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

Final Report

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Cover photo: Concrete strip trial section, Bagamoyo.

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Abstract

This draft final report provides a consolidation of the achievements made on the *Long Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania* project. The main goal of the project was to provide technical assistance to the Local Government Infrastructure and Transport Research Centre (LoGITReC) which is the research entity of Tanzania Rural and Urban Roads Agency (TARURA). This report highlights a record of capacity building outcomes based on a combination of training workshops and field monitoring training exercises. The scope of the training programmes was informed by the requirements considered and identified from the outset of the project, on the basis of relevant knowledge and field skills required by council managers, regional coordinators, engineers and technicians from TARURA and lecturers from two technical universities for practical implementation of the LTPP monitoring programme of trial sections. The content of this report will be fully discussed during a stakeholder dissemination workshop in Dar es Salaam on 13 February 2019. The outcome of the workshop including recommendations and action plans will be incorporated into a final report of the project.

Key words

Low volume roads, pavement materials, long-term pavement monitoring, LTPP section, capacity building

Acronyms, Units and Currencies

AfCAP	Africa Community Access Partnership
CML	Central Materials Laboratory
CSIR	Council for Scientific and Industrial Research
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development (UK)
DIT	Dar es Salaam Institute of Technology, Tanzania
FWD	Falling Weight Deflectometer
HQ	Head Quarters
IRI	International Roughness Index
LCC	Life-cycle costs
LoGITReC	Local Government Infrastructure and Transportation Research Centre
LTPP	Long-Term Pavement Performance
LVR	Low-volume road
MERLIN	Machine for Evaluating Roughness Using Low Cost Instrumentation
MUST	Mbeya University of Science and Technology, Tanzania
PMU	Project Management Unit
ReCAP	Research for Community Access Partnership
SCRIM	Side force test device
TANROADS	Tanzania National Roads Agency
TARURA	Tanzania Rural and Urban Roads Agency

Executive summary

This is a draft final report on the work undertaken on the project titled *Long Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania*. The main goal of the project was to: carry out a review of trial sections on roads in two districts of Tanzania (i.e. Bagamoyo and Siha), refine and implement the regional protocols for establishment and monitoring of road trial sections, and build capacity at Tanzania Rural and Urban Roads Agency (TARURA) through problem-based learning training workshops and field monitoring training exercises. The Council for Scientific and Industrial Research (CSIR) was appointed by Africa Community Access Partnership (AfCAP) through Cardno Emerging Markets (UK) Ltd to undertake this assignment. The CSIR worked in close collaboration with the main beneficiaries of the project, i.e. TARURA and two technical universities in Tanzania—Dar es Salaam Institute of Technology (DIT) and Mbeya University of Science and Technology (MUST).

The draft final report is one of the project's milestone deliverables, and will be discussed during a stakeholder final dissemination workshop in Dar es Salaam on 13 February 2019. The outcome of the workshop including recommendations and action plans to be considered by TARURA will be incorporated into the final report of the project. Preliminary conclusions that are made in this report will refined for the final project report. This report presents summaries of activities and milestones achieved on the project to date. More detailed information about the methodology and outcomes is presented in the six project reports that have been submitted to Cardno Emerging Markets (UK) Ltd.

Objectives

The main objectives of the assignment was to:

- Conduct a review of the existing 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 order to evaluate the nature and quality of information available from these road trials;
- In light of the outcome of the review, refine and implement the existing regional protocols for establishment and monitoring of road trial sections during implementation of monitoring surveys to ensure that the establishment of road trials and collection of the information is standardised;
- Conduct field surveys on the two selected demonstration/trial sections in order to collect performance data in accordance with the monitoring processes provided in the refined guidelines/protocols;
- Provide in-service training to build capacity within LoGITReC and other stakeholder institutions on practical implementation of the harmonised protocols/guidelines and maximizing the uptake and utilisation of the project outcomes

Following the restructuring within PO-RALG and related delays in decisions by TARURA to undertake the workshop training and field monitoring programmes, there was a need to revise the planned project activities and deliverable dates, which led to two amendments to the original contract.

