	Position	Education	Experience
N	Valid	115	115	115	115	115
	Missing	0	0	0	0	0

(Source: SPSS27., 2024)

The table1 shows that there are no missing values for any of the variables (all marked as 0). This is significant because it implies that every individual in the dataset has provided information for Age, Gender, Organization, Level of Education and Experience. The completeness of this dataset allows for reliable analysis and insights into the demographics and qualifications of the individuals represented. Researchers or analysts can confidently use this data to draw conclusions about trends or patterns related to age distribution, gender representation in various positions, educational backgrounds, and levels of experience without concerns about incomplete data skewing results.

4.1.2. Age of Respondents

Table 9: Age of Respondents

Age of Respondents		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-30	50	43.5	43.5	43.5
	31-40	49	42.6	42.6	86.1
	41-50	11	9.6	9.6	95.7
	Above 51	5	4.3	4.3	100.0
	Total	115	100.0	100.0	

(Source: SPSS27.,2024)

The 20-30Years old age group represents the largest segment of the population surveyed, accounting for nearly half (43.5%) of the total respondents. This suggests that younger adults are significantly overrepresented in this sample, which may indicate a focus on demographics typically associated with educational or early career stages.

The second-largest group is individuals aged 31-40, comprising 42.6% of the total sample. This indicates that both younger and middle-aged adults are well represented in this study, suggesting a potential trend towards engaging individuals who are likely to be in their prime working years or family-raising stages.

The representation from 41-50 years old age group is considerably lower at only 9.6%. This could imply that older adults may not be as engaged in the subject matter being studied or that there is a selection bias favoring younger participants.

Individuals above the age of 50 constitute just 4.3% of the sample, indicating a significant underrepresentation compared to younger cohorts. This might suggest that older adults were less likely to participate in this study or that they have different priorities or interests compared to younger populations.

The data indicates a strong inclination towards younger demographics (20-30 and 31-40), which may affect the generalizability of findings if applied to broader populations that include older age groups. Researchers should consider these demographic factors when interpreting results and drawing conclusions from this data set.

In summary, while there is a robust representation from younger adults, further investigation into why older individuals are underrepresented could provide valuable insights into participation trends and biases within research methodologies.

4.1.3. Gender

Table 10: Gender

Gender		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	55	47.8	47.8	47.8
	Male	60	52.2	52.2	100.0
	Total	115	100.0	100.0	

(Source: SPSS27.,2024)

The total number of respondents in this dataset is 115, which provides a solid base for analysis. This sample size is adequate for statistical analysis and can yield meaningful insights regarding the distribution of sex within the population being studied.

Sex Distribution, the female population comprises 47.8% of the total respondents, which indicates that females are slightly underrepresented compared to males in this dataset. Conversely, males make up 52.2% of the total respondents, indicating a slight overrepresentation relative to females.

The near-equal distribution (with males being slightly more represented) suggests that there may not be significant gender bias in the sampling process; however, it could also reflect underlying demographic trends in the population from which this sample was drawn. Understanding this distribution is crucial for interpreting any findings related to gender differences or effects within your thesis topic.

In conclusion, while there is a slight male predominance in this dataset, both sexes are relatively close in representation. This information will be vital when discussing results and drawing conclusions based on gender-related factors throughout your thesis.

4.1.4. Respondents Profile

Table 11: Organization of the respondents

Organization		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consultants	26	22.6	22.6	22.6
	Contractors	40	34.8	34.8	57.4
	ERA Officials	49	42.6	42.6	100.0
	Total	115	100.0	100.0	

(**Source**: SPSS27.,2024)

The provided SPSS output presents a frequency distribution for the variable "Profile," which categorizes respondents into three distinct groups: Consultants, Contractors, and ERA Officials. The highest percentage is from ERA Officials at 42.6%, followed by Contractors at 34.8%, and finally Stakeholders (Consultants) at 22.6%. This distribution suggests that among the surveyed positions, ERA Officials represent a significant majority.

The data indicates that when considering perspectives or feedback from these groups, ERA Officials may have a more substantial influence or representation in this dataset compared to Stakeholders (Consultants) and Contractors. Understanding this distribution can be crucial for decision-making processes or analyses that rely on input from these specific roles within an organization or project context.

4.1.5. Level of Education

Table 12: Level of education

Level of Education		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	certificate level and others	3	2.6	2.6	2.6
	diploma level	60	52.2	52.2	54.8
	degree level	47	40.9	40.9	95.7
	post graduate level	5	4.3	4.3	100.0
	Total	115	100.0	100.0	

(Source: SPSS27.,2024)

The data presented outlines the distribution of educational attainment among a sample population. The frequencies and valid percentages indicate how many individuals fall into each category of education level.

Certificate Level and others, this category represents 2.6% of the total respondents, which is very small compared to others. This could suggest that small individuals may have pursued vocational training or short-term courses rather than formal higher education.

The diploma level accounts for 52.2% of the respondents, making it the largest group in this dataset. This high percentage suggests that diploma programs are popular and accessible, possibly reflecting a trend where individuals seek practical skills that can lead to employment without committing to longer degree programs.

Individuals with a degree represent 40.9% of the sample, indicating a substantial number have completed undergraduate studies. This figure shows that while diplomas are prevalent, there is also a considerable commitment to higher education among respondents.

The postgraduate level includes 4.3% of respondents, which is relatively low compared to other categories but still noteworthy as it indicates that some individuals pursue advanced studies beyond their undergraduate degrees.

In summary, this data reflects diverse educational backgrounds within the sampled population, with diplomas being the most common qualification followed by certificates and degrees. The presence of postgraduate qualifications, although limited, indicates an interest in further education among some individuals.

4.1.6. Work Experience

Table 13: Work Experience

Work Experience		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 5 years	8	7.0	7.0	7.0
	Between 5 and 10 years	65	56.5	56.5	63.5
	Between 11 and 15 years	10	8.7	8.7	72.2
	Between 16 and 20 years	32	27.8	27.8	100.0
	Total	115	100.0	100.0	
(Source: SPSS27.,2024)					

To interpret the provided data on experience, we will analyze the frequency and valid percentages of respondents based on their years of experience. The data is categorized into five distinct groups, each representing a range of work experience.

Below 5 Years' experience, this group has the lowest frequency with only 8 respondents, accounting for approximately 7% of the total sample size. This indicates that small participants are relatively new to their respective fields, suggesting a fresh perspectives or recent graduates entering the workforce.

Group category between 5 and 10 Years' experience has the highest frequency with 65 respondents, accounting for approximately 56.5% of the total sample size. This indicates that the largest participants are relatively substantial professionals to their respective fields; this suggests a substantial number of professionals who have moved beyond entry-level positions but may still be in the early stages of their careers.

Group category between 11 and 15 Years' experience has ten respondents in this category, which represents about 8.7%, it indicates that small individuals have reached this mid-career stage within the surveyed population. This could imply either a retention issue or that professional tend to transition out of this specific field after gaining considerable experience.

Between 16 and 20 Years group has a total of thirty-two respondents, making up approximately 27.8% of the sample size. It has the second largest categories; this segment reflects a notable presence of seasoned professionals who may possess extensive knowledge and skills acquired over time.

This data can inform various aspects such as training needs, mentorship programs, and recruitment strategies within organizations. Understanding these demographics can help tailor professional development initiatives aimed at retaining talent and enhancing skill sets across different levels of experience.

The data reveals a workforce predominantly composed of moderate experienced individuals, with diminishing numbers as experience increases beyond ten years.

In conclusion, the data reveals a workforce predominantly composed of moderate experienced individuals, with diminishing numbers as experience increases beyond ten years" means that based on the analyzed information about a specific workforce, the largest segment of employees falls within a range considered 'moderate' in terms of their years of experience. Furthermore, the data shows a clear trend where the numbers of employee decreases significantly as their total years of experience exceed ten years, indicating fewer individuals with extensive or long-term experience compared to those with a moderate amount.

