DEVELOPMENT OF ROAD MAINTENANCE MANAGEMENT SYSTEM FOR UNPAVED ROADS IN KENYA

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Development of Road Maintenance Management System for Unpaved Roads in Kenya

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DECLARATION

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

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DEDICATION

To all who stood by my side when I had a terrible road accident during the course of this study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BOQ	Bill of Quantities
DRE	District Roads Engineer
DFID	Department for International Development
ERA	Ethiopia Roads Authority
GHA	Ghana Highway Authority
GPS	Global Positioning System
GIS	Geographic Information System
GTZ	Gesellschaft für Technische Zusammenarbeit
HDM	Highway Design Manual
IMF	International Monitory Fund
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KRICS	Kenya Road Inventory and Condition Survey
KfW	Kreditanstalt Für Wiederaufbau
LPO	Local Purchase Order
LSO	Local Service Order
MOR	Ministry of Roads
MOR&PW	Ministry of Roads and Public Works
MS	Microsoft
MRP	Minor Roads Programme
PMM	Pavement Management Methodology
RAR	Rural Access Roads
RE	Regional Engineer
RFCNS	Road Functional Classification and Numbering System
RM	Regional Manager
RMMS	Road Maintenance Management System
RMPS	Road Maintenance Planning System
SQL	Structured Query Language

TANROADS	Tanzania National Roads Agency
TRL	Transport Roads Laboratory
URCI	Unsurfaced road condition index
V.A.T	Value Added Tax

ABSTRACT

Road maintenance management is a big challenge in most countries in the world today. Technology however has been effectively used to solve some of these problems in some countries.

The aim of this study was to identify problems and shortcomings of current road maintenance practise and develop a computerised road maintenance management system for unpaved roads in Kenya. A questionnaire was used to elicit data on the current unpaved road maintenance practices in the country. Stratified and proportionate sampling techniques were used to select the respondents who participated in the study. Data collected was analysed, summarised and described using qualitative statistical techniques.

The results showed that road maintenance works are not properly and efficiently planned, prioritised and tendered. The current methods of monitoring and reporting on time, physical and financial progress of road works are not standard and inefficient since they take more time and involve a lot of paperwork.

As a solution to the current practise shortcomings, a computer based road maintenance management system was developed which incorporates all the stages of a maintenance cycle i.e. road inventory survey, road condition survey, road prioritisation, road

maintenance plan, tender evaluation, contracts time schedules and progress, measurement and certification, work and financial progress reporting.

Raw and collected data were used to validate the system and it showed that it is able to produce road inventory survey and road condition survey reports, prioritise roads and evaluate tenders, monitor time, physical work and financial progress of contracts among others.

The developed system was found to be efficient, flexible for use since it can be used with any contract document specifications and can also be customised for use in any part of Kenya with different needs, requires less labour, reduces the amount of paperwork, is less prone to errors and requires less time to carry out various road maintenance management tasks. It can also minimise corruption and increase openness. It is hoped that adoption of the management system will lead to improvement in unpaved road maintenance in the country.

CHAPTER ONE

INTRODUCTION

1.1 Background

The provision of well maintained physical infrastructure is key to economic growth, employment generation and poverty reduction. Production costs, competitiveness and access to markets depend on the quality of infrastructure. Poor state of infrastructure acts as a major constraint on economic performance and is a major factor in rising levels of poverty (IMF, 2003). According to the joint development partners statement released in 2004, the transport sector in Kenya contributes about 6% of the gross domestic product (KRB, 2005). It also provides the necessary linkages for promoting national and international trade, economic growth, poverty reduction and wealth creation. Roads alone constitute 80% of the entire infrastructure and are therefore vital in the nation's growth (MoR&PW, 2004). This growth and development can be realised if the roads are well constructed and maintained. Efficient road maintenance enhances poverty eradication by improving access between regional and rural communities which ultimately, augment socio-economic growth and development.

There is a problem, however, which is common throughout the world especially in the developing countries - the neglect of maintaining roads. Constructing new roads cost money, but without maintaining the existing roads properly, they deteriorate very quickly. This deterioration will very fast affect road transport in general. The situation in

many countries concerning the road condition is not only urgent, it is critical (Kjell, 2003). It is important to know the costs involved in road maintenance and the costs of not maintaining roads.

An analysis by the World Bank of how 85 countries allocated road maintenance funds showed that, spending $12B on preventive maintenance would have eliminated reconstruction costs of $40B. The result is that an average net cost of $330M is wasted on avoidable reconstruction in each country (Harral, 1988).

If resources are inadequate which is the case usually, there is only one rational course of action: *Maintain existing roads before funding new ones.*

Fortunately this concept of road maintenance is slowly getting entrenched in most countries, and now huge resources are allocated towards road maintenance. For example, in Kenya the government established the Road Maintenance Levy Fund (RMLF) in 1994 which saw its collections increase from KES 9.25 billion in 2003/2004 financial year to KES 18 billion in 2008/2009 financial year (KRB, 2008). KES 17 million (under 20% KRB allocation kitty) is allocated to each constituency for maintenance of roads of class D and below, which are mostly unpaved roads. More funds (under 12% KRB allocation kitty) are allocated to unpaved roads with particular special needs like bottlenecks sections during rainy seasons. Other sources of road maintenance funding include tea and coffee cess, donors etc. On average KES 6 billion are available annually for unpaved roads maintenance in Kenya; but even with these

huge resources, the road maintenance needs in the country are not fully met (MoR&PW, 2006). There is however a challenge of effectively utilising these limited funds; there is lack of an efficient maintenance management system.

The use of an efficient Road Maintenance Management System (RMMS) helps to optimise the use of limited resources available for maintenance works, to have a systematic approach and planning of road maintenance works programmes and to reduce the entire transport costs through proper and timely maintenance works.

The success of road maintenance system largely depends on the maintenance approach. In Kenya, the force account approach has been in place for a long time until June 2006 when the government adopted the utilisation of private sector contractor's services. This approach involves a number of procedures like; road inventory, road condition survey, road prioritisation, road maintenance plan, tender evaluation, contracts time schedules, measurement of works and certification and work and financial progress reporting. The approach has a number of components in it and requires good management practices in order to achieve good results. For example, there is the need of assessing quantities for preparing tender documents and developing tender evaluation criteria. Maintenance of unpaved roads in Kenya is managed by district roads engineers. The roles of the engineers are to maintain roads database in the district, plan, implement and report maintenance works among other duties.

There are existing management systems elsewhere in the world; but each country requires a system that is customised to its maintenance requirements since conditions of each country are different. Procurement procedures, for example, in Kenya are different from those in the U.K which affects tendering management process.

There has been no comprehensive computerised management system that has been designed to suit the Kenyan conditions despite some attempts by the ministry of roads and the Kenya Roads Board to develop one (Robison, 2005).

There is need of developing a comprehensive computerised road maintenance management system in order to achieve better maintenance results.

1.2 Problem Statement

Inefficiency, poor road maintenance management methods, corruption among other reasons are attributed to the poor conditions of roads in Kenya (Robinson, 2005). This is illustrated by the many corruption studies conducted in the past which have shown the Ministry of Roads as one of the corrupt government institutions (TI, 2006). Poor road maintenance management methods largely promote these vices, for example, a maintenance management system which is not efficient is bound to allow weak areas for corruption to flourish like during the tendering process. Other areas such as prioritisation of roads for maintenance is usually abused by politicians and other interest groups at the expense of the common man. The funds allocated for unpaved road maintenance may not be enough for maintaining all roads but if well utilised can improve the conditions of

roads every year and with time many roads will be covered. Ways of improving management of these maintenance funds need to be addressed. There have been attempts to introduce changes in the past to improve management but challenges always emerge.

In the early 70's and 80's the government utilised force account (in house) road maintenance approach through the Rural Access Roads (RAR) and Minor Roads Programmes (MRP). Later road maintenance services for unpaved roads were procured through the Local Service Orders where contractors were instructed to maintain roads without contract documents detailing specifications (Robinson, 2005). Both these approaches were inefficient since they lacked competiveness and motivation. In 2006 the more motivating contracts maintenance approach was introduced where small scale contractors are required to enter into contracts with the government with more enhanced contract requirements as opposed to the earlier approaches. This approach, however, presents many management challenges to the regional road maintenance engineers such as keeping a databank of road inventory and condition survey, prioritising roads for maintenance, tendering, monitoring contracts schedules, measuring and reporting physical and financial progress of contracted road works which were not part of the earlier approaches (Robinson, 2005).

For the public to get value for their maintenance funds, the maintenance engineers, as managers of these funds, have to employ efficient maintenance management systems which do not compromise quality and efficiency. This calls for careful planning, implementation and accounting for all maintenance activities since without an efficient

maintenance management system, this approach is bound to fail like the other approaches.

Infrastructure is listed as one of the key pillars that will stimulate growth and achievement of the vision 2030 with ways of improving efficiency and effectiveness of infrastructure at all levels of planning, contracting and constructing identified as one of the targets in the vision. Roads alone contribute 80% of the total infrastructure in Kenya and therefore to achieve this vision on development, ways of improving efficiency have to be employed especially in the rural areas in order to open routes to markets. Hence the need to utilise good road maintenance practises that improve management efficiency.

Currently there isn't an efficient computerised road maintenance management system for use by the regional road engineers (Robinson, 2005). It is against this background that a computerised road maintenance management system for unpaved roads is developed to address the shortcomings of the current practise.

1.3 Study Objectives

1.3.1 Overall Objective

The broad objective of the study was to develop a computerised road maintenance management system for unpaved roads in Kenya with a view of standardising maintenance management practises and increasing efficiency.

1.3.2 Specific Objectives

The specific objectives of the study were to:

1. Study the current unpaved road maintenance and management practise in Kenya and identify problems/shortcomings faced.
2. Develop a model for unpaved road maintenance and management in Kenya.
3. Develop and validate a computerised unpaved road maintenance and management system based on the developed model.

1.4 Scope and Limitation of the Study

The focus of this study was on unpaved roads in Kenya and it involved thirty district roads engineers drawn from all the provinces of Kenya except Nairobi. During validation of the road maintenance management system, tests were done to check its functionality. The limitations encountered include poorly kept records in the district roads engineers' office and reluctance to fully cooperate in some instances.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Road maintenance need not be a heavy burden on a nation and economy, when considering the costs and benefits involved. The fact is that spending too little on road maintenance is a greater burden on an economy. Unless a nation has too many roads, or roads of the wrong type, proper road maintenance gives an enormous overall saving to a nation. Technical publications often cite the statistics that for every additional $1 a developing country spends on road maintenance, road users save $3 (Heggie, 1996). Thus, the compelling argument for proper road maintenance is the benefit to users, and thus to the economy.

Fortunately the importance of addressing road maintenance properly is now well understood and is illustrated by the consequence of neglect. For example, the World Bank estimated that of the 85 countries receiving their assistance for roads, the cost of reconstruction has been between three and four times the cost of the preventative maintenance that should have been undertaken earlier (Harral, 1988). The effect on road users is also significant, with vehicle operating costs increasing by similar or greater amounts.

Road maintenance entails varied operations and to achieve better results, good management practises have to be employed. Planning of works is very important. It is worthless to spent more resources in poorly planned work than to use less resources in the planning stage and come up with good plans that will ensure proper expenditure of resources (Kjell, 2003). In fact unplanned or poorly planned road maintenance ends up being more expensive than well planned and executed maintenance. Suitable data storage methods are necessary for reference purposes. This ensures speedy retrieval of information whenever needed. Decision support tools are also essential. Knowing what to do and when to do it is important (Toole, 2000). A computer supported system in road maintenance increases efficiency by reducing the time required to carry out some operations as well as minimising errors.

2.2 Road Maintenance Management Experience from other Countries

The World Bank through its studies has found out that each country needs a road maintenance management system that is unique to its conditions. This is so because the roads sector policies are different in each country (Hoban, 1994). The maintenance approaches, procurement and management methods are also different in each country. The experiences from Ghana, Ethiopia and Tanzania in road maintenance management are discussed below.

2.2.1 Ghana

Road works in Ghana is managed by the Ministry of Roads and Transport through the Ghana Highway Authority (GHA) which has transformed road maintenance over the

years from a predominantly force account (in house) approach to at least 90% execution of works by contracting. A Road Maintenance Project financed both by GHA and Gesellschaft für Technische Zusammenarbeit (GTZ) is currently developing a computerised Road Maintenance Management System (RMS) which seeks to provide tools for effectively and efficiently managing road maintenance in Ghana. This system is expected to cover planning, budgeting and work execution components. Under planning and budgeting component, road inventory, road condition survey and data storage system will be covered; under work execution component, maintenance activities, performance standards and work supervision will be considered (GHA, 2007).

This system is expected to increase efficiency by reducing the paperwork and time required to manage road maintenance works by Ghana Highways Authority. This system is being customised to Ghana road sector policies.

The transition from the force account to contracting out works is similar to the changes in Kenya. Similarly there is need for Kenya to transform from using manual management methods to the use of computerised management systems in road maintenance.

2.2.2 Ethiopia

The road transport system in Ethiopia comprises about 36,500 km of roads (87% unpaved) which represents 95% of passenger/freight movements in the country. The

road network has expanded since the establishment of Ethiopian Roads Authority (ERA) in 1951 similar to the three roads authorities in Kenya. The increase arose mainly from expanding the rural road network in the 1970s and 1980s. Since the change of Government in 1992, the road sector policies have had some significant reforms. A roads fund operating under its own board was established to independently manage funds for road maintenance similar to the Kenya Roads Board (KRB). The funds are obtained from a fuel levy and government-designated road user charges and is allocated to all operating agencies to assure a stable flow of funds for road maintenance. In addition the method of operations has changed from the traditional Force Account to contracting out works to contractors (ERA website).

The continued policy and institutional reforms, and the different management systems establishment have resulted in an improved resource allocation and utilization. A Pavement Management System (PMS) and Road Functional Classification and Numbering System (RFCNS) have been developed with the classification of the national road network and the numbering for all of the Federal Road Network completed. The Pavement Management System by ERA covers mainly resource allocation and management of road works. These systems are customised to the needs of Ethiopia (Negede, 2005).

This Ethiopian case shows that with the right policies in the roads sector in a country such as the introduction of more effective implementation bodies such as the roads authorities in Kenya and the utilisation of efficient maintenance management systems, better results can be achieved in the utilisation of resources.

2.2.3 Tanzania

Road works in Tanzania are managed by Tanzania National Roads Agency (TANROADS) and financed under the roads funds board which was formed in the year 2000. TANROADS in 2002 worked with Transport Research Laboratories (TRL) in the development of a road management system under the Department for International Development (DFID) funding. The developed computerised road maintenance system, Road Mentor 4 is used as a network information system that assembles, organises and stores data about road network in the country. The system covers road inventory, paved roads roughness and unpaved roads condition survey (TANROADS, 2003).

Again this system increases efficiency though road maintenance in Tanzania is done through the force account approach which does not pay much attention to other modules of project management like tender evaluation. In the Kenyan case a system has to be developed that considers such areas as tendering since works are contracted to contractors and customised to the Kenyan procurement procedures. The Tanzanian

system like other systems elsewhere has been reviewed several times to accommodate changes in the roads sector policies in that country.

It is evident that countries including Kenya's neighbours are now adopting efficient computerised methods in road maintenance management which are customised to their needs. It is important for Kenya to also develop and utilise an efficient computerised road maintenance management system customised to the Kenyan needs like the new procurement procedures.

2.3 Road maintenance development in Kenya over the years

Rural Roads Access (RAR) programme which was employing labour based methods was introduced in Kenya in 1974 (Mambo, 2005). This programme focused on opening up of rural access roads. Later in 1984 the government alongside development partners initiated the Minor Roads Programme (MRP) as a successor of RAR. MRP concentrated on improving the existing minor roads using the force account approach and at the same time maintaining the RAR roads by applying the lengthmen system.

Roads 2000 programme was initiated in 1992 for maintenance of rural roads as a successor of the earlier programmes. All along the strategy has been to employ 100% force account (in house) method; but in 1997, the government, as part of its road sector reforms, introduced the utilisation of private sector small scale contractors to improve on

management as some risks are transferred to the contractors. Local Purchase Orders (LPO) and Local Service Orders (LSO) were employed in this approach. Local Purchase Orders is where the government buys equipment and material for its own use. For example in the resealing units, the ministry buys materials and the ministry's staff supervise casuals in patching potholes. Local Service Orders is where the government through its staff like District Roads Engineers (DREs) instruct small scale contractors to carry out road works without contract documents with clear specifications. This was done without any proper estimation of quantities. In fact a one page instruction would act as a contract between the government and the contractor (Goss, 2004). Competitive tendering was not carried out and there were no contract documents that would include specifications and drawings. This approach was prone to corruption and inefficiency.

In June 2006 the government, as part of its roads reforms and started procuring maintenance works through competitive tendering and use of specifications with contract documents (MoR&PW, 2006). In this new approach district road engineers were required to carry out proper estimation of quantities and prepare tender documents. They are further required to evaluate tenders, supervise works, measure and prepare payment certificates.

This approach poses some management challenges to the maintenance engineers since there are many tasks that have to be achieved through several stages like preparation of payment certificates which were not part of the earlier approaches. The problem is that

there is no clear efficient system to be followed in carrying out these operations which makes each engineer to devise ways (most of the time manual) of carrying out these tasks. If all the operations are to be done manually then efficiency would be compromised. The need of a computerised road maintenance management system is inevitable.

2.4 Review of existing Road Maintenance Management Systems in Kenya

2.4.1 Road Maintenance 1 (RM1)

This is a Microsoft Excel spread sheet system used by the ministry of roads and public works to estimate maintenance costs (MOR&PW, 2005). It indicates total quantities of each activity but does not show how they are arrived at and the specific chainages of each activity. In this system road inventories, condition surveys, road prioritisation and contract management tools like time, physical work and financial progress reports are not considered.

2.4.2 Road Maintenance Management System by Gath/Netcom

This is a Microsoft Access database management system that was developed in 2004 for use in Nyanza province. This system was designed to take road inventory and condition survey data from the Kenya Road Inventory and Condition Survey system (KRICS) developed by Jorgensen Consultants for the ministry using Global Positioning System (GPS) and Geographic Information System (GIS) facilities.

The system has no facilities to prepare and cost work activities, prioritise interventions, report on work progress and prepare payment certificates as well as reporting on financial progress (Robinson, 2005).

2.4.3 Road Maintenance Management System

This system was developed by the Roads 2000 consultant in Nyanza province. It was designed for preparing of work plans and reporting of work progress from the district level to the ministry's headquarters. This system does not consider road inventory, condition survey, road prioritisation, maintenance plans, tender evaluation, preparation of certificates and reporting on financial progress.

2.4.4 Road Maintenance Management System by Knights – Com

This system was developed using Microsoft Access database for use at the district level. It was designed to report mostly on financial progress based on the force account approach.

The system does not consider road inventory and road condition assessments. Road prioritisation and maintenance plans are not taken into account in this system either (Robinson, 2005).

2.5 Review of road maintenance management and the current practise in Kenya

2.5.1 Road Inventory

Road inventory is a set of information about the basic engineering and traffic characteristics of a road network (TRL, 1995). It defines the key features of each section

of road and indicates the level of traffic use. The content of the inventory should be directly relevant to maintenance management. When it is first drawn up, it should be as simple as possible. The following items should be included:

- Type of surface.
- Cross-section width - carriageway and shoulders
- Traffic volume

As the inventory is built up, information on the following items can be added:

- Structures like pipe culverts, box culverts and bridges
- Junctions location
- Socio-economic features along a road
- Road furniture like road signs, road markings and guard rails.

Data on other factors influencing maintenance needs are important, such as rainfall and runoff, topography and soil conditions. These factors can influence the degree of priority given to various operations when the work programme is prepared. In addition, data about the distribution and engineering properties of soils will be useful in identifying possible sources of maintenance materials.

When recording these data, it is important to include the chainages of various items for quick future reference and should be well stored. In Ghana road inventory captures items like road lengths, surface types, settlements, regions among others (GHA, 2007).

Current practise in Kenya

The Kenya Roads Board in the year 2003 devised a method of carrying out road inventory in the districts. This involves the indication of road names and road lengths (Goss, 2003). It does not consider details of an individual road properties like rainfall, traffic, structures found along a road etc. From this method it is difficult to know road details clearly since all one can know are the road name and length. This method is manual making it difficult to retrieve information which can easily be lost. Without well documented road inventory information, it becomes complicated to plan for maintenance activities.

2.5.2 Road Condition Survey

This is an account of the road state at a particular time. For convenience this is done and updated every year. Different organisations classify road conditions under different classifications for example the united stated army classify unsurfaced roads using the unsurfaced road condition index (URCI) method where conditions are classified as excellent, very good, good, fair, poor and very poor conditions (Haas, 1995). In the developing countries, visual methods are mostly used to survey the conditions of unsurfaced roads. The classifications and ratings of the conditions of roads in whatever organisation have to be standard to achieve uniform survey of road conditions. The road conditions are used as indicators of the extent of maintenance activities required and to prioritise inventions.

Current practise in Kenya

The Kenya Road Board developed a criterion for carrying out condition survey in 2003. A five measurement scale is used to describe the various conditions of a road, as excellent/very good, good, fair, poor and bad conditions (Andreas, 2005). Excellent/very good condition is where a road is maintainable with camber and drainage intact while good condition is where a road is maintainable with camber and drains requiring light maintenance. Fair condition is where a road is maintainable with camber and drainage requiring some reshaping. Poor condition is when a road is passable but un-maintainable, with no camber and thus requiring reinstatement. Bad condition is when a road is impassable therefore requiring reconstruction. An interval is chosen, say, every 200 m and an applicable scale assigned to each section then summed up and averaged to find the average deterioration rate of the whole road. The maintenance engineers have always found it difficult to carry out these condition surveys but KRB is working towards making condition surveys a precondition to funding (KRB, 2008).

2.5.3 Road Prioritisation

The purpose of prioritisation exercise is to vet and rank potential roads in a programme area based on predetermined common set of criteria. The criteria used in ranking roads generally reflect physical condition of a road, scope of investment and socio-economic impact of the investment to be made. The selection and prioritisation procedure for road investment on low volume roads should follow a simplified guideline. Criteria used in the selection of roads should be by-and–large dependent on readily available information

like road condition, population etc, or data which can be collected without much difficulty. Each selection criterion should be given numerical value and weight for ease of comparing various evaluation parameters (Road Note 1, 2003). There are various approaches used for prioritising roads in various countries; for example, in Ghana, it is done by considering technical factors and the community inputs while in India technical and social factors are considered. (Hoban, 1994).

Current practise in Kenya

In most of the districts, roads are selected for maintenance without regard to particular technical or socio-economic criteria or even according to their condition. Political or other interests influence the selection of roads for maintenance (Robinson, 2005).

2.5.4 Road Maintenance Plan

From the maintenance ranking and with availability of funds, roads are earmarked for maintenance. The maintenance engineer and his staff do inspections in the field to determine what needs to be done depending on the conditions of the roads and availability of funds. A list of maintenance activities and their locations are then identified with their estimated quantities measured and the estimated cost of execution determined using market rates. This is done to avoid variations during the implementation of maintenance works (Robinson, 2005).

Current practise in Kenya

Estimation of quantities for maintenance is done by using the Road Maintenance Form 1 (RM1). This method is not accurate since quantities are approximated in broader terms

without clear details. For example estimation of quantities on grading is done per kilometre without details on the width of the road to be graded and specific chainages are not indicated on bush clearing (Goss, 2003). This leads to errors in estimation of quantities and location of activities which increases the chances of variation orders when the works start.

2.5.5 Tender Evaluation

Tender evaluations largely depend on the procurement regulations of a country or organisation. These procedures have to be standard with clear criteria set to promote openness and reduce corruption. Where it is possible computerised systems can be used for evaluation of bids in order to avoid any possible manipulation.

Current practise in Kenya

The maintenance engineers usually invite contractors to tender and a pre-tender site visit is organised for all the invited contractors and each contractor returns his bid on a set date after which bids are opened in front of all of them and evaluation of bids is done thereafter. There is no particular standard criterion followed when evaluating bids. The lowest bid financially, is normally considered for award without necessarily analysing the contractor's responsiveness to instructions to tenderers and technical ability. This often leads to award of contracts to undeserving contractors who underperform (Robinson, 2005).

2.5.6 Contract management

This involves contracts schedules and time progress, monitoring of physical work progress, measurement and payment of works and reporting on financial progress. Important contract schedules like dates of contracts award, commencement of work, start of defects periods and end of contracts need to be recorded. These schedules help a maintenance engineer to monitor the time progress of contracts. Reports on physical work progress are very important in managing contracts. This enables an engineer to know which contracts are lagging behind in terms of physical work so as to find reasons and possible measures for improvement. Financial progress is also important aspect of contract management since it can be used by an engineer to monitor how finance is used in a contract. In order to manage a contract efficiently, a good management system has to be used.

Current practise in Kenya

2.5.6.1 Contracts schedule

From tendering up to the end of contracts a lot of scheduling is done such as the dates of tendering, evaluation, contract periods, defects liability periods etc. Currently there is no particular criteria followed in recording and monitoring contracts schedules in the districts, every engineer follows his/her own method if any (Robinson, 2005).

2.5.6.2 Physical Work Progress Reports

There is some work progress reporting formats that are used by the District Roads Engineers to report to Kenya Roads Board at the end of the financial year. This format

gives a generalised summary of work progress over the financial year. The format cannot be used to monitor physical work progress of each contract since it was designed for reporting to KRB on general overall road contracts progress (Goss, 2004). Through this method efficiency of closely monitoring physical work progress of contracts is compromised. As a way of increasing management efficiency, a standard detailed physical work progress reporting format that captures details of each contract should be developed and if possible it should have a provision of transferring information electronically to the ministry's headquarters and Kenya Roads Board.

2.5.6.3 Financial Progress Reports

In the private contractors' maintenance approach, contractors are supposed to be paid for what has been properly done and measured through payment certificates. Currently there is no clear standard system of measurement of work done and payment (Robinson, 2005). Different District Roads Engineers use different methods to pay and monitor financial progress of contracts. Some District Road Engineers would for example combine all activities and summarise them in one page as the payment certificate without any specific details like chainages and dimensions of graded area in a given road as they used to do under the Local Service Order method (Robinson, 2005). This leads to errors where a contractor would be paid more or less than what he did. A standard measurement and payment format should be developed for use. This format can be computerised so that once measured quantities from the field are entered in the system,

the payment certificate is automatically generated. This will beside minimising errors, reduce the time required to prepare payment certificates hence increasing efficiency.

2.6 Summary of Literature Review

The literature reviewed can be summarised as:

- Countries are now moving from the traditional manual methods of managing road maintenance to modern methods such as the use of technology to improve efficiency.
- There have been several changes in the road maintenance approaches from force account to utilisation of private contractors which presents management challenges.
- In the past, there have been attempts to develop road maintenance management systems but there has been no successful attempt.
- There are several challenges being experienced from the current road maintenance management practise such as, inefficiency of the maintenance management system, openness to corruption and maintenance operations not being practised in a standard way in all the districts.

This research has made a milestone in a successful attempt to develop a proposed computerised road maintenance management system for unpaved roads in Kenya.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this chapter the methods used to establish the current unpaved road maintenance practise in Kenya and their weaknesses are described. In it, a description of the population, sampling size, sampling procedures, data collection tools and data collection procedures are given. Finally the method used to develop and model the computerised system is briefly described.

3.2 Establishing the current unpaved road maintenance and management practise and their weaknesses in Kenya

In order to understand the current unpaved road maintenance and management practise in Kenya the methods used included questionnaires and secondary literature.

3.2.1 Population Distribution and Sampling

The data required during the study of the current road maintenance practices was gathered from the district roads engineers (DREs). There were 149 districts in Kenya at the time this study was carried out. This means that there were 149 district roads engineers. The distribution of the districts by province is as shown in Table 3.1.

Table 3.2.1.1: Districts Distribution in Kenya

Province	No. of Districts
Rift Valley	43
Central	11
Eastern	28
Nyanza	21
Western	19
Coast	13
North Eastern	11
Nairobi	3
Total	**149**

This study only focused on rural roads and the 3 districts in Nairobi were not included in the study. This means the accessible population of the study was made up of 146 DREs.

A sample size of 30 DREs was used in the study. According to Oates (2005) a minimum sample size of 30 is acceptable in a survey. Stratified and proportionate representation sampling method was used to draw samples from the provinces. This was chosen because it provides equal or better precision than a simple random sampling, the sample size of each stratum is proportionate to the population size of the stratum and is cheaper. Table 3.2.1.2 shows the distribution of the sample size by province.

Table 3.2.1.2: Samples Distribution per Province

Province	Frequency (Districts)
Rift Valley	9
Central	2
Eastern	6
Nyanza	4
Western	4
Coast	3
North Eastern	2
Total	**30**

3.2.2 Data collection

Questionnaires were sent to DREs to elicit data on current practise. The questionnaire had two sections. The first section was on the respondents characteristics. The second part was for capturing data on road inventory, road condition survey, road prioritisation, road maintenance plan, contracts time schedules and progress, tender evaluation, measurements and certification, work and financial progress reporting. The questionnaire used is shown in appendix 2.

3.2.3 Data analysis

The data collected using the questionnaires were coded and entered into a computer and analysed using software package for statistics and simulation (SPSS) software. The analysed data were summarised, described and then presented in the form of frequency and percentages. The output revealed weaknesses as detailed in sections 4.2.1 to 4.2.9 that led to development of a computerised Road Maintenance Management System.

3.3 Current road maintenance practise

Information about the current road practises in the districts was captured using the DRE questionnaire. The questionnaire elicited data in the following areas; road inventory and condition survey, road prioritisation, road maintenance plan, tender evaluation, contracts schedules, work measurement and certification, work and financial progress reporting. The findings are given under the sections 4.2.1 to 4.2.9.

3.4 Method used in Designing and Developing the proposed computerised Road Maintenance Management System (RMMS) for unpaved roads in Kenya

With the knowledge and the understanding of the current maintenance practise of unpaved roads in Kenya from the analysed data collected from the questionnaires, a road maintenance management model was developed with modules as shown in Figure 3.4. which form a complete road maintenance management cycle.

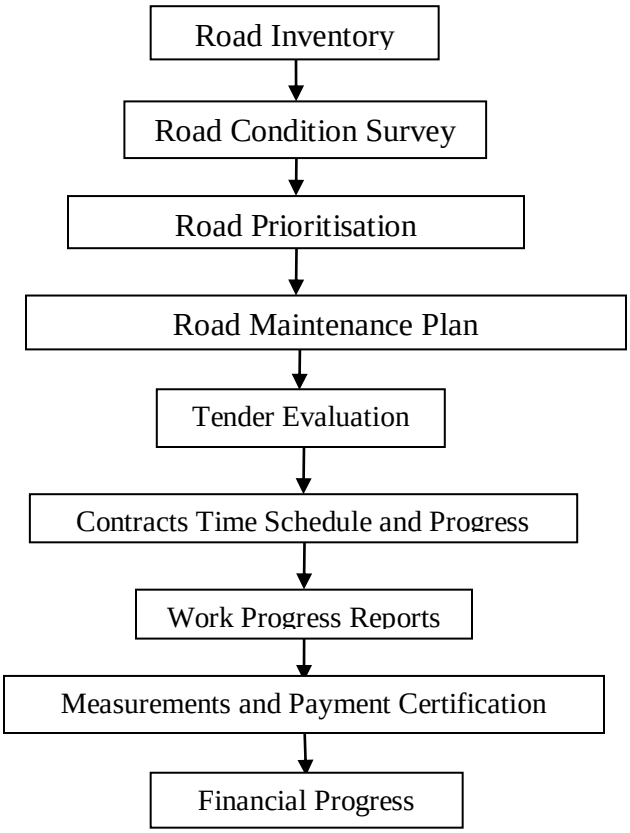


Figure 3.4: Modules Sequence Flow Chart

For each of the modules, a criterion was designed in Microsoft Excel that overcomes the challenges currently faced as found out during the study. From the developed criteria, flowchart diagrams were designed for each module and data flow diagrams modelled.

Databases were then developed for each module using Microsoft Sequence Query Language 2000 (MS SQL 2000) server. This was chosen because:

- It has powerful data handling and processing capabilities making it an overall lead in developing an application that has high data requirements.
- It is easier and faster to build a database since it is readily structured.

The interface design was developed using Visual Basic software. This was chosen because;

- It is a visual-oriented language; it aids user training, learning and support hence raising user acceptability of the system.
- It is enhanced with graphical components thus enhancing the design of a user friendly interface.
- It has the facility to create highly complex yet easy to use interfaces.

Finally Crystal Reports software was chosen for report generation and presentation. This was chosen because it can analyse data and produce summarised reports.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Introduction

In this chapter, the analysed results from the questionnaires are presented in frequency and percentage tables. These results are further discussed with a view of understanding how unpaved road maintenance management is practised currently in Kenya. Finally a summary of the findings is given.

4.2 Current road maintenance management practise findings

The results from the questionnaires were analysed in frequency and percentage tables and discussed in sections 4.2.1 to 4.2. 9. This gave a deeper understanding of the current unpaved road maintenance management practise in Kenya.

4.2.1 Road Inventory and Condition Survey

Table 4.2.1.1 shows distribution of DREs carrying out road inventory and condition survey. 57% of the respondents indicated that they do not carry out road inventory and condition survey in their districts while 43% carry out road inventory on annual basis. Reasons advanced for not carrying out these surveys include; a lot of time is required to carry out the inventory and condition survey, it involves lots of paperwork, poor KRB methods/forms of carrying out the survey, lack of sufficient funding, lack of adequate personnel and transport. Of interest in this study is the time required for the exercise, involvement of lots of paperwork and poor methods/forms from KRB.

Table 4.2.1.1: Road inventory and condition survey frequency

How often do you carry out road inventory and condition survey in your district?		
	Frequency	Percent (%)
Not done	16	57
Annually	12	43
Total	28	100.0

Table 4.2.1.2 shows the findings of what methods the DREs use while carrying out road inventory and condition survey. The forms for carrying out road inventory and condition survey from KRB which 25% of DREs use, need to be improved so that they can be more user friendly and methods of reducing time and paperwork devised. This will encourage the other 18% of DREs who use their own methods to use a standard method and the 57% who do not to carry out road inventory and condition survey in their districts at least on annual basis. If road inventory data are not available a road maintenance engineer will not manage road works well since this information is required for planning. Similarly road condition survey data is required for making maintenance intervention decisions. The importance of these surveys cannot be ignored if maintenance works have to be managed well.

Table 4.2.1.2: Road inventory and condition survey methods used currently

Which methods do you use on road inventory and condition survey?		
	Frequency	Percent (%)
KRB forms	7	25
Use own methods	5	18
Not been carrying out inventory survey	16	57
Total	28	100.0

Table 4.2.1.3 shows what difficulties the DREs faced on road inventory and condition survey. One or more of the following factors; inadequate funding and transport, length of time and amount of paperwork involved were found out to be the most common difficulties in carrying out these surveys. Lack of adequate personnel and inadequate KRB forms were other challenges on this exercise. It is hoped that the recent changes in the Ministry that saw the creation of Kenya Rural Roads Authority (KeRRA) will solve some of these problems like funding, transportation and personnel; but the need of maintenance management system is inevitable to take care of difficulties such as requirement of and the involvement of lots of paperwork during this exercise.

Table 4.2.1.3: Difficulties faced in road inventory and condition survey

What difficulties do you face on road inventory and condition survey?		
	Frequency	Percent (%)
Inadequate Funding	5	18
Inadequate Transport	4	14
Few Personnel	2	7
Inadequate Funding and Transport	2	7
Inadequate Funding and Personnel	2	7
Inadequate Funding, Transport and Personnel	2	7
Takes more time	4	14
Inadequate KRB forms/method	3	11
Involves a lot of paper work	4	14
Total	28	100.0

4.2.2 Road Prioritisation

All the DREs sampled pointed out that the funds allocated for road maintenance annually are not enough to meet all the maintenance demands. This calls for careful methods of road maintenance prioritisation so that only the roads which are

economically and technically viable are considered for maintenance. Unfortunately there is no particular criterion that can be followed by the DREs for prioritisation. There are only guidelines from the ministry and KRB which may not be applied equally by all DREs. It is better to work with a standard criterion which is specific on factors to be considered. This will avoid the practise where each DRE would use his own method considering different factors. It was also found that 48% of DREs tend to use the area Members of Parliament (MPs) influence during prioritisation of roads. This method is subjective; for his own political reasons a member of parliament may influence maintenance of a road which is less deserving. Given that the funds used to maintain roads are funds collected from tax payers, then a more equal approach should be used in prioritising roads for maintenance. There is therefore need to develop a standard criteria for prioritisation of unpaved roads for maintenance.

From the experience of the DREs sampled, the average score for technical factors during prioritisation is 40%, socio-economic factors 40% and stakeholder's priorities 20%. Response of what the DREs think about maintenance funds allocation, existence of prioritisation criteria, what they use and average scores for various prioritisation criteria are given in Tables 4.2.2.1 - 4.2.2.5.

Table 4.2.2.1: Adequacy of road maintenance funds

Are the funds allocated annually for road maintenance enough?		
	Frequency	Percent (%)
No	0	0
Yes	29	100
Total	29	

Table 4.2.2.2: The existence of road maintenance prioritisation criteria

Is there a particular road maintenance prioritisation criterion from the ministry or KRB?		
	Frequency	Percent (%)
Yes	0	0
No	29	100
Total	29	100

Table 4.2.2.3: Road maintenance prioritisation criteria used

What road prioritization criteria do you use before embarking on the maintenance exercise?		
	Frequency	Percent (%)
Own criteria	9	31
KRB guidelines	2	7
Ministry guidelines	4	14
MP's influence	14	48
Total	28	100

Table 4.2.2.4: Grading of road prioritisation factors

As an engineer how would you grade (award marks) to the following factors in prioritization of roads for maintenance	
Factor	Average Score (%)
Technical factors	40
Socio-economic factors	40
All stakeholders priorities	20

Table 4.2.2.5: Frequency of road prioritisation factors usage

How frequent do you use these factors during road prioritization exercise?					
Factor	Not used (%)	Occasionally (%)	Frequently (%)	More frequently (%)	Total (%)
Technical factors	38	31	24	7	100
Socio-economic factors	40	29	22	9	100
All stakeholders priorities	44	24	20	12	100
MP's influence	8	23	42	27	100

4.2.3 Road Maintenance plan

66% of the sampled DREs indicated that they use their own methods when carrying out assessment of quantities for preparation of tender documents. This is because the Ministry's or KRB method is either inadequate for use or it takes more time, involves a lot of paperwork or even inaccurate as found out in section 4.3.1. This confirms the concerns raised by the Kreditanstalt Für Wiederaufbau (KfW) Roads 2000 consultant that the RM1 form used by the ministry is inaccurate and too general (Robinson, 2005). There is need to develop a method that takes less time to use, less paperwork, accurate, user friendly and standard for use countrywide. This will ensure that there is uniformity and efficiency in assessing quantities for preparation of road maintenance tender documents. Good planning of maintenance works helps in reducing variations when work starts. Response of the methods used by the DREs sampled and the difficulties they face are given in Tables 4.2.3.1 and 4.2.3.2.

Table 4.2.3.1: Methods used for assessing quantities for tender documentation

What method do you use when assessing quantities for preparation of tender documents?		
Method	Frequency	Percent (%)
Standard forms from the ministry/KRB	10	34
Own method	19	66
Total	29	100

Table 4.2.3.2: Difficulties faced in assessment of quantities

What difficulties do you experience in assessment of quantities for preparation of tender documents from the method you use?		
	Frequency	Percent (%)
Time consuming	5	17
Involves a lot of paper work	6	21
Inaccurate	4	14
Time consuming & a lot of paper work	4	14
Inaccurate, time consuming & a lot of paperwork	6	21
Inadequate ministry/KRB method/forms	4	14
Total	29	100

4.2.4 Tender Evaluation

It was found out that 62% of the DREs use only financial competitiveness of bidders in evaluation of tenders. The new procurement act requires that before a tender is awarded to any bidder, thorough evaluation must be carried out. For road works this should in include an evaluation of the technical capability of the bidder to carry out the works. It is evident from the study that most DREs experience problems with contractors who have initially won contracts; the problems are ranging from poor quality of works, delays in

execution of works and poor management of works by the contractors. 52% of the sampled DREs say that the reason why they have such problems with contracts is because they were properly technically vetted during evaluation process. In order to have the right contractors working for the public, proper standard evaluation criteria which take care of all the factors have to be developed for use in the districts. The criteria have to be developed in such a way that corruption would be minimised. Tables 4.2.4.1 to 4.2.4.3 shows the views of the sampled DREs on tender evaluation.

Table 4.2.4.1: Factors considered during tender evaluation currently

What factors do you consider when evaluating tenders?		
	Frequency	Percent (%)
Responsiveness to instructions to tenderers & financial competitiveness	2	7
Technical capabilities & financial competitiveness	6	21
Financial competitiveness	18	62
Technical, financial & responsiveness to instructions to tenders	3	10
Total	29	100

Table 4.2.4.2: Problems posed by contractors who have won contracts in the past

What problems do you experience with contractors who have been awarded contracts?		
	Frequency	Percent (%)
Poor quality of works	10	34
Delays in contract execution	8	28
Poor management of works	5	17
Poor quality & delays of works	6	21
Total	29	100

Table 4.2.4.3: Omissions during tender evaluation in the past

What do you think was omitted during the evaluation of bids that resulted in problems during execution of contracts?		
	Frequency	Percent (%)
Responsiveness to instructions to tenderers	5	17
Technical capabilities	15	52
Responsiveness to instruction & technical capabilities	9	31
Total	29	100

4.2.5 Contract Time schedules and Progress

All the sampled DREs pointed out that there is no particular standard criterion from the ministry or KRB for monitoring contracted road works. This leaves the DREs to use their own varied methods, and others (41%) do not take much interest in monitoring schedules of contracts. When contractors are not closely monitored, they may delay implementation of works which will lead to delayed services to the people. From the DREs sampled, those who attempt to keep and monitor time schedules experience some problems like loss or misplacement of information or the method taking too long. A good manager would for example have good system that can be used to schedule activities like, say, opening up drains just before rainy season. Such a system can be prepared in form of software so that the manager would not have to take much time trying to retrieve information or lose it. It is also important to have an efficient standard time monitoring system that can be used countrywide. Tables 4.2.5.1 to 4.2.5.3 give

findings from the sampled DREs on contracts monitoring methods and problems encountered.

Table 4.2.5.1: Availability of contracts time monitoring methods

Is there a particular standard criterion from the ministry/KRB for monitoring time schedules of contracted works?		
	Frequency	Percent (%)
Yes	0	0
No	29	100
Total	29	100

Table 4.2.5.2: Methods of monitoring contracts time schedules

How do you keep and monitor time schedules of contracted maintenance road works?		
	Frequency	Percent (%)
Using forms	11	38
Using computers	2	7
Little effort on time and monitoring schedules	12	41
Using forms and computers	4	14
Total	29	100

Table 4.2.5.3: Problems encountered with contracts time schedule method in use

What are the problems with the time schedule monitoring method you use?		
	Frequency	Percent (%)
Loss of information	10	34
Time consuming	11	38
Loss of information & time consuming	8	28
Total	29	100

4.2.6 Measurement and Certification of Works

All the DREs sampled indicated that there is no particular criterion for measuring and certifying works from the ministry or KRB. The DREs use their own methods which may lead to various difficulties including involvement of a lot of paperwork, requirement of much time, and encountering errors. This is a process that has to be handled carefully so as to avoid errors and make it as efficient as possible. There is need to develop a good system that would reduce the paperwork, errors and time required to prepare payment certificates. The views of the sampled DREs on measurement and certification of works are given in Tables 4.2.6.1 and 4.2.6.2.

Table 4.2.6.1: Availability of standard methods of preparing payment certificates

Is there a particular standard criterion from the ministry/KRB for preparing payment certificates?		
	Frequency	Percent (%)
Yes	0	0
No	29	100
Total	29	100

Table 4.2.6.2: Difficulties of payment certificates preparation

What difficulties do you face with preparation of payment certificates?		
	Frequency	Percent (%)
Time consuming	7	24
Errors encountered sometimes	5	17
Involves a lot of paperwork	7	24
A lot of paperwork & time consuming	4	14
Errors encountered, paperwork & time consuming	6	21
Total	29	100

4.2.7 Physical work and financial progress monitoring

Tables 4.2.7.1 and 4.2.7.2 show the response to what the DREs use and problems they face in monitoring physical work and financial progress. 45% of the DREs sampled said that they use ministry or KRB methods of monitoring physical work and financial progress of contracts. The remaining either use their own methods or do not take keen interest. The DREs who use their own methods do so because the ministry or KRB methods take a lot of time, involves a lot of paperwork or are not adequate/comprehensive. The DREs, as managers of maintenance works in the districts, should closely monitor both physical work and financial progress of contracts in their districts. This will reduce problems like, for example, more work being done by the contractors then they make claims later which would lead to contract sums being exceeded. To avoid these problems, there is need to develop a standard effective system for monitoring physical work and financial progress of contracts.

Table 4.2.7.1: Methods of monitoring physical and financial progress of works used currently

How do you monitor and report on the physical work and financial progress of road contracts?		
	Frequency	Percent (%)
Using standard forms from the ministry	13	45
Using own forms	11	38
None	5	17
Total	29	100

Table 4.2.7.2: Difficulties faced from methods used during reporting

What difficulties do you experience with in the mode of monitoring and reporting physical work and financial progress you use?		
	Frequency	Percent (%)
Takes more time	7	29
Contract sums are exceeded sometimes	6	25
Leads to more work done sometimes	5	21
Inadequate documentation from KRB/ministry	6	25
Total	24	100

Tables 4.2.8 and 4.2.9 show the views of the DREs on the effectiveness of the current road maintenance management system and their thoughts on how to improve it. 55% of the respondents feel that the current maintenance management system used in the districts is ineffective while 14% are not sure and only 31% think it is effective. Certainly it is clear that the current road maintenance management system has to be improved to make it more efficient and user friendly. To improve the current system, the DREs think that standard criteria and computerised systems should be used among other measures. This confirms the concerns raised during the roads 2000 national steering committee that an efficient comprehensive road maintenance management system is needed for management of road works (KRB, 2007). This will help the government in delivering goods and services to the people and will go in line the government's 2030 vision. Improved infrastructure is listed as one of the goals of the vision's targets.

Table 4.2.8: Effectiveness of the road maintenance management system used currently

In your view how effective is the road maintenance management system being used in the districts		
	Frequency	Percent (%)
Effective	9	31
Not sure	4	14
Ineffective	16	55
Total	29	100

Table 4.2.9: The Improvements needed on road maintenance management

In your opinion what should be done to improve road maintenance management in the districts?		
	Frequency	Percent (%)
Use of std methods/criteria	6	21
Use of computerized systems	7	24
More funds	8	28
Improve human resource	3	10
Use standard methods/criteria & more funding	5	17
Total	29	100

4.3 Summary of weaknesses in the current practise and recommendation

The main weaknesses in the current road maintenance management practise as found out during the study can be summarised as the practise;

- Takes more time
- Involves a lot of paperwork
- Involves many personnel
- Prone to corruption

- Not standard in maintenance operations
- Not efficient

It was therefore recommended that a computerised road maintenance management system be developed as a solution to the problems and weaknesses encountered in the current road maintenance management system.

CHAPTER FIVE

SYSTEM DEVELOPMENT AND VALIDATION

5.1 Introduction

Following the recommendation given in chapter four section 4.3, a computerised road maintenance management system was developed as described in this chapter. First the design of each system module is described and the development of the system and it's validation with collected data is discussed. The system performance and results of the validation tests are also presented. Finally the developed system performance is compared with other systems and its benefits discussed.

5.2 Modules Design

Based on the understanding of the current challenges faced and the recommendation given in section 4.3 templates or forms for each module were designed in Microsoft excel. Design of each module is described in sections 5.2.1.1 to 5.2.1.8.

5.2.1 Modules Design description

5.2.1.1 Road Inventory

A two part criteria was designed for road inventory. The first part was used to capture the general details of a road such as district of location, constituency of location, road name and number, length, start and end chainages, traffic flow, average annual rainfall, principal subsoil type, transverse gradient and surfacing type. These details give the

general overview of a road. The second part was used to capture the summary of major structures found along a road like culverts, major socio-economic features and road signs along a road.

Road inventory sample data collection forms are shown in appendix 1.1.1 and 1.1.2.

5.2.1.2 Road Condition

A criterion was developed that was used to assess the conditions of a road at a given time. For standardisation purposes the assessment scale developed by KRB was used. This assessment method is in five scales of excellent/very good, good, fair, poor and bad conditions. The good condition for example is when a road is considered to be maintainable with the road camber and side drains requiring some light maintenance. Poor condition is when a road is un-maintainable with no camber therefore requiring reinstatement. Details of these scales are given in appendix 1-2b. By applying this method, a road is assessed after every 200m and its condition scale indicated. At the end, the various condition rates are summed and averaged together to get an overall deterioration rate for a given road. The overall rate is in the region of 1 to 5. The higher the rate, the worse the road condition is and the more attention it requires. The condition rates are compared for different roads in the next stage of road prioritisation to help decide which roads need maintenance. A sample of road condition form is shown in appendix 1.2.1.

5.2.1.3 Road Prioritisation

A Criterion for road prioritisation was developed which considers technical and socio-economic factors and stakeholders priorities. The technical factors considered included average traffic flow, average deterioration level, deterioration rate and constraints to flow of traffic. Socio-economic factors include cost and benefit of intervention, economic potential of area served, centres & population served and poverty index of the area. Some of the data were primary and others like population served by a road were secondary. The stakeholders in the study area were issued with questionnaires to fill in their priorities of roads to be maintained. This is considered to promote the road maintenance ownership in the communities.

To avoid any biasness from the stakeholders, the researcher scored in each category of the technical and socio-economic factors. Technical factors contributed 40%, socio-economic factors 40% and stakeholders' priority 20% giving a total of 100% for each road (these percentages for each factor were deduced from the questionnaires). After arriving at the total marks for each road, all the roads' scores were compared and ranked to come up with a maintenance priority list. This ranking was used as a maintenance decision making tool. Samples of the road prioritisation forms are shown in appendix 1.3.1 and 1.3.2.

5.2.1.4 Road Maintenance and Improvement Plan

A standard road maintenance and improvement plan was designed that was used to capture quantities of all various activities like bush clearing, earthworks, drainage works, shaping, gravelling etc. This was used to record maintenance and improvement needs assessment on each of the prioritised roads. Quantities of each proposed activity were indicated against its chainage. The quantities of each activity were summed up and transferred to a bill of quantities table. Appropriate rates derived from the averages of each activity under the Roads 2000 were used to multiply with the respective quantities to arrive at estimated costs for each activity and hence the total engineer's maintenance estimate. This estimated cost was used for planning purposes. Samples of road maintenance forms are shown in appendix 1.4.1 and 1.4.2.

5.2.1.5 Tender Evaluation

A standard tender evaluation criterion was developed. This was considered in three stages of; responsiveness, technical capabilities and financial competiveness. Stage one on determination of contractor's responsiveness to instructions to tenders is in two parts. Part (a) is about the consideration of mandatory requirements like filling and signing of form of tender in the tender document. Contractors who pass all the requirements of this part proceed to part (b) on other non mandatory requirements like declaration by a contractor, and then marks are awarded to each contractor. Contractors with more than say 50% marks at part (b) proceed to the next stage.

Stage two is on technical abilities of contractors. Several factors like experience in similar works done previously, experience of key personnel to be engaged, etc, were considered and marks awarded to each contractor. Contractors with more than say 70% are allowed to proceed to the next stage. Stage three was on comparison of contractor's rates to determine the lowest bidder. Having considered responsiveness of contractors and their technical capabilities and eliminated those who do not qualify, the lowest bidder financially at stage three was then recommended for award. All this process was automated to avoid any undue external influence. Samples of tender evaluation forms are shown in appendix 1.5.1, 1.5.2 and 1.5.3.

5.2.1.6 Contract Time Schedules and Progress

A standard format of recording various contract schedules such as tendering dates, commencement of works dates etc, was designed. This format was used to monitor time progress of contracts to know for instance what percentage of time is left before the end of a contract. A sample of contract time schedule and progress form is shown in appendix 1.7.

5.2.1.7 Measurements and payment certification

A criterion was developed for preparing payment certificates. This criterion has sections of inputting quantities for the planned works, rates and the measured quantities from the field for each activity. The next section was used to prepare a summary of quantities of each item like say site clearance then another one for capturing summaries of all items.

Finally the criterion had a payment summary that showed all the previous payments made, the current payments and the totals. This section showed the total work done, value added tax deductions and money for retention where applicable. The amount due to the contractor after all deduction was reflected at the end. Samples of measurements and certification forms are shown in appendix 1.8.1, 1.8.2 and 1.8.3.

5.2.1.8 Work Progress Reporting

A work progress reporting format was designed to capture physical work progress of each activity. For each contract, quantities from the maintenance plan were indicated as planned works and done works reported. The done quantities of works were expressed as a percentage of the planned works to know progress made. There was also a column for indicating any remarks like reasons for work delay. A sample of work progress form is shown in appendix 1.9.

5.2.1.9 Financial progress

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 total amounts of work done, value added taxes (VAT) and retentions funds were summed up for all certificates. This total amount was expressed as a percentage of the contract sum so as to check on the financial progress of a contract. A sample of financial progress form is shown in appendix 1.10.

5.2.2 Flowchart Diagrams

Based on the designed data forms, flowchart diagrams were designed for each of the modules and tender evaluation module is used to illustrate this in figure 5.2.2.

The process starts when the user keys in the bidder's data like say bidders code, road name, road number etc and mandatory requirements such as signature on tender form, qualification information, and confidential business questionnaire. The system then checks whether the bidder meets this criteria and eliminates those who do not meet (using the 'No' path) and only allows those that meet to proceed through the 'yes' path. The user enters responsiveness data for the bidder such as provision of key personnel curriculum vitaes and the system proceeds to check whether the bidder meet the threshold set and eliminates those that do not meet.

After this stage the user enters the technical ability data of the bidder and the system checks whether the bidder meets the minimum percentage of marks set out by the tender committee at this stage and eliminate those who do not qualify. For each bidder that qualifies after the technical ability stage, the user enters the rates of each activity and the system stores all the data and proceeds to check for another bidder to repeat all the process. After the stores the data for all the bidders, it then automatically ranks the bidders from the lowest financially having met all the other requirements and generates a tender evaluation report for the tender committee without any external influence.

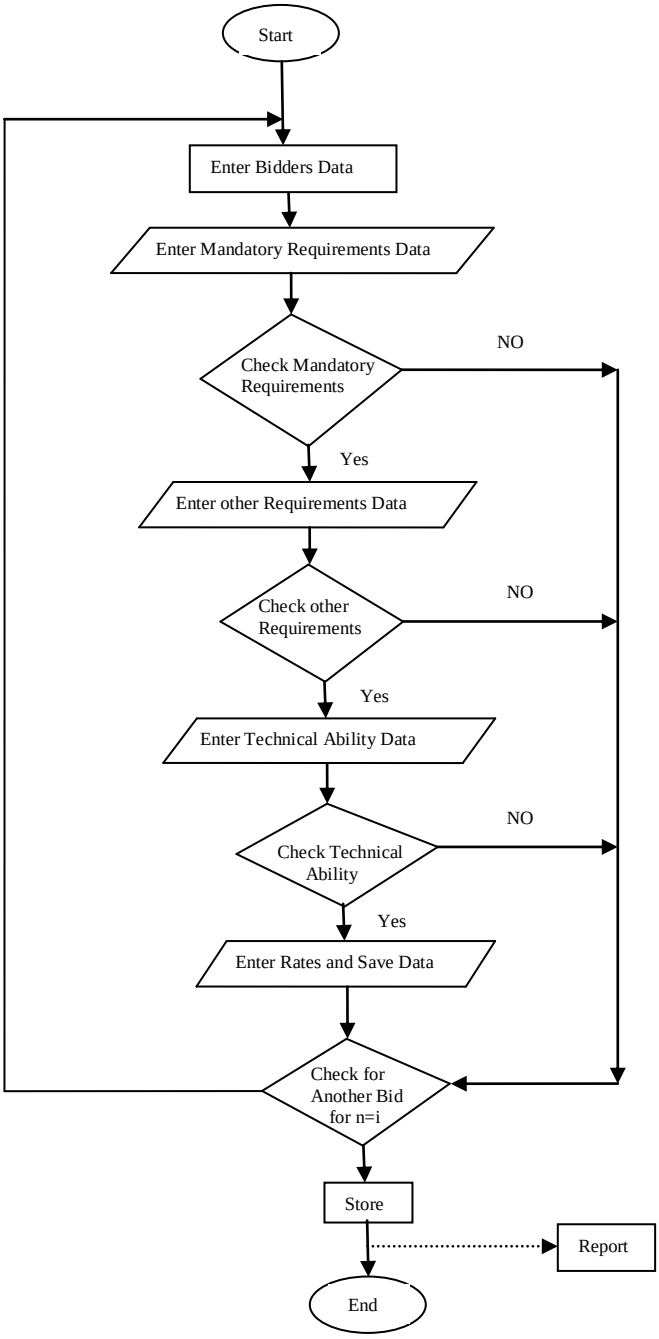


Figure 5.2.2: Tender Evaluation Flowchart Diagram

5.2.3 Data Flow Diagram (DFD)

A DFD is a modelling tool that allows analysts to picture a system as a network of functional processes connected to one another by flows and data stores. They illustrate how data (inputs) are processed by the system into information (output). Only the first level of DFD was used in this study. It shows how the various modules are linked together. Level 2 data flow diagram shows how data is linked up within a module.

Terms used in the data flow diagrams

Process

Process is that part of the system that transforms inputs into outputs and is illustrated in Figure 5.2.3.1.

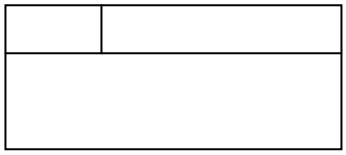


Figure 5.2.3.1: Process representation

Flow Line (Data Flow)

This is represented by an arrow into and out of a process. It is used to describe the movement of packets of information from one part of the system to another. Figure 5.2.3.2 shows this representation.

Figure 5.2.3.2: Flow line representation

Data Store

This is a database or where data is stored.

Figure 5.2.3.3: Data store illustration

Entities

These are external entities with which the system communicates. They are the sources and destinations for the system's inputs and outputs for example, in figure 5.2.3.5, the contractor information is entered in the system as the input and the engineer generates reports as the output.

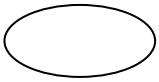


Figure 5.2.3.4: Entity illustration

Level 1 data flow diagram is illustrated in figure 5.2.3.5.

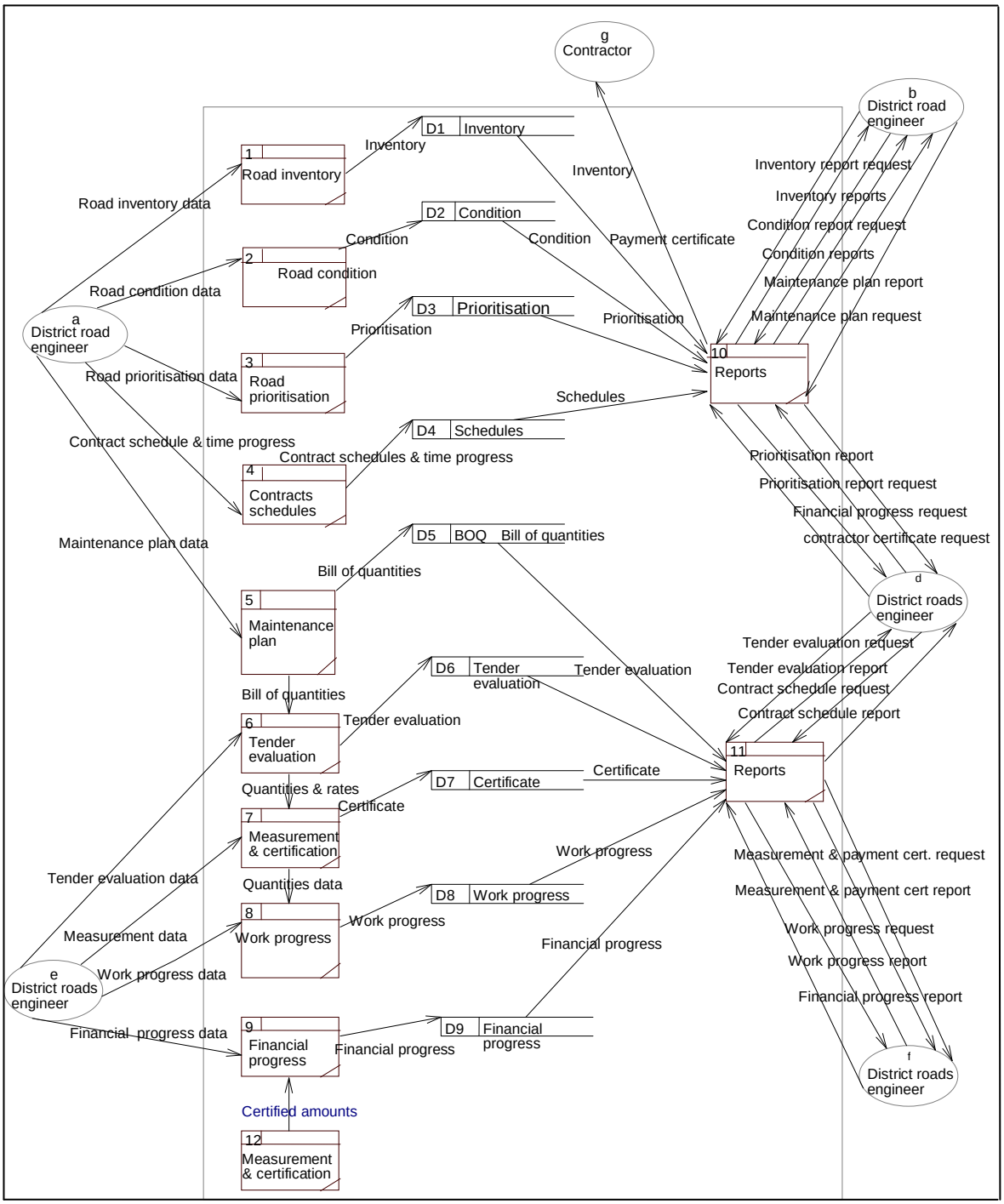


Figure 5.2.3.5: Level 1 Data Flow Diagram

The flow of information in the DFD starts when the DRE feeds road inventory data into the system. This data is processed by the road inventory module and the results stored in the data store D1. The road inventory report is produced by the system upon request from the DRE. The same is repeated for other modules.

5.2.4 Database design

5.2.4.1 Database Division

The database has been segmented into:

Parameters Tables: This is data that is repeatedly entered which contains similar parameters. Same maintenance plan activities can be applied to multiple maintenance plans. Hence these activities are parameterized. This makes the system user friendly and time saving.

Data tables: This saves data details entered when carrying out a particular activity. They model document files and cabinets used for storing data. They were structured according to how data is entered in a manual system to enable easier retrieval.

Example of database development is illustrated in figure 5.2.4.1.

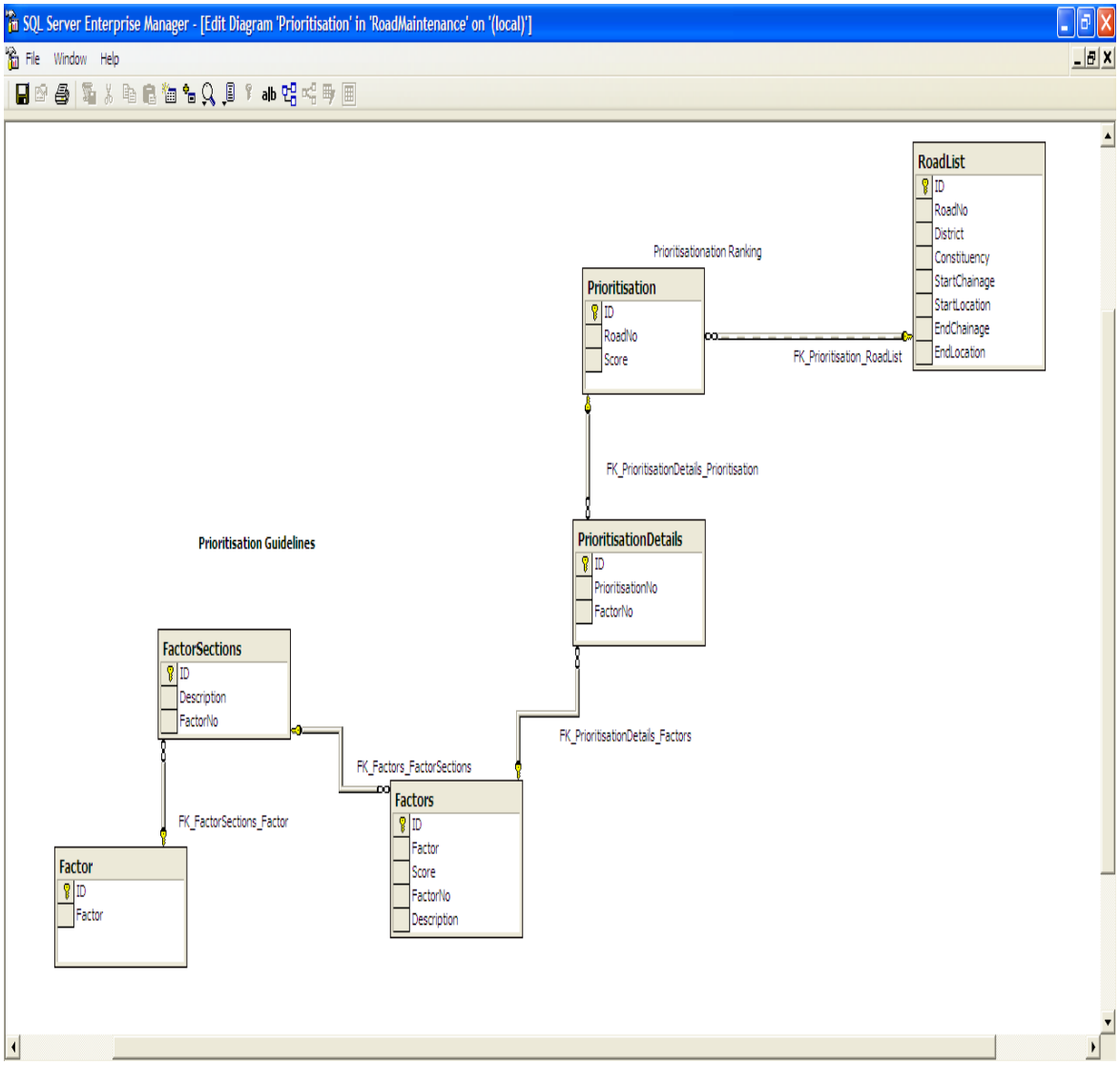


Figure 5.2.4.1: Road prioritisation database

The home page of the system is as shown in Figure 5.2.4.2.

Figure 5.2.4.2: System home page

5.2.5 System-User Dialogue

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

1. The user switches on the computer and selects RMMS.
2. System prompts the user to log in.
3. User enters the password to log in.
4. System displays the functional menu.
5. User selects menu of choice.
6. System displays data entry sheet.
7. User enters data and saves.

8. User repeats steps 5 to 7 for all required modules.
9. User selects report menu, required report and filters information.
10. System generates the required report.

5.3 Road Maintenance Management System Validation

Data collected from a sample of five roads in Rongai constituency of Nakuru district were used for validating the first four modules of the system. On road inventory and condition survey, data were collected by driving through the roads and stopping at appropriate chainages to collect the required information such as details of structures along a road. Some of the data for road prioritisation were collected from the roads while other data such as population served were collected from government agencies. Data for maintenance plans were collected by driving along the roads and identifying proposed maintenance activities. Existing contracts data for past contract was used to test the other modules of the system; tender evaluation, contract time schedules and progress, work progress reporting, measurement and certification and financial progress. The collected data were entered in the system modules and are illustrated in sections 5.3.1 to 5.3.10.

5.3.1 System Setup

General system data were entered in the setup menu; the data includes district names, constituency names in a district, prioritisation guidelines and general parameters. The prioritisation technical, socio-economic and stakeholders factors and their scores were entered in the system setup and saved for use under the prioritisation module. General

parameters such as common structures found along a road like cross culverts, common socio-economic features along a road such as subsistence farming and common road furniture like warning signs were also entered in the setup. The system setup menu in the system is shown in Figure 5.3.1.

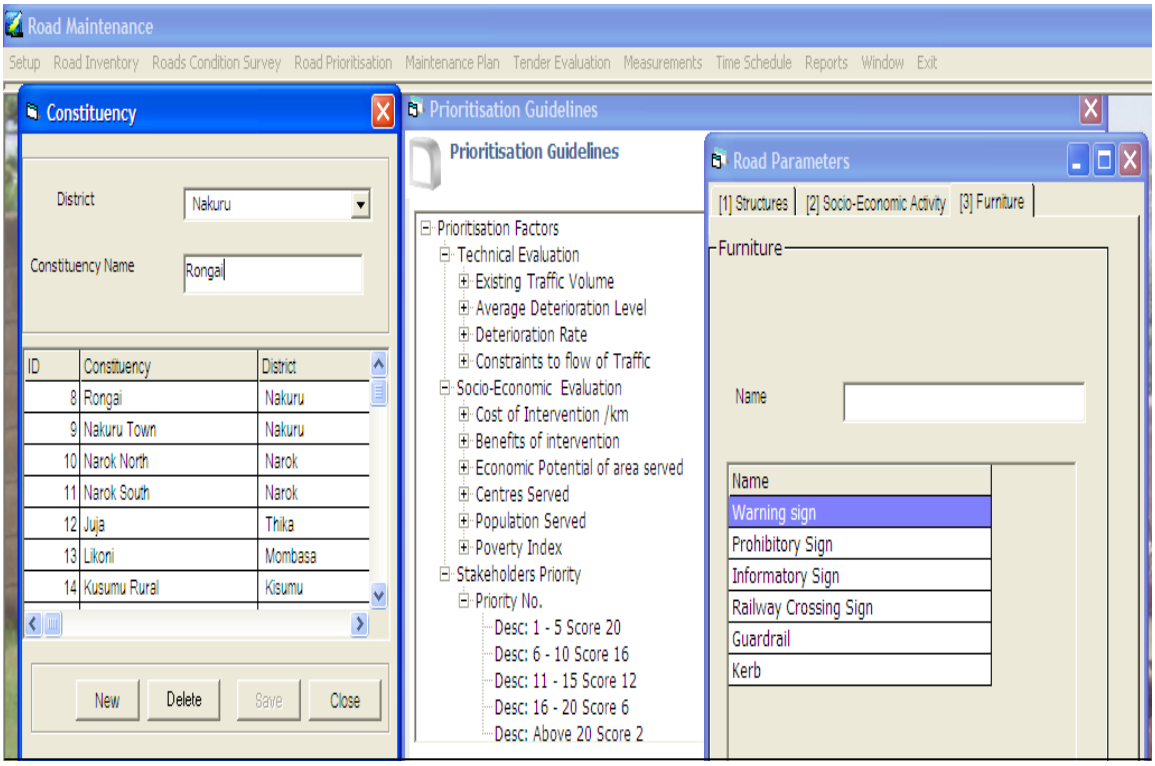


Figure 5.3.1: System Setup Menu

5.3.2 Road Inventory

Collected data on road inventory were entered in the system. These included; general data, principal subsoil type, traffic flow, average annual rainfall, transverse gradient, road surfing type, major structures, socio-economic features and road furniture along a

road. These details gave the general overview of the roads (refer to section 5.2.1.1). Road inventory data entry window is shown in Figure 5.3.2.

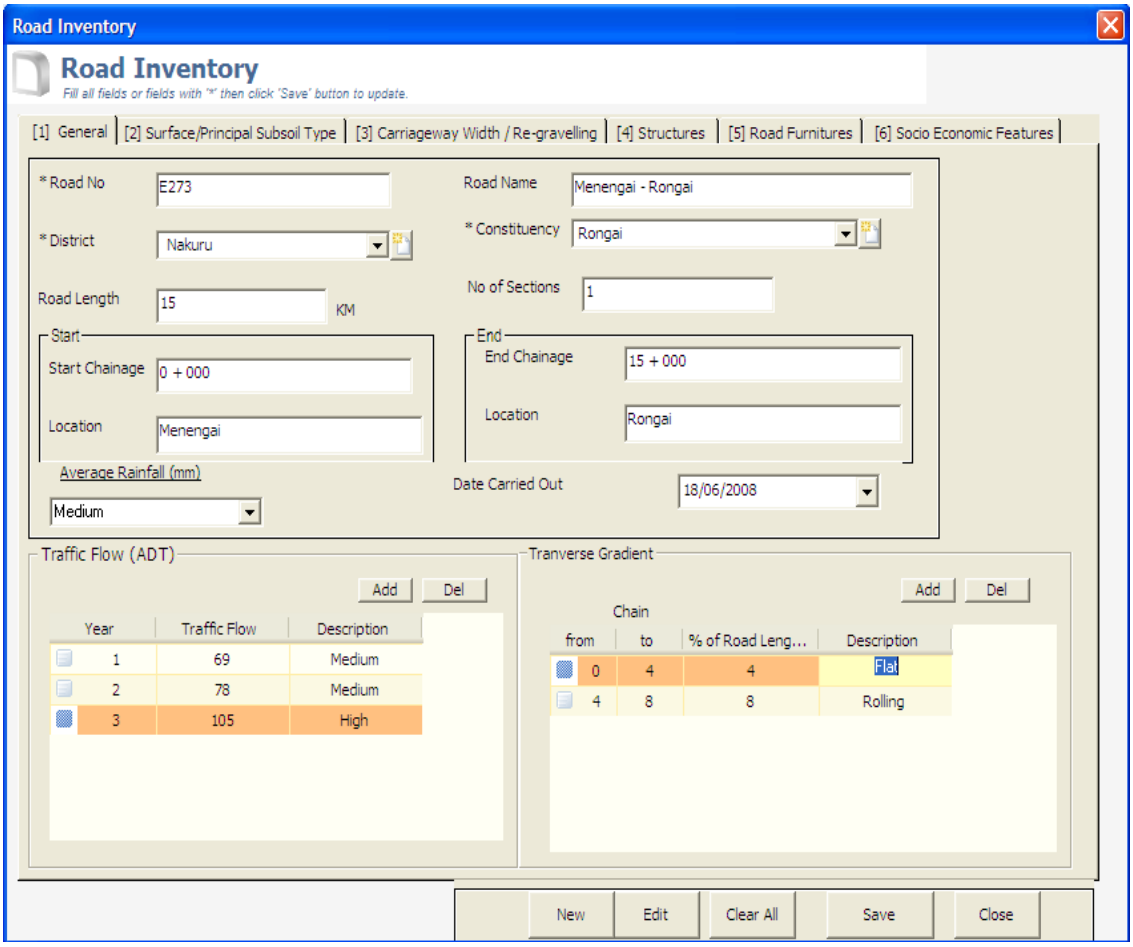


Figure 5.3.2: Road Inventory Data Entry Window

5.3.3 Road Condition Survey

Road condition data collected were entered in the road condition module in the system. These data included; general road details, carriageway deterioration and structures

conditions. From this the average road condition was automatically calculated by the system (refer to section 5.2.1.2 for the significance of road condition survey). Road condition data entry window is shown in Figure 5.3.3.

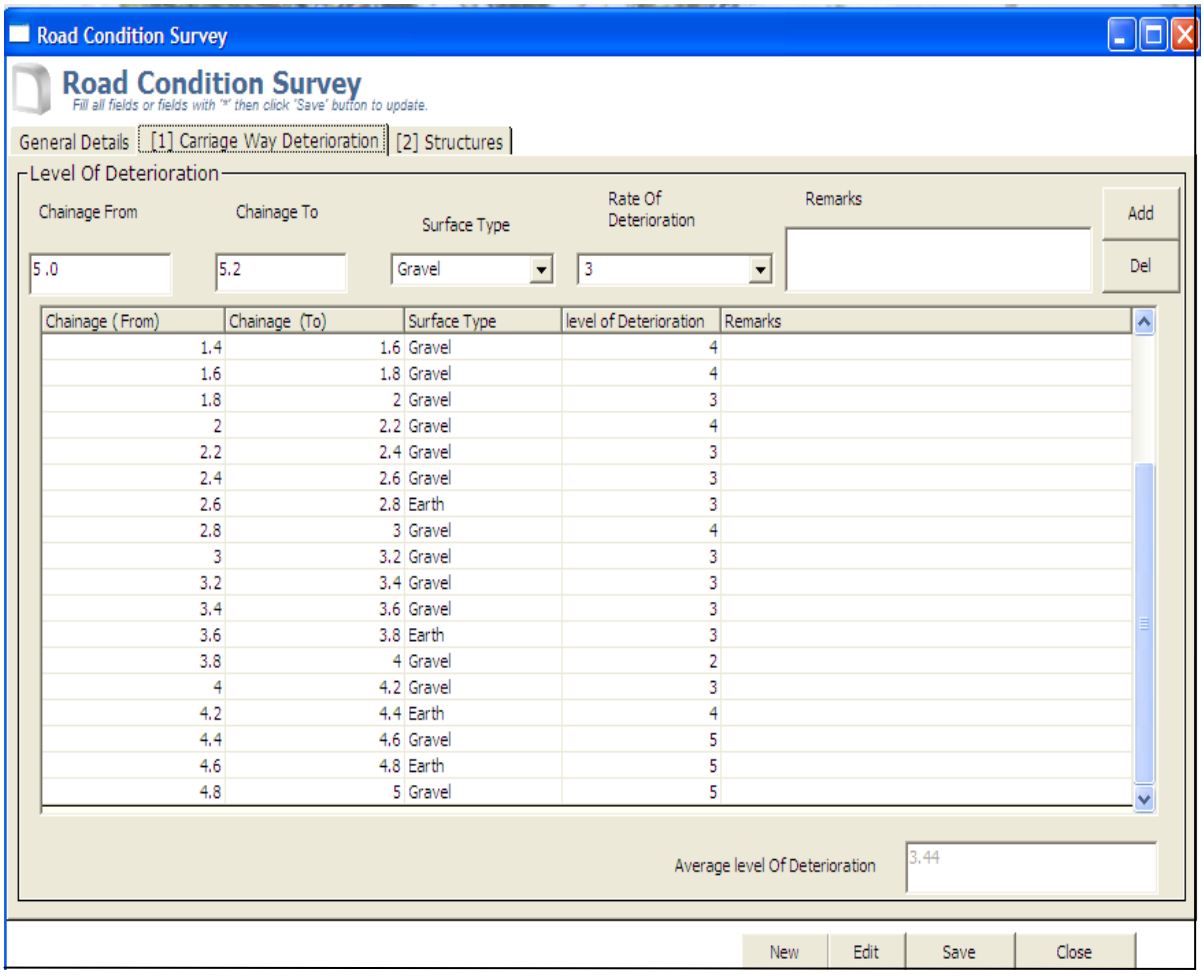


Figure 5.3.3: Road Condition Data Entry Window

5.3.4 Prioritisation

The collected prioritisation data were entered in the system for the five roads considered. These data were in three parts; technical factors, socio-economic factors and stakeholders priority. Using the order of marks as set out in the system's setup, the

system summed up marks for each road and ranked the roads automatically and generated a priority list (refer to section 5.2.1.3). The road prioritisation data entry window is shown in Figure 5.3.4.

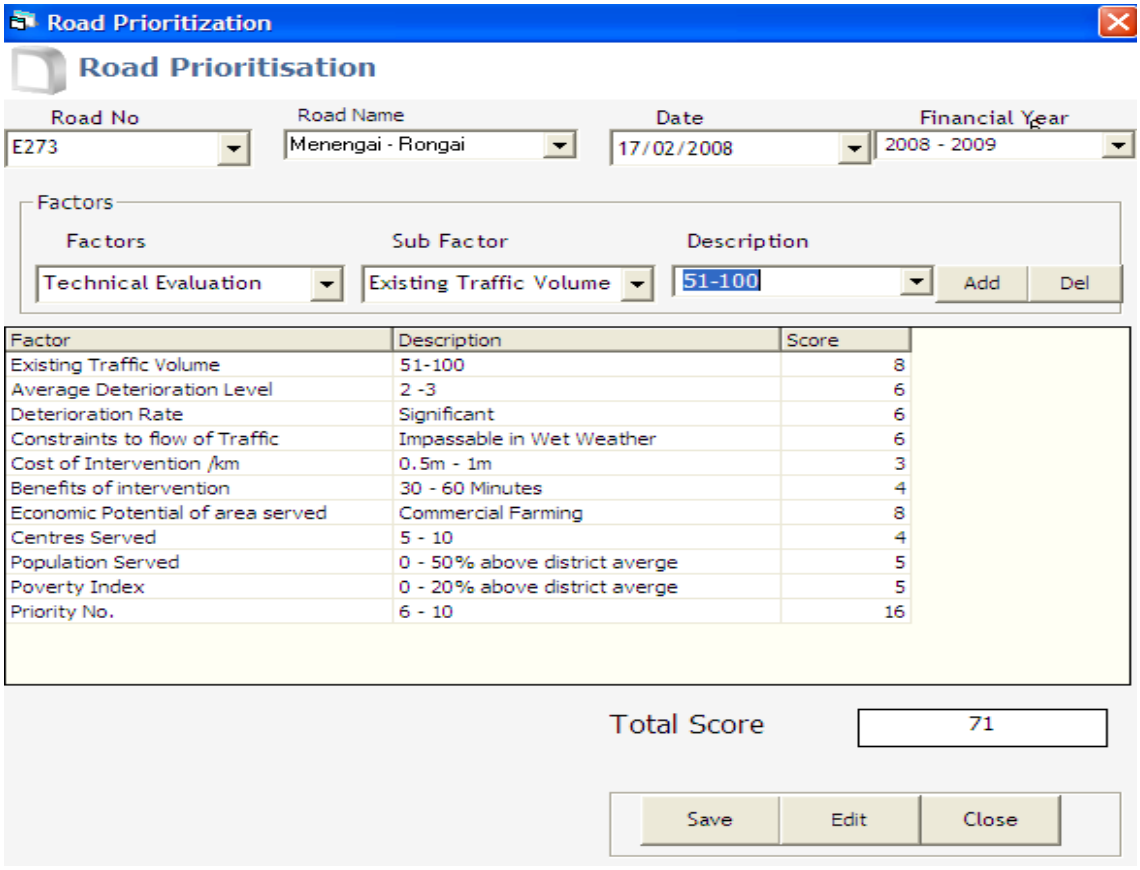


Figure 5.3.4: Road Prioritisation Data Entry Window

5.3.5 Road Maintenance Plan

Data collected from the field for road No. E273 which was prioritised under the prioritisation module was entered in the system to test this module. Quantities of bush clearing and grading were used and engineer's estimate rates as derived from the roads 2000 programme were entered and the system generated engineer's estimates in a bill of quantities table (refer to section 5.2.1.4). Road maintenance plan data entry window is shown in Figure 5.3.5.

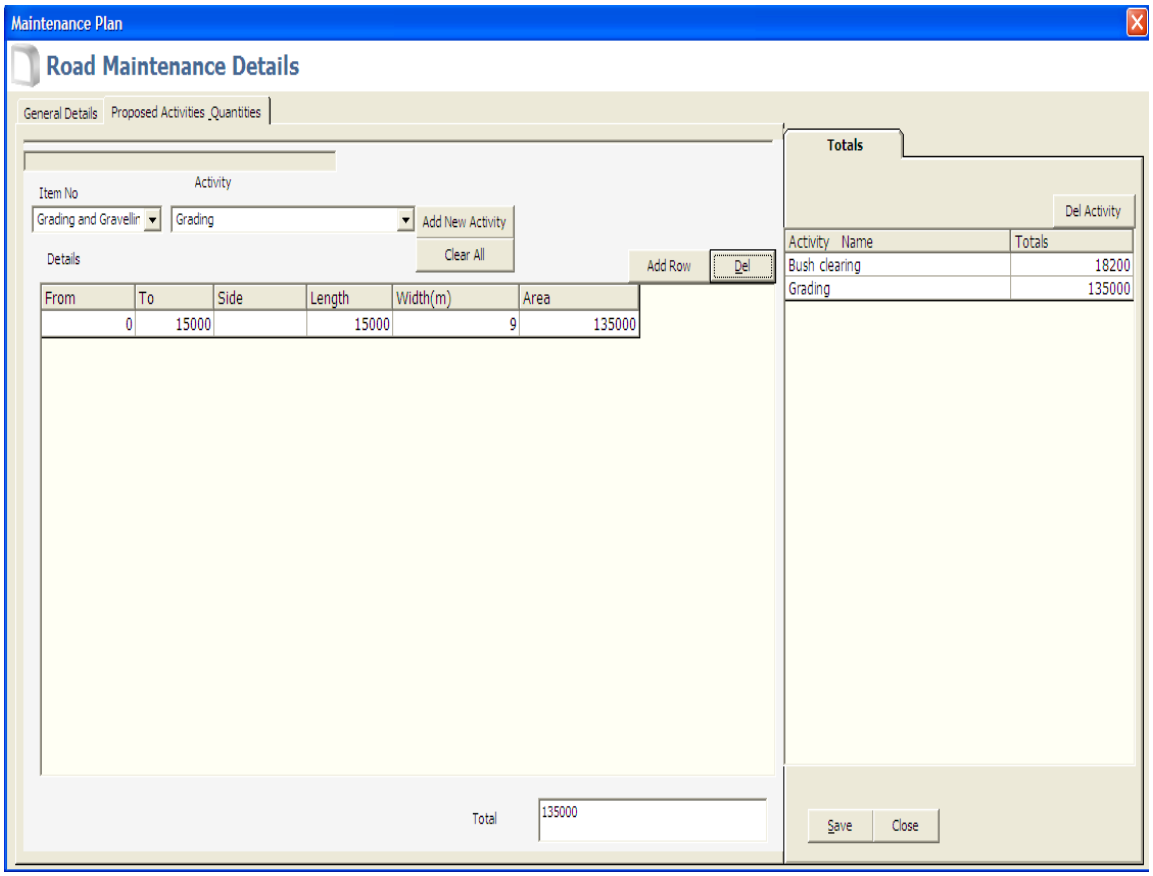


Figure 5.3.5: Road Maintenance Plan Data Entry Window

5.3.6 Tender Evaluation

Existing tender data on road No. E273 in Nakuru district which was tendered and awarded to a contractor under the annual routine maintenance programme in July 2007 was used to test this module. Four contractors were competing for this tender. The tender data were evaluated using this system then compared with the results of the evaluation by the districts roads engineer. A tender evaluation criterion was set where all mandatory requirements had to be met and a pass mark of 50% (using findings from the questionnaires) for other responsive requirements. Technical capability pass mark was set as 70% to stress the importance of technical abilities of contractors. The tender evaluation committee is expected to set their own criteria depending on their requirements because this is expected to be different from one tender to another and from location to location. The data were subjected to all the three stages of evaluation in this system (refer to section 5.2.1.5). The data entry window showing the responsiveness, technical ability and financial competitiveness stages is given in Figure 5.3.6.

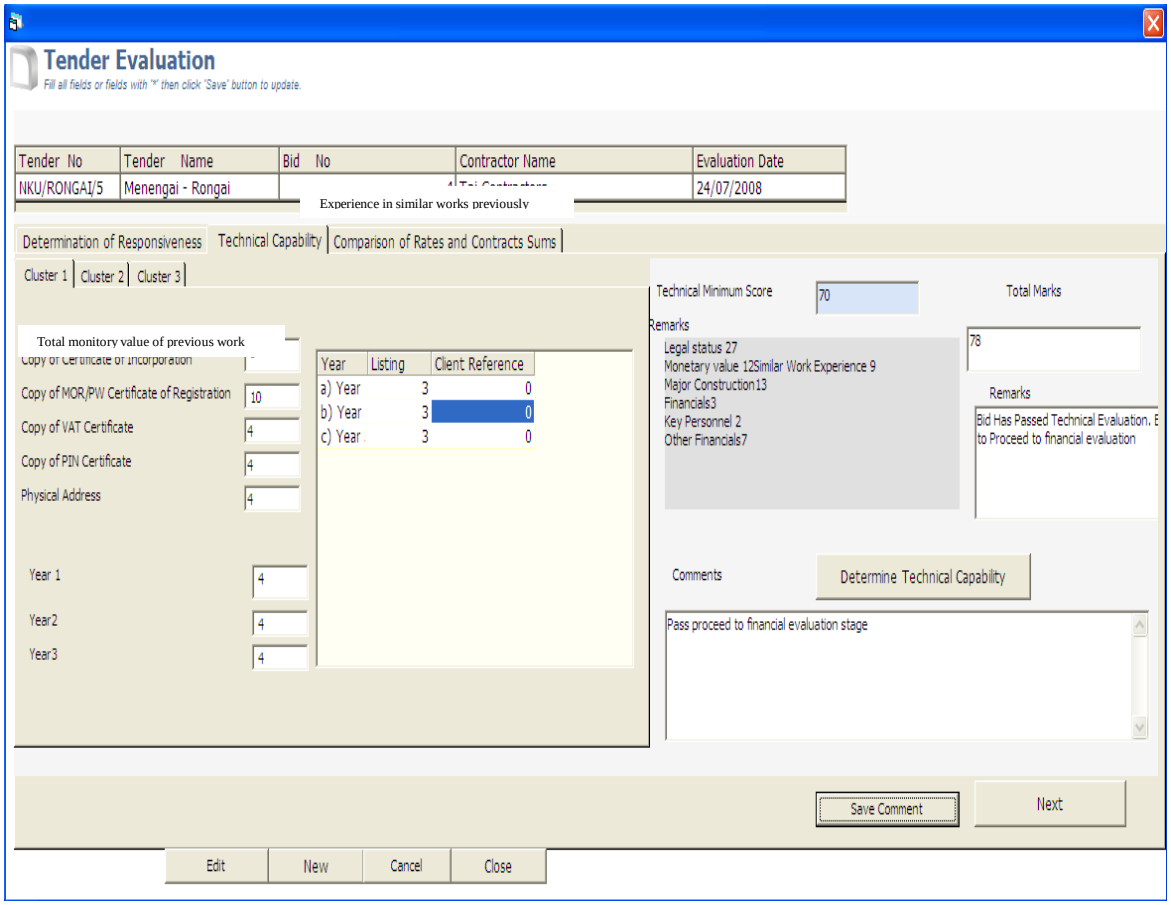


Figure 5.3.6: Tender Evaluation Data Entry Window

5.3.7 Contracts Time Schedules and Progress

Existing contract time schedules for some past contracts in Nakuru district were used to test this module. Data on various schedules, the contract periods and defects liability period were entered in the system as shown in Figure 5.3.7 (refer to section 5.2.1.6).

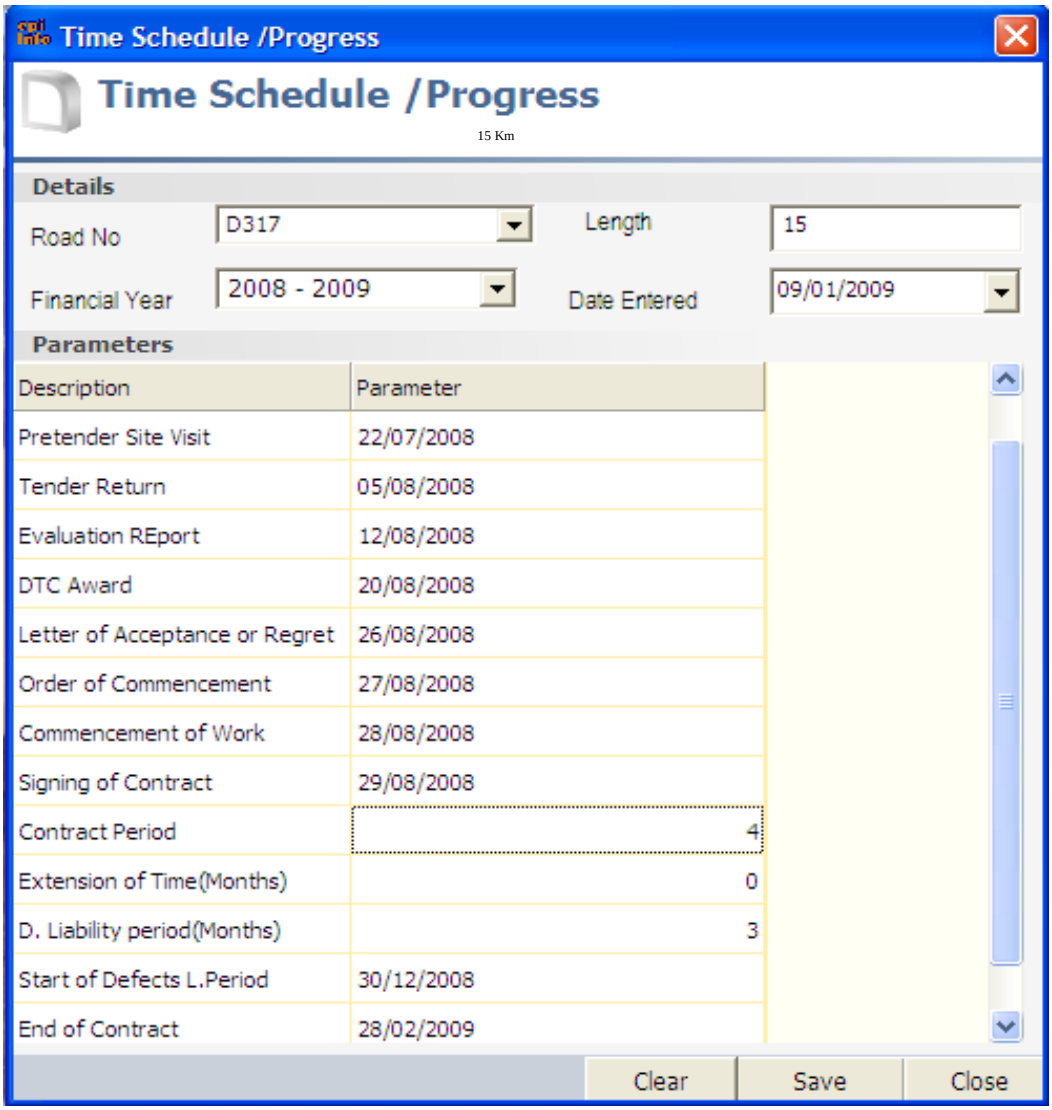


Figure 5.3.7: Time Schedule and Progress Data Entry Window

5.3.8 Work measurements and certification

Existing empirical past contract data of Menengai – Rongai road was used to test this module. First quantities were generated from the road maintenance plan as planned works and rates from the winning contractor in the tender evaluation stage were used for

payment purposes. Quantities of completed work or already done which had been measured from the field were entered and the system then generated payment reports. (refer to section 5.2.1.7) The joint measurement data entry window is shown in Figure 5.3.8.

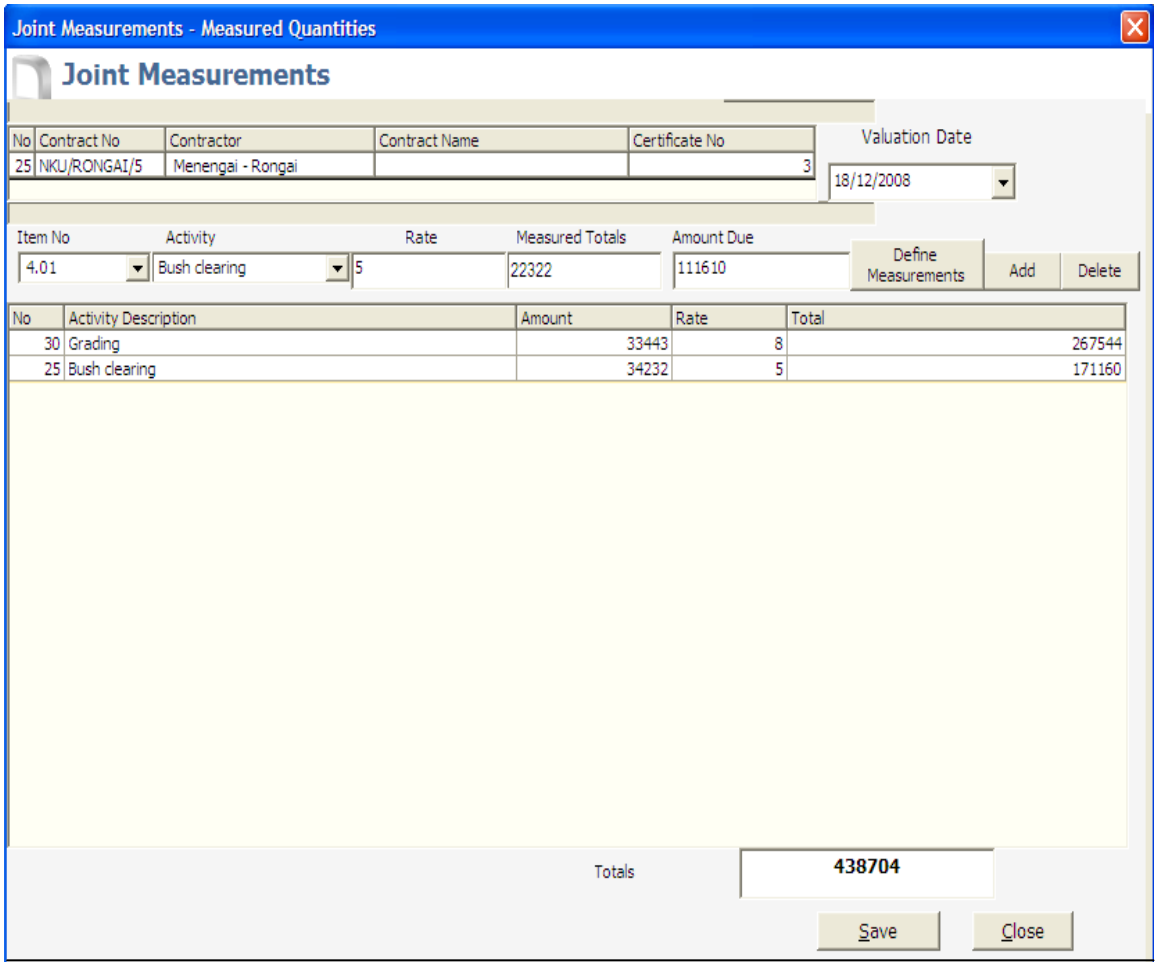


Figure 5.3.8: Measurement Data Entry Window

5.3.9 Work Progress Reporting

This was generated as a report from "planned work quantities" entered in the maintenance plan module and "done work quantities" in the certification module in section 5.3.8. The "works done" were expressed as a percentage of the planned work to show physical work progress.

5.3.10 Financial Reporting

Existing empirical past contract data of Menengai – Rongai road was used to test this module. This was generated as a report from data entered under the tender evaluation and payment and certification stage to show the percentage certified amount based on the contract sum.

5.4 System Performance and Validation Results

After the RMMS was developed, data collected from the field for the first four modules (road inventory, condition survey, prioritisation and maintenance plan) were entered into the system. Existing data on contracts were used to validate the other five modules, refer to Fig. 3.4. The performance of the system and the results of the tests are discussed in sections 5.4.1 to 5.4.10.

5.4.1 System Setup

General system data entered in the setup menu were available for use under the other modules. The districts and constituencies entered could be accessed with a dropdown under road inventory module as well as the other modules. General parameters defined

under the system menu (refer to section 4.9.1) were also available for use under the road inventory module. Prioritisation factors earlier defined in section 4.3.2.3 could be accessed for use with a dropdown under the prioritisation module as illustrated in Figure 5.4.1.

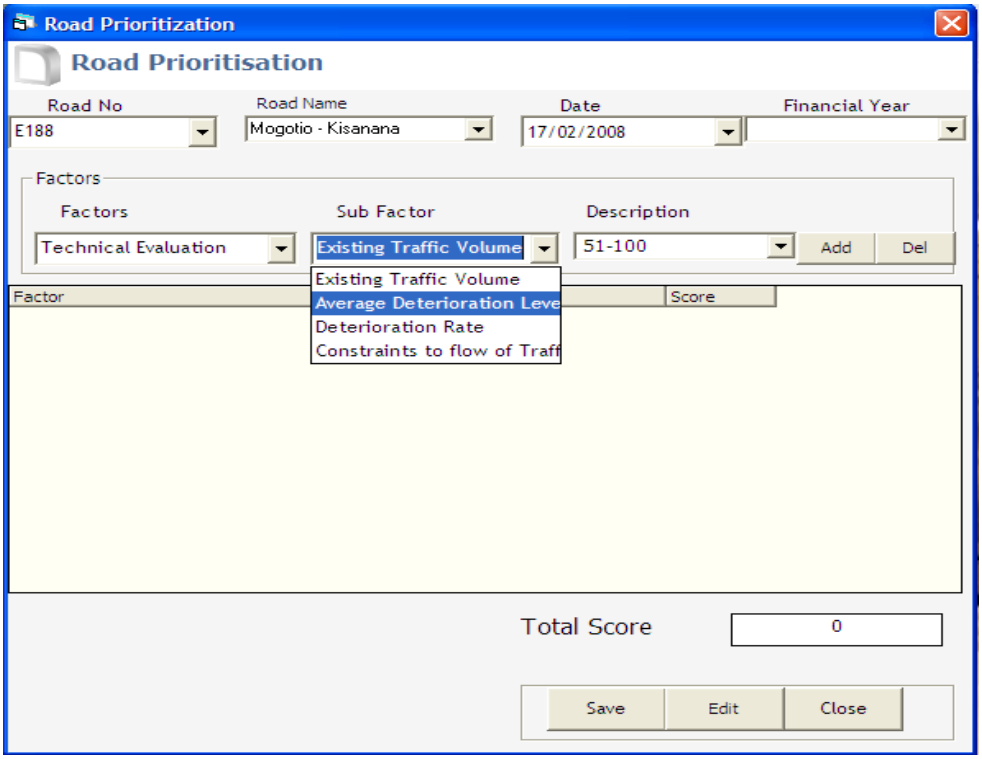
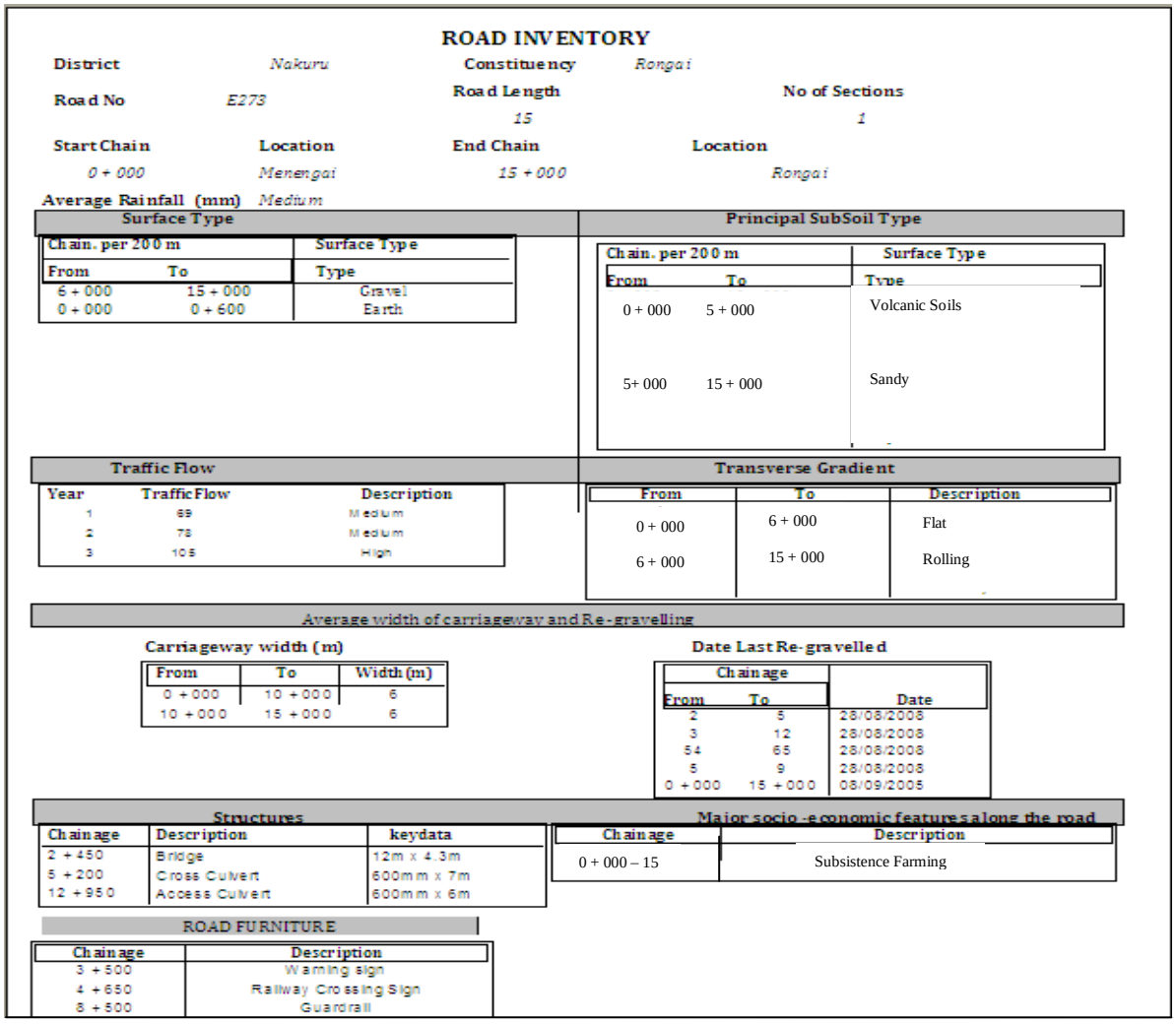


Figure 5.4.1: Road Prioritisation setup Window.

5.4.2 Road Inventory

Road inventory survey was carried out for roads D365, D316, E188, E267 and E273. The system can generate road inventory survey report from the data entered for each of the roads. Table 5.4.2.1 shows inventory output for road E273.

Table 5.4.2.1: Road Inventory system generated report for road E273



ROAD INVENTORY

District: Nakuru | Constituency: Rongai

Road No: E273 | Road Length: 15 | No of Sections: 1

Start Chain: 0 + 000 | Location: Menengai | End Chain: 15 + 000 | Location: Rongai

Average Rainfall (mm): Medium

Surface Type

Chain. per 200 m		Surface Type
From	To	Type
6 + 000	15 + 000	Gravel
0 + 000	0 + 600	Earth

Principal SubSoil Type

Chain. per 200 m		Surface Type
From	To	Type
0 + 000	5 + 000	Volcanic Soils
5+ 000	15 + 000	Sandy

Traffic Flow

Year	Traffic Flow	Description
1	69	Medium
2	78	Medium
3	105	High

Transverse Gradient

From	To	Description
0 + 000	6 + 000	Flat
6 + 000	15 + 000	Rolling

Average width of carriageway and Re-gravelling

Carriageway width (m)

From	To	Width (m)
0 + 000	10 + 000	6
10 + 000	15 + 000	6

Date Last Re-gravelled

Chainage		
From	To	Date
2	5	28/08/2008
3	12	28/08/2008
54	65	28/08/2008
5	9	28/08/2008
0 + 000	15 + 000	08/09/2005

Structures

Chainage	Description	keydata
2 + 450	Bridge	12m x 4.3m
5 + 200	Cross Culvert	600mm x 7m
12 + 950	Access Culvert	600mm x 6m

Major socio-economic features along the road

Chainage	Description
0 + 000 – 15	Subsistence Farming

ROAD FURNITURE

Chainage	Description
3 + 500	Warning sign
4 + 650	Railway Crossing Sign
8 + 500	Guardrail

In addition the system also generates a summary of list of roads and their lengths; the list can be filtered by district or constituency as shown in Table 5.4.2.2. This information will help new staff in a district to understand the road network in their area of operation; in this way continuity is achieved.

Table 5.4.2.2: Road List system generated report

ROAD LIST

Date 24/07/08

Distict	Constituency	Road No	Road Name	Length(km	Sections	Start Chain	Location	End Chain	Location
Nakuru	Rongai								
		D365	Menengai - Mogotio	10	1	0 + 000	Menengai	10 + 000	Mogotio
		D316	Kisanana- Menengai	12	1	0 + 000	Kisanana	12 + 000	Menengai
		E188	Mogotio - Kisanana	18	1	0 + 000	Mogotio	18 + 000	Kisanana
		E267	Njoro - Salgaa	7	1	0 + 000	Njoro	7 + 000	Salgaa
		E273	Menengai - Rongai	15	1	0 + 000	Menengai	15 + 000	Rongai

Since road inventory data can be entered and updated regularly, the system can be used to improve the current practise in the districts where there are no well documented details of roads. The road inventory information can then be used for planning purposes for example when preparing annual work plans which is a requirement by the Kenya Roads Board. Various annual road inventory information stored in the system can be compared together. The system presents road maintenance managers with the advantage of making quick reference of any road data anytime hence saving time. They will also be able to have their roads data stored better in a computer therefore avoiding a lot of paperwork and loss of information therefore increasing management efficiency.

5.4.3 Road Condition Survey

A report was generated from the system showing a summary list of average road conditions for the roads surveyed. The average level of deterioration for each surveyed

road was compared for the five roads using the KRB scale and road E273 was found to be the worst condition compared to the others as shown in Table 5.4.3.

Table 5.4.3: Road Condition system generated report

ROAD CONDITION SURVEY LISTING Date 24/07/08

Road Condition Survey Listing for the year 2008 - 2009

District	Constituency	Road No	Road Name	Length	Date Carried	Start Chain	Location	End Chain	Location	Average level deterioration
Nakuru	Rongai									
		E267	Njoro - Salgaa	2	06/2008 00:0	0	Salgaa	2	Rongai	2.50
		D365	Menengai - Mogotio	2	12/2007 00:0	0	Menengai	1	Mogotio	3.22
		D316	Kisanana- Menengai	2	06/2008 00:0	0	Kabarak	2	Menengai	3.00
		E188	Mogotio - Kisanana	3	06/2008 00:0	0	Kabarak	2	Rongai	2.38
		E273	Menengai - Rongai	5	12/2007 00:0	0	Menengai	15	Rongai	3.44

A road maintenance engineer can use the road conditions as one of the factors to make decisions on what road to maintain before the other. By carrying out road condition surveys on annual basis and storing data in the system, a maintenance engineer can compare the condition of a road with the previous year's conditions and therefore be in a position to tell if there is improvement in his network or not. The road condition surveys can also be done before and after improvement of a road and stored in the system to assess the impact of improvement.

The road condition is used in the next module of the system as a factor in prioritising roads for maintenance in a given network.

5.4.4 Road Prioritisation

A road prioritisation report was generated from the system for the five roads considered. This report gave the total marks scored on technical capability, socio-economic factors and stakeholder's priorities. The system combined the total marks for all factors and automatically ranked the roads. Rank 1 means that road has the highest priority for maintenance.

Once data on the roads are entered, the system is able to prioritise roads in a given network automatically without any external influence. This will improve the current prioritisation practise in districts in which there is no clear criteria for road maintenance prioritisation; it will ensure that road maintenance funds are used on the most deserving roads. It will support the district roads management in making maintenance decisions. Besides it will also reduce political influence on road maintenance prioritisation. The generated report is given in Table 5.4.4.

Table 5.4.4: Road Maintenance Ranking system generated report

ROAD MAINTENANCE/IMPROVEMENT RANKING

District:- NAKURU Financial Year 2008 - 2009 Date 24/07/08

Constituency	Road No	Road Name	Technical Score	Socio-Economic Score	Stakeholders Score	Total Score	Ranking
Rongai							
	E273	Menengai - Rongai	26	29	16	71	1
	E267	Njoro - Salgaa	26	23	16	65	2
	E188	Mogotio - Kisanana	25	24	12	61	3
	D316	Kisanana- Menengai	22	26	12	60	4
	D365	Menengai - Mogotio	25	18	12	55	5

It was compared to Nakuru district road priority workplan during the same financial year, 2008-2009 and which gave the order or ranking for the five roads starting from rank 1 as E188, D265, D316, E273 and E267, (KRB, 2008). Road E273 which was ranked 1 by the developed system was ranked 3 in the district. The DRE indicated that the member of parliament and some few stakeholders influenced him to follow this order. This shows how inconsistent and unprofessional the road maintenance process is carried out in the districts.

5.4.5 Road Maintenance/Improvement Plan

A road maintenance plan report was generated for the data entered for road No. E273 as shown in Table 5.5.5. This report detailed the item numbers, description, quantities, rates and estimated cost of each activity. It also showed the total cost of all activities, contingency amounts (if required) and the total maintenance estimates.

This method improves efficiency and accuracy as opposed to the current RM1 forms used in the districts which generalise quantities; for example, grading is estimated in kilometres but paid in square meters (Goss, 2005). The developed system presents an advantage of closely managing works during execution since a maintenance engineer can use the chainages in this plan when instructing the contractor to carry out works. The chainages are not indicated in the RM1 forms currently used in the districts. The quantities and costs quoted through this method are more accurate since they are specific for each chainage. This ensures that there are less variations of quantities once works start. The maintenance quantities are used for tendering, measurement and certification,

work and financial progress reporting as well as planned works. The paperwork required for preparing the maintenance plan using this system is less and errors are minimised. This reduces the time required on the other modules since they are only entered once.

Table 5.4.5: Bill of Quantities system generated report

BILL OF QUANTITIES

Road No	*E273*	**Date**	*14/08/08*
Road Name	*Menengai - Rongai*	**Length**	*15 Km*

Item No	Description	Unit	Quantity	Rate	Engineer's Estimate
4.01	Bush clearing	m^2	000.00	4.00	196,000.00
10.01	Grading	m^2	,000.00	8.00	1,080,000.00
10.02	Gravelling	m^3	00.00	1,200.00	2,160,000.00
		Total			3,436,000.00
		Contigency amount =:	5 %		171,800.00
		Total Cost			3,607,800.00

5.4.6 Tender Evaluation

Four contractors, namely BEMA, Tai, Falcon and Timbo tendered for road E273. Through the system, of the four contractors who tendered, one was disqualified namely Falcon Road Contractors at the technical evaluation stage because he had 61% which was below the 70% pass mark required. As it were, however, Falcon Road Contractors was the one awarded the contract through the traditional system because he had the lowest tender sum; the DRE only considered financial competitiveness of the contractors. This illustrates the concerns raised by consultants managing the KfW

Roads 2000 programme that the DREs only consider financial competitiveness of contractors when evaluating tenders (Robinson, 2005).

It is important to note that the system cannot allow the user to proceed with evaluation of a contractor if he does not meet all the mandatory requirements. If a contractor meets these requirements, other requirements are checked and if he passes this stage then the technical evaluation stage is enabled by the system, otherwise it is remains disabled thus blocking access to the next stage. A contractor who passes both responsiveness and technical stages would be allowed by the system to be evaluated financially. This facility is useful in that it makes sure that evaluation is done only after a contractor meets all the set requirements therefore making it difficult to manipulate the process and hence check corrupt ways of tender award. This will ensure that contractors who win contracts are technically capable, a factor largely omitted by DREs during tender evaluations and pointed out as a common difficulty during execution of works (as found out by the study and discussed in section 4.3.4).

The system generates a report on recommendations and comments of mandatory requirements. It can generate total marks for both other responsive and technical requirements as well as illustrated in the table 5.4.6.1.

Table 5.4.6.1: Mandatory, other requirements and technical capability generated report.

RESPONSIVENESS AND TECHNICAL CAPABILITY EVALUATION REPORT

Name *Menegai Rongai* **Date** *14-Sep-2008*

Tender No *NKU/Rongai/5*

MANDATORY REQUIREMENTS

Contractor	Recommendation	Comments
BEMA Contractors	Passed	Pass proceed tonext stage
Tai Contractors	Passed	Pass proceed to the next stage
Falcon Road Contractors	Passed	Pass proceed to next stage
Timbo Road Contractors	Passed	Pass proceed tonext stage

OTHER REQUIREMENTS

Contractor	Marks	Comments
BEMA Contractors	100	Bid is Responsive. Proceed To Technical Evaluation
Tai Contractors	100	Bid is Responsive. Proceed To Technical Evaluation
Falcon Road Contractors	75	Bid is Responsive. Proceed To Technical Evaluation
Timbo Road Contractors	75	Bid is Responsive. Proceed To Technical Evaluation

TECHNICAL CAPABILITY

Contractor	Marks	Comments
BEMA Contractors	89	Pass proceed to financial evaluation
Tai Contractors	78	Pass proceed to financial evaluation
Falcon Road Contractors	51	Bid Has Failed Technical Evaluation. Bid Cannot Proceed To Financial Evaluat
Timbo Road Contractors	83	Pass proceed to financial evaluation

A report was also generated for the financial evaluation as given in Table 5.4.6.2.

Table 5.4.6.2: Bill Item Tender Comparisons generated report

FINANCIAL EVALUATION REPORT

BILL ITEMS

Name

Tender No NKU/Rongai/5 Date 14-Sep-2008

CONTRACTOR	BILL NAME	ITEM NAME	QTY	ENG RATE	ENG AMOUNT	CON RATE	AMOUNTS FROM RATES	BOQ AMOUNT
Tai Contractors								
	Site Clearance							
		Bush clearing	49,000	4	196,000.00	5	245,000.00	245,000.00
		Total BOQ			196,000.00		245,000.00	245,000.00
	Grading and Gravelling							
		Grading	135,000	8	1,080,000.00	7	945,000.00	945,000.00
		Gravelling	1,800	1,200	2,160,000.00	1,250	2,250,000.00	2,250,000.00
		Total BOQ			3,240,000.00		3,195,000.00	3,195,000.00
		Total Bid Amounts			**3,436,000.00**		**3,440,000.00**	**3,440,000.00**
BEMA Contractors								
	Site Clearance							
		Bush clearing	49,000	4	196,000.00	4	196,000.00	196,000.00
		Total BOQ			196,000.00		196,000.00	196,000.00
	Grading and Gravelling							
		Grading	135,000	8	1,080,000.00	9	1,215,000.00	1,215,000.00
		Gravelling	1,800	1,200	2,160,000.00	1,000	1,800,000.00	1,800,000.00
		Total BOQ			3,240,000.00		3,015,000.00	3,015,000.00
		Total Bid Amounts			**3,436,000.00**		**3,211,000.00**	**3,211,000.00**
Timbo Road Contractors								
	Site Clearance							
		Bush clearing	49,000	4	196,000.00	5	245,000.00	255,000.00
		Total BOQ			196,000.00		245,000.00	255,000.00
	Grading and Gravelling							
		Grading	135,000	8	1,080,000.00	10	1,350,000.00	1,350,000.00
		Gravelling	1,800	1,200	2,160,000.00	1,100	1,980,000.00	1,980,000.00
		Total BOQ			3,240,000.00		3,330,000.00	3,330,000.00
		Total Bid Amounts			**3,436,000.00**		**3,575,000.00**	**3,585,000.00**

The system has a facility for ranking the contractors automatically according to their bids from the lowest to the highest after they pass the responsiveness and technical evaluation stages successfully. It can also pick out errors from contractors by comparing the amounts calculated from the rates and the amounts entered by the contractors in the tender document. This can certainly improve the current practise by reducing time required for tender evaluation and minimise corruption thus increasing efficiency. Table 5.4.6.3 shows tender sums comparison and ranking.

Table 5.4.6.3: Tender sums comparisons and Ranking generated report

FINANCIAL EVALUATION REPORT

TENDER SUMS COMPARISON

Name Date *14-Sep-2008*

Tender No *NKU/Rongai/5*

CONTRACTOR	RATE AMOUNTS	BOQ AMOUNT	CORRECTION	COMMENTS
Tai Contractors	3,612,000.00	3,612,000.00	*0*	*Okay*
BEMA Contractors	3,371,550.00	3,371,550.00	*0*	*Okay*
Timbo Road Contractors	3,753,750.00	3,753,750.00	*-10000*	*Tender sum is greater than BoQ sum*

ORDER BY TENDER SUM

CONTRACTOR	RANK
BEMA Contractors	*1*
Tai Contractors	*2*
Timbo Road Contractors	*3*

5.4.7 Contracts Time Schedule and Progress

From the contracts data entered, the system generated a report of the various schedules, contract periods and defects liability periods. The system has a facility to filter reports per district, constituency and the financial year. This report can help the maintenance engineer in monitoring the dates of the various schedules and the time progress of each contract. From the report a user would know what percentage of time has elapsed in a given contract. In managing maintenance works a maintenance engineer would easily tell which contract is behind schedule and can find out what would be causing the delay and possibly take the necessary measures. This module can be used as a good management tool and can help improve the current practise in the districts where there is

no specific guidance on monitoring contracts schedules as discussed in section 4.3.5. The generated report is shown in Table 5.4.7.

Table 5.4.7: Contracts Time Schedule and Progress generated report

Time Schedule/Progress

Date 20/02/2009

Tender Number NKU/RONGAI/5

District	Constituency	Road No	Length (km)	Tender Dates				DTC Award	Reply Letter	Order of Commencement	Work Commencement	Contract Signing	Contract Period	Ext. of Time	% of Time Elapsed	Liability Period	Start of Defection	End Of Contract
				Invitation To Tender	Pretender Site Visit	Tender Return	Evaluation Report											
Nakuru	Rongai																	
		D365	10	5/13/08	5/14/08	5/15/08	5/16/08	5/17/08	5/20/08	5/22/08	5/23/08	27/05/2008	3	1	69	2	9/17/08	11/14/08
		D365	0	2/20/08	2/21/08	2/22/08	2/23/08	2/19/08	2/21/08	2/22/08	2/23/08	20/03/2008	3	0	29 69	3	7/17/08	11/20/08
		E273	15	7/18/08	7/25/08	8/7/08	8/14/08	8/21/08	8/22/08	8/23/08	8/26/08	27/08/2008	3	0	72	3	11/27/08	2/27/09
		E273	15	7/19/08	7/22/08	8/5/08	8/12/08	8/20/08	8/26/08	8/27/08	8/28/08	29/08/2008	4	0	98 51	3	12/30/08	2/28/09

5.4.8 Measurement and payment certification

Table 5.4.8 shows summaries of bill numbers, items total amounts for items and statements of payment reports. From the data entered, the system generated a report showing the quantities, rates and amounts as they were entered in the contract document. The system generated this from data saved under the road maintenance plan (section 5.4.5) and the winning tender rates evaluated (section 5.4.6). From the entry of the quantities of work done, the system generated a report showing total previous quantities as saved under previous certificates (Table 5.4.8.1, column 7), the current (Table 5.4.8.1, column 8) and the totals (Table 5.4.8.1, column 9).

The system, by multiplying the quantities by the rates, generated the previous total payment, the current payment and the total payment for each item and the certificate (Table 5.4.8.1, column 10, 11 and 12 respectively).

The system also generated the previous (KES 948,675), current (KES 879,300) and total (1,827,975) amounts summary for all the items considered under each certificate (Table 5.4.8.2, column 3, 4 and 5 respectively).

Finally the system generated the total payment of the total work done, then deducted the value added tax and retention money for both previous (KES 743,017.11), current (KES 720,116.38) and total (KES 1,497,048.49) amounts for each certificate (Table 5.4.8.3, column 2, 3 and 4 respectively).

The advantage of this system is that once measured quantities from the field are entered, quantities and summaries of amounts of money for each activity and items are generated automatically then the VAT and retention deductions are made and amount of money due the contractor calculated. This means that the engineer only needs to input measured quantities in the system then generates and prints a payment certificate as the output. This should take a short time and involve little paperwork as opposed to the current practise where certificates take so long to prepare, and besides, there is no particular criterion for preparing certificates given that the maintenance approach is relatively new. The system can also help the maintenance engineers monitor their contracts financially since it can show the contract sum, previous payment, current payment due and total

payments thereby guiding the engineer on how he is spending funds in a given contract. This can increase efficiency since it will reduce time and paperwork required during the preparation of payment certificates.

Table 5.4.8.1: Bill Nos Amounts system generated report

MINISTRY OF ROADS

WORK DONE - BILL NOS

Construction Firm: BEMA Contractors

Contract Name : Menengai - Rongai

Contract No : NKU/Rongai/5

District : Nakuru

Certificate No : 2

Valuation as at 17-December-2008

BILL OF QUANTITIES **Site Clearance**

ITEM NO	DESCRIPTION	UNIT	BILLED			MEASURED QUANTITY			ACTUAL AMOUNTS (KSHS)		
			QTY	RATE	AMOUNT	Previous	This Certificate	To Date	Previuos	This Certificate	To Date
4.01	Bush clearing	m2	49,000.00	4	196,000.00	8,925.00	6,500	15,425.00	35,700.00	26,000	61,700.00
	TOTAL				196,000.00				35700	26000	61700

BILL OF QUANTITIES **Grading and Gravelling**

ITEM NO	DESCRIPTION	UNIT	BILLED			MEASURED QUANTITY			ACTUAL AMOUNTS (KSHS)		
			QTY	RATE	AMOUNT	Previous	This Certificate	To Date	Previuos	This Certificate	To Date
10.01	Grading	m2	135,000.00	9	1,215,000.00	49,775.00	63,700	113,475.00	447,975.00	573,300	1,021,275.00
10.02	Gravelling	m3	1,800.00	1000	1,800,000.00	465.00	280	745.00	465,000.00	280,000	745,000.00
	TOTAL				3,015,000.00				912975	853300	1766275

Certified by the Contractor's Representative *Name* .....

Signature .....

Certified by the Engineer's Representative *Name* .....

Signature .....

Table 5.4.8.2: Summary of Work Done Amounts system generated report

MINISTRY OF ROADS

SUMMARY OF WORK DONE

Construction Firm: **BEMA Contractors**

Contract Name : **Menengai - Rongai**

Certificate No : **2**

Contract No : **NKU/Rongai/5**

District **Nakuru**

Valuation as at **17/12/2008 17:02:19**

BILL NO	DESCRIPTION	BILLED AMOUNT	ACTUAL AMOUNTS (KSHS) Previuos	This Certificate	To Date	% age Complete
4	Site Clearance	196,000.00	35700	26000	61700	0.31 %
10	Grading and Gravelling	3,015,000.00	912975	853300	1766275	0.59 %
	SUB TOTAL (KSHS	3,211,000.00	948675	879300	1827975	
	CONTIGENCY	160,550.00				
	GRAND TOTAL (KSHS)	3,371,550.00	948675	879300	1827975	

Certified by the Contractor's Representative *Name* .....

Signature .....

Certified by the Engineer's Representative *Name* .....

Signature .....

Table 5.4.8.3: Payment Statement system generated report

MINISTRY OF ROADS

SUMMARY OF STATEMENT FOR PAYMENT ON ACCOUNT

Construction Firm: BEMA Contractors

Contract Name : Menengai - Rongai

Contract No : NKU/Rongai/5

Certificate No : 2

Valuation as at 17-Dec-2008

	PREVIOUS CERTIFICATE	THIS CERTIFICATE	TOTAL (kshs)
TOTAL OF WORK DONE	948,675.00	879,300.00	1,827,975.00
LESS 16% VAT REBATE	130,851.72	121,282.76	252,134.48
SUB TOTAL 1	782,123.28	758,017.24	1,575,840.52
LESS RETENTION MONEY	39,106.16	37,900.8 720,116.38	78,792.03
TOTAL PAYMENTS	743,017.11	720,116.38	1,497,048.49
LESS PREVIOUS PAYMENTS			743,017.11
SUB TOTAL 2			754,031.38
NOW DUE TO CONTRACTOR			754,031.40

Certified by the Contractor's Representative *Name* .....

Signature .....

Certified by the Engineer's Representative *Name* .....

Signature .....

5.4.9 Work Progress Reporting

The generated report on work progress is shown in Table 5.4.9. It was generated using quantities entered in the road maintenance plan module, rates under tender evaluation and quantities of work done under certification module. This report indicated the constituency, road name and the contractor carrying out the works.

The planned quantities (column 6) are shown in the report as they were indicated under the maintenance plan module (what was planned to be achieved). The done quantities

(column 8) is also reported as what has been achieved so far. The report also expressed the work done as a percentage of the planned work on each activity (column 9).

These reports can help the district roads engineers manage their contracts closely since they can easily tell from the system which activity for example is lagging behind in terms of physical works (from the percentages). 1,800m^3 of gravelling was planned to be achieved but only 745m^3 has been achieved so far, which is 41% complete. From this the maintenance engineer can investigate why gravelling is lagging behind and possibly mitigate it.

The system presents the engineers with an efficient management tool which can store data of previous works done and all data are stored in one system therefore avoiding the problem of losing information and saving time. This system can be an improvement of the current practise where quantities of work done are expressed in a general format without indicating percentage of work done.

Table 5.4.9: Work Progress system generated report

MINISTRY OF ROADS

WORK PROGRESS

Constituency	Road No	Road Name	Contractor	Progress				
				Activity Name	Planned	Variation	Done	%
Rongai	E273	Menengai - Rongai	BEMA Contractors	Bush clearing	49,000.00	21,625.00	*15,425.00*	*31%*
				Gravelling	1,800.00	743,665.00	*745.00*	*41%*
				Grading	135,000.00	936,050.00	*113,475.00*	*84%*

5.4.10 Financial Progress

Table 5.4.10 shows the generated financial report. Data entered during the contract award in the tender evaluation and payment and certifications modules are used to generate this report automatically. This report shows the name of the contract and the contractor. It also shows the number of payment certificates (column 6) and their valuation dates (column 7).

Table 5.4.10: Financial Progress system generated report

FINANCIAL PROGRESS REPORT

Financial Progress Report For district Nakuru

Date : 22-February-2009

Constituency	Road No	Contract Name :	Contractor	Contract Sum	Cert No	Valuation Date	Certified Amount	VAT Rebate	Retention	Net Total	% Certified
Rongai	E273	Menengai - Rongai	BEMA Contractors	3,371,550	2	15-Oct-08	723,100	99,737	31,168	592,195	21
					-	17-Dec-08	879,300	121,282	37,900	720,118	26
			Total				1,602,400	221,020	69,068	1,312,313	47

The system also reported the amounts of certified works (column 8), VAT due (column 9), retention (column 10) and the net amount due contractor on each certificate (column 11). The system summed up the amounts for all certificates on certified works, VAT, retentions and the net amount to the contractor. It then calculated the percentage of certified works compared to the contract sum of the contract (column 12).

This part of the system can help the district roads engineers monitor the financial progress of their contracts. They will be able to know what percentage of funds is left to be spent in a contract besides knowing the amounts of each certificate. Column 12 is calculated by dividing column 8 by column 5. This can be an improvement to the current practise in the districts where there is no particular guidance in monitoring financial progress.

5.5 Comparison of the system with existing systems in Kenya

The performance of the developed system can be compared with other systems as shown in Table 5.5 depicting its superiority over the existing systems.

Table 5.5: Comparison of developed RMMS and other systems

Features/Operation	**RM1**	**RMMS by Gath/Netcom**	**RMMS by Roads200 Nyanza**
Road Inventory	No provision	Feature included but manual	No provision
Road Condition Survey	No provision	Feature included but manual	No provision
Road Prioritisation	No provision	No provision	No provision
Road Maintenance Plan	Allows for a general planning of works	No provision	No provision
Tender Evaluation	No provision	No provision	No provision
Contracts Time Schedule and progress	No provision	No provision	Can monitor time progress of contracts
Measurement and certification	No provision	No provision	No provision
Work Progress Reporting	No provision	No provision	Can report work progress
Financial Progress Reporting	No provision	No provision	Can report financial progress

5.6 Management benefits of the system

The RMMS developed in this study can be used to make maintenance decisions for unpaved roads, reduce corruption and to increase management efficiency among others.

5.6.1 Decision support

The system can be used as a decision making tool; for example, in deciding which roads to maintain, the road prioritisation module which also considers road condition as a factor is used. By using this system, political factors which often interfere with road maintenance prioritisation decisions would be reduced and the maintenance engineers can always have supporting documentation on how they arrived at their decisions.

The system can also assist in making decisions during the tender evaluation stage. The evaluation criteria ensure that deserving contractors are awarded contracts hence weeding out undeserving contractors who would otherwise underperform. The system can further guide the maintenance engineer in making some contractual decisions in regard to issues like delays in contract completion, and financial commitments since it can show how contracts time and physical works are progressing and how funds are being spent in a contract.

5.6.2 Reducing corruption

The system can reduce corruption which is perceived to be rampant in road works. Politicians for example, influence road prioritisation but if this system can be used such influences can be reduced. Another area where corruption would manifest itself is

during tender evaluation. Common practises at this stage include bribes, gifts, nepotism, tribalism etc. By using this system, external influences can be minimised and openness enhanced hence reducing corruption.

The system outlines the financial progress of a contract right from the start to the end and stores all details. This reduces the chances of financial manipulation.

5.6.3 Increasing Efficiency

The system increases maintenance efficiency in a number of ways.

1. At the road inventory stage, the system stores all the road inventory information for use under all the other modules and are available to users anytime under one unit. This reduces the paperwork and time required in looking for information from hard material hence increasing efficiency and being economical.
2. Road condition survey information can be stored in the system and updated every year. This information will assist the maintenance engineer in monitoring the changes in road conditions. The road conditions are also as a guide in making maintenance intervention decisions.
3. The road prioritisation process helps in coming up with road maintenance prioritisation decisions which are documented and supported by facts.
4. Road maintenance plans help maintenance engineers in deriving quantities for preparation of tender documents and can also be used in managing contracts; for example, an engineer can use it to issue site instructions since the proposed list of activities is accompanied by chainages in the maintenance plans.

5. A maintenance engineer can use this system to monitor the time progress of contracts more easily and detect delays, for example, in contracts.
6. The tender evaluation process is normally very important since if the wrong contractor is chosen to carry out works, the results may be disappointing. This system helps in making the tender evaluation process fair and faster with well supported tender award recommendations.
7. The system also assists in monitoring both physical work and financial progress of contracts. This will enable maintenance engineers to closely manage contracts by knowing the extent to which physical work has been done and by how much. They will also know how much work has not been done and how much funds is left.
8. Generally this system reduces the amount of paper work required during the management of road works since all the information will be stored in the system. This reduces the cost of documentation.
9. The system also reduces the time required to do most of the works. Information can be stored in the system and retrieved very easily.
10. The system is flexible and can be used with any tender evaluation criteria set by a tender evaluation committee since the criteria changes from one contract to another and from one region to another.
11. The system can also be used with any tender document like labour based works and mechanised works which are usually different in activities and specifications.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions were made based on the findings of the study:-

1. Majority DREs do not carry out road inventory and condition survey. This means that roads data are not available in the districts for planning purposes. This implies that road maintenance works are not well planned and documented.
2. There are no clear road prioritisation guidelines in the districts from the Ministry of Roads/KRB leaving the DREs to use their own varied methods which often include the influence of the members of parliament (MPs). This means that prioritisation of roads for maintenance is not done in a standard way and professionally therefore funds for maintenance are not utilised in the expected way.
3. The method used currently for preparing road maintenance plans is not accurate and is prone to errors. This implies that the contract documents prepared by the DRE are not accurate leading to variation of quantities and contract sums once, work starts.
4. Majority of the DREs only consider financial competitiveness of contractors during tender evaluation of bids from contractors. This means that contractors who are not technically qualified can win contracts as long as they have the lowest bids. This leads to poor quality of works, delays among other problems.

5. The DREs do not have a clear way of measuring and monitoring time, physical work and financial progress of contracts. This implies that management practise is not efficiency.
6. The current management methods are manual, time consuming and involves a lot of paperwork. This means that efficiency is compromised.
7. The developed system is efficient as it:

a) Can reduce the amount of time required to manage road maintenance works for example, road inventory data once saved in the system can be used in all the other modules and is easily available.
b) Uses standard criteria with clear guidelines for all the road maintenance operations cycle.
c) Can reduce the amount of paperwork required since all information can be stored in the system, hence being economical.
d) Can reduce the personnel required for road maintenance management, hence of great help, given that there are insufficient personnel in the districts already.
e) Can reduce the chances of corruption since it uses clear criteria and is automated.
f) Is flexible and can be used with any prioritisation criteria, evaluation criteria and tender documents.
g) Can increase road maintenance management efficiency.

6.2 Recommendations

1. The Ministry of Roads, the new Kenya Rural Roads Authority and Kenya Roads Board should issue clear adequate guidelines in the various road maintenance operations and devise good methods of implementing them in order to improve maintenance management.
2. This system is recommended for adoption because of the inherent advantages over the current way of managing road maintenance.
3. This study considered only unpaved roads. Development of a paved road maintenance management system is recommended for future studies.

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APPENDICES

Appendix 1: Sample Modules Data Forms

Appendix 2: Research Questionnaire

Appendix 3: System Installation Guideline

Appendix 1: Sample Modules Data Forms

Appendix 2: Research Questionnaire

Appendix 2: Research Questionnaire

Part I – Respondents Characteristics

a) Please thick your gender? Male ☐ Female ☐

b) Please thick your highest level of education?

Postgraduate ☐ Degree ☐ Higher Diploma ☐

c) Which province is your district in?

Coast ☐ Central ☐ Western ☐ Rift Valley ☐

Nyanza ☐ Eastern ☐ North Eastern ☐

Part II – Road Maintenance Data

1. **i)** How often do you carry out road inventory and condition survey in your district?

Annually ☐ Not carrying out ☐

ii) Which methods do you use on road inventory and condition survey?

Using forms from KRB ☐

Using own methods ☐

Not been carrying out surveys ☐

iii)	What difficulties do you face on road inventory and condition survey?	Please thick
	Inadequate Funding	
	Inadequate Transport	
	Few Personnel	
	Inadequate Funding and Transport	
	Inadequate Funding and Personnel	
	Inadequate Funding, Transport and Personnel	
	Takes more time	
	Inadequate KRB forms/method	
	Involves a lot of paper work	

2. **i)** Are the funds allocated for road maintenance enough to meet the maintenance demands? Yes ☐ No ☐

   ii) Is there a particular road maintenance prioritisation criterion from the ministry or KRB? Yes ☐ No ☐

iii)	What road prioritization criteria do you use before embarking on the maintenance exercise	Please thick
	Own criteria	
	KRB guidelines	
	Ministry guidelines	
	MP's influence	

iv)	How frequent do you use these factors during road prioritization exercise? (Please thick)				
	Factor	Not used	Occasionally	Frequently	More frequently
	Technical factors				
	Socio-economic factors				
	All stakeholders priorities				
	MP's influence				

v)	As an engineer how would you grade (award marks) to the following factors in prioritization of roads for maintenance	
	Factor	Average Score (%)
	Technical factors	
	Socio-economic factors	
	All stakeholders priorities	

3. **i)** How do you carry out assessment of quantities for preparation of tender documents? (Please thick)

By filling in standard forms from ministry or KRB	
Using my own developed forms	
Other methods (Specify)_____	

ii)	What difficulties do you experience in assessment of quantities for preparation of tender documents from the method you use?	Please thick
	Time consuming	
	Involves a lot of paper work	
	Inaccurate	
	Time consuming & a lot of paper work	
	Inaccurate, time consuming & a lot of paperwork	
	Inadequate ministry/KRB method/forms	

4 i)	What factors do you consider when evaluating tenders?	Please thick
	Responsiveness to instructions to tenderers & financial competitiveness	
	Technical capabilities & financial competitiveness	
	Financial competitiveness	
	Technical, financial & responsiveness to instructions to tenders	

ii)	What problems do you experience with contractors who have been awarded contracts?	Please thick
	Poor quality of works	
	Delays in contract execution	
	Poor management of works	
	Poor quality & delays of works	

iii)	What do you think was omitted during the evaluation of bids that resulted in problems during execution of contracts?	Please thick
	Responsiveness to instructions to tenderers	
	Technical capabilities	
	Responsiveness to instruction & technical capabilities	

5 i) Is there a particular standard criterion from the ministry/KRB for monitoring time schedules of contracted works?

Yes ☐ No ☐

ii)	How do you keep and monitor time schedules of contracted maintenance road works?	Please thick
	Using forms	
	Using computers	
	Little effort on time and monitoring schedules	
	Using forms and computers	

iii)	What are the problems with the time schedule monitoring method you use?	Please thick
	Loss of information	
	Time consuming	
	Loss of information & time consuming	

6. i) Is there a particular standard criterion from the ministry/KRB for preparing payment certificates?

Yes ☐ No ☐

ii)	What difficulties do you face with preparation of payment certificates?	Please thick
	Time consuming	
	Errors encountered sometimes	
	Involves a lot of paperwork	
	A lot of paperwork & time consuming	
	Errors encountered, paperwork & time consuming	

7.i)	How do you monitor and report on the physical work and financial progress of road contracts?	Please thick
	Using standard forms from the ministry	
	Using own forms	
	None	

ii)	What difficulties do you experience with in the mode of monitoring and reporting physical work and financial progress you use?	Please thick
	Takes more time	
	Contract sums are exceeded sometimes	
	Leads to more work done sometimes	
	Inadequate documentation from KRB/ministry	

8.	In your view how effective is the road maintenance management system being used in the districts	Please thick
	Effective	
	Not sure	
	Ineffective	

9.	In your opinion what should be done to improve road maintenance in the districts?	Please thick
	Use of std methods/criteria	
	Use of computerized systems	
	More funds	
	Improve human resource	
	Use standard methods/criteria & more funding	

4. In your opinion what should be done to improve road maintenance in the districts? (Please thick)	
Use of std methods/criteria	
Use of computerized systems	
More funds	
Improve human resource	
Use standard methods/criteria & more funding	

Appendix 3: System Installation Guideline

Appendix 3: System Installation Guidelines

The system requires the following components:

- Microsoft SQL Server 2000 Edition
- An Installable version of the RMMS is provided.

1. First install MS SQL 2000 into your computer.
2. Using the installation package provided, double click to start the installation process
3. After installation create a desktop icon

Running the System

Double click on the icon of RMMS created in the programs menu. Enter the supplied password and click enter to login.

Suggested System Specifications

To attain the best performance while running the system, the following suggestions should be followed:

1. Have a screen resolution of at least 1024 by 768 pixels.
2. Memory: at least 256 MB of RAM
3. Processor: preferably 1.4 GHz or higher
4. Hard Disk space: at least 10GB.
5. Operating System: Windows XP