Scope of work

The scope of work comprises three main tasks that were undertaken to achieve the goals of the project:

1. Task 1 (Review of existing trial sections): To evaluate the nature and quality of information available from existing trial sections, and undertake in-depth review of the two selected existing road trials.
2. Task 2 (Review and implementation of existing regional guidelines/protocols for establishing and monitoring trial sections): To refine and implement existing regional guidelines/protocols to ensure that the establishment of the trial sections and collection of the information is standardised across Tanzania and the African region.
3. Task 3 (Monitoring of trial sections): To conduct field surveys on the trial sections, and collect performance data in accordance with the monitoring processes provided in the refined guidelines/protocols developed as part of Task 2. This task involved the following key activities:

- Assist personnel from TARURA including council managers, regional coordinators, district engineers in Siha and Bagamoyo and LoGITReC, and lecturers from academic institutions to carry out monitoring activities on the two project sites with the purpose of ensuring that they are fully conversant with the monitoring methods and equipment, and that they can carry out LTPP /trial section layout markings and measurement.
- Conduct four problem-based learning training workshops to ensure that personnel involved in the programme are fully conversant with the monitoring methods and that they carry out the measurements of the identified parameters to the required standard and report on the results accordingly.
- Conduct two monitoring training exercises. These exercises were used to assess the level of competency achieved by individuals who participated in the respective activities.
- Provide training to the TARURA staff and representatives from the academic institutions on practical implementation of LTPP protocols. It was expected that the project team would participate in at least two monitoring rounds during the duration of this assignment.

The scope of work was successfully implemented except that only one full monitoring could be undertaken instead of two as planned. This was mainly due to the restructuring within PO-RALG followed by the establishment of the Tanzania Rural and Urban Roads Agency (TARURA), which affected the implementation of the timing of the monitoring rounds. However, two comprehensive and extensive field monitoring training programmes were implemented to capacitate LoGITReC/TARUARA engineers and technicians for future monitoring and sustainability of the LTPP programme in Tanzania.

Summary of project activities and outputs

A key component of the project was monitoring which comprised of four structured problem-based learning training workshops and two field monitoring training exercises. These involved field demonstrations on long-term pavement performance (LTPP) monitoring methods and instruments, as well as structured in-class presentations and field data collection and analysis. An average of 12 personnel from TARURA including council managers, regional coordinators, engineers and technicians from TARURA, and lecturers from DIT and MUST participated in the training workshops and monitoring exercises.

- Project technical outputs – these are a refined LTPP Guideline for establishing and monitoring of trial sections in Tanzania and 11 technical reports (including this draft final report) that have been prepared for this project:
  1. Mobilisation Report - covers project team mobilisation, and the start-up meeting held with the AfCAP PMU.
  2. Inception Report – covers the preparatory activities, detail methodology and programme for conducting the assignment including proposed timelines and a brief description of the trial sections to be assessed in this project.
  3. Task 1 Report –presents detail review on available information and data on the two trial sections, including recommendations on data storage, a plan for capacity building, and recommendations for presentation to stakeholders.
  4. Task 2 Report – presents the outcome of the review of existing regional LTPP protocols/guidelines for establishment and monitoring of road trial sections, and a refined guideline for managing pavement performance monitoring programme in Tanzania. The expected outcome of the second task of the project is standardised regional guidelines/protocols for the establishment of road trials and information collection from established road trials. The protocols/guidelines to be developed are aimed at supporting the future establishment of LTPP sections not only for Tanzania, but also for other sub-Saharan African countries. The project concept is therefore geared towards regional harmonisation of the practice.
  5. Task 3 Reports – comprises of;
     a. Five Technical Progress Reports – present activities and outcomes of four problem-based learning training workshops and two field monitoring training that were carried out at

Bagamoyo and Siha project sites, and provide an assessment of the competence demonstrated by individual personnel who participated in the training programmes.

b. Capacity Building and Skills Report – is a follow up report that provides detailed information and analysis of data presented in the five progress reports. Detailed information on the training of staff from the Local Government Infrastructure and Transport Research Centre (LoGITReC) and an assessment of competence/capacity levels of each participant in specific areas and aspects requiring further training are presented.

6. Draft Final Report – this is the current report that consolidates up-to-date activities of the project, and presents a summary of project outcomes, challenges, conclusions and preliminary recommendations. The information presented in this report constitutes the focal point of discussion during the project's dissemination workshop preceding the Final Project Report.

Key outcomes

The main outcome of this project is transfer of knowledge and expertise to staff from LoGITReC, which is a research entity within TARURA, engineers, and lecturers from two technical institutions in Tanzania. It is expected that personnel who participated in the training programmes of this project will be able to carry out monitoring surveys and evaluation of trial sections in accordance with standard protocols.

The preparation of the refined guidelines/protocols was one of the key outcomes of this project. The prepared guideline is to be used to conduct monitoring on current and future LTPP/trial sections and ensure that the establishment of road trials and collection of the information is standardised in Tanzania. Key aspects of these guidelines will be presented at the final stakeholder's workshop of the project, and to AfCAP for further review and adoption for the country. This project contribute towards the current AfCAP regional project that seeks to harmonise the regional monitoring guideline for LTPP sites across the region and thereafter adapted for each country's LTPP programme.

The following are specific outcomes of the project:

- The objectives of the four problem-based learning training workshops and two field monitoring training exercises were fully achieved based on the assessments and the general consensus from the evaluations by the participants. These training sessions were beneficial to participants and particularly, TARURA as they are aware of the advantages of establishing and monitoring trial sections, and maintenance activities that should be incorporated in LTPP programmes.
- Transfer of knowledge and expertise to technicians, engineers and staff from academia through the training programmes was successful. This was accomplished through a combination of four training workshops and two field monitoring training exercises, and addressing the needs of participants in terms of challenges of monitoring and data analysis. Participants demonstrated a measure of understanding of the information to be collected during monitoring of trial sections.
- On the basis of the competence evaluations, the majority of the participants of the training programmes demonstrated that they have acquired the necessary knowledge and skills in the establishment and monitoring of trial and LTPP sections. Ten (10) participants who were closely observed during the field monitoring training are declared proficient in measurement and marking out of LTPP / trial sections.
- Participants of the training programmes acknowledged that the skills and knowledge acquired from the project will be shared with other TARURA regional coordinators and council managers through arranged study visits to trial sections of the two sites.

Challenges

Both technical and logistical challenges were faced by the project team during the implementation of the project. The main challenge was however, the institutional restructuring within PO-RALG that happened at the early stage of the project. This was a national exercise, hence very little could be done to avert the effect on the project planning and scheduling. In consultation with the AfCAP PMU, the project team re-aligned project activities to fit into the time lost during the re-structuring process.

Other specific challenges include the following:

- Prior to the inception stage of this project, no centralised and structured database existed at PO-RALG for the two project sites. Indications are that no systematic information management procedures were subsequently followed after the project implementation period. As a result, accessibility to information and some of the historic data from Bagamoyo and Siha sites was therefore limited
- The project road in Bagamoyo district suffers predominantly from issues stemming from the lack of drainage and poor subgrade materials. Areas with black cotton soil were impassable during the period of the monitoring exercise (rainy season), while large erosion channels also make travelling along this road very difficult. Planning for future maintenance of trial sections should take note of the impact of these adverse conditions.
- In Siha, the primary challenge was steep gradients and slippery road surfaces. Hence, safety at the site was a concern. Thus, careful consideration needs to be given to monitoring of the Siha trial sections during rainy conditions.
- Location of wheel paths to take rutting measurements was challenging as the pattern of vehicular traffic was in most cases spread across the entire road widths of the trial sections.
- The period between the two monitoring exercises was limited to allow for gathering of adequate information on maintenance, in order to carry out a comprehensive life cycle cost analysis

Observations and lessons learnt

The following are key observations and lessons learnt:

- The outcomes of the project have provided an insight into the immediate needs of research in low-volume roads and particularly, establishment and monitoring of LTPP/trial sections, to assist TARURA/PO-RALG in meeting its aim of supporting rural development and poverty alleviation. Based on the interim discussions with stakeholders, it is considered that the project has successfully met its delivery objectives.
- The project has defined a direction for the development of a research capacity in monitoring of trial sections through the capacity building programme, which is expected to have an impact beyond TARURA/PO-RALG, as staff from technical institutions of higher learning were involved. It has also developed skills related to the effective application of protocols/ guidelines for the establishment and monitoring of LTPP trial sections in Tanzania.
- Some of the equipment proposed in the AfCAP LTPP Guideline were perceived as more applicable to high-volume roads than for traditional low-volume roads. For instance, the use of Side force test device (SCRIM) and Falling Weight Deflectometer (FWD) were seen as not appropriate for low-volume roads with traffic capacity similar to the two project roads in Siha and Bagamoyo districts.
- The general consensus was that all four problem-based learning training workshops and two monitoring exercises were beneficial to participants and particularly for TARURA as they have become aware of the advantages of establishing and monitoring LTPP trial sections. Accordingly, participants were of the opinion that LoGITReC staff and the academia should assume a lead role in the establishment and monitoring of LTPP sections on rural roads in Tanzania.
- Personnel who participated in the training programmes achieved satisfactory level of competence to establish and going forward able to undertake monitoring of the trial and LTPP sections without a support of the service provider. However, the collaboration between TARURA and the lecturers from the DIT and MUST, who participated in this project should be strengthened. This is crucial for the future success of the establishment and monitoring of trial and LTPP sections in Tanzania.
- On the basis of the evaluations of the training programmes, it is apparent that participants gained the necessary knowledge on: elements and condition assessment of drainage systems, data analysis and interpretation to assess performance of trial sections, evaluation of appropriate construction methods, and elements of whole life-cycle cost analysis of trial sections.
- The lack of a proper maintenance programme is the most likely contributing factor to the observed poor performance of some of the road sections.

Recommendations – Project related

The following recommendations are made:

- Based on the fact that sourcing for data and information was a challenge during the inception stage, it is recommended that TARURA appoints an individual specifically responsible for Technical Data Management Systems (TDMS) for low-volume roads. LoGITReC should ensure that all historic and future data from the monitoring of the trial sections is stored in a secure server and be protected.
- LoGITReC should enhance coordination and management of information on the two demonstration sites. Clarity is required on the roles and responsibilities of LoGITReC and the District Engineer's offices in terms of managing and monitoring the trial sections in future. It is noted that LoGITReC is a research entity, while the District Engineer's office will still be responsible for maintenance of the sections.
- A dedicated training on application of the DCP-DN pavement design method should be considered for Tanzania. This is based on the continued interest expressed by participants when the DCP laboratory and field testing, data analysis and interpretation were introduced as part of training workshops. TARURA is to take responsibility since this will add value to future projects on new trial sections.
- As monitoring on the Bagamoyo site was carried out from September 2011 to April 2014, and that for Siha was from January 2013 to April 2014, TARURA should consider to undertake further monitoring programme systematically in the next three to four years starting from May 2019. This takes cognisance of the fact that there was no monitoring of these sites after April 2014. For these trial sections, ten (10) years monitoring is recommended to establish sufficient data to compare performance of the various surfacing options.
- Monitoring team should comprise researchers and technicians from TARURA, and academia. Although logistics to include personnel from the academia might be a constraint, it is not encouraged that monitoring teams are dominated by technicians. It is important that skilled personnel are included in the monitoring, particularly where the terrain is difficult (e.g. Siha site), and during rainy seasons.
- Monitoring should be carried out by the same person or groups for consistency, and follow acceptable guidelines. Trial sections should be monitored at six monthly intervals, in May (rainy season) and November (dry season). More frequent monitoring can be made if required, but will be dictated by available budget allocation. It is strongly recommended that monitoring periods be adhered to as significant delays risk lack of confidence in the outcomes of the project.
- More time should be allocated to training workshops and field demonstration exercises. It is recommended that a minimum of two weeks (instead of one week planned for this project) should be planned and budgeted for these training programmes.
- The *Guideline for the Monitoring of Experimental and LTPP Sections in Tanzania* should be trialled further on the two sites for possible enhancement, and to demonstrate new methods and equipment proposed in the guideline document.
- The overall presentation skills of the technicians were rated below average. Further development of their skills in this area is recommended as it will assist in better information sharing. The process of transforming knowledge-base to practice requires good information dissemination skills, it is for this reason that sufficient training of the engineers in technical report writing should take place in order to ensure the outcomes from the project appropriately benefit the road sector in Tanzania.

Recommendations – General

A number of general recommendations are made for the benefit of TARURA regarding future projects:

- The current staff composition of LoGITReC shows that there is a need to recruit at least one researcher to provide in-depth data analysis capability to effectively contribute to future LTPP projects.
- LoGITReC does not currently have most of the equipment for LTPP monitoring. In addition, some of the available equipment appear to have manufacturing (available MERLIN, not to standard) issues when compared with standardised equipment for monitoring.
- 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 shoulders is ensured.

- Use of hand-packed stone surfacing is only recommended where adequate maintenance can be assured, with appropriate treatment of problematic subgrades.
- Use of unreinforced concrete slabs should be discouraged especially on the steep sections such as those in Siha district. The performance of both the 75 mm and 100 mm thick slabs is poor, as evidenced by the development of cracks. However, it is worth noting that the Final Report (Roughton International) on the demonstration sites pointed out that some cracking were suspected to have been caused by poor construction techniques used by the contractor. Quality control and assurance procedures should therefore, be enforced during construction.
- On the steeper sections (Siha site, gradients more than 12%), it is recommended that thin mesh-reinforced concrete or asphalt surfacings should be considered for future demonstration sections. There is generally potential gain in whole life cycle cost using these alternative surfacing.
- The rapidly deteriorating seal surfacing requires that timely maintenance interventions be carried out. Crack sealing or resealing should be carried out before the start of the rainy season or fog spray be applied to rejuvenate the surfacing, to avoid the existing surfacing prematurely reaching the end of its service life.
- For LTPP projects, it is recommended that greater emphasis should be placed on medium to long-terms benefits including research outputs and capacity building, otherwise allocation of budget could become a problem since generally, most road agencies are looking for short-term gains in their annual budgets.
- The range of pavement materials options for the construction of trial sections should be extended to include the use of construction waste materials such as recycled concrete and asphalt (depending on distance from available source) as well as stabilised material for areas that experience high amount of annual rainfall.
- TARURA should seek to integrate the refined *LTPP Guideline* into a national standards for low-volume roads in the country.
- Road markings should form part of TARURA's contracts, and maintenance activities on trial sections.

Implementation of project outcomes

TARURA can immediately implement recommendations and action plans provided in the project reports to address issues related to establishment and monitoring of existing and new trial and LTPP sections. Thus, an implementation initiative is recommended. In order to ensure that the achievements of the project have a long term impact and sustainable benefits to similar projects in the future, the following should be considered:

- The administrative and organizational arrangements within TARURA should support the trained team's efforts to collect and process data, evaluate and implement the programme to ensure adherence to the protocol/guideline throughout the monitoring period. The role and staffing requirements should carefully be thought through and the wider organizational context has to be considered, to ensure the capacity built is not lost by being deployed to other divisions where they can no longer play a critical role in the monitoring programme.

- Sustainability will depend on the continuous commitment of TARURA to implement and maintain the LTPP programme. To ensure that LTPP monitoring is sustainable, it is recommended that source of funding in a form of a specific budget line be identified to cover both operational expenses and equipment acquisition where necessary and costs of maintenance of the trial sections. The lack of such an arrangement threatens the successful implementation of the monitoring programme in the future.

- Budgetary arrangements are currently centralized and may affect the timing of when the monitoring will be undertaken, if there is no budgeting responsibility within the Councils to support the monitoring programme. Authority and responsibility should be given to LoGITReC and Councils to make the decisions essential to ensure effective delivery of the monitoring programme. In this regard it is the control of the budget, schedules and staff utilisation and further capacity building. The system should allow for purchases and supplies to be made without lengthy delays for authorization. This will enable provision of quality monitoring services and ensure that monitoring is performed according to the planned schedule.

- It is the goal of the project team as set out in the project proposal that the linkage between LoGITReC (TARURA) and the academic institutions, remains dynamic in terms of the established skill set and will continue working together to strengthen the implementation of the monitoring programme and establishment of the Problem-Based learning approach at the academic institutions. This linkage is also crucial until the level of research capability at LoGITReC improves.
- Capacity building should be an integral part of the project design, construction, and implementation of the demonstration sites, and subsequent monitoring and evaluation process. Aspects of skills development should be considered throughout the different stages of establishing trial sections as it is not only important to effective delivery on the monitoring programme, but also to the success of outcomes of other future projects to validate new technologies.

1 Background

1.1 Project context

The Prime Minister's Office – Regional Administration and Local Government (PMO-RALG), now rebranded President's Office – Regional Administration and Local Government (PO-RALG), of Tanzania has set up a local government transport programme with the aim of supporting rural development and poverty alleviation. In 2009 the Africa Community Access Programme (AfCAP) through the UK Department for International Development (DFID), supported the request by the PMO-RALG to assist with the establishment of trial sections to demonstrate alternative pavement surfacings suitable for low-volume roads in Bagamoyo and Siha districts in the country. 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-season access on rural roads, using low-cost solutions and locally available materials.

The demonstration sites were constructed as part of AfCAP 1 and initial monitoring was undertaken by Roughton International. The data collected from the trial sections would among others, inform practitioners on the performance of the different road design options. It was envisaged that the design and construction techniques demonstrated in the two districts would be incorporated into national manuals.

Construction of the trial sections in Bagamoyo was completed in September 2011, and the sections on the Siha site was completed in September 2012. Immediately following construction of the trial sections, baseline data were collected with subsequent monitoring visits made according to the planned schedule by the service provider (Roughton International). The baseline data for Bagamoyo site were collected one month following construction while the data for Siha site were collected four months after completion of construction. The subsequent performance data collected in 2014 monitoring visit was never analysed and no additional data had since been collected.

The inconsistency, especially in the monitoring of trial sections over time was identified as a recurring problem in several countries, on projects supported by AfCAP. A systematic evaluation of the existing trial sections in Bagamoyo and Siha districts was therefore needed, including the methods for collecting data and quality of monitoring data, compared to standard protocol requirements. Under ReCAP (AfCAP 2) it became logical to select the existing trial sections on the demonstration sites to evaluate them and serve as sources of quality research outcomes for adoption in practice.

The Council for Scientific and Industrial Research (CSIR) was appointed by AfCAP through Cardno Emerging Markets (UK) Ltd to undertake an assignment on *Long Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania*. The project is aimed at carrying out a review of the trial sections in the Bagamoyo and Siha districts and build capacity in the establishment and monitoring of LTPP/trial sections in Tanzania. The trial sections are located on Bago to Talawanda road in the Bagamoyo District (about 20.3 km in length) and on Lawate to Kibongoto road in the Siha District (about 13 km in length). The Bago - Talawanda road represents areas along the coast with significant 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 - Kibongoto road represents areas with steep gradients between 14 to 30%, slippery, volcanic soils, wet climatic zone with more than three months high annual rainfall.

Apart from the need to review existing guidelines to ensure that a systematic method of evaluation and monitoring is in place, capacity building was identified as an essential component of the project to ensure that knowledgeable and skilled personnel are available to effectively continue condition assessment of the trial sections over a number of years. Capacity building was therefore, a key component of monitoring task of the project and is considered crucial in sustaining long-term pavement performance (LTPP) monitoring programme, and ensure that better quality data are collected on the existing and future trial sections.

Ultimately, there was a need to transfer knowledge and expertise to staff at Local Government Infrastructure and Transport Research Centre (LoGITReC), which is a research entity within the Tanzania Rural and Urban Roads Agency (TARURA), and build the required capacity to enable them to carry out monitoring surveys and evaluation of trial sections.

1.2 Project concept

1.2.1 Standardisation of guidelines for LTPP establishment and monitoring

The gathering of information from LTPP monitoring programme of trial sections is influenced by the initial objectives of the project and the envisaged outcome of the programme. The pavement structures of the sections may also be designed based on different methods, for example catalogue method, design charts from design manuals or the Dynamic Cone Penetrometer (DCP) method. The potential therefore, exists that the available data may not always provide the information that is needed to assess the impact of an array of factors in a consistent manner to assist in conclusively demonstrating the effectiveness of different options in design, material utilisation and construction methods. