Long Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania

Task 1 Report: Review of existing trial sections

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Cover photo: Concrete strip trial section on Bago to Talawanda road in the Bagamoyo District, Tanzania

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Abstract

The Africa Community Access Programme (AFCAP) is providing funding for research and capacity building in Tanzania through the project: **Long-Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania.** The purpose of this project is to develop capability, through mentoring, on how to establish, carry out the monitoring surveys and evaluation of trial sections.

The project will provide technical assistance, primarily aimed at providing training to LoGITReC research staff, including technicians and engineers from President's Office-Regional Administration and Local Government (PO-RALG), on all aspects of Long-Term Pavement Performance (LTPP) assessment. However, other technicians and engineers from CML and TANROADS as well as academia, are to benefit from the project. The capacity building is to be achieved through an integrated approach using the review process of the two trial sections located on the Bago to Talawanda road in the Bagamoyo District and on the Lawate to Kibongoto road in the Siha District in Tanzania.

The in-service training to the LoGITReC research staff, in the monitoring, performance data collection, of the existing trial sections is to be conducted using the Regional Guideline for Establishing and Monitoring Trial Sections that will be revised as part of this assignment. As an outcome of the project, LoGITReC research staff and others in the roads sector and academia in Tanzania, should be capable of implementing Long-Term Pavement Performance programmes using the harmonised protocols/guidelines.

This Task 1 Report summarises the initial findings of the project team on the review of the two trial sections located on the Bago to Talawanda road in the Bagamoyo District and on the Lawate to Kibongoto road in the Siha District, in terms of the validation of available information, visual inspection on the condition of the sections and scoping of a training programme and implementation of capacity building. The findings and recommendations are to be presented to Road Research Steering Committee at a workshop to be arranged by PO-RALG.

The key findings can be summarised as follows:

- No structured database exists at PO-RALG for the demonstration sections. As a result, there is lack of centralised data and documentation storage, leading to problems in accessing information. This project is to assist in establishing information management system.

- Defects have been observed on some of the sections, in the form of cracks, both longitudinal and transverse cracks on concrete slab surfacing, moderate to severe side erosion between the gravel shoulder and the concrete strips along some of the concrete strip sections, loosening of stones on the hand-packed stone section, severe and extensive erosion tracks on engineered gravel section, but isolated locations and occurrence of sedimentation build up in drains.

- The lack of proper maintenance programme is the likely contributing factor to observed poor performance of some of the road sections. However, the state of road sections on the Siha site show that they are being maintained when compared to the Bagamoyo site, where there were more areas with deterioration.

- Connected to the above, there seems to have been a lack of proper hand over of project documentation as well as documentation between the consultant, contractor and PMO-RALG (Po-RALG) involved in the project at the time.

- The quality of the available information can be categorised in two parts. The data based on the monitoring prior to 2014 is provided in summary form in reports and is considered reliable, while data after 2014 is considered uncertain as no analysis was conducted and is substantially incomplete. The quality and extent of available data is critical for effective back analysis on the performance of the trial sections.

The following are key recommendations:

- LoGITReC to enhance coordination and management of information on the two demonstration sites. LoGITReC should ensure that all historic data from the monitoring of the trial sections is collected and centralised storage is established.

- Key to overcoming some of the observed defects is a need to optimise maintenance programmes to ensure that the benefits of the established demonstration sites are not undermined. To this end, clarity is also required on the roles and responsibilities between LoGITReC and the District Engineer's offices in Siha and Bagamoyo, in terms of managing the monitoring of the sections in the future. Based on the outcomes of the optimised maintenance programme, similar protocols can be established for use by District Engineers across the country.

- Based on in-service performance in the last five years the following surfacing options are considered more cost-effective and are thus recommended for adoption in similar environments. (i) lightly reinforced concrete slabs for steep slope sections, (ii) concrete strip sections on flat and rolling terrains, but proper maintenance of the gravel in the centre and shoulders is essential and (iii) concrete paving blocks in areas where there are frequent, heavy turning vehicles.

Key words

Low volume roads, long-term monitoring, pavement performance, demonstration section.

AFRICA COMMUNITY ACCESS PARTNERSHIP (AFCAP)

Safe and sustainable transport for rural communities

AFCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa. The AFCAP partnership supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. AFCAP is brought together with the Asia Community Access Partnership (AsCAP) under the Research for Community Access Partnership (ReCAP), managed by Cardno Emerging Markets (UK) Ltd.

See www.AFCAP.org

Acronyms

AFCAP	:	Africa Community Access Partnership
CSIR	:	Council for Scientific and Industrial Research
DFID	:	Department for International Development (UK)
LGA	:	Local Government Authority
LoGITReC	:	Local Government Infrastructure and Transportation Research Centre
LTPP	:	Long-term pavement performance
PO-RALG	:	President's Office, Regional Administration and Local Government
ReCAP	:	Research for Community Access Partnership
SEACAP	:	South East Asia Community Access Programme
TPMDM	:	Tanzanian Pavement and Materials Design Manual

Contents

1 Introduction

1.1 Background

The Africa Community Access Programme (AFCAP) through the UK Department for International Development (DFID) supported the request by the President's Office Regional Administration and Local Government (PO-RALG) to assist with the implementation of demonstration sites in two districts in Tanzania. The request was in line with AFCAP project initiatives in sub-Saharan Africa that seek to improve sustainable access to economic and social opportunities for poor rural communities, and to provide all weather access on rural roads using low cost solutions and locally available materials. The two demonstration sites are located on the Bago to Talawanda road in the Bagamoyo District (about 20.3 km in length) and on the Lawate to Kibongoto road in the Siha District (about 13 km in length). The Bago - Talawanda road represents areas along the coast, black cotton soils, flat terrains with slopes between 0% and 6%, and moderate climatic zone with less than three months high annual rainfall. The Lawate - Kibong'oto road represents areas with steep gradients of up to 30%, slippery, volcanic soils, wet climatic zone with more than three months high annual rainfall.

The designs for the sections at Bagamoyo were based on the Tanzanian Pavement and Materials Design Manual (TPMDM), with modifications made to obtain an environmentally optimised design that is suitable for low-volume roads. On the hand, the designs at Siha were based on the Dynamic Cone Penetrometer (DCP-DN) method in order to fully utilise the in situ subgrade strength and allow designs that only have one pavement layer below the surfacing.

All demonstration sections on the Bago and Talawanda road, but the concrete geocells were completed by September 2011; these were then monitored in September/October 2011. The concrete geocells were completed in January 2012 and first monitored in February 2012, with subsequent monitoring visits carried out in April 2012, September 2012 and April 2013. The construction of sections at Siha began in March 2012 and was completed in September 2012. The baseline data for this section were collected in January 2013, with one monitoring visit carried out in April 2013. Monitoring activities were carried out for four years on Bago - Talawanda road and three years on Lawate - Kibongoto road, with an ultimate goal of gathering information that can be used to assess the performance of the pavement options, local materials (for both pavement and surfacing) and design & construction methods for low-volume roads in Tanzania.

A need has been recognised, for a systematic evaluation of the trial sections, including the methods for collecting data and quality of monitoring data, compared to standard protocol requirements. Thus the main objective is to carry out a review of the trial sections from the two sites, refine and implement the existing regional protocols for establishment and monitoring of road trial sections, and to ensure that data collected from demonstration sections are consistent with regional protocols. An important aspect of the project is to incorporate structured capacity building in order to enhance road research capacity within LoGITReC in Tanzania, as well as providing training to district engineers and technicians from the local government.

This report presents the outcomes of Task 1 activities of the project, i.e. extensive review of existing trial sections information and the assessment of training needs to develop scoping of a training programme and implementation of capacity building.

1.2 Project scope

The scope of works for the current project was detailed in the Inception Report submitted to Cardno in March 2017.

1.3 Objective of this Report

The objective of this report is to present

- the findings of the review of the analysis of available information and data on the two trial sections, including recommendations on data storage.
- the observations made from coarse site inspection, and
- a plan for capacity building as well as recommendations for presentation to Roads Research Steering Committee.

1.4 Key tasks carried out

The key tasks undertaken by the project team during the in-country visit included meetings with the respective District Engineers in Bagamoyo and Siha, coarse site inspection and documentation review to establish extent, quality of available information, including location of historic data.

The discussions held in the course of the meetings, assisted the project team to:

- Understand the administrative arrangements during the execution of the project;
- Identify how the monitoring was undertaken and who was involved;
- Identify main constraints facing the respective District Engineer's offices to implement effective maintenance programmes, which are likely to impact on performance of the trial sections and therefore the future of the project;
- Finalise the targeted training programme.

2 Information compilation and synthesis of current practice

The project team conducted a review of technical reports and accessible guidelines from both international and regional sources to provide the guidance on assessing adequacy and extent of existing information on the establishment and monitoring of demonstration sections. The review was therefore to include the available documents, such as materials testing records, site meetings records, monitoring method reports, contract documents for routine maintenance of the sections and any failure investigation reports. A number of project reports were further to be identified on the basis of the information gathered during the course of the deliberations. The review provided the background information about current practices and recent developments that have taken place related to AFCAP projects.

This activity was carried out on the basis of information provided by the respective District Engineers and CML on the construction of the demonstration sections. The information was particularly important because it gave the project team some insight into what had transpired during construction of the two sites. A fact-finding study was conducted by the project team to assess the current status of the trial sections. Relevant information and documentation on the trial sections were sourced and reviewed. The information that was made available was further reviewed to establish methodology followed, as well as improvements required for similar projects in the future.

The key aspects that were considered during the information compilation phase, include relevant information on design, construction and performance and methods of monitoring. Under this project, the pavement sections are represented by several combinations of surfacing: concrete paving blocks, concrete slab, flexible geotextile, concrete strips, double surface dressing, bituminous penetration macadam and gravel wearing course. The project team acquired the documentation on the methods used by the service provider that monitored the demonstration sections in Bagamoyo and Siha.

The team has collected international guidelines on establishment and monitoring of experimental sections, including the draft Guideline for the monitoring of experimental and LTPP Sections in Mozambique, recently prepared under an AFCAP supported project, made available by the Team Leader's Delegate, Mr Nkululeko Leta. The review of relevant guidelines is on-going. Verification of as-built data as well as collected performance data is to be undertaken to evaluate information consistency.

The following documents from sub-Saharan Africa countries (Tanzania, Malawi, Botswana and South Africa), the USA, Asia were reviewed to derive information relevant to the project. These documents include best practices and design standards that are based on extensive research work from these countries.

- **Design and construction of demonstration sites for district road improvement in Tanzania, Final Report, 2013**

  This report summarises all project activities including the selection of demonstration sites and the design, construction and monitoring of the demonstration sections. Following completion of construction works at Bagamoyo and Siha sites, baseline monitoring data were collected and compared with data collected in subsequent monitoring periods in order to assess the performance and suitability of the surfacing options. Construction costs and whole life costs have been described and quantified in this report. The report presents an assessment of the staff from the Central Materials Laboratory and the respective District Engineer's offices, who participated in the monitoring work to indicate their ability to continue the monitoring work following completion of the Consultant's services. It was concluded that the staff were fully capable of the monitoring work following their continued participation. The report also indicated that further monitoring and analysis is expected to be undertaken over a period of eight years.

- **Research consultant to support the design, construction and monitoring of demonstration sites for district road improvements in Tanzania, Quarterly Report during the Monitoring Phase, April 2012.**

  This report details the findings from the data collection carried out on the Bagamoyo and Siha demonstration sections in April 2012, 6 months after construction had been completed. The methods of monitoring the demonstration sections are as follows:

  - Visual inspection;
  - Photographic logging;
  - Surface profile measurement between beacons;
  - Surface rut measurement using a standard straight edge;
  - Surface roughness using a MERLIN apparatus;
  - Surface texture measurement using sand patch testing;
  - Dynamic Cone Penetrometer (DCP) testing;
  - Classified traffic counts;
  - GPS Monitoring;

  The report indicated that three further monitoring stages were to be carried out by the consultant, culminating in October 2013.

- **Back analysis of previous constructed low volume roads in Mozambique, AFCAP/MOZ/001/G, Final Report, CPR1612, June 2013**.

  The report provides information on the activities carried out and the data collected during the execution of the project. The report provides results of the analysis and the recommendations and conclusions from the results of the analysis. The project was aimed at evaluating the performance of low volume roads constructed 10 years ago and earlier. The criteria used for the selection of the study sections included the road classification, traffic levels, age of road, construction type, current pavement condition and the local knowledge and expertise of the staff from the National Roads Administration of Mozambique (ANE). Twenty-one sections on eight roads in six provinces were selected for the study. Activities and the reconnaissance surveys that were carried out in the project are presented. The report gives a detailed account of the field surveys particularly data collected from the measurements carried out in the field and the materials tests results.

- **Malawi Low Volume Roads Study: An investigation into the use of Laterite instead of crushed stone or stabilised material as a base course for bituminous surfaced roads. Report by Scott Wilson Kirkpatrick & Partners/Henry Grace & partners and Imperial College of Science and Technology, UK. December 1988**

The objective of the investigation was to ascertain if plastic laterite could be used successfully in place of crushed stone or stabilised material as base course for low volume roads beneath a thin bituminous surface. The report discusses the results of a one kilometre trial section that was part of a 51 km road in the Vipya highlands of Northern Province during 1984 and 1985. The report concluded that after five years of trafficking the trial length of pavement had performed as effectively as the adjacent lengths with crushed stone. The study confirms similar experience in Kenya, and concluded that with appropriate construction techniques lateritic gravels can be used as a cost-effective base/subbase for low volume road with bituminous surfaced pavements.

- **Analysis of Pavement Monitoring Sections in Botswana. InfraAfrica (Pty) Ltd. /CSIR, January 2010**

  One of the main objectives of the project was to provide data required for the revision of Botswana Roads Design Manual with regard to the design and specification of low volume roads. Marginal materials were successfully used for construction. Good drainage and high standards of construction were considered to be contributory factors to good performance. It was reported that majority of the low volume surface roads with traffic level of 3 million E80soutperformed their expected performances.

- **Low Volume Rural Road Surfacing and Pavements. A Guide to Good Practice (Cook et al, 2013)**

  This Guideline is aimed at engineers, road managers and others involved with the planning, design, construction or maintenance of low volume roads in developing and in temperate regions. It is intended to provide key knowledge and guidance on a range of proven road surfacing and paving techniques that offer relatively low cost and sustainable solutions for road works, focusing on the optimal use of local resources, in often challenging physical and operational environments. This guideline would strongly be beneficial to this project. The Guideline compiles vital information on lessons learnt from the design, construction, supervision and monitoring of a range of surface and paving types trialled and investigated in the Cambodia, Laos and Vietnam SEACAP projects. There is therefore, a wealth of information that will benefit this project.

- **Design Manual for Low Volume Sealed Roads, Malawi Ministry of Transport and Public Works (2013)**

  The Manual serves as a standard reference and source of good practice for the design and construction of low volume sealed roads in Malawi. The aim of the Manual is to provide all practitioners with comprehensive guidance on the wide range of factors that need to be addressed in a holistic manner when undertaking the upgrading of unpaved roads to a paved standard. This manual contains guidelines in design and construction, and would serve as one of the important documents to benefit this project.

- **Low Volume Roads Manual, Tanzania Ministry of Works, Transport and Communication (2016)**

  The Manual draws on the outputs of a number of research projects that have been carried out in Tanzania since the 1990s. The findings provide performance-based information on low volume roads in Tanzania. In particular, this manual is a recent document that builds on similar manuals developed in other sub-Saharan African countries over the years.

- **Labour enhanced construction for bituminous surfacings, Southern African Bitumen Association (Sabita Manual 11, 1993)**

  The purpose was to provide a manual, which will give recommendations on bituminous surfacings suitable for labour enhanced construction, and to guide and advise the practitioner who may be getting involved with this for the first time. The manual covers the choice of bituminous surfacings for labour enhanced construction, with information on the limitations of the construction technique to be used. It also includes criteria for, choosing the surfacing to suit objectives of job creation, maximisation of labour, and skills transfer.

- **Appropriate bituminous surfacings for low volume roads and temporary deviation, Southern African Bitumen Association (Sabita Manual 10, 2011)**

  This Manual provides a guideline for both the surfacing and the maintenance of low volume roads, and addresses issues related to all-weather access to rural and urban communities. The main focus of the Manual is to provide information for the upgrading and maintenance of low volume surfaced roads and to guide practitioners in the selection of an appropriate bituminous surfacing for different conditions.

- **A Guideline for the establishment and monitoring of sections on the road network to measure Long Term Pavement Performance (LTPP), July 2014**

  The main objective of this document is to provide a guideline for the establishment of experimental sections constructed on the road network as part of research-related initiatives, and monitoring of the Long Term Pavement Performance (LTPP). The document may also be used for short-term monitoring of research sections set-up for certain specific objectives. Examples of typical forms used for logging the information collected on site are given in the appendices to this report. However, it should be noted that the layout of the forms and the format of the data collected for similar measurements can differ between countries.

- **Comparison of the US and Australian Long Term Pavement Performance (LTPP) Data on Asphalt Pavements, February 2009.**

  This report focused on identification of the test sites in the US-LTPP program that were similar to Australian LTPP test sites for a comparison of their estimated performance in terms of roughness, rutting and structural linear deterioration rates. The performance of asphalt concrete on a granular base and asphalt concrete on a bound base were compared. These pavements were located in comparable climates. Twenty-four test sections of the Australian LTPP program and 108 section of the US-LTPP were selected for the comparison. The comparison showed that in the asphalt concrete on a granular base group the US sections had similar roughness and structural deterioration rates to those of Australian sections, but slightly lower rates of rutting deterioration. However, for the asphalt concrete on a bound base group, the deterioration rate comparisons of the Australian and US sections was much closer for all performance parameters except the mid-lane (between wheel paths) deflection (structural deterioration), indicating that further analysis should be carried for these pavement groups in the future. The findings provided some indication of the comparison of the performance between the two LTPP programs and demonstrated a viable approach to further analysis, as well as giving an overview of the data available for future comparisons.

- **Guideline for the Monitoring of Experimental and LTPP Sections in Mozambique. (First Draft) Project Reference: MOZ2093A. January 2016.**

This is a draft guideline that summarises the background to planning appropriate experimental sections and then monitoring them to ensure that the maximum benefit is obtained. The scope of the report covers the optimal experimental design requirements and the types and uses of various monitoring techniques. Among other things, the guideline discussed standardisation of testing and evaluation procedures and equipment to ensure monitoring consistency, ability to obtain consistent data from the monitoring of pavements over the long term, and procedures to obtain practical data for the development of improved standards and specifications based on the outcomes of monitoring.

- **Long-Term Pavement Performance Inventory Data Collection Guide. Publication No.: FHWA-HRT-06-066. March 2006;**

  The primary purpose for this guideline is to provide a uniform basis for data collection during long-term monitoring of the performance of pavement test sections constructed under an LTPP programme. The guideline provides details on how to identify the test section, describe the geometric details of its construction and the material properties of its structural constituents, and identify construction costs and costs of subsequent maintenance and repair before the long-term monitoring effort. This document provides data sheets and instructions to collect inventory data for the LTPP program. The inventory data sheets have been taken from the original long-term monitoring data collection guide and modified to reflect evolution in planning for long-term monitoring of pavements. This was done partially to maintain some consistency with the long-term monitoring pilot study databases, but primarily to take advantage of the work already accomplished for the Federal Highway Administration (FHWA) during the long-term monitoring studies.

- **Low Volume Rural Road Surfacing and Pavements: A Guide to Good Practice, June 2013;**

  This Guideline compiles the lessons learnt from the design, construction, supervision and monitoring of a range of surface and paving types demonstrated and monitored in the Cambodia, Laos and Vietnam SEACAP projects, together with the knowledge compiled in the SADC Guideline, and other relevant programmes such as the ongoing AFCAP research. Its scope ranges from engineered natural surfaces (earth roads), through gravel to the various unbound, natural stone, bituminous, cement-based and clay brick surfacing and pavement layers.

- **Recommendations on the use of marginal base course materials in low volume roads in South Africa. South Africa Dept. of Transport. Research Report RR 91/201. November 1996**

  This report highlights an investigation into the performance of 57 sections of roads that were constructed using marginal quality base course materials. The study showed that current material standards are generally too high for low volume roads and emphasised that good drainage and construction quality are the primary requisites for good performance of low volume roads.

The documents reviewed provide relevant and well-documented information on low-volume roads. These reports present approach towards the use of locally available materials for low-volume road construction, construction techniques, as well as appropriate design standards based on extensive research carried out in the respective countries, over a number of years. In addition, studies presented in these reports involve construction/as-built data, monitoring and back-analysis, which will add value to the review process of the draft Guideline for the monitoring of experimental and LTPP Sections.

The following reports on the project were accessible from the AFCAP website (*www.research4cap.org*):

- Inception Report/ Site Selection (November 2009)
- Final Design Report Phase 1 and 2 - Bagamoyo and Siha (November 2010)
- Demonstration sites along the Bago - Talawanda Road - Quarterly Reports
- Demonstration sites along the Lawate – Kibongoto Road - Quarterly Reports
- Final Construction Report Phase 1 - Bagamoyo (August 2011)
- Final Construction Report Phase 2 – Siha (September 2012)
- Design, Construction and Monitoring of Demonstration Sites for District Road
- Improvements - Sociology Report (May 2012)
- Workshop Report – Bagamoyo and Siha (May 2013)
- Final Performance Monitoring Reports – Bagamoyo and Siha (June 2013)
- Final Report (October 2013)

3 Desk top study on historic data

3.1 Data collection

All available data were examined to evaluate the historic data and further inform appropriate variables to be captured. The purpose is to enhance the list of appropriate variables to be considered in the database schema and linked to the regional database development project. It was expected that analysis of these data could provide the research team with a better understanding of data collection methods used and also assist in decision-making on whether all existing sections should be included as candidates for further monitoring.

It is important that the PO-RALG is aware of future data collection requirements and the specific parameters required for design, construction and monitoring. To ensure that all data from the two sites were well documented, the project team developed tables for PO-RALG to complete for assessment. The contents of the tables in terms of available data are as follows:

Pavement Design Reports

1. Draft design report
2. Final design report

As-Built Reports

1. As-built materials test results
2. Design data for surfacing types
   - Structural (pavement) designs
   - Asphalt mix designs
   - Surface seals
   - Concrete mix designs

- Stabilisation designs

3. Drainage
4. Climate

<u>Construction and maintenance data</u>

- Contract documents
- Progress reports
- Final contract report
- Photo record (construction process)
- Traffic data including loading
- Climate
- Maintenance (Reports)

<u>Monitoring and Investigation</u>

- Visuals (riding quality, potholes, cracks, rutting, etc.) – Reports
- Drainage evaluation
- Rut depth measurements
- Cracking measurements
- Density/moisture
- DCP tests
- Gravel loss
- Roughness
- Test pits, sampling, Lab testing

Appendix A shows individual tables and the responses received from respective District Engineer's offices, in a form of a tick (√) to indicate availability of a particular data. The responses in the tables show that majority of the data were not documented or collected. At the time of reporting, data/reports for most of the ticked boxes could not be verified as they were not made available to the project team.

3.2 Demonstration sections

The demonstration sites were monitored based on the following methods:

- Visual inspection
- Photographic logging
- Surface profile measurement between beacons
- Surface rut measurement using a standard straight edge
- Surface roughness using a MERLIN apparatus
- Surface texture measurement using sand patch testing
- Dynamic Cone Penetrometer (DCP) testing
- Classified traffic counts
- GPS Monitoring

It is reported that data collection was referenced to the same point during the monitoring phases by installing beacons at regular intervals along the demonstration sites. The locations of the beacons will have to be re-established during the next monitoring exercise. Project reports show that the data collection frequency was at 6 month intervals, with the exception of DCP testing and GPS monitoring, which were done yearly. According to the original contract with AFCAP, the consultant was required to monitor the demonstration sections for one year following construction completion in April 2013. However, it is reported that an additional year of monitoring was carried out by the consultant following an extension to the original contract. PO-RALG was therefore, expected to monitor the sections and collect data for analysis in the following eight years. Thus, monitoring was to continue for a period of ten years following construction completion date. It was expected that throughout the various monitoring stages engineers and technicians from the two Districts (Bagamoyo and Siha) were to assist with the data collection and analysis thereby developing skills in carrying out the monitoring. In addition, postgraduate master's degree students from the University of Dar es Salaam were to assist in the field work, and use the data to obtain their degrees.

PO-RALG and TANROADS-CML, with the involvement of District engineers, have carried out one additional monitoring visit to both demonstration sites. The raw data for 2013 monitoring of the Siha demonstration site has been made available. However, the latest set of performance data has not yet been analysed. Due to the fact that only partial data of the last monitoring has been made available to the project team, it has categorised the data, from quality point of view, as uncertain.

3.2.1 Bagamoyo site

The Bagamoyo demonstration site is located on the road from Bago to Talawanda. The terrain is rolling in nature with a number of steep sections. Mostly, small villages and farming community can be identified with this road. The road is a sandy earth road and the subgrade varies along the course of the road. The road has sections of black cotton soil, sand, silt and clay. The road has poor drainage and has no culverts, drifts or ditches. The only drainage structures on the road are an old arch bridge and a recently constructed concrete bridge near Talawanda. Bagamoyo has a humid climate and relatively stable temperatures, both in terms of night-day, and summer-to-winter. The driest and coolest season is June through early October. Short rains occur from November through February, and long rains occur March through May, peaking in April. Temperatures are high from November to May and at their highest in January.

A review of the project reports revealed that the initial design called for a carriageway width of 3.5 m, with a 1 m gravel shoulder. However, due to budget constraints, it was agreed by the Consultant, the District Engineers, PMO-RALG and Technical Manager for AFCAP that for the project in Bagamoyo, the carriageway width would be reduced to 3.0 m with a 1.0 m gravel shoulder with passing bays at regular intervals.

The design approach, depending on the type of surfacing for the different sections, was based on either the experience gained from other projects under South East Asia Community Access Programme (SEACAP) or the Tanzanian Pavement and Materials Design Manual (TPMDM). The pavement designs, according to TPMDM, are determined through a combination of subgrade assessment (in terms of CBR) and standard traffic categories, which are defined in mesa. For the Bagamoyo site, pavement designs for all bituminous sections were carried out in accordance with the TPMDM. The designs for concrete sections were largely based on SEACAP experience, whilst the concrete geocells, which were provided by Hyson in South Africa, were designed in accordance with design guidance and specifications provided by Hyson. The designs for hand-packed stone were based on SEACAP experience by the consultant, whilst the concrete paving block surfaces were designed in accordance with the South Africa Segmental Block Pavement Manual. A list of the demonstration sections constructed in Bagamoyo is given in Table 1.

Table 1: **Constructed Sections in Bagamoyo**

Demo Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
1	0.030	0.230	0.200	Single Otta seal with a sand seal (26 mm)
2	5.340	5.520	0.180	Hand packed stone (150 mm)
3	5.560	6.080	0.520	Concrete strips (100 mm - Reinforced)
4	6.080	6.740	0.660	Geocells (75 mm)
5	8.000	8.240	0.240	Double surface dressing (20 mm)
6	9.980	10.670	0.690	Concrete strips (100 mm - Unreinforced)
7	11.200	11.400	0.200	Double sand seal (20 mm)
8	12.200	12.580	0.380	Gravel wearing course
9	16.240	17.100	0.860	Concrete strips (100 mm - Reinforced)
10	18.480	18.740	0.260	Concrete strips (100 mm - Reinforced)
11	19.000	19.200	0.200	Gravel wearing course
12	20.040	20.260	0.220	Slurry Seal (8 mm)

3.2.2 Siha site

The Siha demonstration site is located on the road from Lawate to Kibongoto. The road has a subgrade consisting of brown/red silt for the first 2.5 km. This material has been mixed, scarified and compacted with some local volcanic gravels and acts as a very good gravel wearing course. The gravel wearing course extends to km 3+500. In comparison with the Bagamoyo site, this road has high level of traffic especially during market days. The majority of the road stretch has a clayey red soil as an in-situ material. This road has a lot of steep hilly sections and is a typical rural road passing through agricultural landscape. The highest rainfall occurs between mid-March and early May, and slightly less between the beginning of November and late December. Maximum rainfall occurs in the forest belt and on the south side of the mountain where it reaches 2000 mm per year. Temperatures are generally mild. The rainfall pattern for this site is similar to the Bagamoyo site.

As was the case with the Bagamoyo site, the initial proposed design for a carriageway width of 3.5 m, with a 1 m gravel shoulder as set out in the TPMDM, was also not implemented. It was agreed by all parties on the project that for the project in Siha, the carriageway width would be reduced to 3.1 m for the first 3.0 km of the road, due to the fact that the traffic along this road, at the time of initial investigation, tended to reduce after km 2.5, the road width was not widened and the existing width was kept.

The pavement designs for bituminous sections were initially based on the TPMDM. However, these sections were re-designed in accordance with the Malawi LVSR Manual. The manual is based on the DCP-DN Design Method, as opposed to the TPMDM or any other CBR Catalogues based methods. The designs are based on a combination of design traffic loading and the maximum penetration rates (DN values) for each in-situ layer. A DCP survey is undertaken along the road and assessed in accordance with the procedure set out in the DCP Pavement Design Method. The designs for concrete pavements, geocells and segmental block surfaces were identical to those used in Bagamoyo.

A list of the demonstration sections constructed in Bagamoyo is given in Table 2. However, the as-built data was not available. During the discussion on completion of the data forms provided in Appendix, it was pointed out by Mr Victor Kimaro, that the contractor did not provide any information in this regard, in-spite of the fact that a request was made during construction.

Table 2: **Constructed Sections in Siha**

Demo Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
1	0.000	0.200	0.200	Concrete paving blocks
2	1.360	1.500	0.140	Unreinforced concrete slab (100mm)
3	1.960	2.180	0.220	Flexible geocells (75mm)
4	2.180	2.580	0.400	Unreinforced concrete slab (75mm)
5	2.580	2.780	0.200	Gravel wearing course
6	2.780	3.640	0.860	Concrete strips
7	4.340	4.540	0.200	Double surface dressing
8	4.540	4.780	0.240	Concrete strips
9	4.780	5.000	0.220	Unreinforced concrete slab (100mm)
10	5.000	6.100	1.100	Concrete strips
11	6.340	6.620	0.280	Unreinforced concrete (100mm)
12	7.720	8.260	0.540	Concrete strips
13	9.670	9.900	0.230	Unreinforced concrete (75mm)
14	10.100	10.300	0.200	Concrete strips
15	10.680	11.200	0.520	Concrete strips
16	11.620	11.820	0.200	Bituminous penetration macadam
17	11.820	12.120	0.300	Lightly reinforced concrete slab (100mm)
18	12.280	12.560	0.280	Lightly reinforced concrete slab (75mm)
19	12.640	13.070	0.430	Lightly reinforced concrete slab (100mm)
20	13.070	13.480	0.410	Gravel wearing course

3.3 Data analysis

The aim of this section is to analyse the existing data based on the available information from the two demonstration sites. However, very limited data are available for analysis. The following sub-sections present surface roughness and rutting measurements data from the baseline study to monitoring period up to April 2014.

3.3.1 Surface roughness – Bagamoyo site

Figure 1 shows minimal increases and decreases in the IRI values during the monitoring periods. The results show the Otta seal is generally the smoothest surfacing of all demonstration sections. Significant increases in IRI values were obtained for the hand packed stone (Demo Section 2) and the gravel wearing course (Demo Section 8). These high values are indication of excessive roughness on these demonstration sections. The IRI values for the Otta seal (Demo section 1) decreased between April 2013 and April 2014.

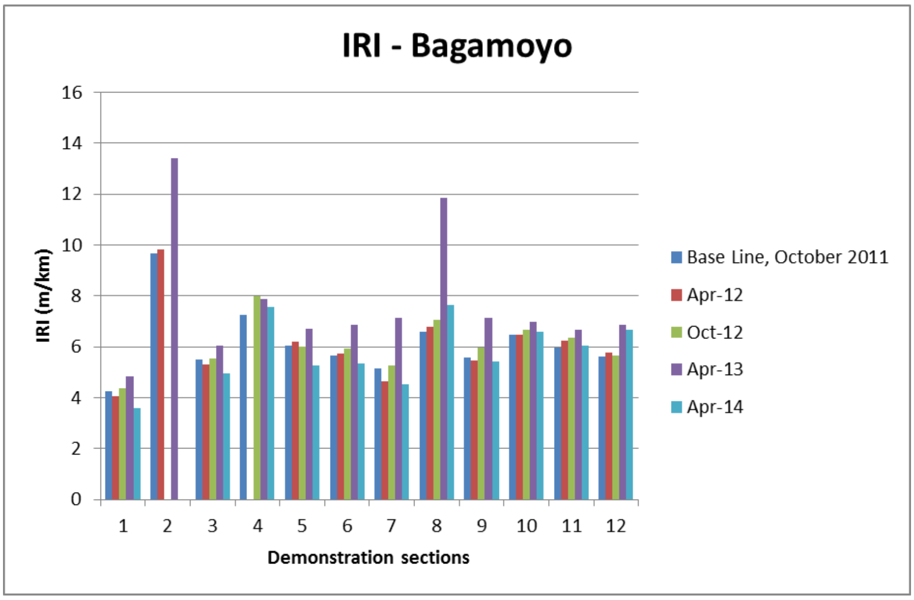

Figure 1: Average Rut Depths at Bagamoyo

3.3.2 Rut depth- Bagamoyo site

Rut depth measurements were undertaken in the bituminous surfacing sections. Figure 2 shows the rut depth results from the baseline study to April 2014. Generally, the average rut depths increased throughout the monitoring stages. The highest increase occurred in the slurry seal, whereas the lowest occurred in the Otta seal. The consistently gradual increases in rut depth suggest that the underlying road base layers are intact.

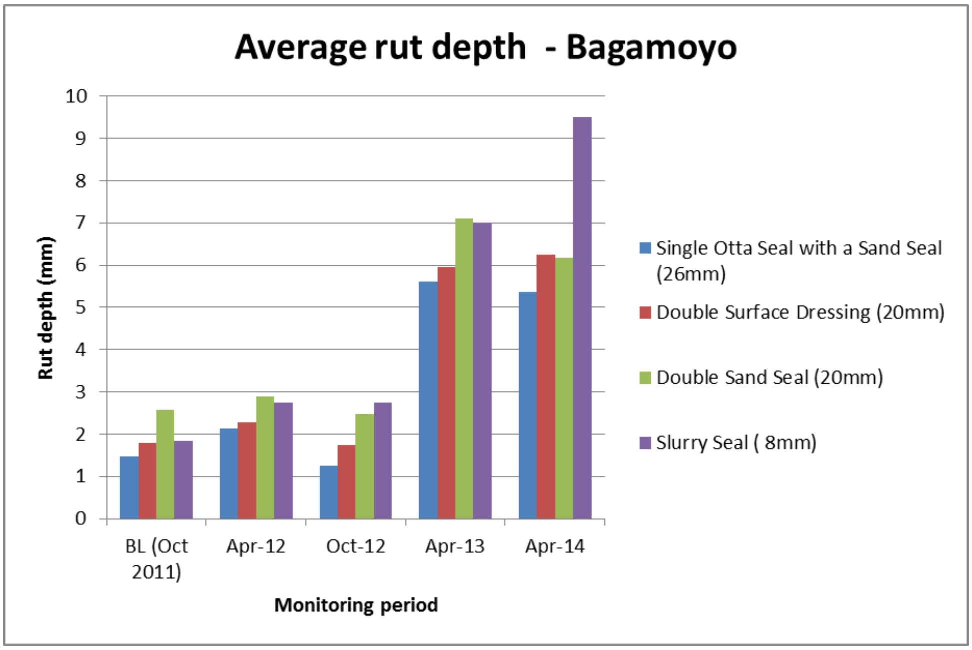

Figure 2: Average Rut Depths at Bagamoyo

3.3.3 Surface roughness – Siha

Figure 3 shows that that the IRI value increased on all sections between the baseline monitoring in January 2013 and the monitoring in April 2013. There was a small increase in IRI values for the gravel wearing course (Demo section 5) from April 2013 to April 2014. On the contrary, the IRI values for the concrete paving blocks (Demo section 1), double surface dressing (Demo section 7), bituminous penetration macadam (Demo section 16) and second gravel wearing course (Demo section 20) decreased by a small amount.

As expected, the concrete sections are much rougher than all other sections, whereas the double surface dressing and concrete paving blocks are considerably smoother. There is significant unevenness in the surfaces of the concrete slabs, which is the main cause of the high IRI values on these sections. The high IRI value of the penetration macadam section is attributed to some unevenness in the surface.

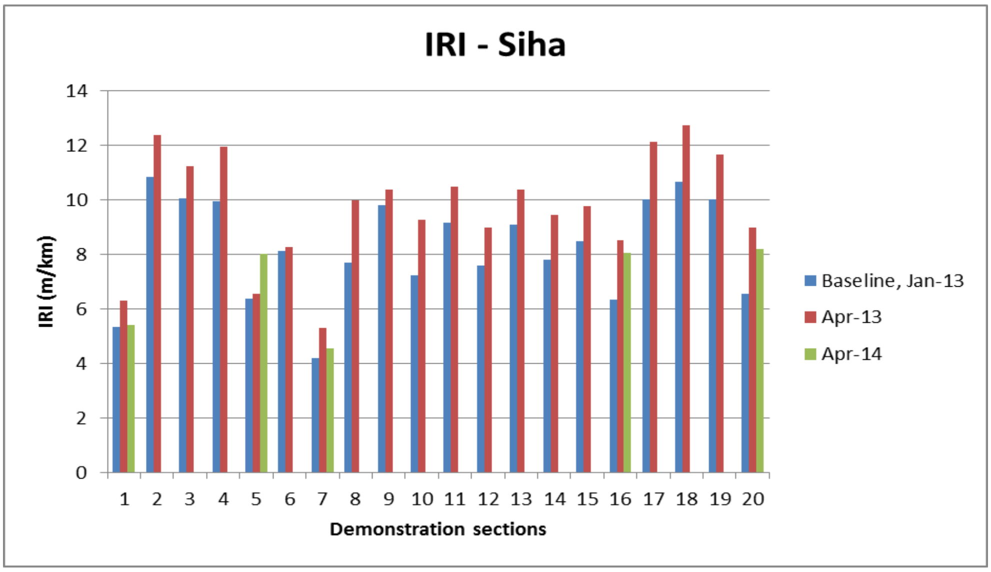

Figure 3: Average Rut Depths at Bagamoyo

3.3.4 Rut depth – Siha

Rut depth measurements in Siha site were carried out on the double surfacing and bituminous penetration macadam surfacings. Figure 4 shows the average rut depths for the two sites during the baseline study, April 2013 and April 2014. Similar to the Bagamoyo sites, there is a steady increase in the average rut depth on both sections. The highest rut depth values were recorded on the penetration macadam section.

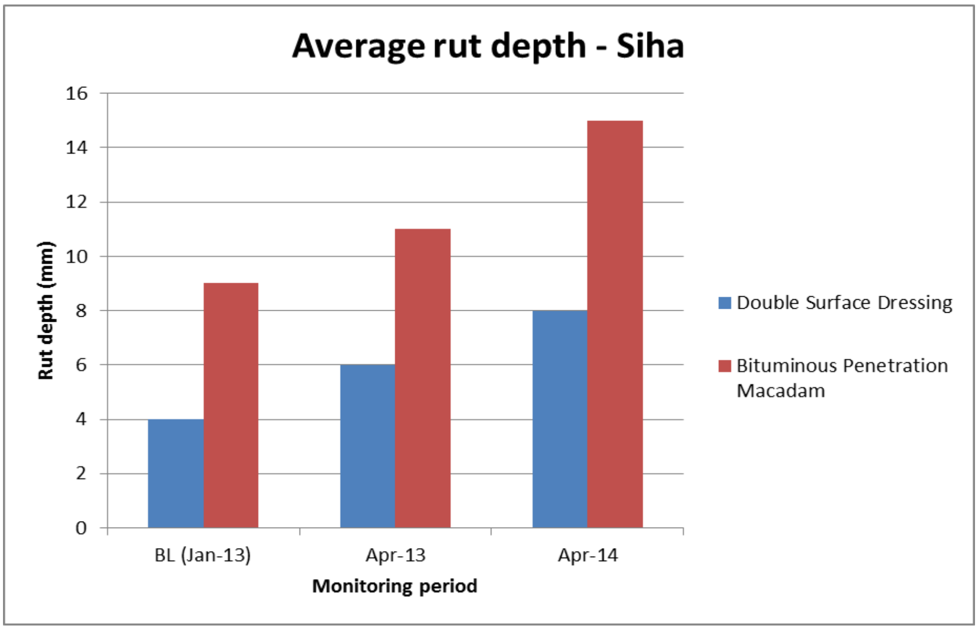

Figure 4: Average Rut Depths at Bagamoyo

4 Performance of Pavement Sections

4.1 General observation and comments

A trip was undertaken by the project team from 19-22 April 2017 to the two sites to evaluate the current state of the surfacings options of the demonstration sites. The team was accompanied by researchers/engineers and technicians from LoGITReC and the District Engineer's offices.

The following is the summary of the observations made from both sites:

- Some demonstration sections have performed well, in particular the concrete paving blocks and concrete strips at Siha site. Concrete paving blocks have been seen to perform exceptionally well at Lawate Market, and this pavement type is particularly well suited to areas where there are frequent, heavy turning vehicles.
- The reinforced concrete slab sections in Siha have also performed well, however the unreinforced concrete slab sections exhibit extensive cracking.
- In Siha, only double seal and penetration macadam were built. These two bituminous surfacing options performed reasonably well in Siha.
- The engineered earth and gravel sections. The performance of the gravel and engineered earth surface could be much better if side drains were kept functional. Routine drainage maintenance before the wet season could assist in ensuring better performance of the sections.
- The hand packed stone surfacing at Bagamoyo has not worked as expected, and requires regular maintenance. The stones have not provided a surface that motorcycles and small vehicles can comfortably drive over as there is severe erosion between hand packed stone with some stones completely dislodged, resulting in increased roughness causing motorists to avoid the section.
- At the Bagamoyo site, geocell pavements have failed with cracks and depressions across significant areas of the sections. This is contrary to earlier assertion that the geocell sections were performing well as a result of their flexibility to prevent crack formations similar to the concrete blocks. However, the geocell sections in Siha have been

performing well, as observed during the last visit. It is noted that the geocell sections in Siha were constructed after those at Bagamoyo, with the same technicians involved in Siha which may explain the better performance as some experience had been gained on construction methodology of the relatively new surfacing type. It is recognised that geocell pavements are new to Tanzania and it is essential that sufficient knowledge and training is provided to contractors prior to the construction.

- The cracking that has occurred in the unreinforced slabs at Siha has not occurred in the concrete strips, and it is thought that the nature of the construction of the strips offers greater flexibility which allows some movement of the strips without causing cracking. The major problem with the concrete strips is that the gravel at the shoulders have severely eroded created a "step" between the gravel and the concrete, causing a road safety issue.
- Greater increases in the average rut depths in bituminous surfacings were observed in Bagamoyo sites compared with the Siha sites. This was expected as the monitoring in Bagamoyo site was carried out over a longer period.
- The lightly reinforced concrete slabs at Siha have performed well with only minor cracks visible. The unreinforced concrete slabs have been problematic due to the extensive cracking that has occurred.

4.2 Site evaluation- Bagamoyo demonstration sections

A trip was undertaken on 19 April 2017 by the project team and engineers/technicians from LoGITReC and the local government to evaluate the current state of demonstration sections. Detailed inspection was conducted on the surfacings, and to establish maintenance programmes that were followed after the Bagamoyo District took over monitoring from the Consultant. Figures 5 to 13 show the state of pavement/surfacing conditions of the Bagamoyo site at the time of site visit.

 Failed surfacing on Otta seal section	 Side drains covered by weeds and chocked by dirt
 Successful drainage system	 Failure- Sections of Otta seal completely ripped off

Figure 5: Observations on Otta-seal sections

<table>
<tr>
<td>
Erosion failure on earth surfaced section</td>
<td>
Side drain problem leading to concrete drift covered by mud</td>
</tr>
<tr>
<td>
Deep gullies on steep sections –erosion problem</td>
<td>
Side drains covered by drains covered by shrub, tall grass</td>
</tr>
</table>

Figure 6: Earth surfacing sections

<table>
<tr><td>
Severe rutting, aggregate loss, gullies</td><td>
Side drains covered by shrub, tall grass</td></tr>
<tr><td>
Aggregate loss, drains covered by shrub, tall grass</td><td>
Severe deformations (rutting) and aggregate loss</td></tr>
</table>

Figure 7: Gravel wearing course sections

Deformations and loss of stones

Severe stone loss

Figure 8: Hand packed stone section

Failed concrete strips (cracking, erosion, gravel loss between strips, etc.)

Concrete strip, gravel shoulders severely eroded

Figure 9: Concrete strip sections

 Surface deformations and corner breaks	 Cracking and severe corner breaks
 Severe rutting in left wheel track	 Good side drain, but vegetation slowly encroaching

Figure 10: Geocell sections

Good performing section, drains covered by shrub, tall grass

Stone loss and exposed geogrid, drains covered by shrub, tall grass

Figure 11: Double seal section

Good performing section

Shoulder failure

Figure 12: Sand seal section

Performance of cement slurry seal (RHS) relatively better than lime slurry seal (LHS), Shoulder failure, drains covered by shrub, tall grass

Figure 13: Slurry seal section

4.3 Site evaluation - Siha demonstration sections

The Siha site was visited on 21 April 2017 by the project team and engineers/technicians from LoGITReC and the local government to evaluate the current state of demonstration sections. Similar to the Bagamoyo site, detailed inspection was conducted on the surfacings, and to establish maintenance programmes that were followed after the Siha District took over monitoring from the Consultant. A few selected photos, Figures 14 to 19, show the state of pavement/surfacing conditions on the Siha site at the time of site visit.

Drainage inadequacy

Slipperiness on-set condition

Figure 14: Scarified existing gravel section

Dominance of longitudinal cracks, vegetation growth on the shoulders

Sedimentation build up, vegetation growth on shoulders

Figure 15: Unreinforced concrete slab (75 mm) section

Longitudinal cracking, vegetation growth on shoulder, clean drain

Close-up of longitudinal cracks

Figure 16: Unreinforced Concrete Slab (100 mm) section

Severe erosion tracks

Figure 17: Gravel wearing course section

Surfacing performing very well, but severe sedimentation build-up

Figure 18: Lightly reinforced concrete (75 mm) section

Water ponding, potholing.

Figure 19: Gravel wearing course section

Geo-cell surfacing performing very well.

Showing compactness of Geo-cell surfacing

Figure 20: Geo-cell section

5 Scoping of a training programme and implementation of capacity building

The objective is to build capacity for LoGITReC, inclusive of PO-RALG and road agencies for the design, construction and monitoring of the various interventions on demonstration sections. The training programme is developed to accommodate both theoretical and practical/on-site concepts of LTPP monitoring, data analysis and management, skills gap analysis. Candidate engineers/researchers and technicians from LoGITReC and PO-RALG are to attend all training modules.

The training will be mainly presented on a modular basis and in line with related projects across sub-Saharan Africa as part of the AFCAP programmes. The resource materials have been identified and are being finalised by the project team for the training.

The assignment is also a component of a set of inter-related projects across Africa as part of the AFCAP programme.

The approach adopted for the training is in four main parts as follows:

1. Holding of formal training workshops (theoretical)
2. Undertaking on-site training
3. Specific training needs assessment
4. Preparation of supplementary training materials

The needs assessment for instance, will establish areas of weakness based on the observations from the site visits, data management techniques currently used by LoGITReC and PO-RALG. It is expected that all trainees will participate in the workshops to encourage consistency of approach and to enable each trainer to contribute in areas where they have specific knowledge and experience. Formal training workshops will be held mostly in Dodoma.

The training will be practically orientated and closely linked to the requirements of the demonstration sections of the two sites. The scope of training for this project is to focus on monitoring and data gathering of pre- and post-construction structural performance assessment. Linked to these factors are climatic conditions and economic performance indicators of the demonstration sections. An essential part of the training process is the establishment of database. At the end of the training participants should understand LTPP data structure and its importance in performance assessment. In practice, LTPP database comprises seven components of data storage. These are:

1. Administration (data on the structure of the database);
2. Inventory (data on the as-built test section – pavement structure, material layer properties, laboratory and field test results, etc.);
3. Periodic pavement performance monitoring information (from visual and automated data capturing methods);
4. Climate (rainfall and temperature - daily, weekly, monthly, annually);
5. Traffic (volume-AADT, composition, axle load data);
6. Social dynamics - data on impacts of road improvements on local communities).
7. Compilation and computation of whole-life costs.

Other database modules included:

- Historical information of material properties
- Historical information on maintenance/rehabilitation interventions
- Historical information on past performance of the sections or road link

5.1 Scope

A major component of the training programme includes:

- Fundamentals of road construction;
- Use of local resources, labour-based methods and intermediate technologies for the construction and maintenance of demonstration sections/low volume roads;
- Evaluation of chemically stabilised road pavement layers;
- Evaluation of thin bituminous seals for low volume sealed roads;
- Evaluation of reinforced/unreinforced concrete and structures;
- Procedures for site supervision including quality control and site records;
- Maintenance of demonstration sections/low volume roads;
- Data analysis, interpretation and reporting.

The overall scope covers the following:

- Planning for the implementation of demonstration sections;
- General responsibilities of the researchers/engineers and technicians;
- Tools and equipment requirements;
- The use of labour intensive and light machines techniques/technologies for construction and monitoring;
- Procurement, storage, control and safe handling of materials;
- Chemical stabilisation of materials for pavement layers;
- Bituminous binders characteristics and applications;
- Quality control;
- Visual inspection of roads, identification of defects, methods of recording and taking photographs of defects;
- Measurement of pavement distress as recorded in the form of rutting, cracking, ravelling, bleeding, potholes etc. This should include methods and equipment required for taking rut depth measurements, the types of surface that the measurements are taken on, how changes in rut depth over time can be monitored and what are the possible causes of increases in average rut depths;
- Purpose of surface profile measurements, methods of carrying out surface profile measurements, advantages/disadvantages of each profile method, the intervals at which measurements are taken, etc.;
- Methods of traffic counting, the importance of including different days in the week in order to capture weekly variations and the importance of assessing changes in traffic over time;
- Equipment used to measure surface roughness, at which point on the road should the measurements be taken, and how the International Roughness Index (IRI), is calculated from the data that is collected;

- Purpose of taking asphalt and concrete cores, the methods of taking cores and the laboratory tests to be undertaken following extraction of the cores;
- Measurements/monitoring of temperature and rainfall data;
- Measurement and evaluation of pavement deflection parameters.

5.2 Informal training

The training of LoGITReC researchers and technicians in generic subjects such as proficiency in the use of spreadsheet, word processing and presentation tools is to be included in LoGITReC's annual planning for training and capacitation of staff.

Candidate researchers and technicians should attend specific courses on topics such as:

- How to conduct field investigations and perform technical audits and forensic investigations;
- Laboratory management and quality systems;
- Data collection, data management and statistical analysis of research data.

It is acknowledged that university undergraduate courses are general in nature and pavement engineering programmes rarely include monitoring of demonstration sections. It is recommended that, as this is going to be the first formal training of this type within LoGITReC and PO-RALG, that special attention is paid to getting young researchers, engineers and technicians involved. This is also an opportunity to initiate Problem-Based Learning approach as a modality to develop road research skills within the academic partner institutions. Since some of the modules could also be of interest to other stakeholders in the industry and the universities, LoGITReC should extend invitation to staff members from these institutions to attend the training programme. However, for effective delivery of the programme, no more than 25 people should attend, to ensure meaningful interaction takes place during the training.

5.3 Evaluation of the training

A questionnaire will be prepared for participants to evaluate content and presentation of the training. Participants will be encouraged to give their views on the overall training programme. For instance, one of the key areas to solicit participants' views will be whether the training entails a good mix of presentations, discussions, non-site and site exercises. The results of the questionnaire will be used to assess the success of the training, and areas that require improvement.

5.4 Training schedule

The training comprises 16 modules. The tentative dates for individual modules are presented in Table 1. At the meeting held on 26 April 2017 at LoGITReC offices in Dodoma, between the Project Leader and LoGITReC team (Dr Magafu and Engineer V. Lwanda), it was agreed that the non-site training modules should be held in Dodoma.

Table 1: Summary of training presentations

Module	Location	Date (TWTF)[1]
Module1:Experimental Design/Experiential Matrix	Dodoma	15 August 2017
Module 2:Setting up test sections – control section	Dodoma	16 August 2017
Module 3: Background to Research Planning and Reporting	Dodoma	17 August 2017
Module 4: Monitoring and research during the construction phase	Dodoma	18 August 2017
Module 5: Monitoring and Research after the Construction Phase	Dodoma	14 November 2017
Module 6: Monitoring of Economic Performance Indicators	Dodoma	15 November 2017
Module 7: Monitoring of climatic conditions	Dodoma	16 November 2017
Module 8: Monitoring of In-Service Pavement Performance	Dodoma	17 November 2017
Module 9: Drainage of the road surface, pavement layers	Dodoma	16 January 2018
Module 10: Analysis of the Physical Performance of Road Sections	Dodoma	17 January 2018
Module 11: Evaluation of Appropriate Construction Methods	Dodoma	18January 2018
Module 12: Economic Analysis (life-cycle cost analysis)	Dodoma	19 January 2018
Module 13: Materials sampling, field and laboratory measurements	Dodoma	13 March 2018
Module 14: Data collection management & linkage to pavement design	Dodoma	14 March 2018
Module 15: Individual presentation	Dodoma	15 March 2018
Module 16: Feedback	Dodoma	16 March 2018

[1] Training will be held on Tuesdays, Wednesdays, Thursdays and Fridays. The timing is subject to approval by LoGITReC to ensure that it fits well with their capacity building needs and implementation plans.

5.5 Capacity building and transfer of knowledge

The project team in consultation with LoGITReC are developing a fit-for-purpose capacity building plan that fulfils LoGITReC's needs. The methodology to be implemented for achieving the objectives and outcomes of capacity building is based on an integrated and hands-on approach to ensure effectiveness of the capability development, including a combination of the training programme and mentoring. The project team involved LoGITReC staff in undertaking the site visit trips. This was aimed at equipping LoGITReC staff from the beginning of project execution, with the long term objective of building sustainable capacity for continuity beyond the life of the project contract. Ms Joseline Kagombora (a young engineer) and Ms Ahsante S. Kamba (civil engineering technician) were part of the team on the Bago to Talawanda road demonstration site and Engineer V Lwanda was part of the team on the Lawate to Kibongoto road demonstration site. They were involved in the meetings, visual inspection of the current state of the demonstration sections, photo logging and processing.

The project team plans to assist LoGITReC with the drafting of targeted skills development plans for individual researchers and technicians, identifying broad areas of training needs that will be required in the short to medium term, investigate potential secondments to other (international) accredited laboratories. It is planned that the requirements of LoGITReC in terms of design, construction and monitoring of demonstration sections, data management and analysis will be addressed in this project.

As part of capacity building, a training evaluation sheet has been developed and will be completed by the researchers/engineers and technicians at LoGITReC and PO-RALG, to serve as a record of knowledge transfer and for monitoring and evaluation purposes by AFCAP. These staff members will be assessed on their competency for performing specific tasks. The matching of required level of knowledge and skills transfer will be achieved by assessing the existing technical competency gaps with respect to monitoring of demonstration sections as well as data management, data analysis and reporting. A capacity building and skills development report will be prepared and recommendations will be made on requirements for further training.

5.6 Supporting training and skills development

LoGITReC managers will be equipped to provide the direction, resources for training and research leaders on the other hand will be expected to train and provide opportunities for development to support their teams in conducting their work to the highest standards. Research leaders have therefore a responsibility to develop and maintain the skills they need in their research while assisting others with their personal development. It is expected that LoGITReC managers and research team leaders recognise and deliver on their responsibilities for mentoring and staff development and ensure young, new researchers, support, technical and administrative staff are supported in understanding and adopting good practice at an early stage and throughout their career.

5.7 Responsibilities of service provider

The following are the responsibilities of the project team from the CSIR:
Lead Trainer:

- Liaison with LoGITReC managers
- Planning and programming
- Design and implementation of training needs assessment
- Preparation of training materials and delivery of theoretical training
- On-site training activities
- Reporting to AFCAP PMU.

6 Conclusions

The following conclusions were reached for the activities undertaken for Task 1:

- No structured database exists at PO-RALG for the demonstration sections. It is anticipated that the on-going Regional Back-Analysis project will provide a preliminary database structure shortly, which will then be shared with the monitoring projects in the country.
- Accessibility to historic information has been limited by the fact that, it seems information was not being centralised or no systematic information management procedures were being followed during the execution of the project. The information on the monitoring prior to 2014 is available in reports and can be considered reliable, while data after 2014 is considered uncertain as no analysis was conducted and is substantially incomplete, at the time of writing the report. The quality and extent of available data is critical for effective back analysis on the performance of the trial sections.
- Most of the Bagamoyo demonstration sections have failed albeit these sections have been successful in achieving the primary aim of providing access to the community since the completion of the project. In comparison, Siha sections generally, show better performance.
- Maintenance is lacking with regard to drainage structures for most sections on the two sites. However, there is a difference in the level of maintenance between the two demonstration sites. The state of road sections on the Siha site show that they are being maintained, compared to the sections in Bagamoyo site, where there were more areas with deterioration.

- Typical forms of deterioration observed on the demonstration sections include severely eroded engineered natural surface, shoulder erosion and cracking of concrete strips, erosion between hand-packed stone with some stones completely dislodged, high rate of gravel loss and deep depressions on the gravel sections.
- Although the demonstration sections are close to six years since construction was completed, some of the sections have experienced forms of premature distresses. However, the extent of the observed distresses is different for the two sites. The stabilised surfacings and single surface dressing for instance at Bagamoyo site are completely ripped off whereas the geocell and concrete strip sections show high levels of distress and based on visual observations of the texture, indications are that failure took place sometime ago. On the other hand, geocell sections in Siha have performed very well and show good compactness.
- Gravel wearing course appears to be unsustainable, without proper and timely maintenance, both in short and long term as demonstrated by the deep depressions, excessive gravel loss, and excessive erosion during rain seasons. There is also potential scarcity of gravel materials and environmental impact concerns.

7 Recommendations

Management

- LoGITReC to enhance coordination and management of information on the two demonstration sites.
- Clarity is required on roles and responsibilities between LoGITReC and the District Engineer's offices, in terms of managing the monitoring of the sections in the future, with LoGITReC being a new entity.

Surfacing performance

- Concrete strip and paving block sections are performing very well. Continued use of concrete strip sections is recommended, on the basis that proper maintenance of the gravel in the centre and gravel shoulder is ensured. Use of concrete paving blocks is recommended in areas where there are frequent, heavy turning vehicles.
- Use of hand packed stone surfacings is only recommended where adequate maintenance can be assured, with appropriate treatment of problematic subgrades.
- Use of lightly reinforced concrete slabs is highly recommended as the reinforcement provides both tensile strength and higher resistance to shrinkage cracking, and these sections have performed successful in Siha. A light steel mesh leads to a small increase in cost.
- The use of unreinforced concrete slabs should be discouraged. The performance of both the 75 mm and 100 mm thick slabs is poor as evidenced by the development of cracks, shown in Figures 15 and 16, from Siha site. However, it is worth noting that, the Final Report on the demonstration sites, pointed out that some cracking may have been caused by the contractor driving heavy trucks over completed concrete sections before allowing them to gain full strength.
- The rapidly deteriorating seal surfacings requires that timely maintenance interventions are carried out including crack sealing before the start of the rainy season or fog spray is applied to rejuvenate the surfacing or resealing is carried out before the existing surfacing reaches the end of its service life.

Potential surfacing options

- Concrete slabs and thin asphalt (20-25 mm thick) have been successful in providing all weather access on steep sections. On the steeper sections, for example similar to those at Siha, it is recommended that ultra-thin concrete or thin asphalt surfacings designed with non-standard aggregate materials (e.g. screened gravels, etc.) are considered for future demonstration sections.

APPENDIX A:

Table A1: As-built data for Bagamoyo site – (Please tick (√) for availability

	Data or report type/ Year																															
Surfacing type	materials test results				Structural (pavement) designs				Asphalt mix designs				Concrete mix designs				Surface seals				Stabilisation designs				Drainage				Climate			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Single Otta Seal with a Sand Sea	√	√			√												√								√	√						
Hand Packed Stone	√	√			√																				√	√						
Concrete Strips (100 mm - Reinforced)	√	√			√								√												√	√						
Geocells	√	√			√								√												√	√						
Double Surface Dressing	√	√			√																				√	√						
Concrete Strips (100 mm - Unreinforced)	√	√			√								√												√	√						
Double Sand Seal (20 mm)	√	√			√																				√	√						
Gravel Wearing Course (150 mm)	√	√			√																				√	√						
Concrete Strips (100 mm - Reinforced)	√	√			√								√												√	√						
Concrete Strips (100 mm - Reinforced)	√	√			√								√												√	√						
Gravel Wearing Course (150 mm)	√	√			√																				√	√						

Table A2: Construction and maintenance data for Bagamoyo site – (Please tick (√) for availability

	Data or report type/ Year																											
Surfacing type	Contract documents				Progress contract reports				Final contract report				Photo record/construction process				Traffic data including loading				Climate/rainfall & temperature				Maintenance (Reports)			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Single Otta Seal with a Sand Sea	√				√	√				√			√	√			√									√		
Hand Packed Stone	√				√	√				√			√	√			√									√		
Concrete Strips (100 mm - Reinforced)	√				√	√				√			√	√			√									√		
Geocells	√				√	√				√			√	√			√									√		
Double Surface Dressing	√				√	√				√			√	√			√									√		
Concrete Strips (100 mm - Unreinforced)	√				√	√				√			√	√			√									√		
Double Sand Seal (20 mm)	√				√	√				√			√	√			√									√		
Gravel Wearing Course (150 mm)	√				√	√				√			√	√			√									√		
Concrete Strips (100 mm - Reinforced)	√				√	√				√			√	√			√									√		
Concrete Strips (100 mm - Reinforced)	√				√	√				√			√	√			√									√		
Gravel Wearing Course (150 mm)	√				√	√				√			√	√			√									√		

Table A3: Monitoring and Investigation for Bagamoyo site – (Please tick (√) for availability

	Data or report type/ Year																															
Surfacing type	Drainage evaluation				Rut depth measurements				Cracking measurements				Deflection measurements (FWD)				Density/moisture				DCP tests				Gravel Loss				Test pits, sampling/ Lab testing			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Single Otta Seal with a Sand Sea			√	√		√				√				√													√	√	√			
Hand Packed Stone			√	√		√				√				√													√	√	√			
Concrete Strips (100 mm - Reinforced)			√	√		√				√				√													√	√	√			
Geocells			√	√		√				√				√													√	√	√			
Double Surface Dressing			√	√		√				√				√													√	√	√			
Concrete Strips (100 mm - Unreinforced)			√	√		√				√				√													√	√	√			
Double Sand Seal (20 mm)			√	√		√				√				√													√	√	√			
Gravel Wearing Course (150 mm)			√	√		√				√				√													√	√	√			
Concrete Strips (100 mm - Reinforced)			√	√		√				√				√													√	√	√			
Concrete Strips (100 mm - Reinforced)			√	√		√				√				√													√	√	√			
Gravel Wearing Course (150 mm)			√	√		√				√				√													√	√	√			

Table A4: As-built data for Siha site – (Please tick (√) for availability

	Data or report type/ Year																															
Surfacing type	materials test results				Structural (pavement) designs				Asphalt mix designs				Concrete mix designs				Surface seals				Stabilisation designs				Drainage				Climate			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Concrete Paving Blocks																											√					
Unreinforced Concrete (100mm) (2)			√																													
Flexible Geocells (75mm)																											√					
Unreinforced Concrete Slab (75mm)																									√		√					
Gravel Wearing Course (5)																																
Concrete Strips (6)																											√					
Double Surface Dressing																									√							
Concrete Strips (8)																											√					
Unreinforced Concrete (100mm) (9)			√																						√		√					
Concrete Strips (10)																											√					
Unreinforced Concrete (100mm) (11)																										√	√					
Concrete Strips (12)																											√					
Unreinforced Concrete (75mm) (13)																									√		√					
Concrete Strips (14)																											√					
Concrete Strips (15)																											√					
Bituminous Penetration Macadam																									√							
Lightly Reinforced Concrete Slab (100mm)			√																						√							
Lightly Reinforced Concrete Slab (75mm)																									√		√					
Lightly Reinforced																									√							

Concrete Slab (100mm)																																
Gravel Wearing Course																								√								

Table A5: Construction and maintenance data for Siha site – (Please tick (√) for availability

	Data or report type/ Year																											
Surfacing type	Contract documents				Progress contract reports				Final contract report				Photo record/construction process				Traffic data including loading				Climate/rainfall & temperature				Maintenance (Reports)			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Single Otta Seal with a Sand Sea		√				√								√					√								√	
Hand Packed Stone		√				√								√					√								√	
Concrete Strips (100 mm - Reinforced)		√				√								√					√								√	
Geocells		√				√								√					√								√	
Double Surface Dressing		√				√								√					√								√	
Concrete Strips (100 mm - Unreinforced)		√				√								√					√								√	
Double Sand Seal (20 mm)		√				√								√					√								√	
Gravel Wearing Course (150 mm)		√				√								√					√								√	
Concrete Strips (100 mm - Reinforced)		√				√								√					√								√	
Concrete Strips (100 mm - Reinforced)		√				√								√					√								√	
Gravel Wearing Course (150 mm)		√				√								√					√								√	

Table A6: Monitoring and Investigation for Siha site – (Please tick (√) for availability

	Data or report type/ Year																															
Surfacing type	Drainage evaluation				Rut depth measurements				Cracking measurements				Roughness				Density/moisture				DCP tests				Gravel Loss				Test pits, sampling/ Lab testing			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
Concrete Paving Blocks							√								√																	
Unreinforced Concrete (100mm) (2)							√								√																	
Flexible Geocells (75mm)							√								√																	
Unreinforced Concrete Slab (75mm)							√								√																	
Gravel Wearing Course (5)							√								√																	
Concrete Strips (6)							√								√																	
Double Surface Dressing							√								√																	
Concrete Strips (8)							√								√																	
Unreinforced Concrete (100mm) (9)							√								√																	
Concrete Strips (10)							√								√																	
Unreinforced Concrete (100mm) (11)							√								√																	
Concrete Strips (12)							√								√																	
Unreinforced Concrete (75mm) (13)							√								√																	
Concrete Strips (14)							√								√																	
Concrete Strips (15)							√								√																	
Bituminous Penetration Macadam							√								√																	
Lightly Reinforced Concrete Slab (100mm)							√								√																	

Lightly Reinforced Concrete Slab (75mm)							√								√																	
Lightly Reinforced Concrete Slab (100mm)							√								√																	
Gravel Wearing Course							√								√																	