DEVELOPMENT OF A PERFORMANCE BASED ROAD MANAGEMENT SYSTEM FOR KENYA

DOMINIC ACHOKA KUNDU

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Development of Performance a Based Road Management System for Kenya

Dominic Achoka Kundu

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DECLARATION

This thesis is my original work and has not been submitted for a degree in any other university.

Signature……………………………………….. Date………………………………..

Dominic Achoka Kundu

This thesis has been submitted for examination with our approval as university supervisors

Signature……………………………………….. Date………………………………..

Prof. Zachary A. Gariy, PhD.

JKUAT, Kenya

Signature………………………………………**..** Date………………………………..

Dr. Timothy Nyomboi, PhD.

KURA, Kenya

DEDICATION

This work is dedicated to my late father Mzee Marius Kundu, my Beloved Wife Violet A. Obuya and my children; Godlisten, Eden, Bethel, Eli and Ella.

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ABBREVIATIONS AND ACRONYMS

PBRM	Performance Based Road Maintenance
PBC	Performance Based Contracting
RMMS	Road Maintenance Management System
RMS	Road Management System
LOS	Level of Service
MoTIHUD	Ministry of Transport, Infrastructure, Housing and Urban Development
KeRRA	Kenya Rural Roads Authority
AASHTO	American Association of State Highway and Transportation Officials
FHWA	Federal Highway Administration
VDOT	Virginia Department of Transportation
IRI	International Roughness Index
JICA	Japan International Cooperation Agency
MoR&PW	Ministry of Roads and Public Works
KeNHA	Kenya National Highways Authority
MOTI	Ministry of Transport and Infrastructure
KURA	Kenya Urban Roads Authority
KWS	Kenya Wildlife Services

SIDA	Swedish International Development Cooperation Agency
IEK	Institution of Engineers of Kenya
EBK	Engineers Board of Kenya
NCA	National Construction Authority

ABSTRACT

Performance based road maintenance (PBRM) entails reinstating the level of service (LOS) of road asset items to defined performance targets with implication of payment reductions on noncompliance. One of the major challenges in highway transportation is road asset management. Maintenance of road assets to best possible condition at minimal cost keeps roads agencies continually searching for innovative approaches for optimum benefits. Many road authorities worldwide are abandoning traditional contracting methods for performance-based road maintenance (PBRM) contracting. High cost of maintenance, poor workmanship, low contractor motivation and reduced user satisfaction are major challenges facing both force account and unit rates contracting methods. Worldwide computer-based programs with modules on performance indicators, performance targets and payment reductions are used in monitoring PBRM works. The current system in Kenya is designed for management of road maintenance works under unit rates methods where payment is based on quantity of work done against mutually agreed unit rates. The objectives of this study were to develop a road management system for performance-based road maintenance and to assess the level of service of roads under PBRM in Kenya. Agile software development method was used to provide the computer-based solution. Qualitative methods were adopted in assessment of the level of service (LOS) of roads in determining conformance of actual performance to the target performance. The LOS of roads showed a performance index of 74.95% indicating noncompliance. A mean score of 63.3425 and 63.3417 for manual Road Management System (RMS) ratings showed insignificant difference demonstrating that both monitoring methods are reliable. At overall performance of 74.95% and non-assessment of LOS by roads agencies this study recommended that LOS must be assessed before payment of PBRM works and payment reductions applied for noncompliance. Monitoring of PBRM works should be carried out using RMS for time saving, increased accuracy and reduced staff. Approval of works at 25.05% below target performance raises the need to establish the extent to which financial losses and non-user satisfaction is experienced in PBRM practice. Further, there is need to enhance effectiveness of the developed road management system by incorporating remote sensing, georeferencing and photographic presentations to upgrade it from the physical data input.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

A road is a passageway for traffic conveyance. Roads make a crucial contribution to economic development and growth by bringing important economic and social benefits. By providing access to socio-economic benefits a road network is instrumental in poverty reduction. The cost of road construction is dependent on design parameters (geometric and pavement) with respect to traffic axles. In Kenya this cost ranges from a minimum of Kshs. 40 million per km for paved roads (MoTIHUD, 2017). Road Maintenance is the process of restoration of usability of the road to acceptable level of service following observed deterioration. Delay in maintenance causes irreversible deterioration of a road network. If insufficient maintenance is carried out roads will require reconstruction or major rehabilitation since deterioration spreads across a road system resulting in high maintenance costs. When roads are in poor condition, every dollar not spent on road maintenance will cost road users $4 -$5 in additional vehicle operating costs, travel time loses, additional accidents and for road organizations $4-$6 in reconstruction and rehabilitation costs (Stankevich, Qureshi & Queiroz, 2005).

Transportation agencies across the world have largely employed the traditional methods of contracting where contractors are paid based on quantity of work done against mutually agreed unit rates. Studies have shown that road authorities face difficulties in controlling quality, time, and cost effectively when using this method of contracting. The traditional unit rates method of contracting is also prone to project delay, cost overrun, little contractor motivation and innovation and low-quality control measures (Zietlow, 2004).

In the late 1980s, transportation professionals introduced performance-based road maintenance (PBRM) contracting method with the objective of resolving challenges arising from traditional method of contracting (Zietlow, 2005). In performance-based road maintenance practice, the contractor is given responsibility and flexibility to maintain the road assets using innovative approaches to yield a product of predefined quality (Ozbek & de la Garza, 2007). PBRM contracting has proven benefits such as savings of 30%- 50%, economic rate of return of 60% at a 12% cost of capital, and reduced need for future capital investments by 30% (Frost and Lithgow,1996; Zietlow, 2015). Payments are based on how well the contractor complies with service level obligations defined in the contract, not on the amount of works and services executed. PBRM contracting allocates a higher risk to the contractor but opens opportunities for increased profit margins resulting from improved efficiencies and effectiveness of design, methodology and technology (Zietlow, 2004).

Such outsourcing must be subject to effective monitoring and evaluation of contractor compliance. A systematic performance measurement system is required to assist in quality evaluation, determination of performance compliance, certification, and payment. Many countries have developed performance-based management frameworks befitting individual practice. There is not such a developed system in Kenya. Success of every contracting method is dependent on management of the maintenance process. For traditional contracting method in Kenya, there exists a computerized Road Management System (RMS) for unpaved road. The existing RMS is limited to input of work items in each work category for payment of items based on quantities achieved at agreed rates (Shrestha, Shrestha and Kandie, 2014). This evaluation and certification approach is not compatible to PBRM where compliance is determined by delivery of entire work section of predefined quality by consideration of key PBRM elements such as performance indicators, performance targets, response time and payment reductions.

The Kenyan government development agenda revolves around effective road network system. Affordable housing, manufacturing, universal healthcare, and food security are development pillars that can only be realized where there is accessibility and mobility. In 2015 the government released a strategic plan for construction of 10,000 Kms of low volume sealed roads in form of hybrid contracting method. Management of these contracts requires knowledge of the key PBRM elements and assessment of level of service (LOS) of asset items for improved road network performance. A computerized management system is necessary to increase data handling and analysis accuracy, reduce time, and lower administrative costs for implementation and monitoring of works. Currently there is no known assessment for road asset level of service, posing danger for under performance of the road network. Cost and time overrun due to variations, poor workmanship, rigid design conditions, and lower contractor innovativeness are among major reasons for the government's preference for performance based contracting method (MoTI, 2014), hence the need for establishing a standardized management and monitory framework.

1.2 Problem Statement

Challenges facing road asset maintenance have resulted in poor road conditions. Mostly higher capital outlay is required to upgrade a road network to desirable service levels. When roads are in poor condition, every dollar not spent on road maintenance will cost road users $4 -$5 in additional vehicle operating costs, travel time loses, additional accidents and for road agencies $4-$6 in reconstruction and rehabilitation costs (Stankevich, Qureshi & Queiroz, 2005). Cost overruns, extension of time, delayed payments, poor workmanship, high administrative costs, and limited resources are major causes for current poorly maintained road network in Kenya. Force account and unit rates contracting methods have not addressed road maintenance challenges (KeRRA, 2015). Traditional contracting methods provide unit prices for work items and payment is based on quantity completed works leading exaggerated project cost, restricted innovation, and high employer risks (Zietlow, 2005).

Deficiencies in PBRM practice has led to failure to realize reported cost savings of between 15% and 30% when performance-based road maintenance contracts are adopted against conventional unit price contracts, lack of expenditure certainty, poor conditions of road assets, and lower road user satisfaction (Reilly, 2009.; Pakkala et all., 2007.; Liautad, 2004.; Zietlow, 2004).

Realization of these benefits is dependent on effectiveness in road maintenance and management. Currently there is no systematic road management framework to guide and provide results on compliance in attainment of service levels in the PBRM practice in Kenya. It is not possible to know whether road assets are maintained as required and whether the road is functional to optimal performance. This has led to payment to contractors without assessment of compliance to required performance targets. As a result, there is reduced user satisfaction on Kenyan roads expenditure uncertainty due to inadequate monitoring of performance-based road maintenance works. The intended benefits of performance-based road maintenance are not met. Therefore, this study seeks to develop a computerized road management system for performance-based road maintenance in Kenya. The developed system will enable road authorities and the public to determine contractor compliance and efficiency. It will enable procedural assessment of level of service of roads under PBRM and ensure computation of performance indices to ascertain contractor compliance before payment of works.

1.3 Objectives

1.3.1 Overall Objective

The overall objective is to develop a road management system for performance-based road maintenance in Kenya.

1.3.2 Specific Objectives

i) To assess the level of service of roads under performance-based road maintenance
ii) To develop a road management system (RMS) towards monitoring of performance-based road maintenance
iii) To assess performance of the developed road management system

1.4 Research Questions

The main research question in this thesis is “Does a road management system enhance road maintenance practice? The answer to this question is embedded in the following sub-questions.

i) Are Kenyan roads maintained to expected levels of service?

ii) Can a road management system improve efficiency and effectiveness in monitoring road maintenance works?
iii) Is the developed road management system reliable?

1.5 Scope and Limitations of the Study

1.5.1 Scope of the Study

This study focused on paved roads in Kenya involving roads under upgrading to bitumen standards with performance-based maintenance component. The projects considered were under the supervision of Kenya Rural Roads Authority (KeRRA) and Kenya National Highways Authority (KENHA). The research comprised assessment of LOS of PBRM guided by road usability, road user comfort and road durability. It led to development of a RMS for monitoring of PBRM works.

1.5.2 Limitations of the Study

There were inadequate records to verify data from the road authorities' offices due to poorly designed PBRM contracts. The roads completed under PBRM contracting were sparsely distributed requiring more but limited time to visit such sites. Due to newness of PBRM practice in Kenya there was shortage of performance measurement equipment necessary for determination of key performance targets towards assessment of level of service.

1.6 Justification and Significance of the Study

Performance based road maintenance is associated with improved conditions of road assets, greater road user satisfaction expenditure certainty and cost savings. These benefits can only be realized after determination of contractor compliance. Assessment of level of service of contracted road assets informs road agencies of compliance to prescribed performance targets that enables a determination on contractor payment. It informs the extent to which payment reductions are applied, hence cost savings in managing and maintenance of roads.

Success of road maintenance and provision of good road network is dependent on good road asset management practice. The developed road management system is essential in providing efficiency and effectiveness in meeting the benefits of performance-based road maintenance by enabling ease, speed and accuracy in field data analysis, reducing work backlog and ensures safe record keeping. This results in a reduction in inhouse workforce, eventually reduces contract administrative costs and provides for project expenditure certainty. The road management system is necessary to assist road authorities and contractors to evaluate and monitor road performance and optimize road maintenance strategies for effective utilization of resources to manage road maintenance contracts in Kenya. This study contributes to knowledge by providing a methodological approach to determining the level of service for management of PBRM.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Road maintenance is the process of reinstatement of the original level of service of the road. Performance based road maintenance is a concept of road maintenance with performance levels defined for each road asset or service provided under the contract with fixed payments if performance levels are met or payment reductions for noncompliance (CAREC, 2018). Roads are enablers of development to areas they serve contributing to national socio-economic growth. A road network in good condition is key to poverty reduction by providing accessibility and mobility. The purpose of road maintenance is to restore the level of service of the road to its original condition. Road maintenance will result in savings in road user costs, reduced vehicle operating costs, travel time saving and increased user satisfaction. Haggie (1996) established that road users save $3 for every $1 utilized on road maintenance. Harral and Faiz (1988) emphasize the importance of road maintenance by confirming that the cost of construction of new roads is four times the cost of maintaining the same road. Similarly, if a road network is not adequately maintained it deteriorates to poor conditions, and this necessitates reconstruction of the entire pavement structure and drainage system.

In recognition of significant investments made by the public in construction, maintenance, and operation of roadway systems, transportation agencies realize that the public holds them accountable for proper management of these assets. To meet these expectations, road agencies choose approaches with asset management concepts that allow cost savings, improved level of service and maximum user satisfaction. The road asset management concept in the transportation sector comprises of preserving, upgrading, and replacing in timely manner roadway assets through cost-effective planning and resource allocation. In many countries road maintenance has been carried out using force account and unit rates contracting methods for many years (World Bank, 2009). These methods are characterized by lack of accountability, political interference, delayed project delivery, escalation of cost, and poor workmanship (Reilly, 2009; Carpenter et. at al., 2003; Hartwig et. al., 2005). According to Zietlow (2004) Performance based road maintenance (PBRM) contracting methods were introduced in the 1990's as a remedy to challenges associated with the traditional contracting methods.

Computer technology enhances the practice of road asset management. Computer software allows road agencies to create programs that perform analyses for decision making (AASHTO, 1998) in road maintenance management. Many road agencies promote computer-based applications in managing a wide range of assets of a highway system (Austroads, 1994). In United States of America, the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) are leading transportation institutions that promote computer-based road asset management (AASHTO, 1998).

In Kenya, the state department of roads commenced development of the current road maintenance and management system (RMMS). This system was developed with features of unit rates contracts comprising of activity description, unit of measurement, quantity of works and unit rate of payment (Shrestha, Shrestha, & Kandie, 2014). The software does not incorporate features such as performance indicators, performance target, response time and payment reduction which are characteristic of performance-based road maintenance contracting.

2.2 Traditional Road Maintenance Methods.

Traditional road maintenance methods are defined by payment against quantity of work achieved. They are designed with unit rates for work items and payments to the contractor based on quantities of measured completed works. Provisions are also made for payment of materials on site, equipment, contractor staffing and contractual preliminaries (CAREC, 2018). There are two types of traditional road maintenance contracting methods.

Force account method: In the early 70's the government of Kenya utilized force account road maintenance approach through the Rural Access Roads (RAR) and Minor Roads Programs (MRP) (KeRRA, 2015). Later road maintenance services were procured through the Local Service Orders with instructions to contractors to maintain roads without contract documents detailing specifications. The transportation agency executes the work by itself. Road officers procure the necessary materials, machinery and labor which are deployed and supervised directly. This method is faced with problems such as lack of accountability and public participation, escalated maintenance costs, and poor-quality control (Robinson, 2005).

Unit rates method: This contracting method was introduced in Kenya in 1980s (KeRRA, 2015), and is currently the dominant contracting method. It comprises outsourcing contractors through competitive bidding and awarding the works to the lowest evaluated bidder. The maintenance system is based on the amount of work done and payment at mutually agreed rates against a bill of quantity item (CAREC, 2018). The employer selects a consultant for the design and supervision of the project or sometimes government employed engineers carry out design and supervision of the project by themselves. Whereas there are advantages to unit rates contracting methods, there are many difficulties in its implementation.

2.2.1 Advantages of Unit Rates Contracting Methods

A study by Haapasalo,. et. al. (2015) demonstrates various advantages from traditional contracting methods. The study assessed factors that influence road maintenance practice. These include customer value, value chain, change control and aligned commercial and business interests. Analysis of these factors reveals the following advantages for unit rates contracting method.

Well established and widely used: Since this is the oldest and the most widely used method, it is familiar to all contractors and is therefore easily recognized and implemented.

Clear separation of roles and responsibilities between client, designers, and contractors: appointing and working with one design consultant/design team allows a one-on-one working relationship to develop between client and design team.

Greater control over design decisions and quality of workmanship: Client retains control and responsibility for the project and as such can strongly influence the functionality and overall quality.

Lower risk for the client as any design flows are identified and verified: Affords flexibility to client, with any variations relatively easy to arrange and manage.

Competitive pricing due to multiple contractors submitting tenders: this method allows for clearer cost comparison between tendering parties. This leads to greater understanding of proposals and competitive equity during the tendering process.

2.2.2 Disadvantages of Unit Rates Contracting Method

Escalation of cost and time: Traditional methods provide for selection of contractors based on lowest evaluated bid criteria. This method is slow and does not favor a life cycle cost approach to projects (Carpenter et al., 2003). Reilly (2009) states that sometimes low-bid environment in traditional methods create uncertainties which causes cost and time overrun. There lies the risk of cost overruns following competition among bidders to offer lower prices to score high in financial evaluation. This may necessitate price variations to the expense of the overall cost of the project. Additionally, factors such as modifications of the plan, changed conditions, poor project coordination, and lack of adequate supervision are likely to contribute to project cost increase (Nafaji and Vidalis, 2002). Additionally, since the government's road authority is accountable for supervision of projects in traditional method of contracting, proficient, and expert personnel is hired and paid by the road agency to supervise contractor performance which increases project cost (Carpenter et al., 2003; Hardy, 2001).

Reduced Level of Service due to Poor Workmanship: Due to competition for jobs in traditional contracting there is tendency for contractors to submit lower bids to win the jobs. The low-bid strategy of contractor selection gives little attention to contractor qualifications or proven ability to perform similar projects in the past. To make economic sense contractors are inclined to provide poor quality works because of the low tender sum submitted to become the lowest evaluated bidder. This greatly increases the risk for compromise with quality to reduced contract sum (Bushey and Kwak, 2000).

Inadequate Motivation: Given that payment is based on quantity of work done contractors are likely to concentrate on conferring a huge amount of works with favorable unit rates to maximize their earnings. It is not uncommon for contractors to neglect small quantity maintenance works of lower unit rates eventually affecting road durability, usability, and user satisfaction. The result is that this method of contracting occasions a circle of heavy rehabilitations due to long periods of neglect and rapid deterioration (Hartwig et al., 2005). Following the short time nature of traditional contracts, the contractor is not motivated to improve quality of service required, reduce maintenance cost or to use new technologies because contractor's obligations are spread within a short period of time.

No proper risk sharing: Since it is the obligation of the transportation agency to prepare project design, the agency also takes responsibility for any inadequacies in the design. Further the road agency is obligated to provide drawings, instructions, specifications, and permits reducing contractors' liabilities by defining most of the unknown conditions (Carpenter et al., 2003). These obligations places major project risks to the road agency and cushions the contractor. The contractor is only required to meet the specifications and the targets (Robinson et. Al., 2006). With this arrangement the contractor is willing to only maintain the road asset to the existing service level but not to improve the condition of the road to reduce future maintenance costs. The component of risk sharing will assist the government to reduce risk of cost and time overrun and improve the quality of works.

High level of corruption: Road construction projects involves extensive and intricate set of activities where parties like consultant, contractor, and government actively work together. Corruption is one of the most common problems manifesting itself in compromise of design, quality, and quantities. (Kenny, 2007). Problems arising from variation orders have caused construction disputes that affect both completion time and project cost. Transportation agencies are always seeking a better method of contracting to resolve or reduce the effect of these problems. Road maintenance and management models used for computing and documenting certification of works will assist in project financial controls and reduce corruption.

Lack of proper training in the public sector: Shortage of trained personnel in the construction industry is a common problem in many countries. Contractors' lack of superintendence skills is among major causes of cost and time overrun (Al-Tabtabai, 2002). Provision of relevant computer software can assist perform road maintenance tasks faster with reduced human resource.

2.3 Performance Based Road Maintenance Contracting

Performance-based contracting was started in the late 1980s by highways professionals (Zietlow, 2005). In 1988, British Columbia in Canada started to contract out road maintenance to the private sector by introducing some performance levels for routine maintenance. During the 1990s, many countries in Latin America such as Brazil, Chile, Peru, and Uruguay started their first PBC pilot projects. At the same time, performance-based contracts developed in Australia and New Zealand as well as in Denmark, Estonia, Finland, and the United States (US). Many other countries followed in the year 2000. In some countries, such as Argentina and Canada, PBCs have almost replaced the traditional contracting methods and have had a chance to evaluate the value-added benefits of using PBCs (CAREC, 2018). The rapid adoption of PBCs worldwide indicates that such contracts deliver better value for money than conventional contracts and can guarantee good condition of road network.

PBRM is a contracting method where the contractor is given responsibility and flexibility to maintain road assets using innovative approaches to yield a product of predefined quality (Ozbek & de la Garza, 2007). Under PBRM the existing road is maintained based on performance indicators to achieve acceptable level of service within specified time. The concept is defined by fixed payments if the level of service is met or payment reductions for noncompliance. Compliance and achievement of specified performance targets is dependent on prescribed response time. This contracting method allocates higher risk to the contractor compared to traditional methods, but it opens opportunities to increase contractor's margins due to possibility of improved efficiencies and effectiveness of design, process, technology, or management. Zietlow (2015) demonstrates that PBRM approach reduces the cost of achieving the specified performance standards. It ensures the road asset condition is consistently performing over the extended period. Payments are based on how well the contractor complies with performance targets, not on quantity of works achieved (Stankevich, Qureshi & Queiroz, 2005).

Today, computerized models are used in decision making and management of construction and maintenance of road works worldwide (Chebon, 2013). The introduction of PBRM contracting in Kenya calls for a systematic performance monitoring approach to assist in assessment of level of service to ascertain performance for roads. This entails monitoring individually the expected performance targets as described in contract documents and PBRM guidelines and, collecting actual data from the field, input in the computerized software for performance analysis. Poor road performance shows that some road assets have not been maintained to expected rating and therefore are subject to payment reductions until the contractor remedies the defects. Currently, unit rates method monitoring is aided by tracking change orders in every activity in the work plan and recording construction progress in detail (Shrestha, Shrestha & Kandie, 2014). This monitoring approach is premised on input of work items in each work category for payment of items based on quantities achieved at agreed rates with minimal considerations for delivery time, quality, and cost. The approach cannot be used for PBRM where compliance is determined by delivery of entire work section of predefined LOS.

2.3.1 Performance Measures

The outcome of performance-based road maintenance is premised of performance measures. These are standards by which contractor’s maintenance works is evaluated. Safety and user satisfaction are overriding elements in the design of performance measures to ensure each asset group is preserved at minimum acceptable performance levels throughout the life of the road. The performance measures are described as performance indicators, performance targets, response time payment reduction, and relative weighting.

Performance indicators: these are items that specify the standards by which the contractor's maintenance work is evaluated. Some of the road elements considered when defining performance indicators are asset type, roadway system and traffic volume (VDOT, 1996,; Frost & Lithgow, 1996). Good practice is to use few key performance indicators instead of many to enable their simplicity and manageability (NCHRP, 2009). The road agency is expected to properly identify which physical attributes on performance indicators of the road network are required and the associated level of service to be achieved.

Performance goals: These are the minimum acceptable levels to be achieved for each performance indicator. A performance goal is quantifiable and can be documented.

Response Time: Response time is the time allowed to the contractor to complete the action towards maintaining road usability. For example, repair of rutting of more than 2cm deep within 28 days means that the contractor must complete repair of identified rutting in 28 days from the time such rutting was detected. Contractors are expected to take an initial action immediately when they find such a situation on the road. The contractor is required to be ready to mobilize resources as fast as possible considering the time limit allowed (Jica, 2016).

Payment Reduction: This is a subtraction of funds from the contractor's claim due non-compliance performance targets. The results of each formal inspection of the service levels and other performance criteria will be recorded detailing the location, non-compliance, and the date by which the contractor must have completed to remedy the cause of non-compliance. If at the date indicated, the contractor has not remedied the cause of non-compliance, independent of the reason given for failure to do so, the contractor is subject to payment reductions in accordance with conditions of contract. Payment reductions are variable over time. If the contractor fails to remedy a cause of non-compliance for which a payment reduction has already been applied, the amount of the payment reduction increases month by month for that cause of non-compliance, without a ceiling being applied, until compliance is established (Pinero, 2003).

Relative Weights among assets: This is a parameter used to establish relative importance among asset items and asset groups (Stivers et al., 1997). For example, in the carriageway group an important item such as road base can receive a relative weight of 8 whereas a less important item such as road marking can receive a relative weight of 3. With respect to asset groups, twice importance can be given to the traffic asset group in comparison to the shoulder asset group. This means that the rating from the traffic asset group will have more impact on the overall evaluation than the rating from the shoulder asset group. These weights will be used in the overall calculation of LOS ratings (Pinero, 2003).

2.3.2 Performance Monitoring

Performance monitoring is the process of carrying surveillance to ensure that the work has been performed in a timely manner and in accordance to the highest workmanship standards, evaluating the contractor's compliance with applicable safety standards, and verifying that all maintenance activities are conducted in a manner that minimizes the impact on the traveling public (Baker, 1999, Poster, 2001). Performance monitoring can be carried out either by the road agency by periodical checks through random, unannounced inspection of performance indicators or by the contractor (Sultana, et al., 2012). Both the road agency and the contractor staff can carry out joint inspection to confirm compliance on the performance on the defined indicators. Performance monitoring can also be achieved using independent consultants contracted by the road agency.

2.3.3 Level of Service Assessment

Different frameworks are used in monitoring performance-based road maintenance works. The Virginia Department of Transportation (VDOT) in the United States of America published a report on assessment of efficiency and effectiveness of performance-based highway maintenance contract between VDOT and VMS, Inc. (VDOT 2000). The report presented results from performance and cost-efficiency evaluation of contractor's works in managing VDOT's interstate assets. Performance monitoring was guided by LOS for asset items, timeliness of response, and cost efficiency (Pinero, 2003).

ISO 9001:2015 guidelines are effective in monitoring Performance based road maintenance works as provided under Clause 9.1 of the Standard on Monitoring, Measurement, Analysis and Evaluation. It demonstrates a process approach with guidelines on data collection and interpretation. The Standard shows data analysis from a variety of inputs in the quality management process (ISO, 2015).

The ISO standard reveals that data related to performance must be evaluated to determine need for improvement, emphasizing its importance in performance by identifying nonconformities and taking corrective actions to eliminate causes of such nonconformities.

Stivers et. al., (1997) researched on quality management concepts, monitoring, and evaluation of existing maintenance quality programs, and subsequently developed a maintenance Quality Assurance (QA) program providing guidance in developing, implementing, and routinely monitoring performance-based road maintenance works. The QA program comprises key maintenance activities that defines maintenance elements to evaluate program quality, customer expectations for collecting road user expectations concerning the LOS at which an agency should maintain the road system, LOS criteria for defining conditions to be met to consider the existing LOS to be acceptable, weighting factors to establish relative importance between maintenance elements, maintenance priorities that establishes the order in which maintenance activities will be executed considering the available budget and formal LOS inspections, analysis and reporting necessary for evaluating periodic LOS based on random inspections of portions of an agency’s highway system (Pinero, 2003).

2.4 Experience in Performance Based Road Maintenance

Canada

In 1998, 1995 and 1996 the provinces of British Columbia, Alberta and Ontario respectively started implementing performance-based road maintenance. These provinces took a stepwise approach, starting with 3-5-year contracts then settled for 10-year contracts upon gaining experience. When the Province of British Columbia first introduced PBRM, they went from in-house road maintenance directly to PBRM (World Bank, 2014).

New Zealand

In 1998, New Zealand awarded the first 10-year performance-specified maintenance contract (PSMC). Two years later, Transit New Zealand introduced shorter 5-year hybrid contracts, which incorporated features of conventional method-based and performance-specified maintenance procurement. In addition to compliance to performance indicators, level of service, performance goals and response times the New Zealand PSMC requires the contractor to provide inspections and management of the road assets using cost effective methods (World Bank, 2014).

United States

In 1996, the Virginia Department of Transportation (VDOT) in the US awarded the first contract for asset management and maintenance based on performance levels with clearly defined outcomes. This contract was an innovative approach to provide a high and well-defined quality of service to the user at lower cost. VDOT estimated that this contract saved 16% over the 5.5-year contract period as the highway is maintained to its pre-existing condition. In December 2000, VDOT issued a report showing that actual conditions improved, resulting in further real savings (Lande, 1999).

Serbia

In 2004, Serbia transited from traditional unit rates contract to Performance based contracting. At that time, many routine maintenance works were still paid on a unit price basis. The contracts had 3-year terms, with a 2-year extension, if the contractor performed well and agreed to continue. Unfortunately, both pilot projects were discontinued after 3 years and 7 months due to lack of funds. The main challenge that the road agency and the contractors faced was lack of sufficiently qualified staff with the road administration, consultants, and contractors. Nevertheless, the PBCs were considered successful, since they significantly improved road conditions, reduced routine maintenance cost by an average 49% (World Bank, 2009).

Chad

In 2001 Chad started a 4-year performance-based road management and maintenance contract with help of the Word Bank. The contract was successful rendering the road in excellent condition. Unfortunately, due to higher vehicle speeds the accidents rates increased substantially. Nevertheless, road users appreciated that the road was always in good condition not only after specific works were completed but throughout the asset life. They attested that they could use the road in the rainy season, which was impossible before (World Bank, 2014).

2.5 Benefits of Performance Based Road Maintenance

The rapid adoption of performance-based road maintenance worldwide indicates that such contracts deliver better value for money than conventional contracts and can guarantee good condition road network. Many countries are preferring Performance-based maintenance because of the benefits that accrue compared to implementing traditional maintenance methods. Following are some of the benefits demonstrated from countries at advanced practice of performance-based road maintenance.

Cost savings in managing and maintaining road assets: The USA Virginia Department of Transportation spent USD 22,400 per mile per year under PBRM against USD 29,500 per mile per year in traditional methods (FHWA, 2005). In New Zealand, there has been a 30% decrease in professional costs and 17% decrease in physical works with traffic growth by 53% (FHWA, 2005). Traditional methods provide for selection of contractors based on lowest evaluated bid, a criterion that does not favor a life cycle cost approach to projects (Carpenter et al., 2003). According to Reilly (2009) low-bid environment in traditional methods create uncertainties which causes cost and time overrun. However, in PBRM contractor selection is based on best value criteria. Since more risks and management responsibilities are carried by the contractor, road agencies ensure management capacity with the potential contractor, and understanding of PBRM and ability to handle the associated risks. The selection process involves choosing a contractor with the capability to provide the required output. The best value contractor selection approach ensures a high-quality product at a low overall cost (Stankevich, Qureshi & Queiroz, 2009).

Studies show that the cost of a road section in traditional unit rates contracts is higher than it would be in PBRM (JICA, 2016). Experience demonstrates that the long-term cost of PBRM is lower than unit rates method. Also considering the social (accessibility) and economic (road user costs) losses due to poor roads, the benefit of PBRM is significant (Zietlow, 2015). Figure 2.1 below illustrates, PBC low cost of maintaining a road section represented by a continuous line with the dotted line representing higher cost incurred in using unit rates contracting.

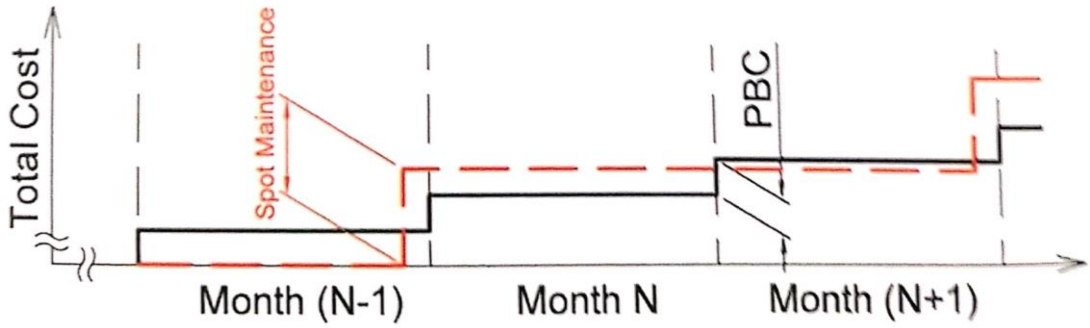


Figure 2.1: Economical Benefit of PBRM over Traditional Contracts

Source: JiCA, 2016.

Expenditure certainty: PBRM payments are designed to a fixed price on a regular schedule. This allows the road agency to exercise full control of expenditures (Stankevich et. al., 2009). The risk of cost overruns from price variations to the expense of the overall cost of the project, design change, poor project coordination, inadequate supervision as is the case with traditional methods is reduced.

Reduction of the in-house workforce: PBRM allows contractors to be responsible for supervision and quality assurance. The road agency changes its focus from supervision to policy, regulation and strategic management resulting in reduced staffing levels. A study by ENRA (2004) demonstrated that in Estonia where 63% of the national network is under PBC, the workforce of the national and sub-national road agencies declined, from 2,046 in 1999 to 692 employees in 2003.

Greater road user satisfaction: Road users become more satisfied with the condition of the roads maintained under PBRM as road agencies notice declined complaints from road users. In Chad for instance, road users expressed appreciation for their roads being in good conditions over extended period. Especially important is that road users in Chad can use the road in the rainy season, which was impossible before (Zietlow, 2004).

Multi-year financing: The practice of PBRM requires consistent funding to sustain the contractor's cashflow. Since the contracts are spread over extended period, long-term payment obligations are legally binding on the financier. The experience from PBRM contracts in Argentina demonstrates how the Treasury was deterred from failing to provide funding for road maintenance (Liautaud, 2004).

Improved conditions of contracted road assets: At end of PBRM contract period road assets are generally returned in improved condition. The Department of Transportation in Texas State, USA, has reported that after the first year of the performance-based contracts, [road] facilities were rated at an average of 91%, an 18-point increase over their pre-contract condition (FHWA, 2005). Argentina has reduced the share of roads in poor condition from 25 percent to less than 5 percent by the end of 1999 due to the PBC approach (Liautaud, 2004). According to Bushey and Kwak, (2000), to make economic sense contractors in traditional methods are inclined to provide inadequate quality works because of the low tender sum submitted to become the lowest evaluated bidder.

LOS is achieved by adhering to the service criteria, performance targets, and response times allowed by the agency. Compliance is achieved only if the performance indicators are in a satisfactory condition. According to Poister (1983), the purpose of evaluation of level of service effectiveness is to indicate the extent to which each asset has been preserved and the minimum acceptable quality levels specified by implementing agency. PBRM can provide good road services to the road users compared to the traditional maintenance contracting using unit rates because sometimes for traditional contracts the LOS of the road may drop too low while in PBRM the road LOS is expected to be maintained over time as specified (JICA, 2016). As shown in figure 2.1 below, LOS by PBRM represented by the continuous line, does not drop below the specified level of service with respect to time. However, the LOS by traditional contracting methods drops low below specified LOS with respect to time.

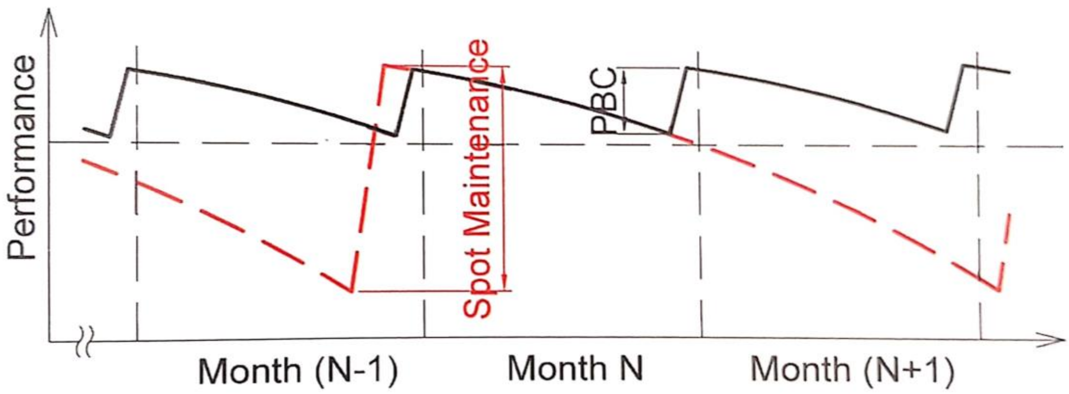


Figure 2.2: Comparison of LOS between PBRM and Traditional Contract

Source: JiCA, 2016.

A road management system enhances the practice of performance-based contracting by simplifying assessment of level of service in determining performance of roads. It provides a process approach on data collection, interpretation, and analysis. Its output leads to determination of need for performance improvement, identifies noncompliance and corrective action to improve the level of service of roads which greatly contributes to higher user satisfaction. Since payment is based on actual performance the system leads to determination and application of payment reductions, reducing risk of payment for works with lower performance indices. This increases expenditure certainty of PBRM contract management. It enables accurate and fast data processing, significantly reducing need for in-house staffing with a consequence on reduced contract administrative costs.

The introduction of PBRM requires contractors to exercise innovation and creativity in execution of works. Road agencies require qualified staff to administer and supervise PBRM work. Knowledge in PBRM is necessary in identification and clear definition of appropriate performance specifications and Design of incentive payment mechanism that encourages the contractor to consistently meet or exceed the specified minimum performance indicators. Such knowledge by the agency staff is instrumental in establishing the actual and desired condition of road assets, specify achievable and realistic performance indicators for each asset item and to establish reasonable response times (World Bank, 2015; Zietlow, 2009; CAREC, 2018)

2.6 Performance Based Road Maintenance in Kenya

In 2010, the concept of performance-based road maintenance was adopted in Kenya on a pilot basis. This method of road maintenance is meant to ensure the road network is maintained in good condition throughout its lifetime. There exists a comprehensive guideline to assist implementing agencies in supervision, and assessment through setting service scope as outputs measured through ascertaining the response time, performance targets, and payment reductions (JICA, 2016). PBRM contracts have been implemented by Kenya Rural Roads Authority (KeRRA) since 2010 (KeRRA, 2015).

The hybrid PBRM in Kenya is composed of upgrading to bitumen standards and 3-year routine maintenance with the main performance indicator being ensuring the level of service is as good as bituminous surfacing. This is a major deviation from the traditional unit rates contracts where the contractor is only responsible for maintenance during the 12-month defects liability period (DLP). In PBC, after the expiry of the defects liability period the contractor is required to maintain the road for a further 3 years at a predefined service level. PBC is a new concept and majority of contractors and roads authority engineers in Kenya often face problems during implementation stages of Performance based road maintenance contracts (KeRRA, 2015).

2.7 Road Management Systems in Kenya

Computerized software are used in decision making and management of road construction and maintenance. Road agencies in Kenya use the computer-based road maintenance and management system (RMMS) for unit rates contracting method. A computer supported system in road maintenance increases efficiency in programming, planning, record keeping, time saving and sequencing of works with minimal errors (Chebon, 2013). Kenya’s current RMMS is only compatible for management of traditional unit rates contracts where contractors are evaluated based on a quantity of work achieved and payments made against mutually agreed unit prices (Shrestha, Shrestha & Kandie, 2014). It does not provide assessment of level of service, monitoring of performance targets, response time and payment reductions as required by performance-based contracts. Therefore, there is need to provide a management and measurement system that is compatible with this emerging practice.

The design of computerized PBRM management system should constitute components for measurement of level of service. The level of service is a performance specification that the contractor is obliged to achieve for a given section of the road. This component is designed comprising elements on key maintenance activities defining maintenance elements to evaluate system quality, LOS Criteria that defines the conditions to be met, weighting factors to establish relative importance between maintenance elements and between each maintenance item under each maintenance element, and analysis and reporting for evaluation of periodic LOS based on random inspections of portions of an agency’s highway system (Pinero, 2003).

2.8 Advantages and Disadvantages of Performance Based Road Systems

Data collection to ascertain condition of assets items is time consuming. Similarly processing and analysis of data for multiple sample units is tedious. The introduction of computerized systems in data filling and analysis increases the speed at which such data can be processed, and results produced. This reduces time for data handling resulting in accuracy and reliability. Complex calculations are also handled easily and faster. Use of computer management systems in management of PBRM works allows for automation of tasks, hence saving a lot of time. Calculation of large dataset is easily handled by excel function. The performance-based road management system will be effective in handling and processing large data.

Computerized management systems are useful for field data storage. Instead of paper files, the computerized management software serves as a data storage center. Such files and information are easily accessible as opposed to manual data handling.

On the other hand, since performance-based contracts are designed for longer periods, contractors with little experience are disadvantaged and will accrue great losses from payment reductions due to noncompliance leading to demotivation. The best value evaluation criteria of PBRM poses risk of project overpricing resulting to high project risks.

The introduction of performance-based road maintenance contracting methods calls for a reduction of staff in the road implementation agencies since the responsibility for quality control is assumed by the contractor. The end effect is government staff layoff and loss of employment for already established populace.

Computer systems are not immune to error. Wrong data entry can be duplicated leading to poor decision making. Development of such programs require specialized skills which are expensive to acquire.

2.9 Literature Review Summary and Research Gap

The approach taken to assess LOS of roads under PBRM contracts may vary from one implementing country to another. Experiences from Serbia and Chad (World Bank, 2009), United States (Lande, 1999), Canada and New Zealand (World Bank, 2014) demonstrates advanced PBRM practice. PBRM practice in Kenya is deficient in many ways. The country adopted guidelines developed by Japan International Cooperation Agency (JICA) Kenya. (JICA, 2016). However, the guidelines are lacking in methodology for assessment of critical parameters that greatly contribute to determination of the level of service of roads. For Instance, whereas the International Roughness Index (IRI) is a reliable parameter for monitoring road unevenness and costs to road users, it is not included as one of the specifications to be assessed by road authorities in Kenya. There is no established methodology for establishing the level of service of a road section. The absence of a methodological approach to assessment for level of service before payment is a major contribution to poor road asset maintenance practice and resultant poor road conditions. This study has established a system for assessment of level of service of roads under PBRM. Adoption of this system will assist road authorities with a systematic methodology and help in realization of the demonstrated benefits from PBRM contracting method.

Chebon, (2013) shows that there have been efforts to develop computerized road management systems in Kenya. Gath Consultants, Ministry of roads and Kenya Roads Board have used computerized road maintenance and management systems. The current road management system developed by then Ministry of Roads & Public Works and Kenya Roads Board is primarily used for management of unit rates contracting. The system is not designed to determine service levels, interpretation of performance targets or to effect payment reductions but to track change orders from quantities of works executed (Shrestha, Shrestha & Kandie, 2014). The progress reports generated by current RMS do not highlight performance of a contractor. This study has developed a road management computerized system with elements of performance-based road maintenance. Unlike the previous management systems in Kenya, this system can interpret performance targets and measure performance of each asset item to define the road's performance and subsequently the extent of contractor compliance. It comprises a module on payment reductions functional when the contractor is noncompliant after a stipulated response time. It effects financial penalties. The developed RMS is useful to road agencies in Kenya for efficient data processing, good time management and reduces contract administrative costs since less in-house staffing is now required.

2.10 Conceptual Framework

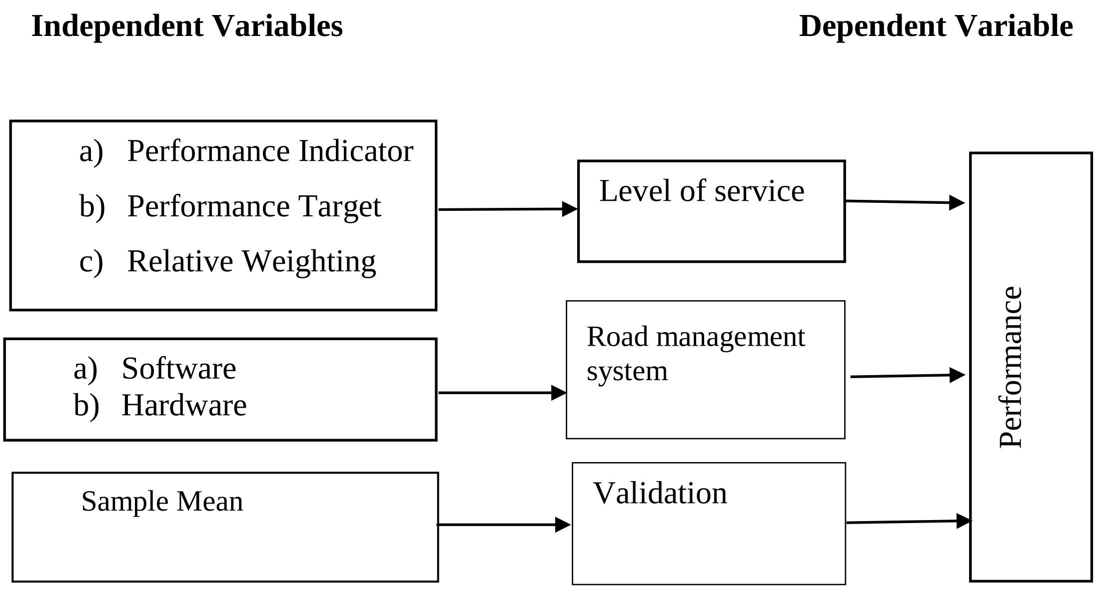


Figure 2.3: Conceptual Framework

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter describes materials and methods used to address study objectives. It outlines how the research was conducted and justification of methods adopted.

3.2 Level of Service of Roads under Performance-Based Road Maintenance

The level of service category is classified depending on the road's traffic volumes as shown in table 3.1 below.

Table 3.1: Standard Service Level Category

Road Type	**Paved Roads**	
Annual Average Daily	High	Standard
Traffic Volume	More than 50,000 VPD	Less than 50,000 VPD
Service Category	High	Standard

Source: Jica, (2016)

3.1.1 Target Population

There were 50 contracts under performance-based road maintenance at the time of this study. This study focused on contracts which had been completed and handed over. Out of the 50 awarded contracts only 13 had been implemented, inspected, and accepted as finally completed. Out of the 13 completed roads, 4 roads were used for assessment of performance of the developed road management system. The remaining 9 roads were used as the population for assessment of level of service of roads under PBRM contracts.

3.1.2 Sampling Procedure and Sample Size

According to Cooper and Schindler (2003), 30% proportion of population under study is sufficient for generalization in research. The arrival at the sample size was based on 95% level of confidence and a margin of error of 5%.

Sample size was determined using Cochran, (1977) formula for finite population.

$$n = \frac{n_0}{1+\frac{n_0}{N}} \qquad \text{.................................... (1)}$$

Where:

$$n_0 = \frac{z^2 p\ (1-p)}{e^2} \qquad \text{...................................... (2)}$$

Where:

e = margin of error,

Z = z-value of the normal distribution,

p = proportion of population

When this formula was applied to the finite population N= 9, the sample size was determined as n=7. This sample size of 7 roads represents about 77.78% of the population. The sample was drawn from the entire population using simple random sampling without replacement (SRSWOR).

The sampled roads were divided into small segments of specific length known as sample units. Each sample unit contained different asset items to be evaluated. For this study, each of the 7 sampled roads was sectioned into 2 sample units resulting into 14 sample units as shown in table 3.2 below.

Table 3.2: Sample Size and Sample Units

S/No.	Name of Road	Number of Sample Units
1.	Kisii - Isibania	2
2.	Angurai - Malaba	2
3.	Busia - Malaba	2
4.	Junc B5 - Ngobit - Lamuria	2
5.	Kijauri - Nyansiongo	2
6.	Muhoroni - Londiani	2
7.	Kisii - Kilgoris	2
	Total Sample units	14

3.2.2 Data Collection and Analysis

Field inspections were carried out to assess the LOS of sampled roads. Data on road roughness, carriageway condition, culverts blockage, number of road signs and length of road marking was collected and recorded. This was carried out using tape measures and physical counting of asset items. Dynamic Response Intelligent System (DRIMS) was used to measure International Roughness Index (IRI). Road agency records were reviewed to corroborate data from field inspections.

Calculation of actual ratings: adopted the method by Stivers et. al., 1997 on Quality Assurance in Highway Maintenance Programs. It uses the matrix in table 3.3 below.

Table 3.3: Matrix for Methodology

Asset grp	Asset Item	Req. to be Inspected	Inspected	passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score req	Actual Rating	Req. Rating
1	2	3	4	5	6	7	8	9	10	11	12	13

Source: Modified from Pinero, (2003)

Comparison of the Actual Ratings versus Performance Targets: actual ratings were compared with specified required ratings using bar charts.

3.3 Development of Road Management System

This objective served to develop a road management software that for monitoring of performance-based road maintenance works. A Web based System was developed with modules as shown in Figure 3.1 below:

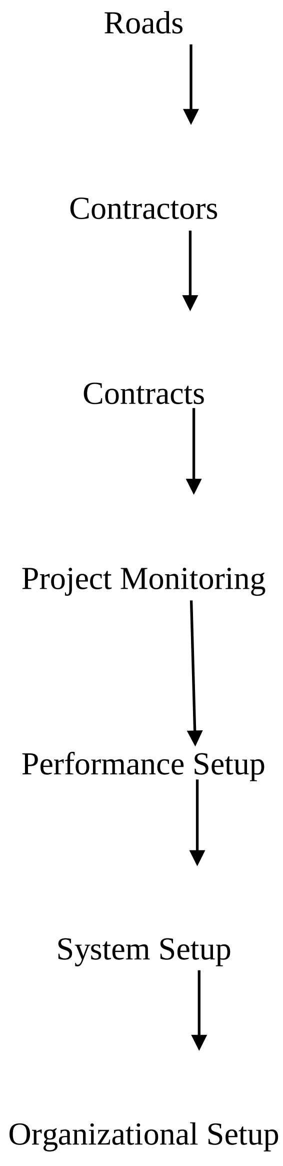


Figure 3.1: Modules Sequence Flow Chart

A web-based solution was chosen because it is easily accessible on any computerized gadget given the current wide internet penetration in Kenya. The System was developed with two layers, namely, database and business layers. C-# Programming language was used, and the user interface developed using blazer framework. Databases were then developed using Microsoft SQL Server due to its reliability and assured Microsoft support. For each of the modules, a criterion was designed for interface between the modules. From the developed criteria, flowchart diagrams were designed for each module and data flow diagrams modelled.

3.3.1 Software

The development was based on Agile software development methodology. This methodology allows the developer to adapt to the user needs as they arise. Agile methodology is good for computer-based solutions since it allows users to experience benefits of a solution in partial development. The methodology is helpful in maintaining user interest as the development process continues.

3.3.2 Software Development

The following steps in system development.

Figure 3.2: Steps in System Software Development

Diagnosis

The diagnosis stage assisted in identification of the problem. The emerging performance-based road maintenance contracting method raises the need to harness monitoring and management of the road maintenance activities. This necessitates development of a computerized system for management of road maintenance works.

Analysis

The problem was analyzed to identify different processes involved in providing the required solution. The processes identified were inspection process carried out before and after work, contracting that defined contract definition and packaging, incidence reporting before, during and after the work, calculation of level of service of asset items, comparison of actual ratings and performance targets, payment reduction process and billing process.

The analysis stage involved identification of key setups required to run the software. These included road names, classification, surface types, contract types and categories. In addition contractor categories, performance targets, response time, taxes, road assets, penalty thresholds and tolerances were also considered as the key setups.

Design

System design involved incorporating PBRM concepts to provide a solution to the problem. A proof of concept was also developed at this stage leading to production of a prototype.

Development

The solution was reviewed on a module-by-module basis. The modules identified were described as contractors, contracts, road inventory, bills, project monitoring, performance setup, system setup and organizational setup.

Deployment

The software was subjected to validation tests. Data was input into the software to validate the software. On board users were trained on system setups.

3.4 Performance of Developed Road Management System

This objective focused on validation of the developed Road Management System for performance-based road maintenance works. This involved using field data from existing PBRM contracts. The validation was done by comparing results from manual and the systems monitoring results using the least squares method.

3.4.1 Data Collection and Analysis

Four (4) road sections were selected with independent asset items. Data was collected using linear measurement tools and the Dynamic Response Intelligent System (DRIMS) equipment. The LOS of these roads was established both manually and using the developed RMS. System validation was carried out by hypothesis testing using the Statistical Data Analysis (SPSS). This involved a comparison of the null hypothesis (H_0) and alternative hypothesis (H_1) of the Independent Samples t.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Level of Service for Roads under Performance-Based Contracts

JICA, (2016) provides a guideline for determination of performance targets for PBRM works in Kenya. Table 4.1 shows the performance requirements for the asset items considered in this study.

Table 4.1: Performance Requirements for Asset Items

Asset Group	Parameter /Asset Item	Service Levels	Performance Requirements	
			High	**Standard**
Roadway	Pavement roughness	Must be kept to acceptable levels	< 2.5mm/m	< 3.5mm/m
	Pavement edge break	All loose pavement edges must be made good	Max 2% of 200m sub section	Max 2% of 200m sub section
	Pothole	All visible potholes must be repaired	No Potholes	3 potholes of max diameter 150mm in 1 km section
Roadside	Clearing of right of way	Road must always be clean, and free from soil, debris, trash.	5% of 200m sub section	5% of 200m
	Road Marking	All road markings are clear and visible	5% of area of road marking in 200m length	5% of area of road marking in 200m length
	Vertical Signs	All signage must be present, complete, clean, legible, reflective, and firmly installed	5% of number of signs in a section of 200m	5% of number of signs in a section of 200m
	Bush Clearing	25mm (min) to 150mm (max)	5% tolerance permitted	5% tolerance permitted
Drainage	Culverts/Drifts	Must be clean and free of obstacles and without structural damage to ensure free flowing conditions	5% of length of drains below defined service level	5% of length of drains below defined service level
	Side Drains, Mitre drains, Cutt off Drains	Must be clean and free of obstructions to always ensure free flowing conditions	5% of length of drains below defined service level	5% of length of drains below the defined service level

Source: JICA, 2016.

The roads were categorized with respect to traffic volumes classified as high category signifying roads with traffic volume greater than 50,000 vehicles per day and Standard category for roads with traffic volume less than 50,000 vehicles per day

Pinero, (2003) states that population in evaluation of PBRM is defined by small segments of a road of specific length known as sample units. For this study, 7 roads were identified in the study area and were divided into 14 sample units, each sample unit containing different asset items to be evaluated. Data was collected using measurement tools for linear measurements and related conversions to determine LOS of pavement. Dynamic Response Intelligent equipment (DRIMS) was used to measure International Roughness Index (IRI). Road agency records were reviewed to corroborate data from field inspections. The matrix for data analysis is shown below in table 4.2.

Table 4.2: Data Analysis Matrix

Asset grp	Asset Item	Req. to be Inspected	Inspected	Passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score req	Actual Rating	Req. Rating	Confidence level
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Data collected from the field was presented in columns 4 and 5, as the number of asset items inspected and the number of items that met conditional criteria specified in the contract respectively. Relative weightings were applied to each asset item within each asset group to establish relative importance among asset items. Each weight (column 6) was multiplied by the number of items required to be inspected (column 3), also with the number of passing samples (column 5), generating a total possible score (column 7) and an actual score (column 8) for each asset item.

Asset group scores were obtained by adding all asset item scores on each asset group. Therefore, the totals for total score (column 7) and Actual Score (column 8) were obtained for each asset group. The actual and required LOS ratings were obtained by dividing the actual or required asset group score by the total possible asset group score.

Table 4.3 below shows calculation sheet for the results in form of actual rating and expected rating.

Table 4.3: Calculation Sheet for Actual and Required Rating

Road Name (1)	Asset Item (2)	Req. to be Inspected. (3)	Inspected (4)	Passed (5)	Weight (6)	Total Score (7)	Actual Score (8)	Actual Rating (9)	Target (10)	Score Req. (11)	Actual Rating (12)	Req. Rating (13)	Confidence Level (14)
Kisii - Isibania						**Section I**							
	Pavement Roughness	72	72	72	0.9	64.8	64.8	100%	100%	64.8			95%
	Vertical Signs	4	3	3	0.1	0.4	0.3	75%	95%	0.38			71.25
	Total				1.00	65.2	65.1			65.18	99.85%	99.97%	83.13%
							Section II						
	Pavement Roughness	28	28	28	0.7	19.6	19.6	100%	100%	19.6			95%
	Pavement edge break	5	5	4	0.1	0.5	0.4	80%	98%	0.49			95%
	Vertical signs	6	6	4	0.2	1.2	0.8	66.7%	95%	1.14			95%
	Total				1.00	21.3	20.8			21.23	97.65%	99.67%	95%

Source: Researcher.

This procedure was repeated for each road. Actual ratings computed were then compared with the performance targets defined by the agency for each asset item within each asset group.

The schedule performance index (SPI) was used to measure conformance of actual progress (earned value) to the planned progress (planned value):

$$SPI = \frac{EV}{PV} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ equation (i)}$$

Where EV = Earned Value (actual rating)

PV = Planned Value (Required rating)

Where; SPI = 1.0 implies an achievement of the objective performance,

SPI > 1.0 implies surpassing of the goal objective.

SPI < 1.0 implies a fall below the goal objective.

4.1.1 Performance Indices

Performance indices for each section of the road were obtained as indicated by PI 1 and then each road's performance index obtained as indicated by PI 2 in table 4.4 below.

Table 4.4: Performance Indices

Name	Section	Expected (%)	Actual (%)	Variance (%)	PI 1	PI 2
Kisii - Isibania	Section I	99.97	99.85	0.12	0.9988	0.9893
	Section II	99.67	97.65	2.02	0.9797	
Angurai - Malaba	Section I	100.00	83.00	17.00	0.8300	0.7183
	Section II	95.60	58.00	37.60	0.6067	
Busia - Malaba	Section I	99.92	40.00	59.92	0.4003	0.7002
	Section II	100.00	100.00	0.00	1.0000	
JNB5 - Lamuria	Section I	99.70	5.60	94.10	0.0562	0.0343
	Section II	99.90	1.25	98.65	0.0125	
Kijauri - Nyansongo	Section I	99.90	90.20	9.70	0.9029	0.9168
	Section II	99.79	92.88	6.91	0.9308	
Muhoroni - Londiani	Section I	98.89	98.38	0.51	0.9948	0.9862
	Section II	95.00	92.86	2.14	0.9775	
Kisii - Kilgoris	Section I	95.52	86.09	9.43	0.9013	0.9085
	Section II	99.48	91.09	8.39	0.9157	

Source: Researcher.

A comparison of actual performance and against expected performance was presented in form of bar charts shown in figure 4.1 below.

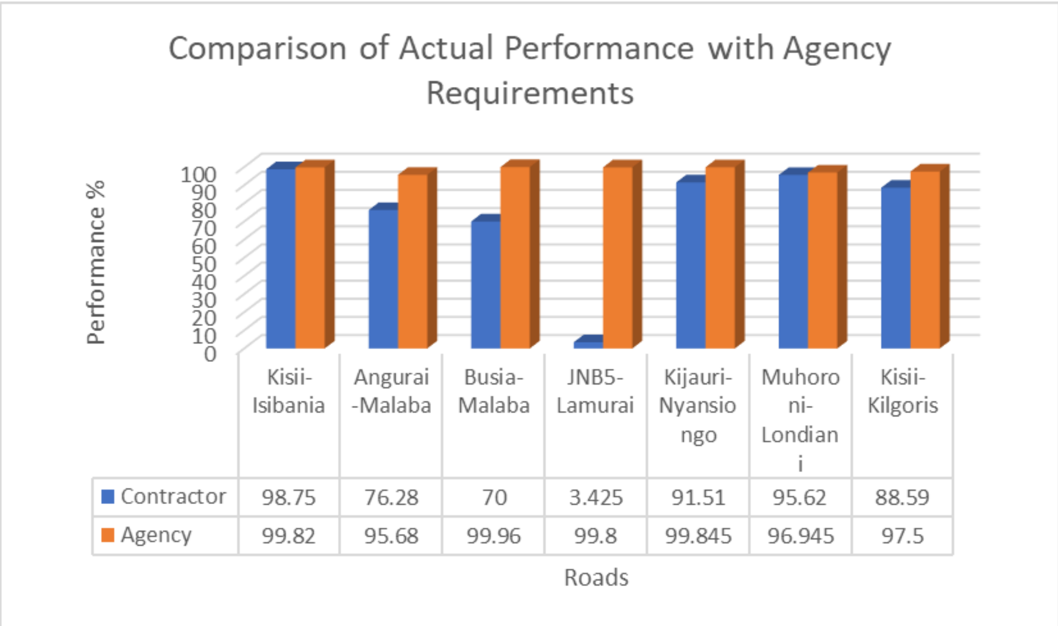


Figure 4.1: Comparison of Actual Performance and Agency Requirements

Based on the outcome for the performance indices, only section II of Busia-Malaba Road achieved the goal objective performance (SPI = 1.00) implying 100% goal target performance achieved while section II of JNBS-Lamuria Road achieved the lowest goal target of performance (SPI = 0.0125) with only 1.25% of the target goal achieved. Overall, Kisii-Isibania Road achieved 98.93% of the target achievement (SPI = 0.9893), Agurai-Malaba Road achieved 71.83% of the target achievement (SPI = 0.7183), Busia-Malaba Road achieved 70.02% of the target achievement (SPI = 0.7002), JNBS-Lamuria Road achieved 3.43% of the target achievement (SPI = 0.0343), Kijauri-Nyansongo Road achieved 91.68% of the target achievement (SPI = 0.9168), Muhoroni-Londiani Road achieved 98.62% of the target achievement (SPI = 0.9862) and Kisii-Kilgoris Road achieved 90.85% of the target achievement (SPI = 0.9085).

Indices from 7 roads with each road having section I and II were gathered for the expected value and the achieved value (actual value). SPSS software was used to obtain an overall performance, (PI = 0.7495). The results showed a standard deviation of ± 0.3475 and standard of error of 0.0929 as shown in table 4.5 below.

Table 4.5: Performance Index Coefficient

Coefficient		**Sd. Error**	**Sig.**	**95% Confidence Interval**	
				Lower level	**Upper level**
1	0.7495265	0.0928709	0.004	0.5674995	0.9315535

**significant at .001

A PI of 0.7495 imply an overall performance of 74.95% which was below the expected by 25.05% with a margin of error of 0.182. The results show that the true performance index lies between 0.5675 and 0.9316.

4.2 Development of Road Management System for Monitoring of Performance Based Road Maintenance.

The management solution was designed in two layers, namely hardware and software to facilitate operationality at different levels. Hardware comprises of physical and visible infrastructure required to host a solution. These include servers, physical machines used by the clients and peripheral gadgets. *Software* comprises the set of instructions required by the hardware to execute its functions. Software is classified as either Operating System or application software. The operating software served as the interface between users and computer.

The PBRM software was developed with applications for monitoring performance-based contracts. Therefore, the software was fed with data at different levels in terms of setup data and transactional data. Setup data was necessary for running the system. This is data considered as static in description and use without changes in the long run and helps in enhancing consistency in the system. Transactional data comprises day-to-day process-based data that varies with contractor performance and road agency operations.

4.2.1 Setup Data

The set-up data is subdivided into System setup data and Performance setup data. Figure 4.2 shows the elements in both Performance and System setups.

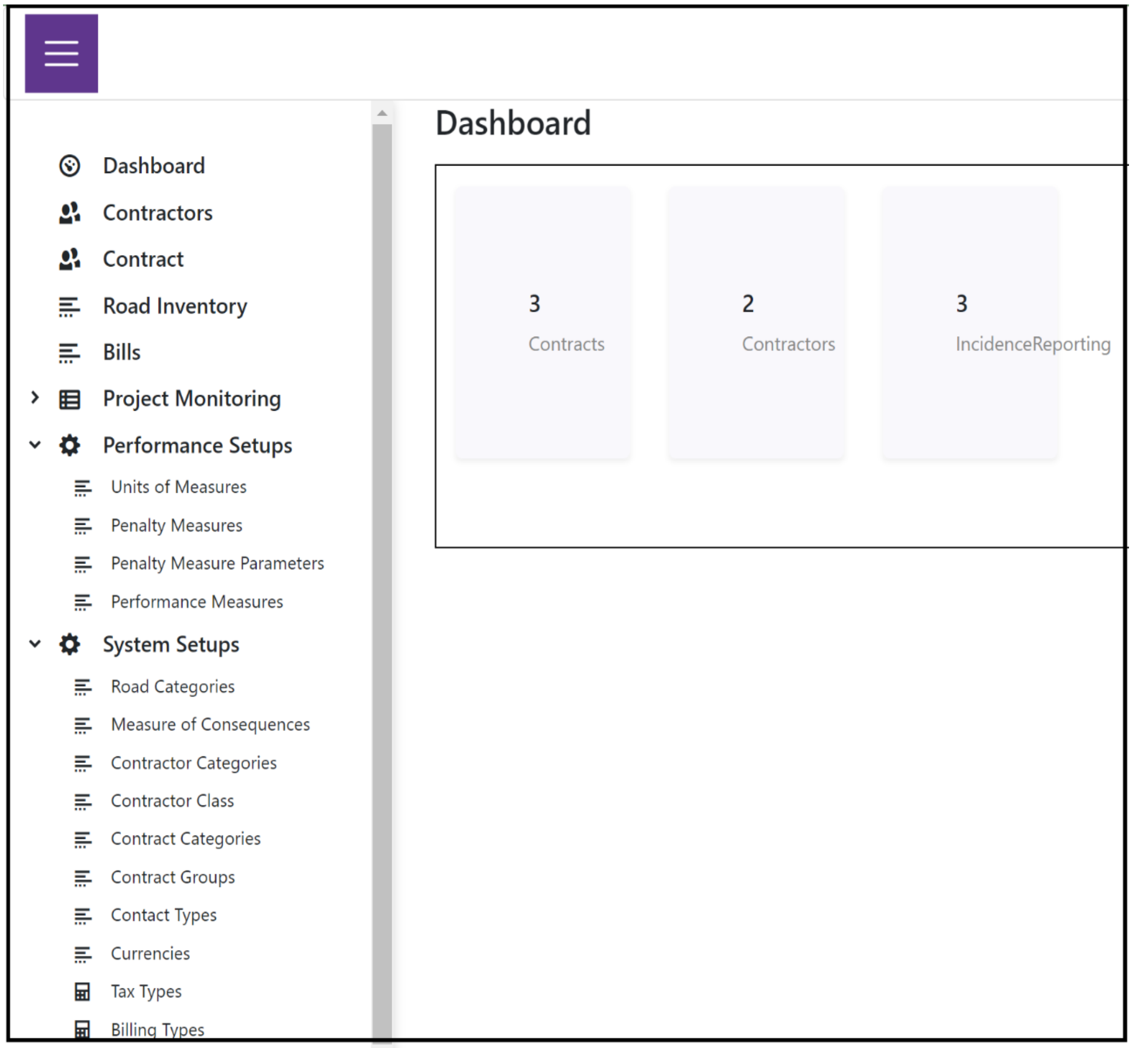


Figure 4.2: Window for Performance and System Setup

4.2.1.1 Performance Setups

Performance Setups are setups defining performance measures that specify standards by which the maintenance works will be evaluated. The setups are specified with consideration to road usability, safety, and durability. They help to ensure individual road assets are maintained at irreducible service levels. The performance setups defined in this module are Units of Measure, Penalty Measures, Penalty Measure Parameters and Performance Measures.

Units of Measure: This is a definite magnitude of quantity classified as a standard for measurement. The unit of measure was significant in defining a physical predetermined quantity. It described compliance in terms of physical measurements. Figure 4.3 shows window for unit of measure submodule.

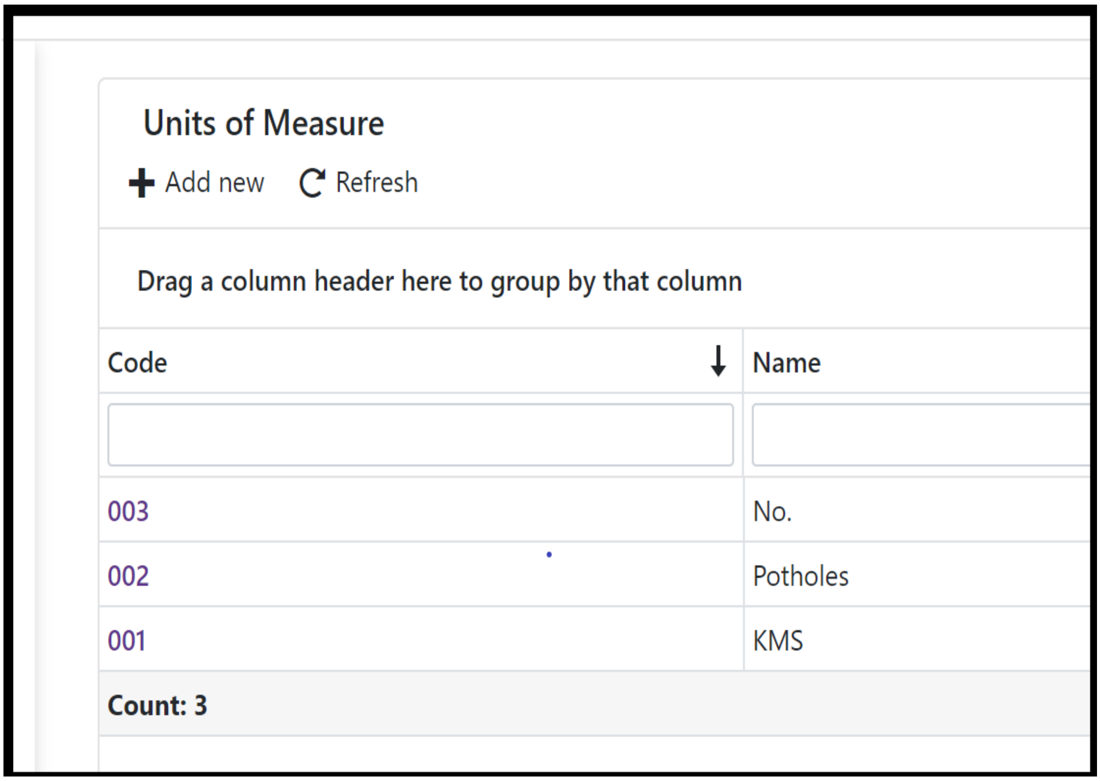


Figure 4.3: Unit of Measure Submodule Window

Penalty Measures: This submodule was designed because of the payment reduction component. It constitutes amounts to be subtracted from the contractor's claim due to noncompliance. If the contractor fails to remedy the cause for noncompliance, penalty increases monthly until the remedies are approved. Table 4.4 shows a window for penalty measures submodule.

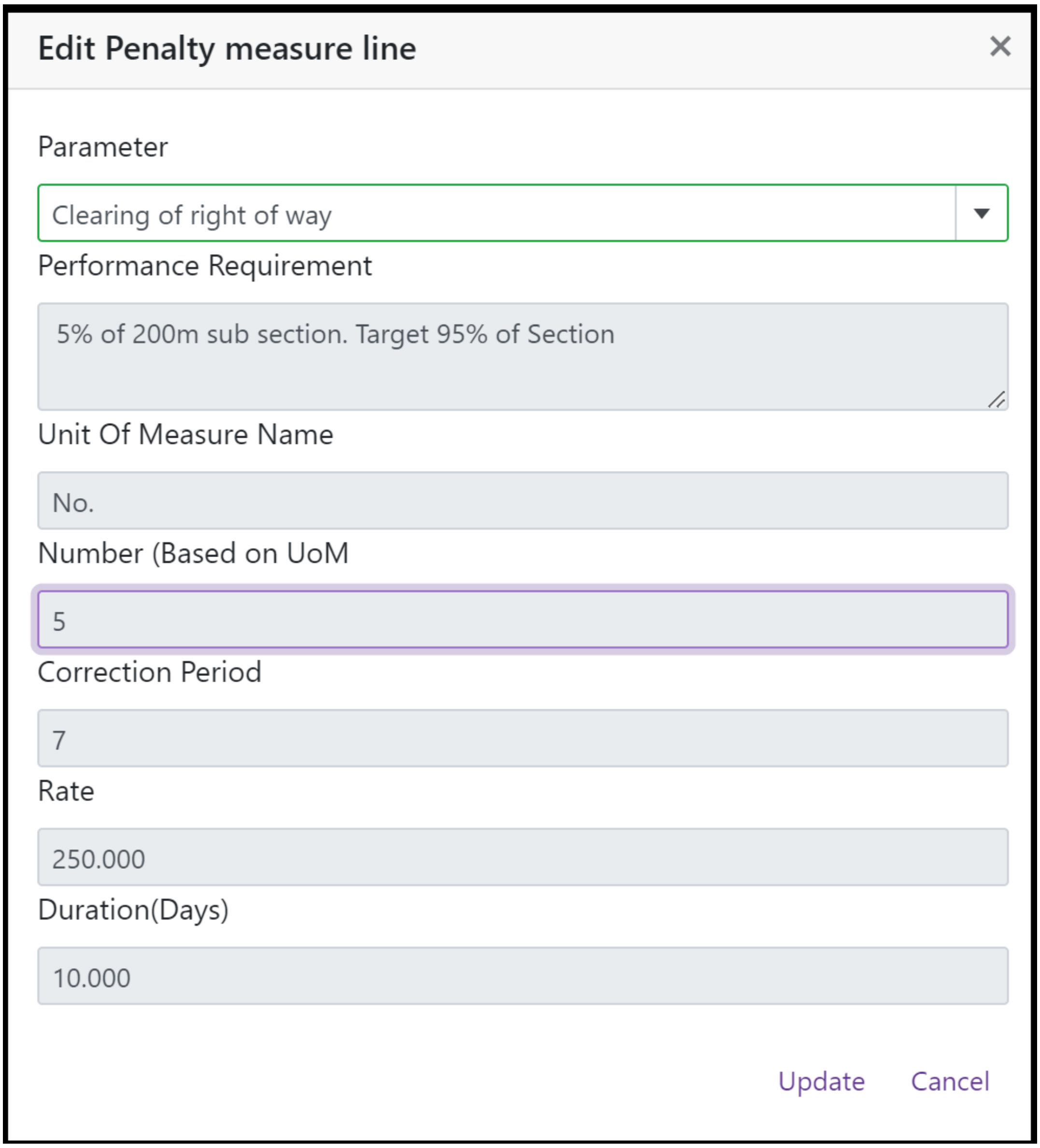
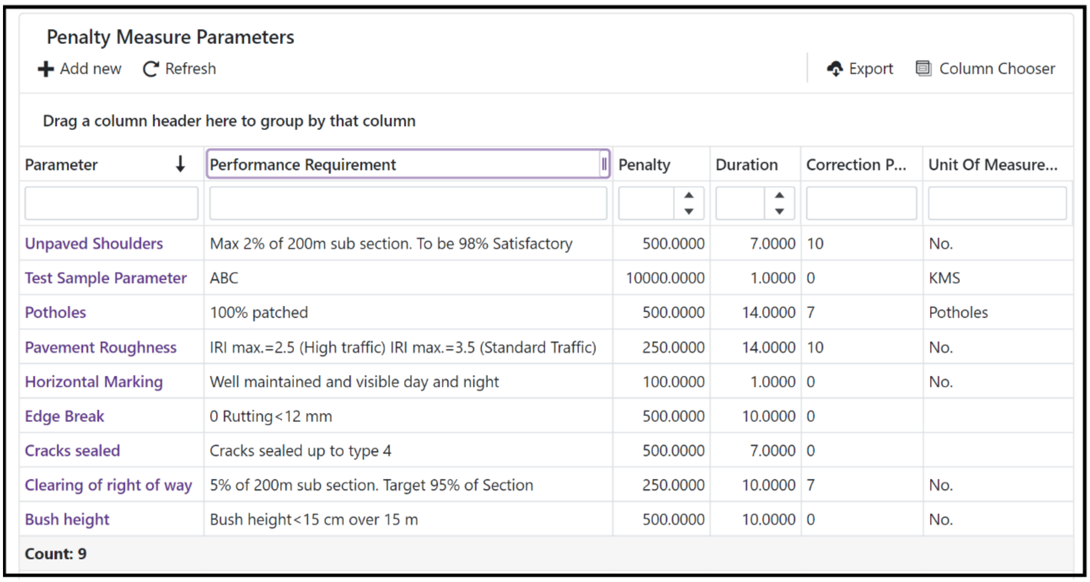


Figure 4.4: Penalty Measures Submodule Window

Penalty Measure Parameters: These parameters described the asset items, the minimum acceptable levels of service to be achieved, and the minimum time allowed for the contractor to remedy damages and achieve road usability. These parameters constitute description of asset items, defining performance targets and response time. Figure 4.5 shows a window for the submodule of penalty measure parameters.



Penalty Measure Parameters

Add new | Refresh | Export | Column Chooser

Drag a column header here to group by that column

Parameter	Performance Requirement	Penalty	Duration	Correction P...	Unit Of Measure...
Unpaved Shoulders	Max 2% of 200m sub section. To be 98% Satisfactory	500.0000	7.0000	10	No.
Test Sample Parameter	ABC	10000.0000	1.0000	0	KMS
Potholes	100% patched	500.0000	14.0000	7	Potholes
Pavement Roughness	IRI max.=2.5 (High traffic) IRI max.=3.5 (Standard Traffic)	250.0000	14.0000	10	No.
Horizontal Marking	Well maintained and visible day and night	100.0000	1.0000	0	No.
Edge Break	0 Rutting<12 mm	500.0000	10.0000	0	
Cracks sealed	Cracks sealed up to type 4	500.0000	7.0000	0	
Clearing of right of way	5% of 200m sub section. Target 95% of Section	250.0000	10.0000	7	No.
Bush height	Bush height<15 cm over 15 m	500.0000	10.0000	0	No.

Count: 9

Figure 4.5: Penalty Measures Parameters

4.2.1.2 System Setups

These are the general setups against which the software solution was anchored. System setups provide unique components that constitute the solution.

Road Categories: This submodule was designed to provide data on classification of roads with respect to traffic volumes. A road is was considered of high traffic if the volume of traffic was greater than 50,000 per day, and standard if the volume of traffic was less than 50,000 per day (JiCA, 2016). Figure 4.6 shows the window for road categories submodule.

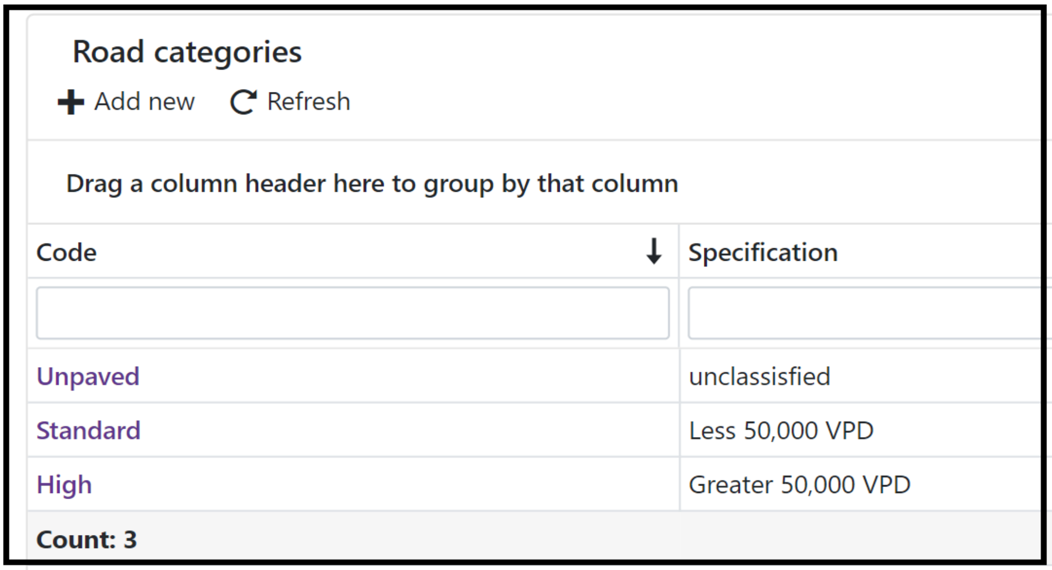


Figure 4.6: Road Categories Submodule

Contractor Categories: A criterion was developed to categorize contractors as either local or foreign. This was aimed at improving reporting, with respect to eligibility for specific contracts, government regulation and staff requirements. Figure 4.7 shows a window for contractor categories submodule.

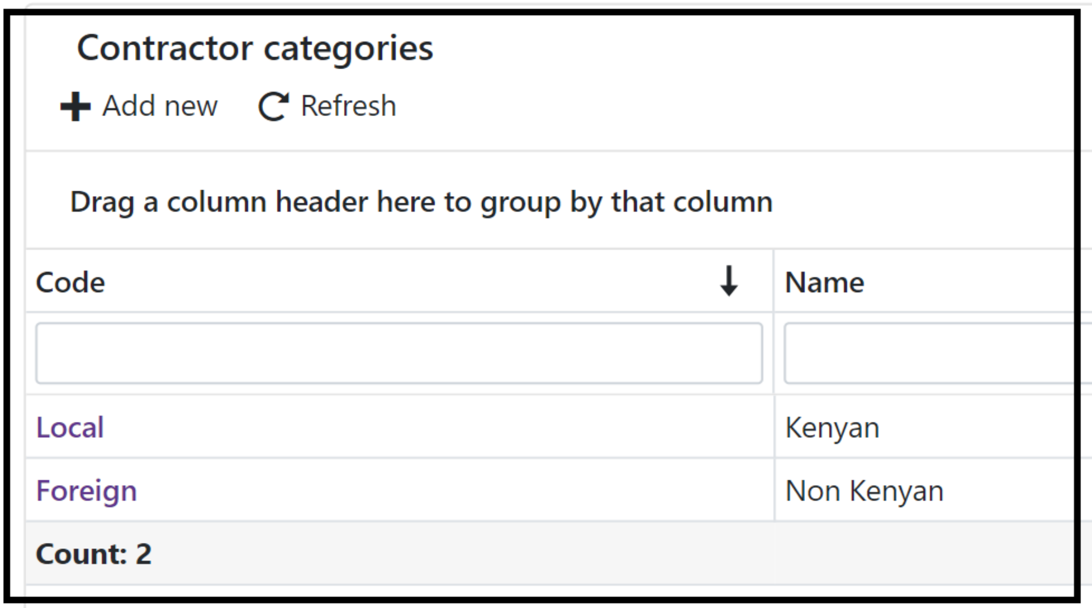


Figure 4.7: Contractor Categories Submodule

Contractor Class: A criterion to aid in procurement and contract financial thresholds was set with respect to classification of contractors as provided by the National Construction Authority of Kenya (NCA). This submodule was important for guidance during tendering for contractor selection. This classification was categorized as NCA 1 – NCA 8, with NCA 8 being of lowest threshold and NCA 1 highest threshold. Figure 4.8 shows the window for contractor class submodule.

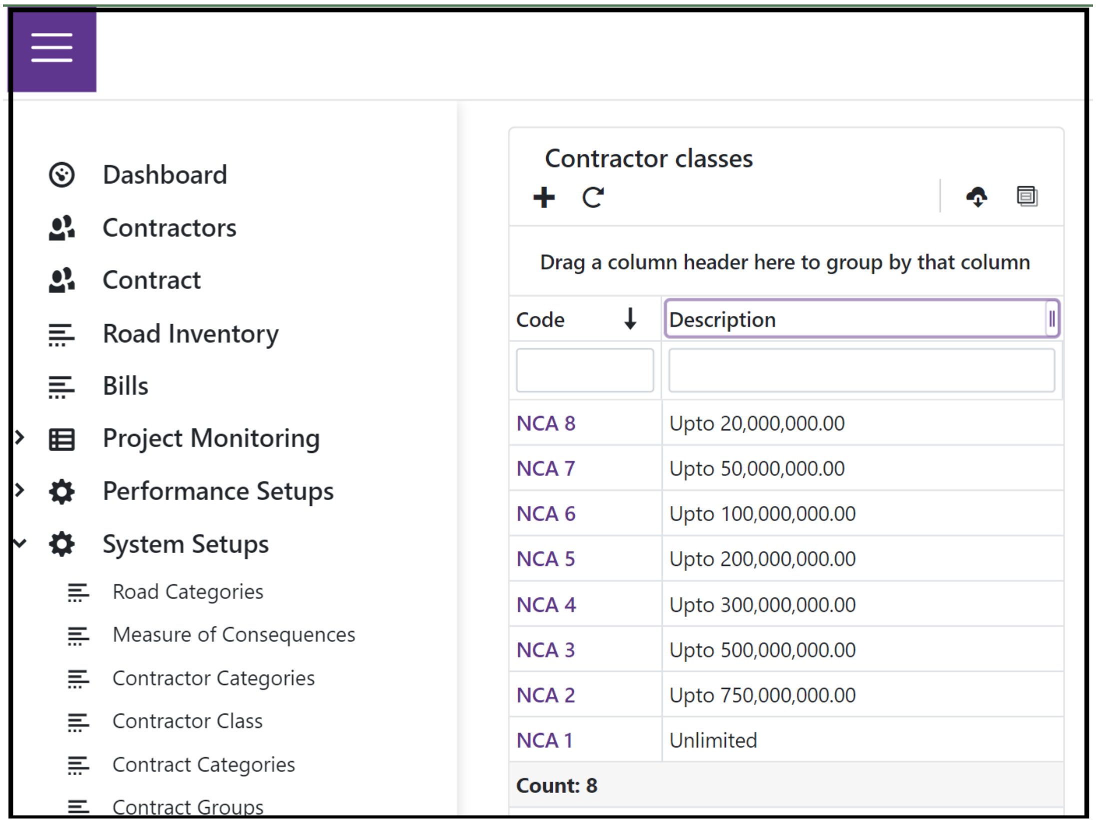


Figure 4.8: Contractor Class Submodule

Funding Source: A submodule was designed to classify the various sources of funding associated with road maintenance in the country. These sources were identified as fuel levy fund, donor funding and Government of Kenya (GoK) funding. Figure 4.9 shows the window for funding source.

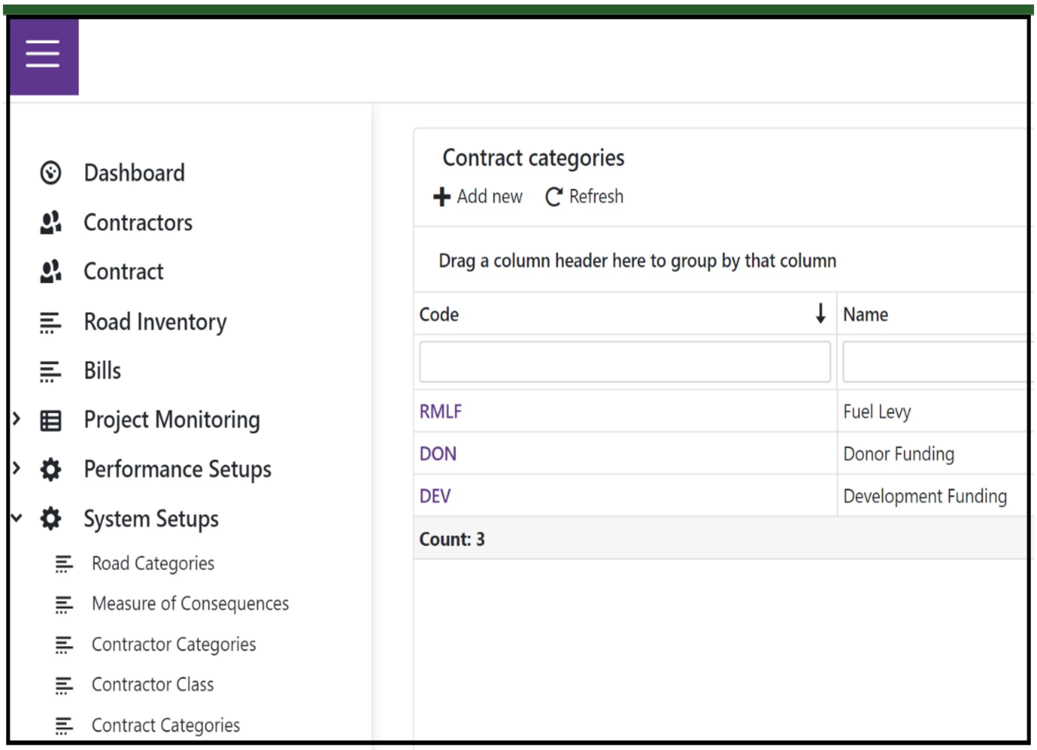


Figure 4.9: Contractor for Funding Source

Contract Groups: The different contract types were categorized with reference to dominant scope of works. This submodule allowed for description of the contract by featuring the various construction elements involved. The contracts were grouped as structures, upgrading, maintenance and rehabilitation. Figure 4.9 shows a window for contract groups submodule.

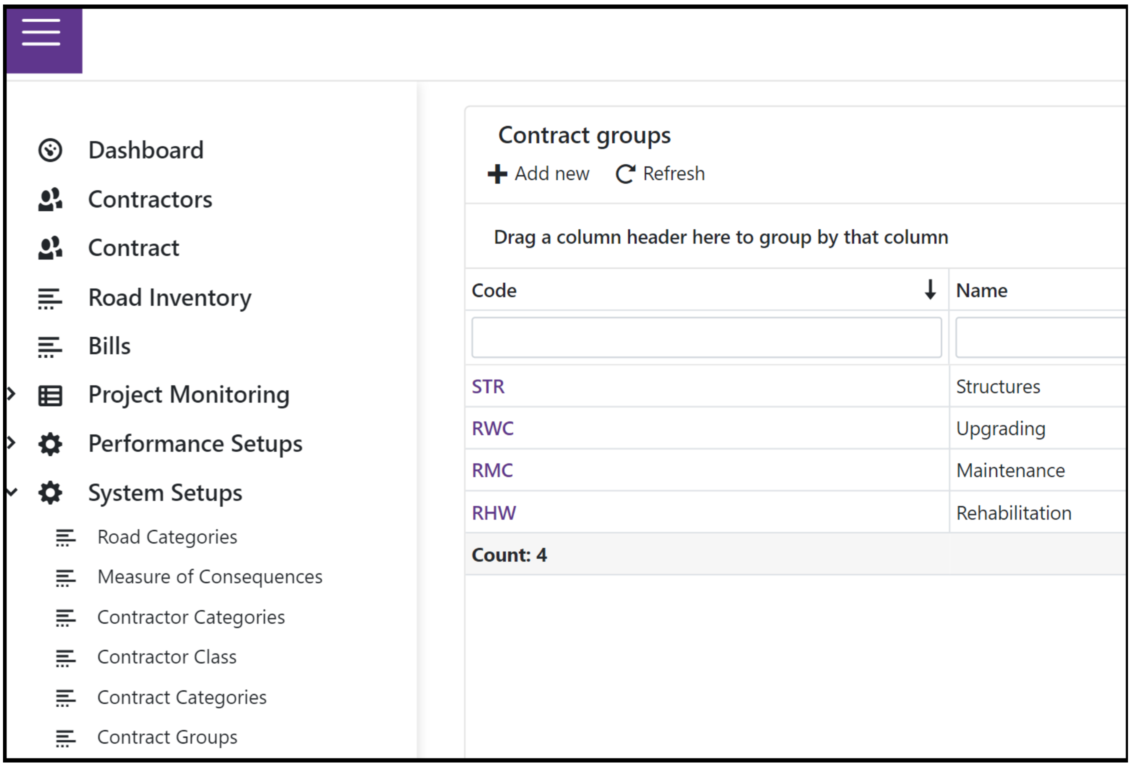


Figure 4.10: Contract Groups Submodule

Contact Types: For purposes of contract administration, a criterion was designed to define authority under the contractor's establishment. Such authorized persons ensure effective contract administration and communication. The different authorities provided for administrative functions in this software are site agent, Power of Attorney, and Director. Figure 4.11 shows a window for Contact type submodule.

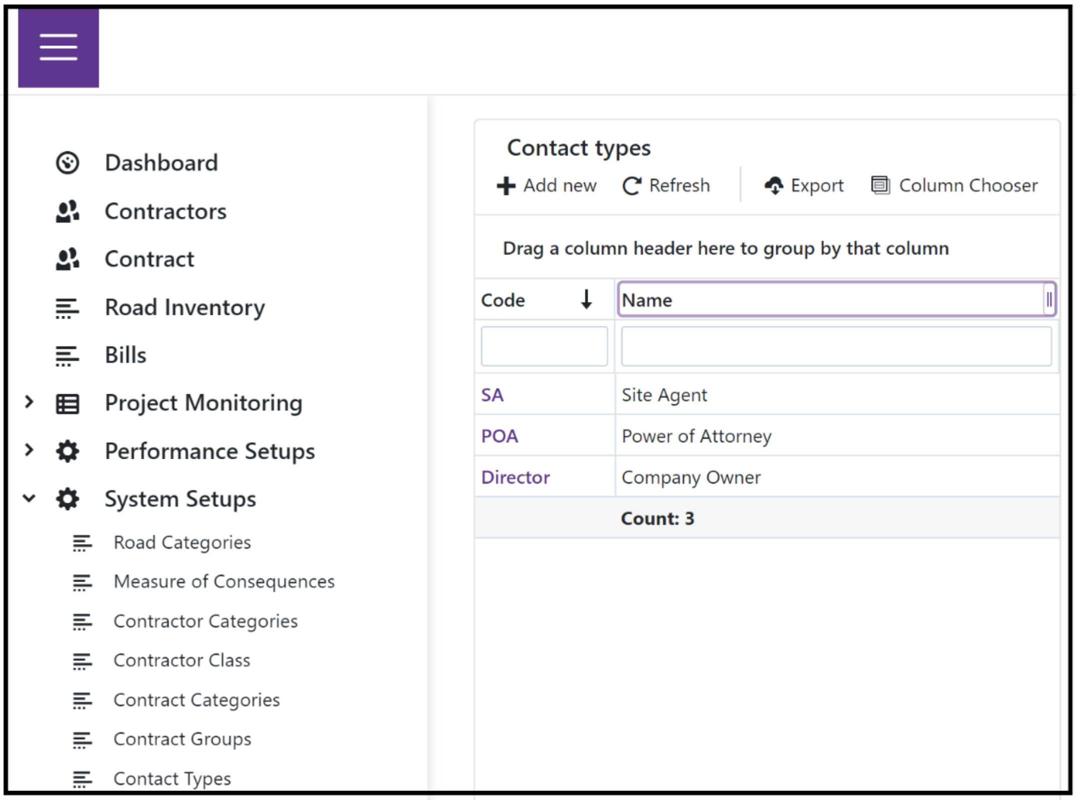
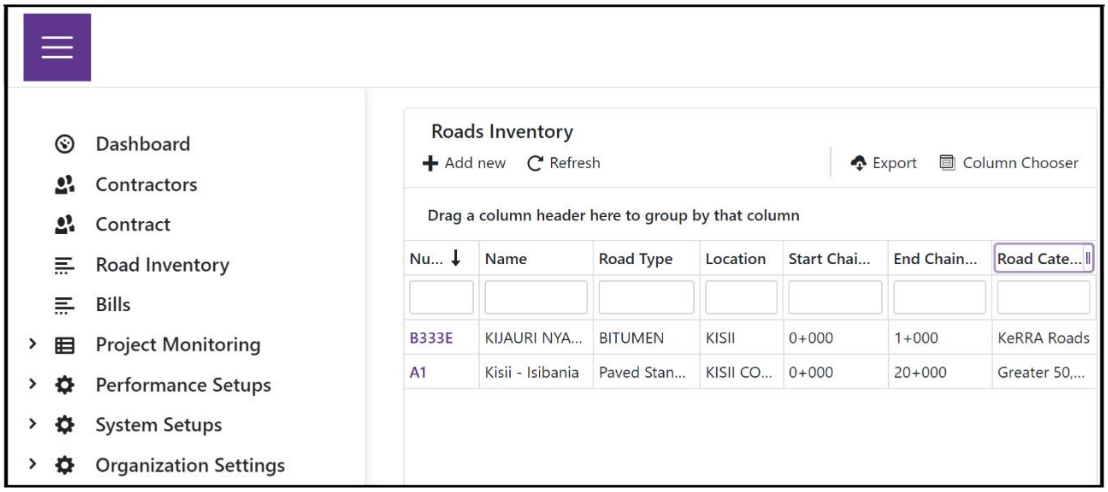


Figure 4.11: Contact Types Submodule

4.2.2 Transactional Data

4.2.2.1 Road Inventory

A criterion was designed to describe the roads by the jurisdiction of the managing road agency. The module shows the road, road number, road length, surface type, road location and service level category. The road inventory window was also enabled with a page for road sectioning during contract implementation. Road Inventory module is shown in figure 4.12.



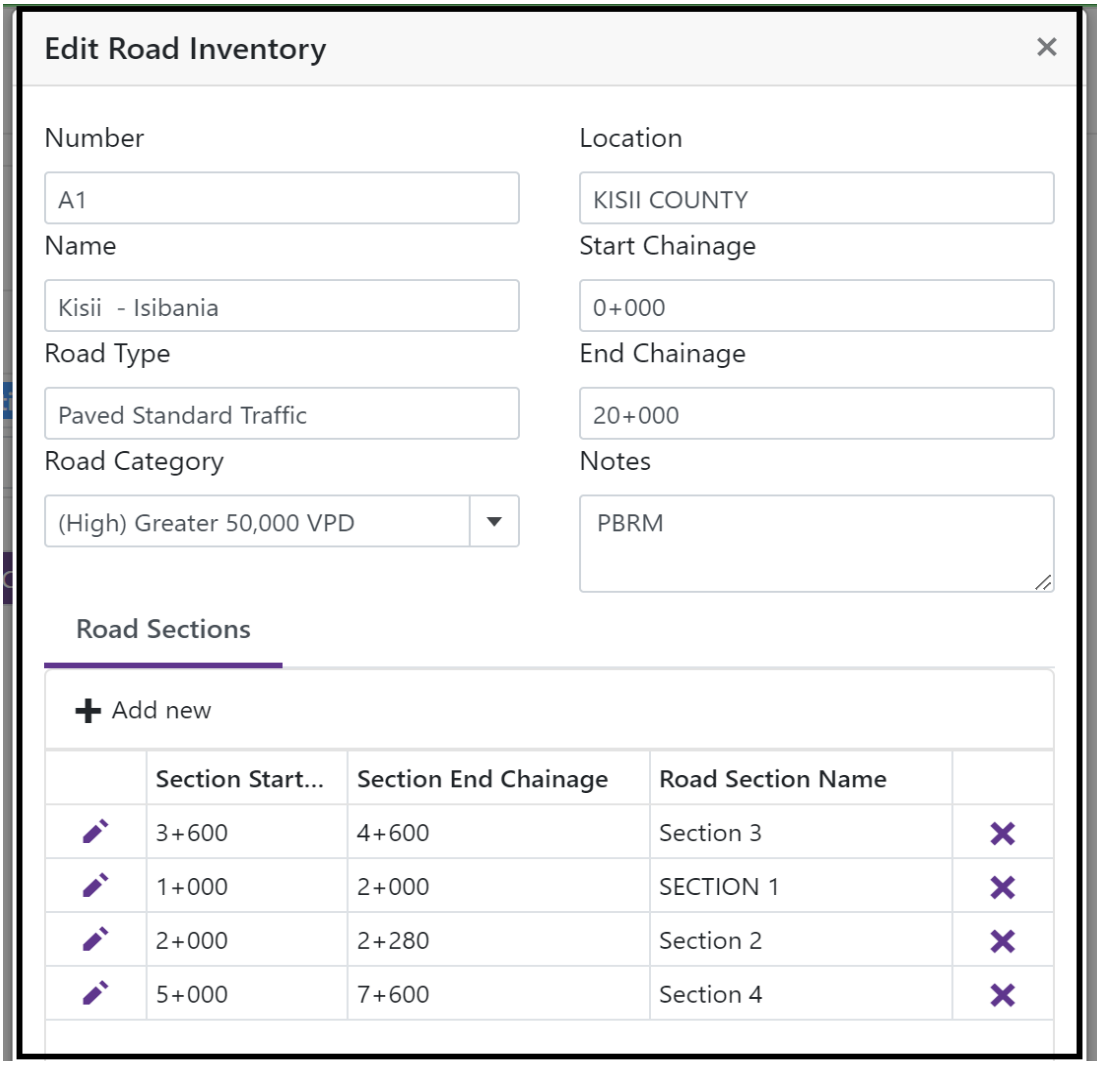


Figure 4.12: Road Inventory Module

4.2.2.2 Contractors

Data on prequalified Contractors was obtained from the road agencies. Each contractor was assigned a vendor's code. Details for contractors were name of the contractor, tax obligations, and contractor's contacts. Contractor's category, and Contractor group was also included to show contracting financial thresholds and nationality for eligibility. Additionally, the contractor's contact person and banking details were input into the system. Contractor module window is shown in figure 4.13.

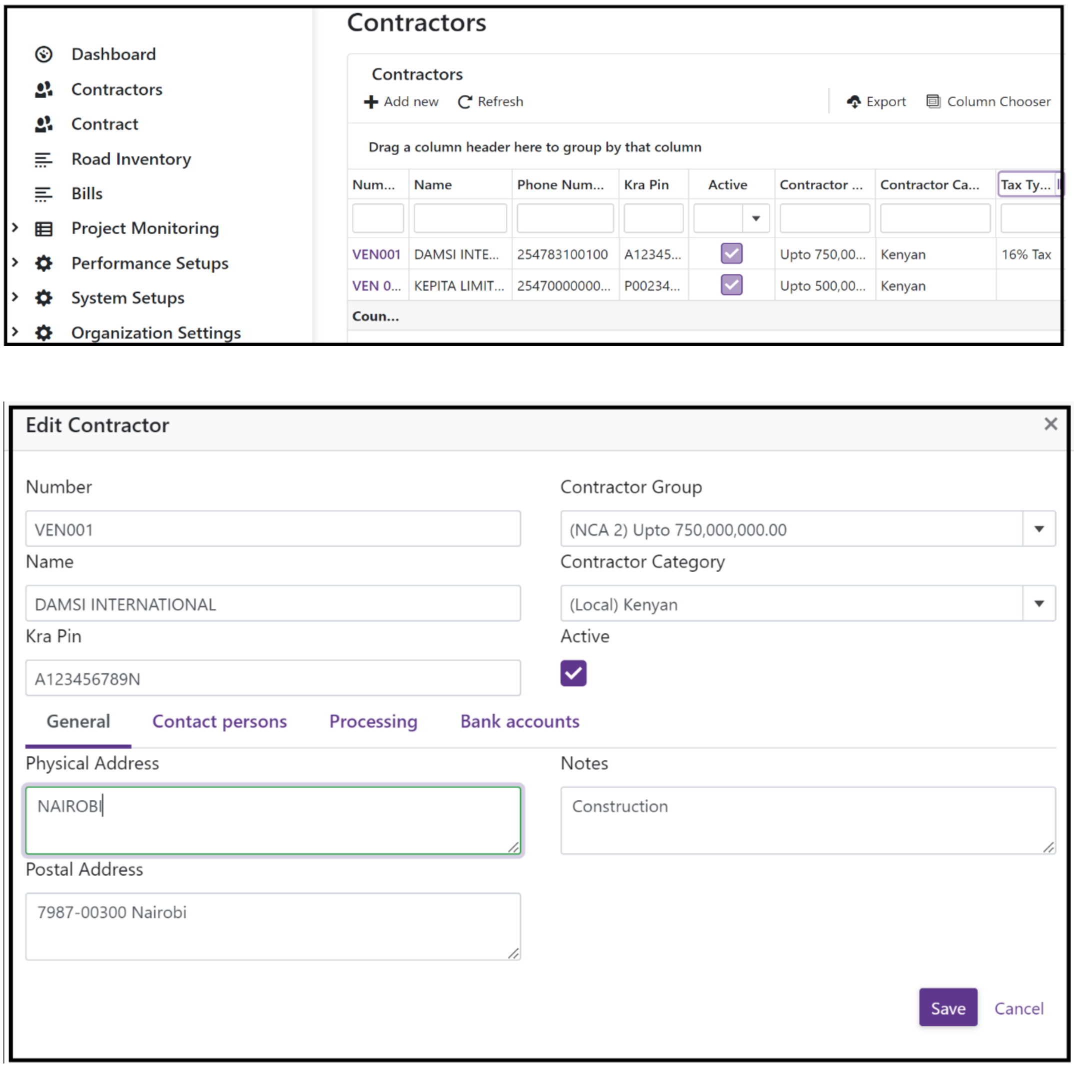


Figure 4.13: Contractor Module Window

4.2.2.3 Contracts

A Criterion for defining contracts was developed considered the scope of works within a contract. The input data comprising a contract were Contract number, contract name, Contractor's name, commencement date, completion date, contract sum, contract period, maximum value of interim payment certificate and advance payment threshold. Performance measures were input to define a contract. These were unit of measure, correction period and payment reduction rate. A contracts module window is shown in figure 4.14.

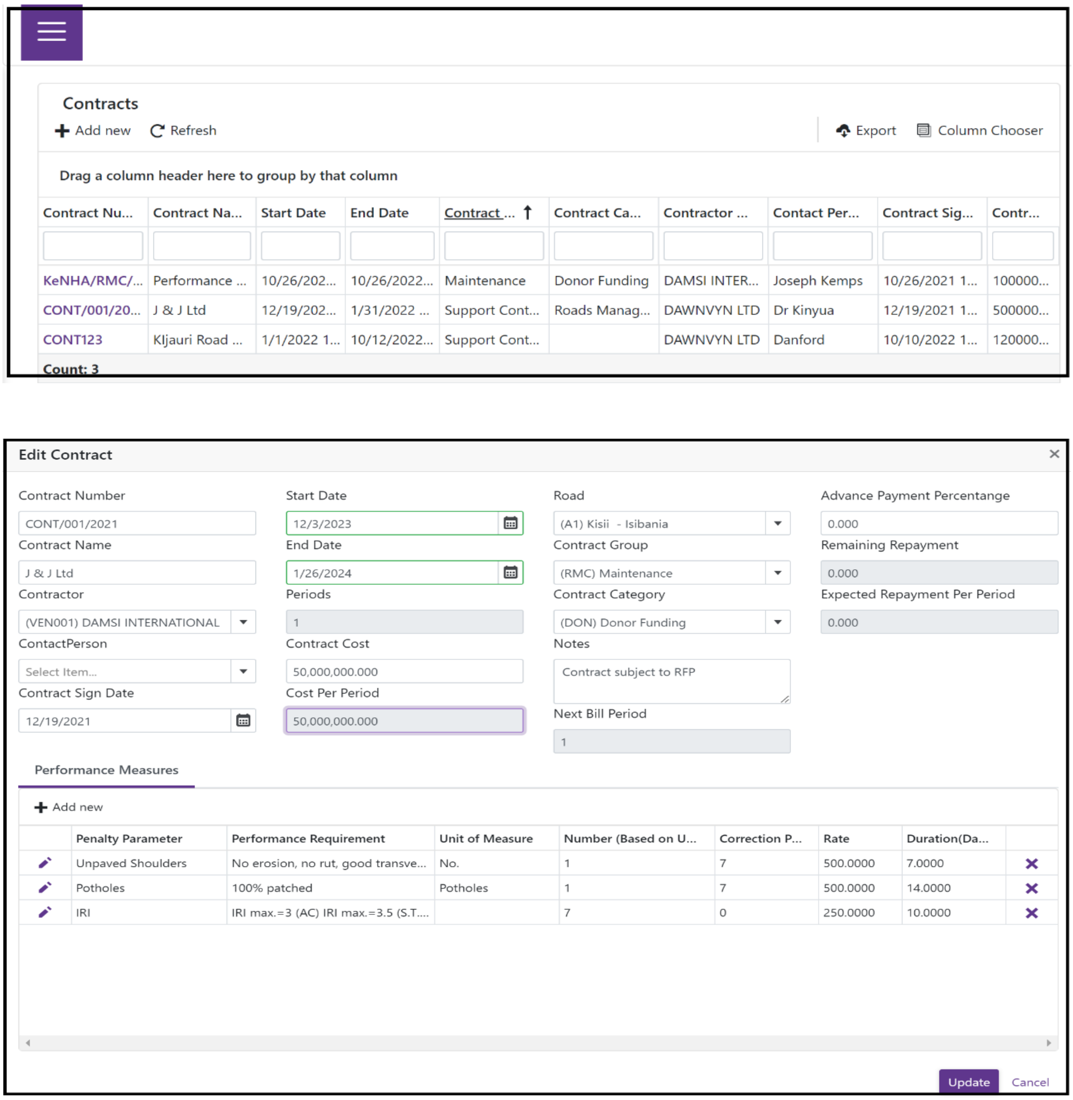
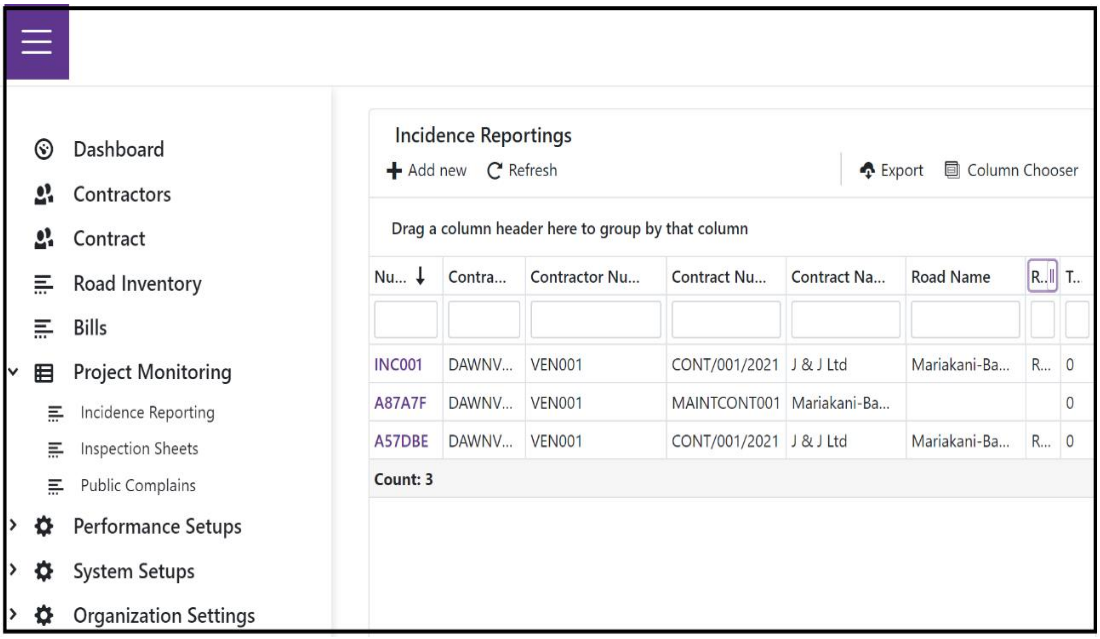


Figure 4.14: Contracts Module Window

4.2.2.4 Project Monitoring

A module for project monitoring was designed comprising submodules on Incidence Reporting, Inspection sheets, and Public Complains. The 3 sub modules are described below.

Incidence reporting: The Incidence reporting Sub Module enabled input of data from physical inspections on road asset condition as measured from the field. It features parameters such as response time, performance target, and quantities measured. A drop-down page was inserted to inform users if the correction measures had been undertaken and the section made good to required LOS. The incidence reporting sub module window is shown in figure 4.15.



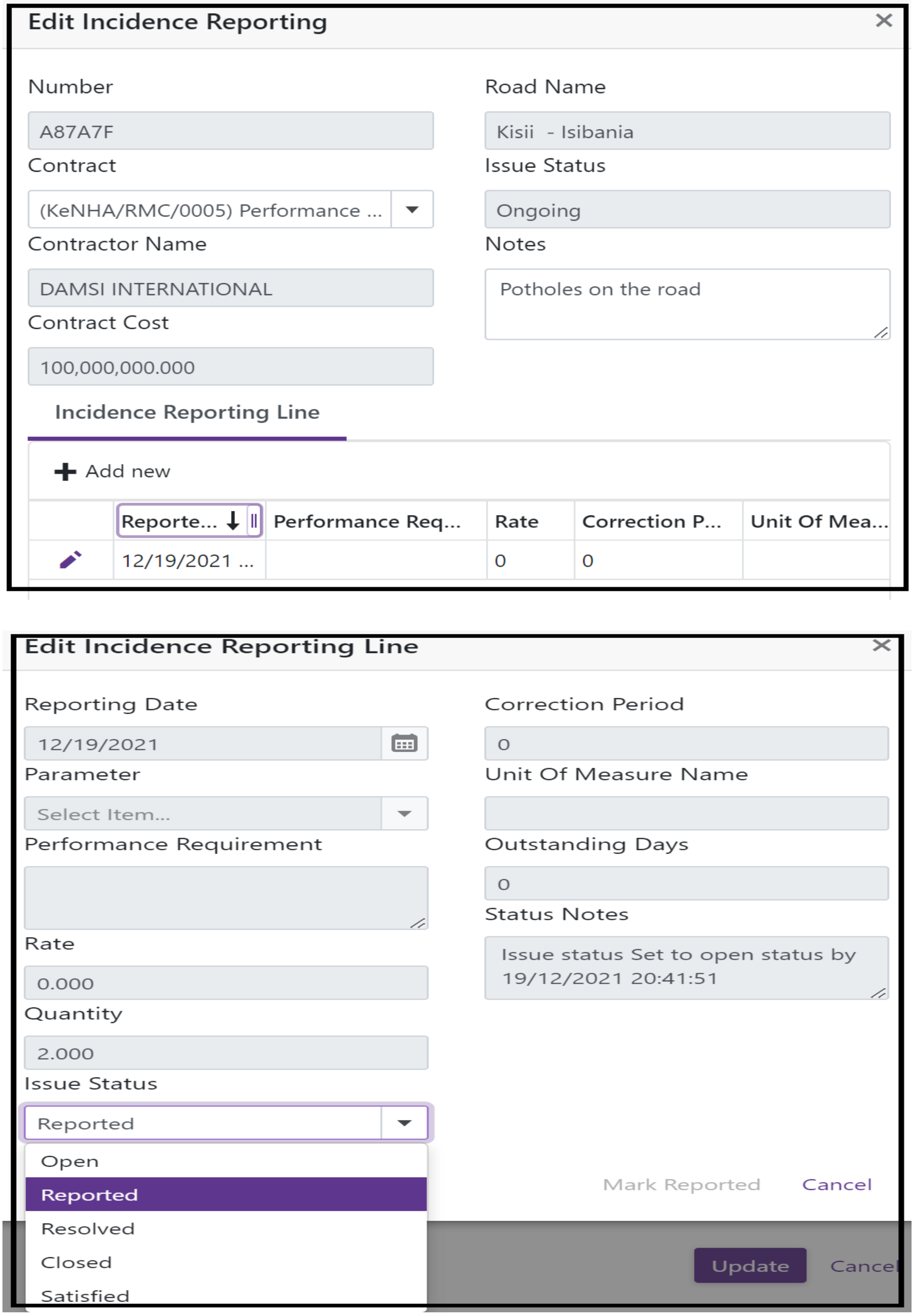
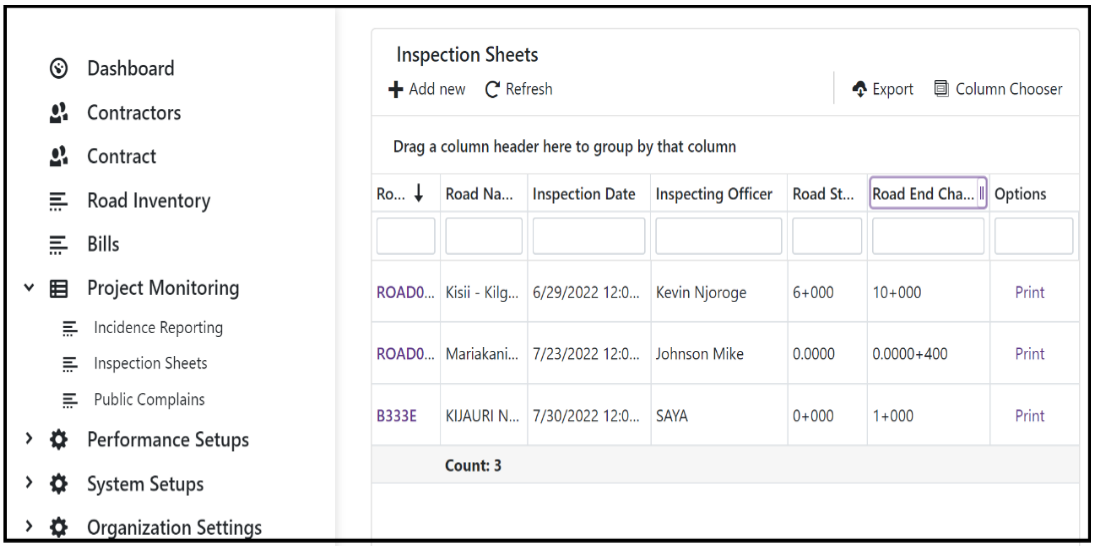


Figure 4.15: Incidence Reporting Sub Module

Inspection Sheets: The Inspection sheet sub module was designed to allow input of data for road assets before and after maintenance. It comprised measurement sheets in excel worksheets to perform calculations towards analysis of contractor performance. the inspection sheet contained details of the road, section start and end chainage, inspection date and contract duration. The Inspection sheet line was designed to isolate each asset item and calculate compliance at asset item level. This incorporated scope of the works, relative weighting for the asset item, performance target required by the agency, resultant score required, and actual rating. Results for contractor performance for the asset group were then summarized and presented in an excel worksheet. The Inspection Sheet sub module window for individual asset item and a summarized worksheet for the asset group are shown in figures 4.16 - 4.20.



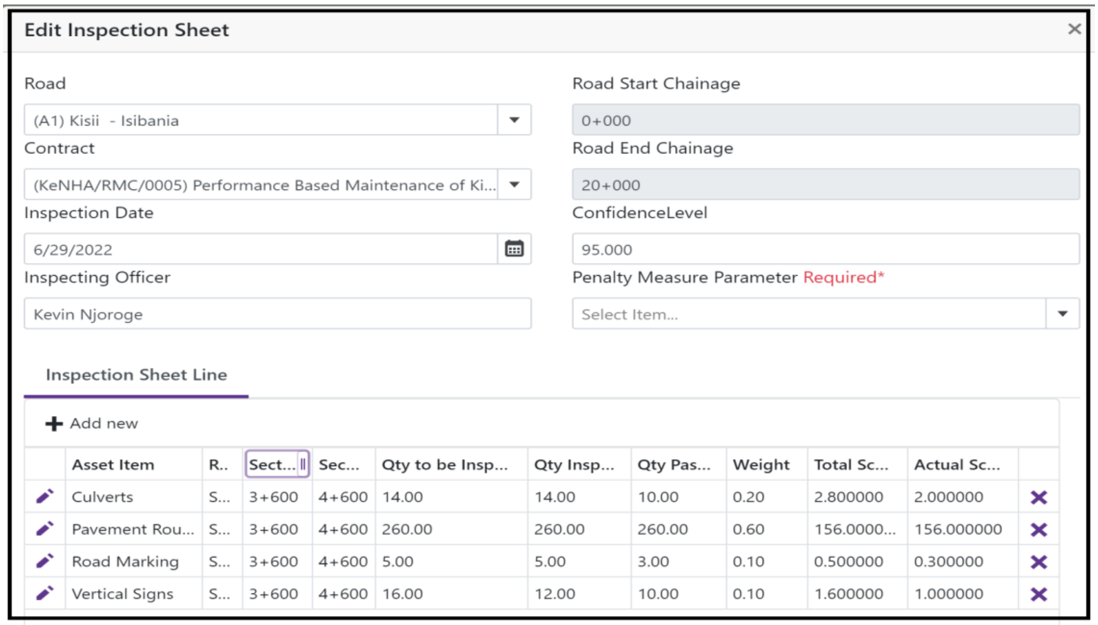


Figure 4.16: Inspection Sheet Sub Module Window

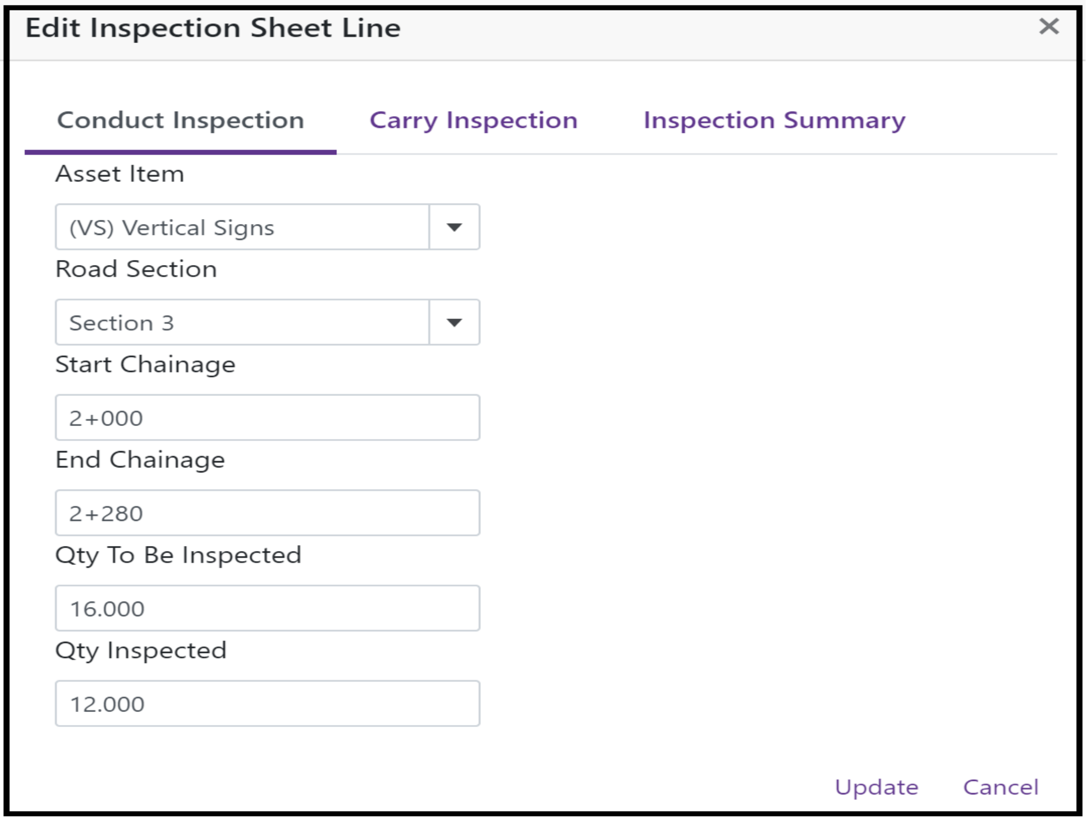


Figure 4.17: Inspection Sheet Sub Module Window

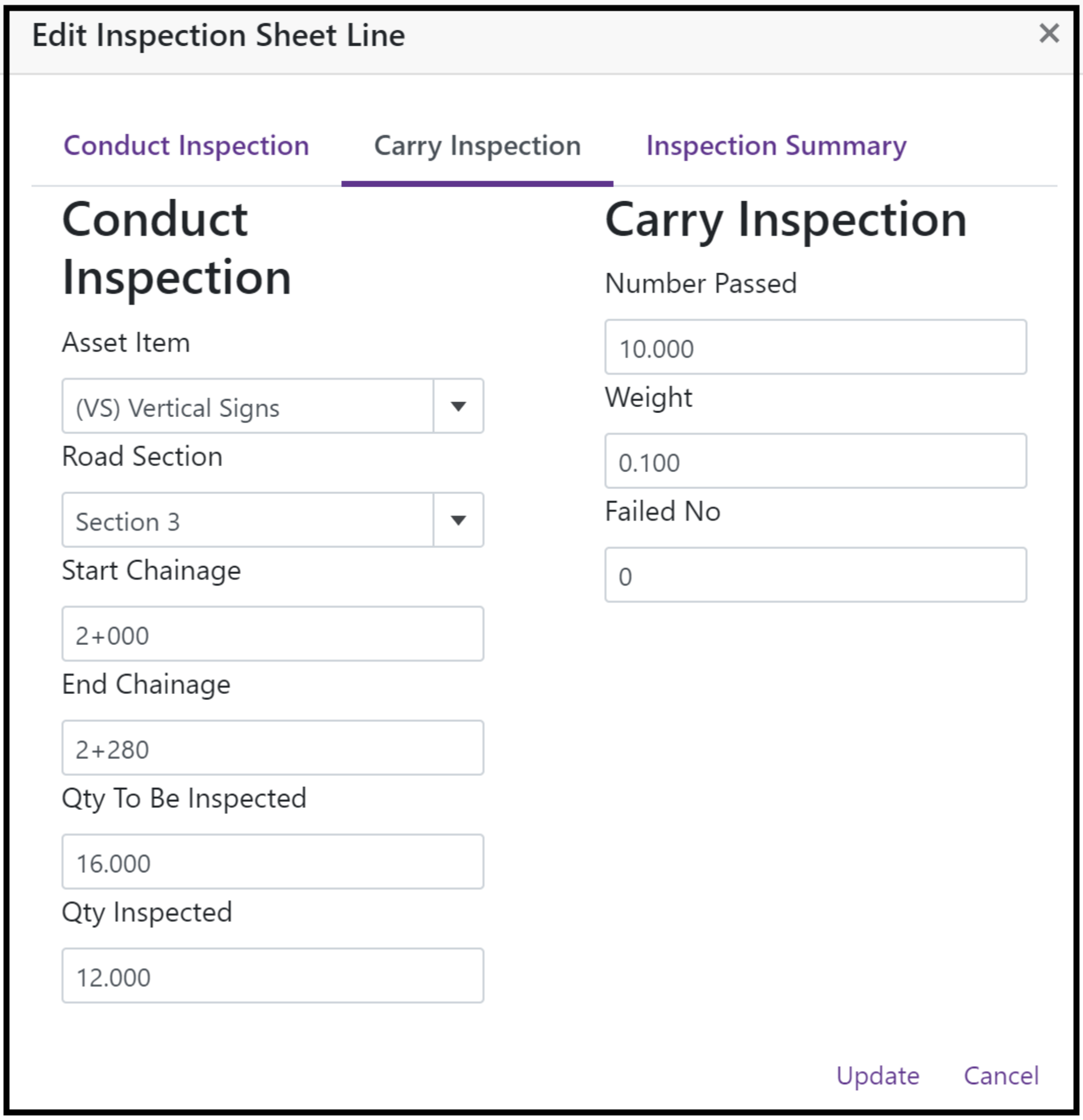


Figure 4.18: Inspection Sheet Sub Module Window

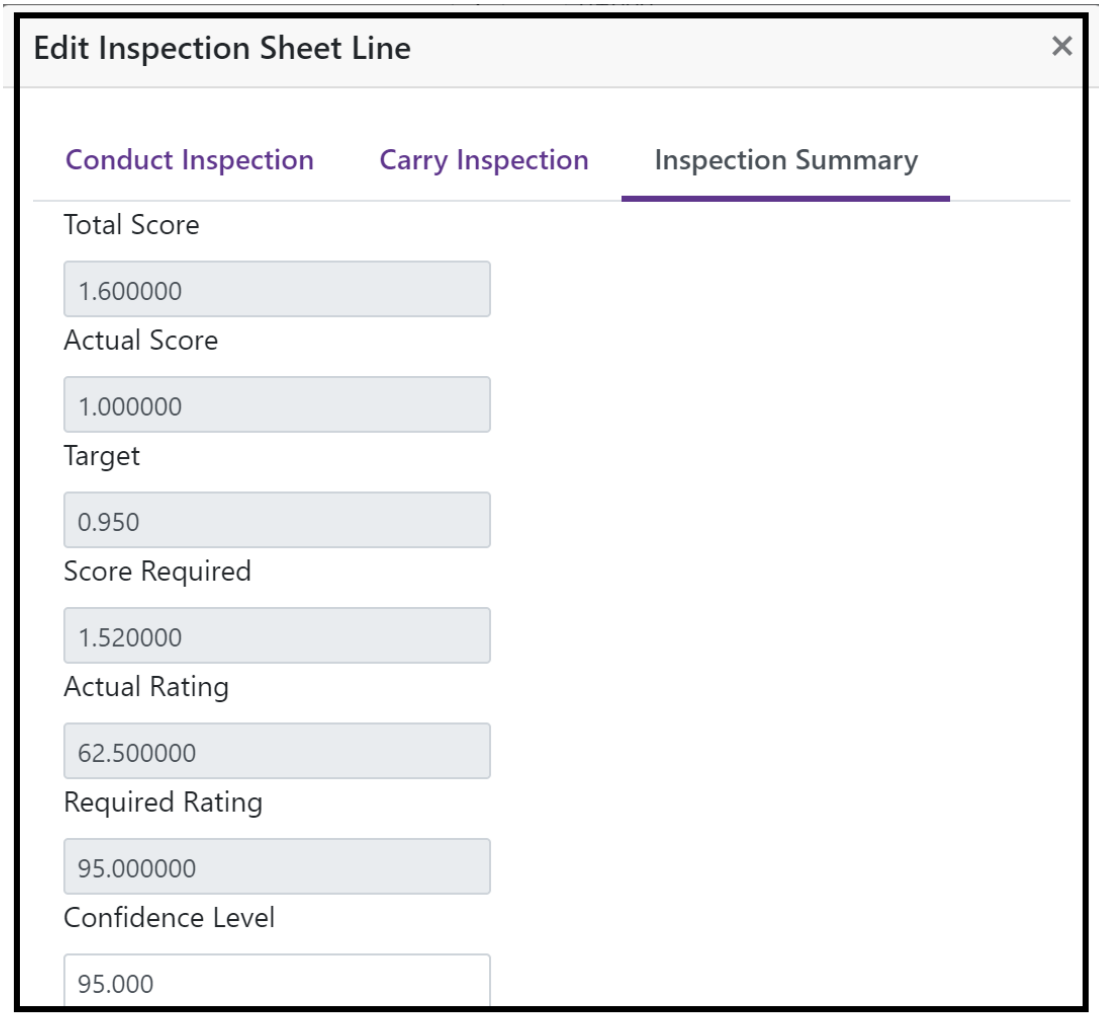


Figure 4.19: Inspection Sheet Sub Module Window

FirmCore Solutions **Inspection Sheet**

ABC Plaza

P.O Box 123456 - 00100 Nairobi

Phone No: 0722123456

E-mail: info@firmcore.co.ke

Road Name: Kisii - Kilgoris Start Chainage: 6+000 Inspector: Kevin Njoroge

Road No: ROAD001 End Chainage: 10+000 Inspection Date: 29 Jun 2022

Asset Item	Start Chainage	End Chainage	Req. to be Inspected	Inspected	Passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score Req.
Vertical Signs	2+000	2+280	16.00	12.00	10.00	.10	1.60	1.00	62.50	.95	1.52

Asset Item	Start Chainage	End Chainage	Req. to be Inspected	Inspected	Passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score Req.
Pavement Roughness	0+000	1+000	260.00	260.00	260.00	.60	156.00	156.00	100.00	1.00	156.00

Asset Item	Start Chainage	End Chainage	Req. to be Inspected	Inspected	Passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score Req.
Culverts	0+00	1+000	14.00	11.00	10.00	.20	2.80	2.00	71.43	.95	2.66

Asset Item	Start Chainage	End Chainage	Req. to be Inspected	Inspected	Passed	Weight	Total Score	Actual Score	Actual Rating	Target	Score Req.
Road Marking	2+000	2+280	5.00	5.00	3.00	.10	.50	.30	60.00	.95	.48
		Total	**295.00**	**288.00**	**283.00**	**1.00**	**160.90**	**159.30**	**293.93**	**3.85**	**160.66**

Total Actual Rating: **99.0056%**

Total Required Rating: **99.8477%**

Confidence Level: **95.00**

1/3

Road Name: Kisii - Kilgoris Start Chainage: 6+000 Inspector: Kevin Njoroge

Figure 4.20: Inspection Work Sheet Summary

Public Complains: A criterion was designed to incorporate public complains platform in the system. This is accessible by the public to lodge comments and provide reports on status of roads under maintenance, contractor performance and other issues related to the project. The Public Complains sub module was necessary to reduce the bulk of supervision and monitoring of road condition. Road users can report condition of the road. An interface was created between road implementing agency and the public through this sub module. The system enabled the public user to select name of the road and to fill in comments as appropriate. These would be submitted to the Project Monitoring Module. The road agency user under Project Monitoring Module reviews the complaint and actions it. This would then be indicated as active or resolved for public information. A Public Complain sub module window is shown in figure 4.18.

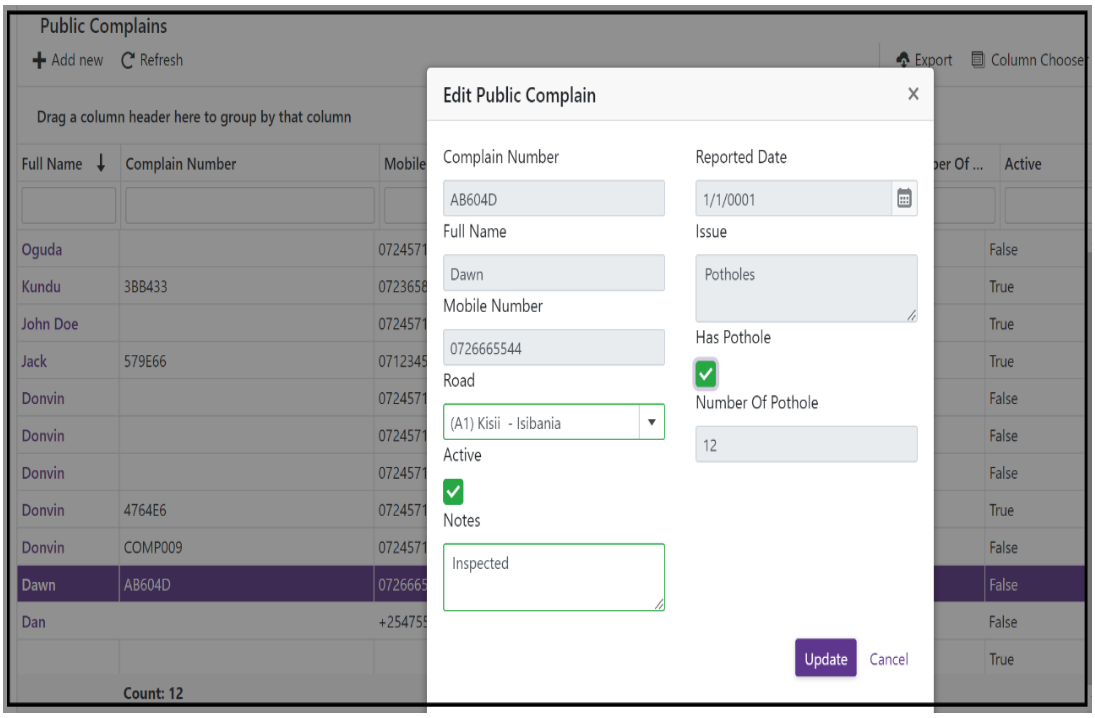
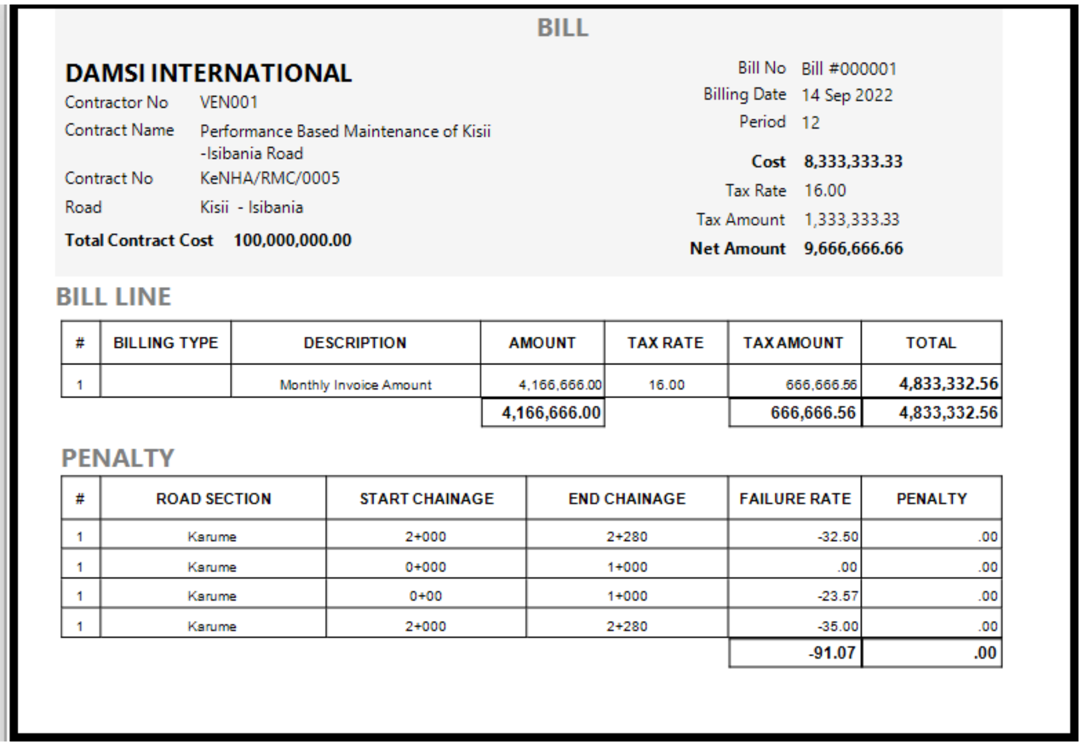


Figure 4.21: Public Complains Sub Module Window

Billing: A format for reporting financial progress was designed. This format was used to record payments certified in each certificate for work done and deductions made. The road sections completed, asset items billed, corresponding penalties for noncompliance, taxes, and contractor compliance status. The module was equipped with a page for input of field data during inspections for each of the assert items in in a contract. This sub module was enabled to generate payment certificates indicating amounts owed the contractor. A Billing module window and sample of generated payment certificate are shown in figure 4.22.



BILL

DAMSI INTERNATIONAL

Contractor No VEN001

Contract Name Performance Based Maintenance of Kisii -Isibania Road

Contract No KeNHA/RMC/0005

Road Kisii - Isibania

Total Contract Cost 100,000,000.00

Bill No Bill #000001

Billing Date 14 Sep 2022

Period 12

Cost 8,333,333.33

Tax Rate 16.00

Tax Amount 1,333,333.33

Net Amount 9,666,666.66

BILL LINE

#	BILLING TYPE	DESCRIPTION	AMOUNT	TAX RATE	TAX AMOUNT	TOTAL
1		Monthly Invoice Amount	4,166,666.00	16.00	666,666.56	**4,833,332.56**
			4,166,666.00		**666,666.56**	**4,833,332.56**

PENALTY

#	ROAD SECTION	START CHAINAGE	END CHAINAGE	FAILURE RATE	PENALTY
1	Karume	2+000	2+280	-32.50	.00
1	Karume	0+000	1+000	.00	.00
1	Karume	0+00	1+000	-23.57	.00
1	Karume	2+000	2+280	-35.00	.00
				-91.07	**.00**

Figure 4.22: Payment Certificate Window

4.2.3 Organizational Setup

This module was developed to define the users and user departments within the organization. The users were assigned usernames, designation and respective departments.

4.2.4 System-User Dialogue

The dialogue between the system and the user follows this order.

i. The user switches on the computer and selects the web link.
ii. System prompts the user to log in.
iii. User enters the password to log in.
iv. System displays the functional menu.
v. User selects menu of choice.
vi. System displays data entry sheet.
vii. User enters data and saves.
viii. User repeats steps 5 to 7 for all required modules.

ix. User filters information.
x. System generates the required report.

4.2.5 System Home Page

The home page of the system is as shown in Figure 4.21.

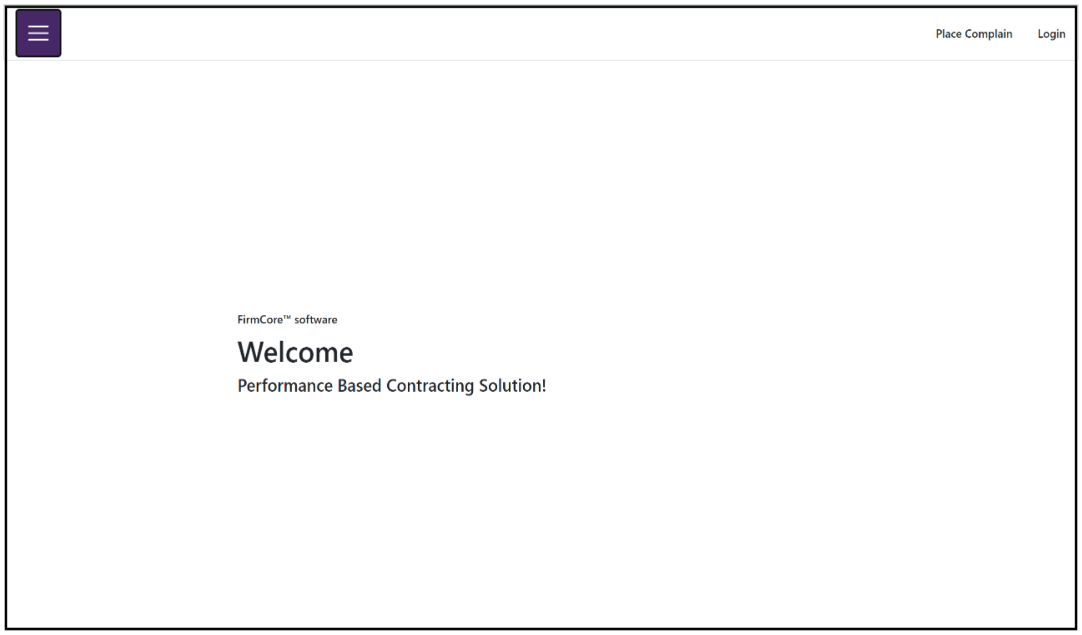


Figure 4.23: System Home Page Window

4.3 Validation of Developed Road Maintenance Management System

It is assumed that manual mode of measurement presented to 2 decimal places is not as accurate as computerized measurement systems usually presented to 9 decimal places. In this regard, this objective sought to establish if there is a significant difference in the results from performance-based road maintenance monitoring manually and using the computerized system (RMS) for a project.

Measurements from 4 Asset groups were collected for actual ratings and required ratings for both manual recordings and System generated results. Independent sample t-Test was carried out on actual ratings to explore the hypothesis test that there is a significant difference in manual and computerized rating results.

Data collected from 4 sample units were used for validating the developed performance monitoring of the system. Field data was collected using measurement tools for linear measurements and related conversions to determine the LOS of pavement. The Dynamic Response Intelligent System (DRIMS) was used to measure International Roughness Index (IRI). Road agency records were reviewed to corroborate data from field inspections.

4.3.1 Hypothesis

The null hypothesis (H_0) and alternative hypothesis (H_1) of the Independent Samples t-Test were expressed as shown below:

H_0: $\mu_1 = \mu_2$ ("the two-population means are equal").

H_1: $\mu_1 \neq \mu_2$ ("the two-population means are not equal").

Where μ_1 and μ_2 are the population means for manual and computerized systems respectively.

4.3.2 Independent Sample T-Test

The Independent Samples t-Test is a parametric test that compares the means of two independent groups to see if there is statistical evidence that the means of the associated populations are significantly different. The test is commonly used to measure statistical differences between the means of two groups, statistical differences between the means of two interventions and statistical differences between the means of two change scores.

4.3.3 Assumptions for the Independent Sample T-Test

For this study, data meet the following requirements.

1. Dependent variable that is continuous (i.e., interval or ratio level) where our data dependent variable is scores that is continuous, hence the assumption is met.

2. Independent variable that is categorical *and* has exactly two categories where we had 2 categories in the data for manual and RMS groups, hence the assumption met.
3. Independent samples/groups (i.e., independence of observations) where the data was measured using 2 independent modes i.e., manual and RMS that were independently recorded, hence the assumption is met.
4. Random sample of data from the population which is met for the data sampled.
5. Normal distribution (approximately) of the dependent variable for each group.

4.3.4 Data Set-Up

The data included two variables rating groups and scores that was used in the analysis. The independent variable was categorical and include exactly two groups i.e., manual (Group 1) and RMS (Group 2). (Note that SPSS restricts categorical indicators to numeric or short string values only.) The dependent variable was continuous (i.e., interval or ratio) which was the scores obtained from the rating systems used. SPSS only makes use of cases that have no missing values for the independent and the dependent variables, so the data was ensured that had no missing value for either variable.

The number of rows in the dataset corresponded to the number of subjects in the study. Each row of the dataset represented a unique unit, and all the measurements taken on that unit appeared in their respective row.

4.3.5 Inference Statistics

The test was carried out using SPSS software and the findings of the study are as shown in table 4.6 and table 4.7 below respectively.

Table 4.6: Group Statistics Means

Group Statistics

	Rating Groups	N	Mean	Std. Deviation	Std. Error Mean
Scores	Manual	4	63.342500000	44.3399995301	22.1699997651
	RMS	4	63.341705492	44.3396678910	22.1698339455

The results indicated that sample size for each group was 4, with means of 63.3425 for manual group ratings and 63.341705492 for RMS group ratings with standard deviation and standard error means as shown.

Table 4.7: Independent T-Test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
									Lower	Upper
Scores	EV assumed	.000	0.999967	.000025	6	0.999981	.0007945078	31.35	-76.72	76.72
	EV not assumed			.000025	6.000	0.999981	.0007945078	31.35	-76.72	76.72

Based on the findings, the Levene's test for equality of variances indicated p>0.05, hence equal variance was assumed. The conclusion was based on row 1 of the results of the independent sample t-Test.

The results indicated that the t-statistics obtained was 0.000025 with p-value of 0.999981 and degree of freedom of 6. The 95% confidence interval of the difference was [-76.72 & 76.72] which implied that the value contained zero, hence the results are not statistically significant.

Since $p > .05$ is greater than the chosen significance level $\alpha = 0.05$, do not reject the null hypothesis. The study concluded that the mean rating scores for manual and RMS is insignificantly different.

Based on the results;

- There was an insignificant difference in mean score between manual and RMS rating scores ($t_6 = 0.000025$, $p > .05$).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. The Level of Service rating for the roads indicated a performance index of 0.7495 implying an overall performance of 74.95% which fell below the expected rating by 25.05%. The required performance was not achieved.

ii. PBRM monitoring systems (RMS) should comprise modules that define Performance indicators, performance targets, relative weightings, and payment reductions on noncompliance. Results by manual monitoring provided actual performance 99.39% and 76.56%. These results compare favorably with developed system results at 99.42% and 76.59% for two independent samples, demonstrating reliability of the developed RMS.

iii. There was a mean score of 63.3425 and 63.3417 for manual and RMS ratings from group statistics. Accept the Null Hypothesis that the two Population means are equal. The 95% confidence interval of the difference was (-76.72 & 76.72). Therefore, there is insignificant difference in mean score between manual and RMS rating ((t_6 = 0.000025, $p > .05$), hence validating the performance of the developed RMS.

5.2 Recommendations

5.2.1 Recommendations from the Study

i. There was overall performance of 74.95% (PPI = 0.7495) being 25.05% below expected performance target. This was not determined by the road agencies. It is recommended that Level of Service must be assessed before payment is effected. Payment penalties should be effected in case of noncompliance with performance targets.

ii. There is no significant difference in the mean scores for manual and RMS ratings (manual = 63.34, RMS= 63.341705492). It is recommended that the monitoring exercise be carried out using RMS because of the benefits of time saving, reduced staff to process data, and data analysis accuracy.

5.2.2 Areas for Further Research

i. There was approval of works at 25.05% below target performance. It is recommended to establish the extent of financial losses and the extent to which user satisfaction has not been met following PBRM practice.
ii. The developed system provides monitoring and analysis based on data collected physically from the field. It is recommended that further study be carried out to enhance the systems effectiveness and reliability by incorporating modules on remote sensing, georeferencing and photographic data presentations.

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