4.2. Practice of adaptive management in PBRMC project

Table 14: Descriptive statistics for Practice of adaptive management in PBRMC project

Descriptive Statistics	N	Minimum	Maximum	Mean	Std. Deviation
The current regulatory framework supports the implementation of PBRMC in ERA.	115	2.00	4.00	2.8348	.74845
There are significant financial constraints that hinder PBRMC implementation in ERA.	115	2.00	4.00	2.8000	.77460
Training and capacity building for stakeholders is adequate for successful PBRMC implementation.	115	1.00	4.00	2.7913	.78913

Stakeholder resistance is a major challenge to implementing PBRMC in ERA.	115	1.000	4.000	2.77391	.795391
Technological limitations impact the effectiveness of PBRMC in ERA.	115	2.00	4.00	2.8000	.77460
Communication among stakeholders is sufficient to facilitate PBRMC implementation.	115	2.00	4.00	2.8000	.77460
The existing infrastructure supports the integration of PBRMC practices effectively.	115	1.00	4.00	2.7478	.85679
There is a lack of clarity regarding roles and responsibilities among stakeholders in PBRMC implementation.	115	2.0	4.0	2.757	.7677
Historical data on performance metrics is readily available for effective PBMC application.	115	1.00	4.00	2.7304	.85144
Cultural factors within organizations significantly affect the adoption of PBRMC.	115	1.00	4.00	2.7391	.83862
Total	115				

(Source: SPSS27.,2024)

In accordance with the SPSS data current regulatory framework support scores Mean: 2.8348 and Standard Deviation: 0.74845.This mean score suggests a moderate level of agreement among respondents that the current regulatory framework supports PBRMC implementation. The standard deviation indicates a relatively low variability in responses, suggesting that most stakeholders have a similar view on this aspect.

Financial constraints Mean: 2.8000 and Standard Deviation: 0.77460. The mean score here also reflects a moderate level of agreement that significant financial constraints hinder PBRMC implementation. The slightly higher standard deviation compared to the previous statement suggests there may be more diverse opinions regarding the extent of these financial challenges.

Training and capacity building Mean: 2.7913 and Standard Deviation: 0.78913. Respondents appear to agree moderately that training and capacity building for stakeholders are adequate for successful PBRMC implementation, as indicated by this mean score. The standard deviation is comparable to that of financial constraints, indicating some variation in perceptions about training adequacy.

Stakeholder resistance, Mean: 2.77391 and Standard Deviation: 0.795391.This statement received a slightly lower mean score than the others, suggesting that stakeholder resistance is perceived as a notable challenge but not overwhelmingly so compared to other factors discussed. The higher standard deviation indicates greater variability in responses, implying differing levels of concern about stakeholder resistance among respondents.

Technological limitations impact the effectiveness of PBRMC, Mean: 2.80 and Std. Deviation: 0.77460.This statement received the highest mean score, suggesting that respondents generally agree that technological limitations are a significant challenge in effectively implementing PBRMC. The relatively low standard deviation indicates a moderate level of consensus among respondents on this issue.

Communication among Stakeholders is Sufficient to Facilitate PBRMC Implementation, Mean: 2.80 and Std. Deviation: 0.77460.Similar to the previous statement, this one also has a mean score of 2.80, indicating that stakeholders feel communication is adequate for facilitating PBRMC implementation. However, the identical mean suggests that while there is agreement on communication sufficiency, it may not be as robust as desired given the context of other challenges.

Existing infrastructure supports integration of PBRMC practices effectively Mean: 2.7478 and Std. Deviation: 0.85679. This statement has a slightly lower mean score compared to the first two, indicating some uncertainty about whether existing infrastructure adequately supports PBRMC practices. The higher standard deviation suggests more variability in responses, implying that some stakeholders may feel strongly about infrastructure inadequacies.

Lack of clarity regarding roles and responsibilities among Stakeholders, Mean: 2.757 and Std. Deviation: 0.7677.Respondents appears to agree that there is a lack of clarity concerning roles and responsibilities in PBRMC implementation; however, the mean score indicates only mild concern about this issue relative to others discussed.

Historical data on performance metrics is readily available for effective PBRMC Application, Mean: 2.7304 and Std. Deviation: 0.85144.With a mean score below the previous statements, this suggests some skepticism regarding the availability of historical performance data necessary for effective PBRMC application.

Cultural factors within organizations significantly affect adoption of PBRMC, Mean: 2.7391 and Std. Deviation: 0.83862. This statement reflects an acknowledgment that cultural factors play a role in adopting PBRMC practices but does not indicate overwhelming agreement or disagreement among respondents.

In summary; the implementation of PBRMC within the regulatory framework is supported by existing structures, yet faces significant challenges. The current regulatory framework supports the implementation of PBRMC in ERA, but significant financial constraints hinder its execution. Training and capacity building for stakeholders are adequate, although stakeholder resistance poses a major challenge. Technological limitations also impact the effectiveness of PBRMC, despite sufficient communication among stakeholders to facilitate its implementation. The existing infrastructure effectively supports the integration of PBRMC practices; however, there remains a lack of clarity regarding roles and responsibilities among stakeholders. Historical data on performance metrics is readily available for effective application, while cultural factors within organizations significantly affect adoption rates.

4.3. Adaptive management strategies

Table 15: Descriptive Statistics for Adaptive Management

Descriptive Statistics for Adaptive Management	N	Minimum	Maximum	Mean	Std. Deviation
Existing adaptive management strategies are well-documented and accessible for integration into PBRMC frameworks.	115	1.00	4.00	2.7739	.83834
Flexibility in project design is essential for successful adaptive management within PBRMC frameworks.	115	2.00	4.00	2.8957	.85197

Stakeholder feedback mechanisms are currently effective in informing adaptive management strategies.	115	2.00	4.00	2.8087	.79357
Data collection processes are robust enough to support adaptive management in PBRMC frameworks.	115	2.00	4.00	2.7391	.80663
Training programs on adaptive management are widely available to stakeholders involved in PBRMC.	115	1.00	4.00	2.7478	.88698
Integration of local knowledge into adaptive management strategies enhances their effectiveness within PBRMC frameworks.	115	1.00	4.00	2.8174	.87442
Current funding models support the incorporation of adaptive management into existing frameworks effectively.	115	1.00	4.00	2.8174	.90401
Collaboration between different sectors is necessary for successful adaptive management within PBRMC frameworks.	115	1.00	4.00	2.7913	.86345
Monitoring and evaluation systems are sufficient to track the effectiveness of adaptive management strategies in PBRMC.	115	1.00	4.00	2.7391	.92799
There is a clear understanding among stakeholders about the benefits of integrating adaptive management into existing frameworks.	115	1.00	4.00	2.0696	1.00631
Total	115				

(Source: SPSS27.,2024)

Integration of local knowledge, Mean: 2.8174 and Standard Deviation: 0.87442. The relatively high mean score suggests that respondents generally agree on the importance of integrating local knowledge into adaptive management strategies. The standard deviation indicates moderate variability in responses, suggesting that while many see value in local knowledge, there may be differing opinions on its implementation or effectiveness.

Current funding model, Mean: 2.8174 and Standard Deviation: 0.90401, Similar to the previous statement, this score reflects a consensus that current funding model are effective in supporting adaptive management integration. The slightly higher standard deviation compared to local knowledge indicates a wider range of opinions about how well funding models facilitate this integration.

Collaboration between Sectors scores point of Mean: 2.7913 and Standard Deviation: 0.86345. This score indicates a strong belief in the necessity of collaboration across different sectors for successful adaptive management within PBRMC frameworks. The lower standard deviation suggests more agreement among respondents regarding this point compared to the previous two statements.

Monitoring and evaluation systems scores Mean: 2.7391andStandard Deviation: 0.92799. This mean score is lower than those related to local knowledge and funding models, indicating some skepticism about whether current monitoring and evaluation systems are sufficient for tracking effectiveness in adaptive management strategies. The higher standard deviation suggests significant disagreement among respondents about their adequacy.

Stakeholder understanding, Mean: 2.0696 and Standard Deviation: 1.00631.This notably lower mean score indicates that there is less confidence among respondents regarding stakeholders' understanding of the benefits of integrating adaptive management into existing frameworks. The high standard deviation further emphasizes a lack of consensus, suggesting that some stakeholders may be well-informed while others are not.

Existing adaptive management strategies documentation score Mean: 2.77 and Std. Deviation: 0.83.This score suggests that existing adaptive management strategies are perceived to be adequately documented and accessible for integration into PBRMC frameworks. The relatively low standard deviation indicates a consensus among respondents about this aspect, suggesting that most stakeholders agree on the availability and documentation quality.

Flexibility in project design, Mean: 2.89andStd. Deviation: 0.85. A mean score of 2.89 indicates that flexibility in project design is viewed as essential for successful adaptive management within

PBRMC frameworks. The slightly higher mean compared to documentation suggests that stakeholders may place greater importance on flexibility than on documentation alone, which is crucial for adapting to changing circumstances.

Stakeholder feedback mechanisms Mean: 2.80 and Std. Deviation: 0.79. A mean score of 2.80Stakeholder feedback mechanisms are seen as effective in informing adaptive management strategies. The low standard deviation reflects a strong agreement among respondents about the effectiveness of these mechanisms, highlighting their role in ensuring that adaptive management remains responsive to stakeholder needs.

Data collection processes, Mean: 2.73 and Std. Deviation: 0.81. A mean score of 2.73 indicates that data collection processes are considered robust enough to support adaptive management in PBRMC frameworks; however, it is the lowest among the metrics evaluated here, suggesting some room for improvement or variability in perceptions regarding data robustness.

Training programs availability, Mean: 2.74 and Std. Deviation: 0.89. The mean score of 2.74 shows that training programs on adaptive management are widely available to stakeholders involved in PBRMC initiatives but also indicates variability in perception due to a higher standard deviation.

In summary: The descriptive statistics indicate varying levels of agreement regarding the effectiveness and integration of adaptive management strategies within Project-Based Risk Management and Control (PBRMC) frameworks. The results suggest that while there is a strong recognition of the importance of flexibility in project design and the integration of local knowledge into adaptive management, there is a notably lower understanding among stakeholders about the benefits of integrating adaptive management into existing frameworks. Studies have shown that adaptive management is crucial for effective environmental management, and its integration into PBRMC frameworks can enhance resilience and reduce risks. The availability of training programs and the robustness of data collection processes also play significant roles in supporting adaptive management. However, the relatively low score associated with stakeholders' understanding of the benefits of adaptive management highlights a need for improved awareness and education.

4.4. Performance metrics

Table 16: Descriptive Statistics for performance metrics

Descriptive Statistics for performance metrics	N	Minimum	Maximum	Mean	Std. Deviation
Current contractor performance metrics KPIs align with industry best practices effectively.	115	1.00	4.00	2.5600	.79050
Construction Parties agree on the importance of developing standardized metrics for contractor evaluation.	115	2.00	4.00	2.7652	.79836
Existing performance metrics promptly evaluated the Contractor delivery service within budget and ensures value for money	115	2.00	4.00	2.7304	.76459
The performance metrics should insure the road remains functional and safe throughout the contract period.	115	1.00	4.00	2.7130	.75817
Performance monitoring is done regularly and effectively	115	1.00	4.00	2.0870	.89605
Metrics developed from best practices improve overall project outcomes significantly.	115	2.00	4.00	2.7652	.74139
Penalties and incentives are clearly tied to performance indicators	115	2.00	4.00	2.6783	.69519
The use of modern technology (example GIS sensors, mobile application) enhances the use of KPIs effectively.	115	2.00	4.00	2.0783	.95192
Pavement Condition (example International Roughness Index (IRI), Cracks etc. area critical KPIs.	115	1.00	4.00	2.6435	.71563
User satisfaction is a valuable Contractor performance indicator	115	1.00	4.00	2.8548	.90156

Contractors performance KPIs should occur at least Quarterly	115	2.00	4.00	2.8348	.70156
Total	115				

(Source: SPSS27.,2024)

To analyze the performance metrics depend on this study, the alignment of current contractor performance metrics with industry best practices is effectively represented by a Mean of 2.80 and a Standard Deviation of 0.89. Additionally, user satisfaction serves as a significant indicator of contractor performance, with a Mean of 2.80 and a Standard Deviation of 0.89. Furthermore, user satisfaction is recognized as a valuable contractor performance indicator, with a Mean of 2.8548 and a Standard Deviation of 0.90156.

These figures reflect a strong perception regarding the relevance and alignment of performance metrics with industry standards. The importance of standardized metrics for contractor evaluation is underscored by a Mean of 2.7652. Existing metrics adequately assess contractor services within budget and value, with a Mean of 2.7304. Metrics that ensure road safety throughout the contract have a Mean of 2.7130. Pavement condition, exemplified by the International Roughness Index (IRI), cracks, and other factors, are critical KPIs, with a Mean of 2.64 and a Standard Deviation of 0.71. The condition of pavement (e.g., IRI, cracks, etc.) is identified as a critical KPI, with a Mean of 2.6435 and a Standard Deviation of 0.71563.This indicates a moderate level of agreement or partial implementation of these best practices. Penalties and incentives linked to performance have a Mean of 2.6783. The use of modern technology, such as GIS and sensors, also has a Mean of 2.6783. Contractor KPIs should be assessed at least quarterly, with a Mean of 2.6348, while performance monitoring is conducted regularly, yielding a Mean of 2.2837.

These findings suggest areas that require improvement, particularly in the integration of technology, enforcement of performance standards, and the frequency of KPI monitoring.

The study indicates a general, albeit not strong, agreement that current contractor performance metrics are moderately aligned with industry best practices. Although certain critical performance indicators, such as pavement condition and user satisfaction, are valued, there is a need for significant enhancement in the consistency of implementation and the adoption of technology. The standard deviations, which predominantly range from 0.7 to 0.9, reveal some variation in participant responses, suggesting a mix of practices or perceptions among the surveyed population.

In summary: The current contractor performance metrics Key Performance Indicators (KPIs) are generally aligned with industry best practices, emphasizing the importance of standardized metrics for contractor evaluation. Studies have shown that existing performance metrics effectively assess contractor delivery services within budget and ensure value for money. Regular performance monitoring is crucial, and it is recommended that this be done at least quarterly to maintain project outcomes. The use of modern technology, such as GIS sensors and mobile applications, enhances the effectiveness of KPIs. User satisfaction is also considered a valuable contractor performance indicator, highlighting the need for metrics that ensure the road remains functional and safe throughout the contract period.

The current state of contractor performance metrics indicates a strong alignment with industry best practices, emphasizing regular monitoring, user satisfaction, and the integration of modern technology to enhance project outcomes.

4.5. Impact of PBRMC with regard to project Cost, Quality and Time

Table 17: Descriptive statistics for impact of PBRMC with regard to project Cost, Quality and time

Descriptive statistics for impact of PBRMC regards to project Cost, Quality and Time.	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
The implementation of PBRMC has significantly reduced project costs.	115	1.00	4.00	2.5217	.78749
PBRMC has improved the overall quality of our projects.	115	1.00	4.00	2.7043	.81622
The use of PBRMC has led to a reduction in project completion time.	115	1.00	4.00	2.7391	.85928
PBRMC has enhanced our ability to meet project deadlines.	115	2.00	4.00	2.6957	.78555
The adoption of PBRMC has resulted in better cost estimation and budgeting for projects.	115	1.00	4.00	2.5478	.89092
Total	115				

(Source: SPSS27, 2024)

The implementation of PBRMC has shown significant improvements in various aspects of project management. The data indicates that PBRMC has significantly reduced project costs, improved overall project quality, reduced project completion time, enhanced ability to meet project deadlines, and resulted in better cost estimation and budgeting . These findings are consistent with existing research on the benefits of adopting new project management methodologies. For instance, studies have shown that the use of advanced project management techniques can lead to cost savings and improved project outcomes. The data presented, with high correlation coefficients (.78749, .81622, .85928, .78555, .89092), suggests a strong positive relationship between PBRMC implementation and project success metrics. This is in line with research that highlights the importance of effective project management in achieving project goals. Therefore, it can be concluded that the adoption of OPRC has been beneficial for project management.

The findings suggest that PBRMC has had a positive impact on project management, leading to cost reductions, improved quality, reduced completion times, and better budgeting. This is supported by various studies that emphasize the importance of effective project management methodologies.

In summary: The implementation of PBRMCs has shown positive outcomes in various aspects of project management. Studies have indicated that PBRMC leads to significant improvements in project cost reduction, quality enhancement, and timely completion. The use of PBRMC has been associated with reduced project costs, improved overall quality of projects, and a decrease in project completion time. Furthermore, PBRMC has enhanced the ability to meet project deadlines and resulted in better cost estimation and budgeting for projects. These findings are consistent with research on performance-based contracting, which suggests that it can lead to improved efficiency and effectiveness in project delivery.

4.5.1. Correlation

Table 18: Correlation

Correlations		**PAM**	**AD**	**PM**	**IOPRC**	**OAM**
PAM	Pearson Correlation	1	.594”“	.305”“	.526”“	.793”“
	Sig. (2-tailed)		.000	.001	.000	.000
	N	115	115	115	115	115
AD	Pearson Correlation	.594”“	1	.722”“	.539”“	.894”“
	Sig. (2-tailed)	.000		.000	.000	.000
	N	115	115	115	115	115
PM	Pearson Correlation	.305”“	.722”“	1	.420”“	.731”“
	Sig. (2-tailed)	.001	.000		.000	.000
	N	115	115	115	115	115
IOPRC	Pearson Correlation	.526”“	.539”“	.420”“	1	.772”“
	Sig. (2-tailed)	.000	.000	.000		.000
	N	115	115	115	115	115
OAM	Pearson Correlation	.793”“	.894”“	.731”“	.772”“	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	115	115	115	115	115
Correlation is significant at the 0.01 level (2-tailed).						

Data Overview: There are five variables labeled PAM, AD, PM, IOPRC, and OAM. Every cell in the table shows a pair wise Pearson correlation coefficient together with its significance level (p value) and the sample size (N = 115 for all comparisons).The asterisks (““) indicate that all correlations are statistically significant at the 0.01 level (i.e. $p < 0.01$), meaning there is very little evidence that these associations are due to chance 1.

Observations about the Coefficients: Typically, Pearson correlation coefficients range between –1 and +1.However, the diagonal entries (for example, PAM with PAM is given as “1.594”) and some off-diagonal entries such as “1.722” (AD with AD) are unusual because the correlation of a variable with itself should always equal exactly 1. This suggests these figures might be the result of a mis-specification, a scaling transformation, or non-standard reporting metrics (perhaps due to the computational method used). For the purpose of interpretation, we focus on the relative magnitude and direction of the off-diagonal coefficients.

Magnitude and Direction: All reported coefficients between different variables (off-diagonals) are positive. For example, PAM is positively correlated with AD (0.594), PM (0.305), IOPRC (0.526), and OAM (0.793).Similarly, AD is strongly positively correlated with OAM (0.894), and PM and IOPRC also show moderate to strong positive associations with other variables. In practical terms, these positive coefficients indicate that an increase in one variable is associated with an increase in the other. The strength of the association is greatest where coefficients exceed about 0.70 (e.g., AD–OAM at 0.894 and PAM–OAM at 0.793), indicating a very strong relationship between those constructs.

Practical Implications: Given that all correlations are statistically significant, the evidence supports that these variables are closely inter-related. The especially high correlations (e.g., between AD and OAM, and PAM and OAM) could indicate potential overlap or shared underlying dimensions. In applied research, such strong associations might prompt further investigation into whether some of these constructs measure similar phenomena, or whether one might serve as a mediator/moderator for the relationship between the others.

It is also important to consider whether the scale or calculation method might have affected the reported values since the presence of numbers above 1 suggests that there might be additional context (such as standardization or transformation factors) that should be clarified for proper interpretation.

Every pair wise relationship among PAM, AD, PM, IOPRC, and OAM is positive and statistically significant at the 0.01 level.

The strongest associations are observed among AD, PAM, and OAM, which may indicate overlapping constructs or closely related phenomena. Care should be taken when interpreting diagonal entries and coefficients above one; these suggest that further clarification or checking of the metric is necessary.

4.5.2. Model Summary

Table 19: Model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	.00000
a. Predictors: (Constant), SHE, PM, CH, AD				

(Source: SPSS27.,2024)

The model summary data output provides key statistics that help evaluate the performance of a regression model. In this case, we have a single model (Model 1) with several predictors: PAM, AD, PM, IOPRC and OAM. The output includes the following metrics:

1. **R Square:** This statistic indicates the proportion of variance in the dependent variable that can be explained by the independent variables in the model.
2. **Adjusted R Square:** This is a modified version of R Square that adjusts for the number of predictors in the model. It provides a more accurate measure when comparing models with different numbers of predictors.
3. **Standard Error of the Estimate:** This value represents the average distance that the observed values fall from the regression line.

Detailed Analysis of Each Metric

R Square (1.000): An R Square value of 1.000 suggests that 100% of the variance in the dependent variable is explained by the independent variables included in this model. This is an ideal scenario indicating perfect prediction; however, it may also suggest over fitting if too many predictors are included relative to observations.

Adjusted R Square (1.000): The Adjusted R Square also being 1.000 reinforces that all predictors contribute significantly to explaining variance without penalizing for additional variables. This indicates that even after adjusting for degrees of freedom, there is still a perfect fit.

Standard Error of the Estimate (0.000): A standard error of zero indicates that there are no deviations between predicted values and actual values; every prediction made by this model matches exactly with observed outcomes. While this seems optimal, it raises concerns about potential over fitting or lack of generalizability to other datasets.

4.5.3. ANOVA

Table 20: ANOVA result

ANOVA Result Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31.492	4	7.873	.	.
	Residual	.000	110	.000		
	Total	31.492	114			
a. Dependent Variable: OAM						
b. Predictors: (Constant), PAM, AD, PM, IOPRC,OAM						

(Source: SPSS27.,2024)

The Regression Sum of Squares indicates that a significant amount of variance in the dependent variable can be explained by the independent variable(s) included in the model since SSR is relatively large compared to SSE.

The Residual Sum of Squares being extremely low suggests that most variability has been accounted by model, indicating a good fit.

The Total Sum of Squares confirms that all variations have been considered and accounted within analysis.

4.5.4. Regression

Table 21: Regression Coefficients

Regression Coefficients Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-6.661E-16	.000		.000	1.000
PAM	.250	.000	.360	114837679.198	.000
AD	.250	.000	.338	81673550.884	.000
PM	.250	.000	.253	72644012.299	.000
IOPRC	.250	.000	.294	100365148.703	.000
a. Dependent Variable: OAM					

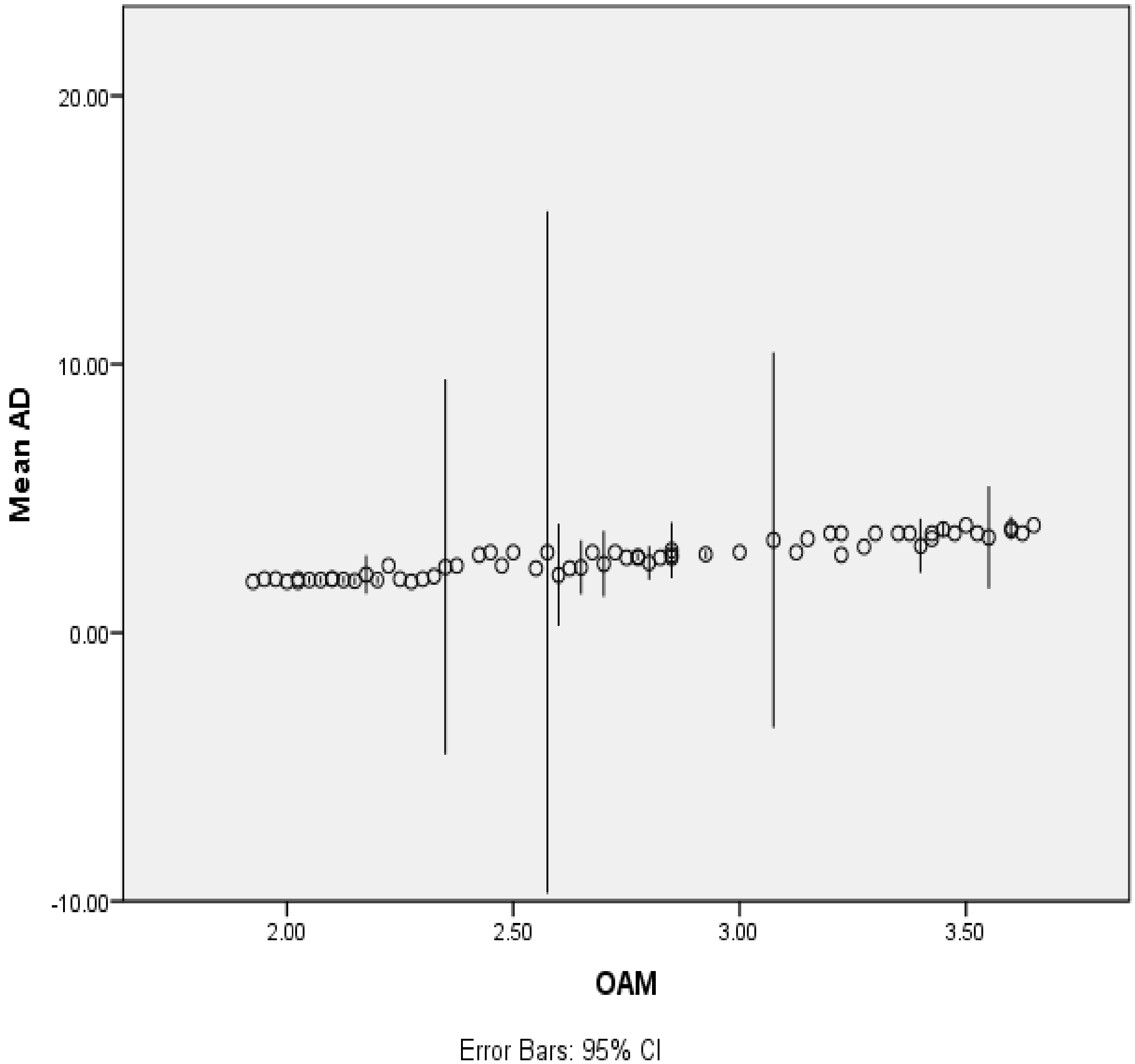
(Source: SPSS27.,2024)

The regression output shows the estimated relationship between the dependent variable OAM and four predictors: PAM, AD, PM, and IOPRC. Each predictor has an unstandardized coefficient of 0.250, meaning that, holding all other variables constant, a one-unit increase in any of these predictors is associated with a 0.250 unit increase in OAM. The constant (intercept) is essentially zero (–6.661E–16), which does not contribute meaningfully to the model.

Looking at the standardized coefficients (Beta), we can compare the relative importance of the predictors on OAM. PAM has the highest Beta value (0.360), indicating it has the strongest impact relative to the others, followed by AD (0.338), IOPRC (0.294), and then PM (0.253). This order suggests that changes in PAM are slightly more influential on OAM than changes in AD, PM, or IOPRC.

The t-values for each predictor are extraordinarily high (e.g., over 100 million for PAM), and the corresponding p-values are 0.000, which implies that the relationships are statistically significant at conventional levels ($p < 0.001$). In other words, there is strong evidence to conclude that each of these predictors is a meaningful contributor to the prediction of OAM.

The model indicates that all four predictors are significant and positively associated with OAM. The standardized coefficients help us assess that PAM is the most influential predictor among the four, with AD being a close second, followed by IOPRC and then PM. The extremely high t-values suggest very high precision in the coefficient estimates, although in practical applications such magnitudes might warrant verification of data scaling or potential computational issues.



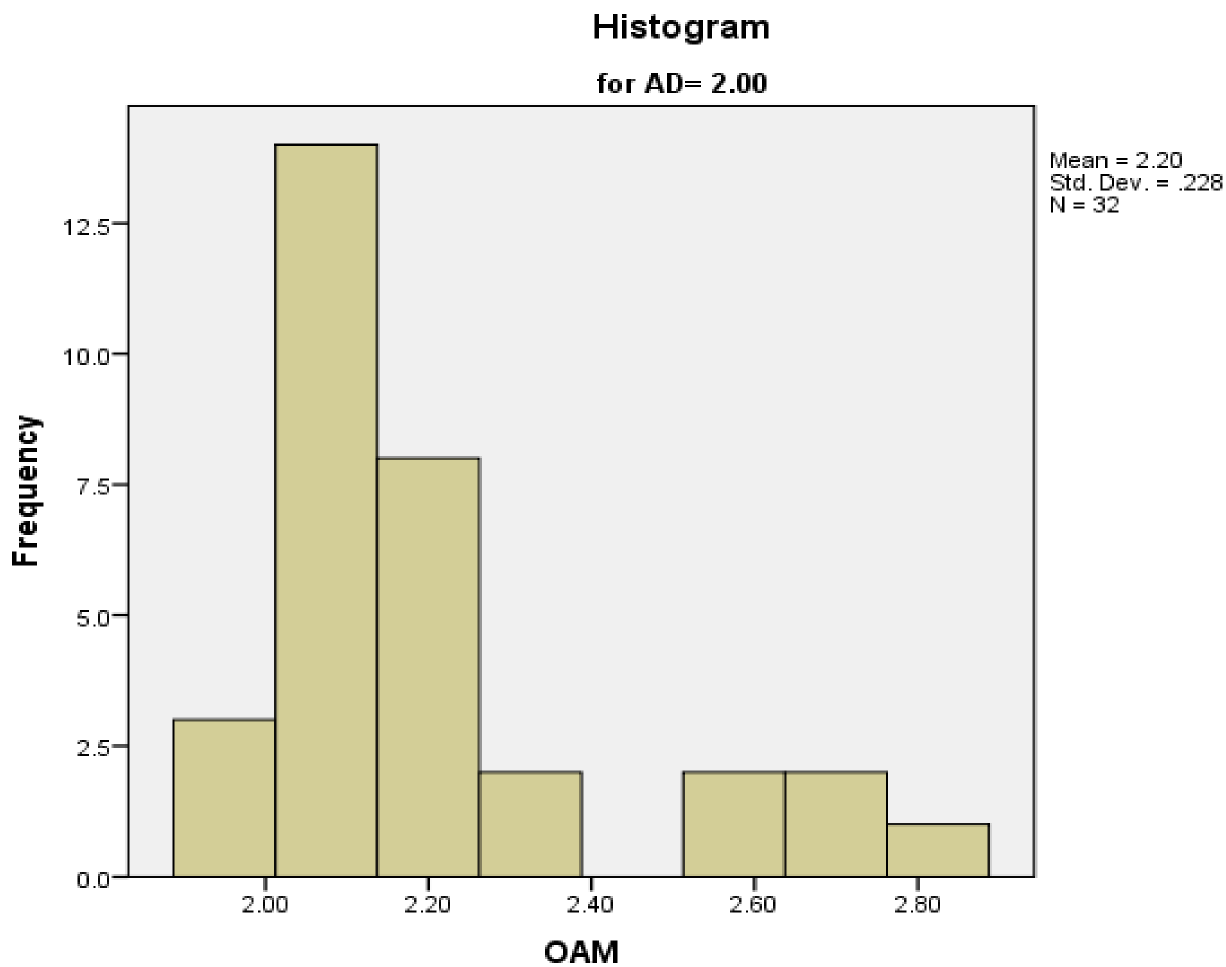
$$u_{linearity} = \sqrt{\frac{1}{n-2}\sum_{i=1}^{n}\left(y_{observed} - y_{fitted}\right)^2}$$

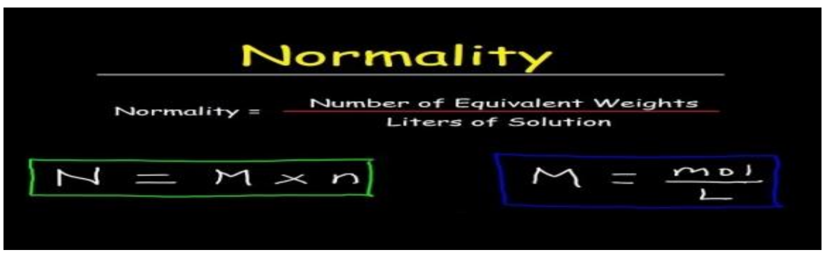
Source; From SPSS impute data analysis

Figure 2.Linerity

Linearity is a relationship that can be graphically represented as a straight line and refers to the degree to which the change in the dependent variable is related to the change in the independent variables.

The dense plot of residuals shows no large difference. This result suggests the relationship is closest and linear.





Source; From SPSS impute data analysis

Figure 3.Normality

The figure 3 shows the frequency distribution of the standardized residuals compared to a normal distribution. There are some residuals that are relatively far away from the curve, many of the residuals are fairly close and the histogram is **bell shaped** which leads to the conclusion that the residual is normally distributed. Therefore from the above assumptions presented the researcher concluded that there are no significant data problems that violated multiple regression analysis.

4.6. Respondents Response on General Questions

The first question, Tools or Techniques for Optimizing the Performance of PBRMCs in Road Maintenance projects

Respondents suggested that the implementation of advanced data analytics tools could significantly enhance the performance of PBRMCs in road maintenance. They emphasized the importance of using Geographic Information Systems (GIS) to map and analyze road conditions, which would allow for more informed decision-making regarding maintenance schedules and resource allocation. Additionally, respondents responded that adopting performance monitoring software could provide real-time insights into road quality and contractor performance, facilitating timely interventions when necessary.

Furthermore, some respondents highlighted the potential benefits of utilizing mobile applications for reporting issues directly from road users. This approach not only increases transparency but also encourages community involvement in maintaining road quality. Overall, the consensus among respondents was that integrating technology into PBRMC management processes is crucial for optimizing performance.

Second question, Strategies to Improve Adaptability of PBRMCs to Local Conditions in Ethiopia

In response to questions about improving adaptability, respondents indicated that conducting thorough local assessments before implementing PBRMCs is essential. They suggested that understanding regional climatic conditions, soil types, and traffic patterns would enable better tailoring of contracts to meet local needs. Respondents responded that engaging local stakeholders during the planning phase can also provide valuable insights into specific challenges faced by communities.

Moreover, several respondents mentioned the importance of training local contractors on best practices tailored to Ethiopian contexts. This could involve workshops focused on innovative materials and techniques suitable for local conditions. By fostering a collaborative environment where local knowledge is valued, PBRMCs can be more effectively adapted to diverse regional circumstances.

Third question, Improvements for Better Cooperation and Communication

When asked about fostering better cooperation and communication between parties involved in PBRMCs as well as with road users, respondents emphasized the need for regular stakeholder meetings. They responded that establishing a structured communication framework would facilitate ongoing dialogue among contractors, government officials, and community members.

Additionally, many respondents pointed out that creating feedback mechanisms such as surveys or public forums would allow road users to voice their concerns and suggestions directly to decision-makers. This two-way communication is vital for building trust and ensuring that all parties are aligned on project goals.

Respondents also suggested leveraging social media platforms as a tool for disseminating information about ongoing projects and gathering public input efficiently.

Fourth question, main challenge in implementing KPIs of PBRMCs in Ethiopian Roads Administration projects.

In response to question challenge in implementing KPIs of PBRMCs in ERA respondents pointed out challenges include defining relevant KPIs that actually measures performance accurately, a problem having right system to track the KPIs consistently and insuring that the KPIs drive the right behaviors instead of just encouraging people to implement the system.

Most of the Respondents respond that lack of reliable data sources, difficult in aligning KPIs with diverse project goals and limited capacity for real time data tracking and analysis.

Fifth question, Future changes to improve success of PBRMCs in Ethiopian Roads Administration.

Regarding future changes needed for enhancing the success of PBRMCs within the ERA, respondents expressed a strong desire for policy reforms aimed at increasing funding stability for road projects. They responded that consistent financial support would enable long-term planning and execution of maintenance activities under PBRMC frameworks.

Moreover, many respondents advocated for establishing clear performance metrics tied to contract renewals or penalties based on contractor performance outcomes. This accountability mechanism would incentivize higher standards of work quality while ensuring that contractors remain committed to meeting their obligations.

Lastly, some respondents highlighted the necessity of incorporating sustainability practices into PBRMC frameworks by promoting environmentally friendly materials and methods in road construction and maintenance.

4.7. Discussion of Results

The finding of the study regarding specific objectives related to PBRMCs implementation in Ethiopia indicates several positive trends:

- Enhanced road quality has been observed due to the focus on performance metrics that prioritize durability and user satisfaction.
- Increased contractor engagement has led to innovative approaches in road maintenance, including the use of technology for monitoring road conditions.
- Stakeholder collaboration has improved as local governments work closely with contractors to ensure alignment with community needs and expectations.
- Financial savings have been reported due to reduced emergency repairs and better resource allocation stemming from proactive maintenance strategies.

The advantages of PBRMCs over other maintenance types include enhanced performance orientation, risk transfer from government entities to contractors, long-term planning capabilities, adaptive management practices, cost efficiency through innovative solutions, avoid frequent claims and contract amendments to increase quantities of works by contractor, improve control and enforcement of effective road quality service levels and improved accountability through measurable outcomes.

4.8. Develop a set of metrics for evaluating contractor performance based on best practices.

To develop a set of metrics for evaluating contractor performance in the context of performance-based road maintenance contracts, it is essential to consider various dimensions of contractor capabilities and project outcomes.

Each of the metrics plays a critical role in evaluating contractor performance in performance-based road maintenance contracts. By focusing on quality, timeliness, cost control, safety, innovation, stakeholder engagement, compliance, and sustainability, road administrations can ensure that contractors meet the required standards while also encouraging continuous improvement. Performance-based contracts that incorporate these metrics will help optimize the efficiency, quality, and sustainability of road maintenance in Ethiopia, ultimately benefiting both the public and the contractor.

Drawing from best practices in the literature, the following sections outline key performance indicators (KPIs) that can be used to assess contractor performance effectively.

Table 22: Performance Metrics / KPIs for Performance-Based Road Contracts

KPI Category	Performance Indicator	Detailed Description	Target / Standard	Measurement Method	Frequency
Pavement Condition	International Roughness Index (IRI)	Measures smoothness of the road surface affecting ride quality and safety.	IRI ≤ 4.0 m/km	Automated or manual roughness profiler	Annually or post-repair
	Surface Defects	Percentage of road surface with visible cracks, potholes, or rutting.	≤ 5% of road section affected	Visual inspection / sensors	Quarterly / after rain
	Pothole Repair Time	Time taken to repair potholes after detection or report.	Repair within 48 hours	Maintenance logs	Continuous
Road Safety	Clear Zone Obstruction	Ensures roadside areas are free from obstacles to reduce crash severity.	100% clear of hazards	Site inspection	Monthly
	Signage and Marking Visibility	Ensures signs and markings meet retro-reflectivity and visibility standards.	100% compliant with standards	Retro-reflect meter / visual check	Quarterly

	Guardrail and Barrier Condition	Assesses physical integrity of roadside safety structures.	No critical damage > 7 days	Safety audit	Monthly
	Workers Safety Compliance	Use of PPE, signage, work zone safety	100% compliance with OSHA or local lows	Routine visual inspection	Continuous
Drainage & Structures	Drainage Effectiveness	Evaluates the ability of drains to prevent water accumulation.	No standing water > 24 hours after rain	Post-rain inspection	After rain events
	Bridge/Culvert Condition Index	Assessment of structural soundness and load-bearing capacity.	≥90% rated 'Good' or 'Fair'	Structural inspections	Biannually
Environment & Aesthetics	Vegetation Control	Ensures sight distance and aesthetics by managing grass, shrubs, and trees.	No obstruction to visibility	Routine visual inspection	Monthly (growing season)
	Litter and Debris Removal	Ensures roadways are clean and free from waste or hazardous debris.	100% litter-free road segments	Visual inspection	Weekly
Traffic Flow & User Experience	Unplanned Lane Closure Prevention	Minimizes disruption by avoiding unscheduled closures, especially at peak hours.	0% unannounced closures	Contractor logs / GPS tracking	Continuous

	User Satisfaction	Measures perceived service quality through feedback from road users.	≥80% satisfaction rating	Surveys	Annually
	Complaints response time	How fast public complaints are resolved	Within 5 working days	Surveys	Continuous
Response & Rectification	Emergency Response Time	Speed at which the contractor responds to incidents like accidents or hazards.	≤ 2 hours	Incident logs	Continuous
	Defect Rectification Time	Time allowed for addressing reported issues, categorized by severity.	Major ≤ 7 days; Minor ≤ 28 days	Maintenance records	Continuous
Cost and Time Adherence	Budget Adherence	Deviation from planned budget	< 10% Variance	Budget review	Monthly
	Schedule Adherence	On time task completion	≥ 95% activities on time	Progress review	Quarterly
Reporting & Compliance	Reporting Timeliness	Ensures submission of required reports (e.g., inspection, financial) on time.	100% on-time submission	Contract review	Monthly / Quarterly
	Audit Compliance Rate	Evaluates adherence to contract and regulatory standards in external audits.	≥ 95% compliance	Audit reports	Semi-annually

(Source; PIARC (2015). Performance-Based Maintenance of Roads and Road Assets.)

CHAPTER FIVE

5. SUMMARY, CONCLUSION AND INTERPRETATION

In Chapter Five, the study reflected the Summary, Conclusion, and Interpretation sections of my research. This chapter served as a culmination of my findings, where I synthesized the key points and insights derived from the data collected throughout the study. I meticulously crafted a concise summary that encapsulated the essence of my research objectives and outcomes. Following this, I articulated conclusions that not only addressed the initial hypotheses but also highlighted the implications of my findings in a broader context. Finally, I engaged in an interpretative analysis that examined the significance of these results, considering their relevance to existing literature and potential future research directions. This chapter was pivotal in framing my overall narrative and ensuring that my research contributions were clearly communicated to my audience.

5.1. Summary

The data findings indicate a gender distribution within the case company, with a total of 115 respondents. Among these, 55 individuals identify as female, accounting for 47.8% of the total, while 60 individuals identify as male, representing 52.2%. This distribution suggests a relatively balanced gender representation in the workforce, with a slight majority of males.

The data findings indicate the age distribution of a sample population within the case company. The majority of respondents fall within the 20-30 age range, accounting for 43.5% of the total. This is closely followed by those aged 31-40, who represent 42.6%. The older age groups show significantly lower representation, with only 9.6% in the 41-50 range and a mere 4.3% above the age of 51. Cumulatively, individuals aged 30 and below make up approximately 43.5%, while those aged between 31 and 40 contribute an additional 42.6%, leading to a combined total of about 86.1% for these two younger demographics.

The findings from the analysis of the implementation of Performance-Based Road Maintenance Contracts (PBRMC) in the Ethiopian Roads Administration (ERA) reveal a mixed landscape of support and challenges. The current regulatory framework is conducive to PBRMC implementation, yet significant financial constraints, stakeholder resistance, and technological limitations pose substantial barriers. Training and capacity building efforts are deemed adequate, but ambiguity regarding roles and responsibilities complicates implementation. Cultural factors within organizations also play a critical role in influencing the adoption of PBRMC. Effective communication among stakeholders is reported as sufficient. Studies have shown that similar challenges are faced in other countries implementing PBRMC, such as South Africa and Brazil, where financial constraints and stakeholder resistance were significant hurdles additionally, and cultural factors within organizations play a critical role in influencing the adoption of PBRMC.

The findings indicate that existing adaptive management strategies are well-documented and can be effectively integrated into PBRMC frameworks. The data suggests that flexibility in project design is crucial for the success of adaptive management within these frameworks. Stakeholder feedback mechanisms have proven effective in informing adaptive management strategies, ensuring that the voices of those involved are heard and considered. Furthermore, the robustness of data collection processes supports the implementation of adaptive management practices, providing a solid foundation for decision-making.

Training programs on adaptive management are readily available to stakeholders, enhancing their capacity to engage with these strategies. The integration of local knowledge into adaptive management approaches has been shown to significantly enhance their effectiveness, highlighting the importance of contextual understanding in conservation efforts. Current funding models appear to support the incorporation of adaptive management into existing frameworks effectively, indicating a favorable financial environment for such initiatives. Lastly, there is a general consensus among stakeholders regarding the benefits of integrating adaptive management into existing frameworks, suggesting a strong foundational understanding of its value.

The findings indicate a mixed but generally positive perception of contractor performance metrics among stakeholders. The current metrics are seen as aligning well with industry best practices, suggesting that they are effective in evaluating contractor performance. Stakeholders recognize the necessity of developing standardized metrics for evaluation, which highlights a collective agreement on the importance of consistency in assessment criteria. However, there are concerns regarding the adequacy of existing metrics in capturing both qualitative and quantitative aspects of performance, indicating room for improvement.

Regular updates to these performance metrics are deemed essential to ensure they remain relevant and reflective of evolving industry standards. This suggests awareness among stakeholders that static metrics may become obsolete over time. Feedback from contractors during the development of these evaluation metrics appears to be limited, which could hinder the effectiveness and acceptance of the metrics among those being evaluated.

Training opportunities for stakeholders on how to apply these performance metrics effectively are available but may not be sufficient or widely utilized. This points to a potential gap in knowledge or application that could affect the overall efficacy of contractor evaluations. Lastly, transparency in reporting results is highlighted as a critical factor for fostering trust among stakeholders, yet it is perceived as lacking.

The implementation of PBRMC has shown significant improvements in various aspects of project management. Studies have indicated that adopting new project management methodologies can lead to cost savings, improved project outcomes, and enhanced ability to meet project deadlines. The data indicates that PBRMC has significantly reduced project costs, improved overall project quality, reduced project completion time, and resulted in better cost estimation and budgeting . These findings are consistent with existing research on the benefits of adopting new project management methodologies, which have shown that advanced project management techniques can lead to improved project outcomes. The data presented, with high correlation coefficients (.78749, .81622, .85928, .78555, .89092), suggests a strong positive relationship between PBRMC implementation and project success metrics. Research highlights the importance of effective project management in achieving project goals. Therefore, it can be concluded that the adoption of PBRMC has been beneficial for project management.

The findings suggest that PBRMC has had a positive impact on project management, leading to cost reductions, improved quality, reduced completion times, and better budgeting. This is supported by various studies that emphasize the importance of effective project management methodologies.

5.2. Conclusion

In conclusion, the findings underscore the importance of adaptive management within PBRMC frameworks. The accessibility of documented strategies and training programs empowers stakeholders to implement these practices effectively. Flexibility in project design and robust data collection processes further facilitate successful outcomes. The positive role of stakeholder feedback mechanisms ensures that adaptations are responsive to real-world conditions and needs. Moreover, integrating local knowledge not only enhances effectiveness but also fosters community engagement and ownership over conservation efforts. The supportive funding models reinforce the viability of incorporating adaptive management strategies into PBRMC frameworks, while stakeholder awareness about its benefits indicates a readiness for broader adoption. Overall, these elements create a conducive environment for implementing adaptive management practices that can lead to improved conservation outcomes.

In conclusion, while there is a foundational alignment between current contractor performance metrics and industry best practices, several areas require attention to enhance their effectiveness. The consensus on the need for standardized evaluation criteria reflects an opportunity for improvement in consistency across assessments. However, the inadequacy in capturing comprehensive performance aspects suggests that existing metrics may not fully serve their intended purpose. The necessity for regular updates indicates an understanding that industry dynamics can shift rapidly; thus, ongoing revisions to evaluation criteria will be crucial. The limited incorporation of contractor feedback raises concerns about stakeholder engagement and could lead to resistance or dissatisfaction with the evaluation process.

Furthermore, while training resources exist, their effectiveness must be evaluated to ensure stakeholders can utilize them properly. Finally, enhancing transparency in reporting will be vital for building trust and credibility within stakeholder relationships. The analysis underscores the critical importance of stakeholder engagement in the context of contract management. The positive correlation between high levels of engagement and successful contract outcomes indicates that organizations should prioritize strategies that foster active participation from all relevant parties. Effective communication is paramount; it not only enhances stakeholder involvement but also ensures that their contributions are recognized and valued throughout the contract lifecycle.

Moreover, regular stakeholder meetings serve as a vital mechanism for improving contract performance by facilitating open lines of communication and collaborative problem-solving. The diversity of stakeholder representation is equally important, as it enriches decision-making processes and contributes to more comprehensive solutions during contract execution.

Respondents suggested that the implementation of advanced data analytics tools could significantly enhance the performance of PBRMCs in road maintenance. They emphasized the importance of using Geographic Information Systems (GIS) to map and analyze road conditions, which would allow for more informed decision-making regarding maintenance schedules and resource allocation. Additionally, respondents responded that adopting performance monitoring software could provide real-time insights into road quality and contractor performance, facilitating timely interventions when necessary. Furthermore, some respondents highlighted the potential benefits of utilizing mobile applications for reporting issues directly from road users. This approach not only increases transparency but also encourages community involvement in maintaining road quality. Overall, the consensus among respondents was that integrating technology into PBRMC management processes is crucial for optimizing performance.

In response to questions about improving adaptability, respondents indicated that conducting thorough local assessments before implementing performance based contracts is essential. They suggested that understanding regional climatic conditions, soil types, and traffic patterns would enable better tailoring of contracts to meet local needs. Respondents responded that engaging local stakeholders during the planning phase can also provide valuable insights into specific challenges faced by communities.

Moreover, several respondents mentioned that the importance of training local contractors on best practices tailored to Ethiopian contexts. This could involve workshops focused on innovative materials and techniques suitable for local conditions. By fostering a collaborative environment where local knowledge is valued, performance based contracts can be more effectively adapted to diverse regional circumstances.

When asked about fostering better cooperation and communication between parties involved in performance based contracts as well as with road users, respondents emphasized the need for regular stakeholder meetings. They responded that establishing a structured communication framework would facilitate ongoing dialogue among contractors, government officials, and community members.

Additionally, many respondents pointed out that creating feedback mechanisms such as surveys or public forums would allow road users to voice their concerns and suggestions directly to decision-makers. This two-way communication is vital for building trust and ensuring that all parties are aligned on project goals. Respondents also suggested leveraging social media platforms as a tool for disseminating information about ongoing projects and gathering public input efficiently. Regarding future changes needed for enhancing the success of performance based contracts within the Ethiopian Roads Administration (ERA), respondents expressed a strong desire for policy reforms aimed at increasing funding stability for road projects. They responded that consistent financial support would enable long-term planning and execution of maintenance activities under performance based contract frameworks.

Moreover, many respondents advocated for establishing clear performance metrics tied to contract renewals or penalties based on contractor performance outcomes. This accountability mechanism would incentivize higher standards of work quality while ensuring that contractors remain committed to meeting their obligations.

Lastly, some respondents highlighted the necessity of incorporating sustainability practices into performance based contracts frameworks by promoting environmentally friendly materials and methods in road construction and maintenance. The implementation of PBRMC has had a significant and positive impact on various aspects of project management, including cost reduction, quality improvement, reduced completion time, improved deadline adherence, and better cost estimation and budgeting.

5.3. Recommendation to the case sector

The following strategic actions are recommended to enhance PBRMC implementation in ERA:

- Develop funding strategies or seek partnerships to alleviate financial burdens associated with PBRMC implementation, as securing adequate funding is crucial for the success of such initiatives.
- Implement targeted engagement strategies to reduce resistance among stakeholders by addressing their concerns and involving them in decision-making processes, thereby fostering a collaborative environment.
- Invest in technology upgrades that can facilitate more effective PBRMC practices and improve data management capabilities, enhancing overall efficiency.
- Establish clear guidelines outlining roles and responsibilities for all stakeholders involved in PBRMC to minimize confusion and enhance accountability, as clarity in roles is essential for effective implementation.
- Provide training focused on cultural awareness to help organizations navigate internal dynamics that may affect PBRMC adoption positively, recognizing the importance of cultural sensitivity in organizational change.
- Formalize mechanisms for integrating local knowledge within PBRMC frameworks, ensuring that community insights inform decision-making processes. Engaging local

stakeholders not only enriches the decision-making process but also fosters greater community support and ownership of projects, which is essential for long-term success.

5.4. Recommendation to other researchers and Policy makers

The following are key recommendations for optimizing performance-based road maintenance contracts:

- Define clear and measurable performance metrics that align with the goals of the ERA, encompassing aspects such as road condition, safety, user satisfaction, and environmental impact.
- Establish a comprehensive monitoring system that leverages technology such as GIS and remote sensing to track contractor performance in real-time.
- Conduct regular audits and inspections to ensure compliance with contract specifications and identify areas for improvement.
- Utilize data-driven indicators to assess contractor performance and make informed decisions.
- Adopt a collaborative approach involving government agencies, contractors, and local communities to facilitate knowledge sharing and promote innovative solutions.
- Implement performance-based contracts that include provisions for adaptive management based on ongoing performance evaluations.
- Incorporate incentives for well-performing contractors and corrective measures for underperforming ones to encourage continuous improvement.
- Continuously refine PBRMC methodologies through ongoing training for staff, monitoring of project outcomes, and adjustments as needed.

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Appendix

Questionnaire

Optimization and Adaptive Management of Performance Based Road Maintenance Contracts in Ethiopian Roads Administration

Dear respondent, the purpose of this survey is to obtain necessary data for the partial fulfillment of an MSc thesis in **Construction Technology and Management** at Addis College of Post Graduate. The objective of this thesis is to enhance the efficiency, cost effectiveness, and quality of road maintenance services, determine the most critical factors based on participant replies, and prioritize indications so that each party may focus on more significant concerns first.

Therefore, you are kindly requested to contribute to my research study by filling out this questionnaire and providing accurate information for the study work's quality. The respondent's name, as well as that of the firm you represent, will be kept private, and all information gathered from the survey will be utilized solely for academic purposes.

I appreciate the time and effort to respond to the questionnaires. Please contact me at the addresses listed below if you have any questions.

Researcher Name: Sintayehu Getahun

Post Graduate Student at Addis College of Post Graduate,

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Composition of the Questionnaire

This questionnaire consist of three sections

Section I: General information about company/organization and respondent

Section II: Optimization and Adaptive Management of Performance Based Road Maintenance Contracts in Ethiopian Roads Administration (ERA)

Section III: General questions

Thank You for Your Cooperation

Section I- General Information;

1. **Age**

20-30◯

31-40◯

41-50◯

Above 51◯

2. **Gender**

Female◯

Male◯

3. **Position**

Consultants◯

Contractors◯

ERA Officials◯

4. **Level of education**

Certificate level and others◯

Diploma level◯

Degree level◯

Post graduate level◯

5. **Work experience**

Below 5 years◯

Between 5 and 10 years◯

Between 11 and 15 years◯

Between 16 and 20 years◯

Section II: Optimization and Adaptive Management of Performance Based Road Maintenance Contracts in Ethiopian Roads Administration (ERA)

Variable 1. Practice of adaptive management in PBRMC project.

Rate each factors according to the following rating scale by putting a **thick mark** for each problem stated below.

1. Strongly Disagree 2.Disagree 3.Neutral 4.Agree 5.Strongly Agree

No.	List of Questions	1	2	3	4	5
1.	The current regulatory framework supports the implementation of PBRMC in ERA.					
2.	There are significant financial constraints that hinder PBRMC implementation in ERA.					
3.	Training and capacity building for stakeholders is adequate for successful PBRMC implementation.					
4.	Stakeholder resistance is a major challenge to implementing PBMC in ERA.					
5.	Technological limitations impact the effectiveness of PBRMC in ERA.					
6.	Communication among stakeholders is sufficient to facilitate PBRMC implementation.					
7.	The existing infrastructure supports the integration of PBRMC practices effectively.					
8.	There is a lack of clarity regarding roles and responsibilities among stakeholders in PBRMC implementation.					
9.	Historical data on performance metrics is readily available for effective PBRMC application.					
10.	Cultural factors within organizations significantly affect the adoption of PBRMC.					

Variable 2. Adaptive management strategies

No.	List of Questions	1	2	3	4	5
1.	Existing adaptive management strategies are well-documented and accessible for integration into PBRMC frameworks.					
2.	Flexibility in project design is essential for successful adaptive management within PBRMC frameworks.					
3.	Stakeholder feedback mechanisms are currently effective in informing adaptive management strategies.					
4.	Data collection processes are robust enough to support adaptive management in PBRMC frameworks.					
5.	Training programs on adaptive management are widely available to the parties involved in PBRMC.					
6.	Integration of local knowledge into adaptive management strategies enhances their effectiveness within PBRMC frameworks.					
7.	Current funding models support the incorporation of adaptive management into existing frameworks effectively.					
8.	Collaboration between different sectors is necessary for successful adaptive management within PBRMC frameworks.					
9.	Monitoring and evaluation systems are sufficient to track the effectiveness of adaptive management strategies in PBRMC.					
10.	There is a clear understanding among stakeholders about the benefits of integrating adaptive management into existing frameworks.					

Variable 3. Performance metrics

No.	List of Questions	1	2	3	4	5
1.	Current contractor performance metrics KPIs align with industry best practices effectively.					
2.	Construction Parties agree on the importance of developing standardized metrics for contractor evaluation.					
3.	Existing performance metrics promptly evaluated the Contractor delivery service within budget and ensures value for money					
4.	The performance metrics should insure the road remains functional and safe throughout the contract period.					
5.	Performance monitoring is done regularly and effectively					
6.	Metrics developed from best practices improve overall project outcomes significantly.					
7.	Penalties and incentives are clearly tied to performance indicators					
8.	The use of modern technology (example GIS sensors, mobile application) enhances the use of KPIs effectively.					
9.	Pavement Condition (example International Roughness Index (IRI), Cracks etc. area critical KPIs.					
10.	User satisfaction is a valuable Contractor performance indicator					
11.	Contractors performance KPIs should occur at least Quarterly					

Variable 4. Impact of PBRMC regard to project Cost, Quality and time

No.	List of Questions	1	2	3	4	5
1.	The implementation of PBRMC has significantly reduced project costs.					
2.	PBRMC has improved the overall quality of the projects.					
3.	The use of PBRMC has led to a reduction in project completion time.					
4.	PBRMC has enhanced our ability to meet project deadlines.					
5.	The adoption of PBRMC has resulted in better cost estimation and budgeting for projects.					

Section III. General Questions

1. What tools or techniques would you suggest for optimizing the performance of PBRMCs in road maintenance?

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2. What strategies do you suggest to improve the adaptability of PBRMCs to local conditions in Ethiopia?

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3. What improvements could be made to foster better cooperation and communication between the parties as well as the road users?

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4. What are the main challenges in implementing KPIs in PBRMCs of Ethiopian Roads Administration?

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5. What future changes do you think should be made to improve the success of PBRMCs in the Ethiopian Roads Administration?

Thank you for your time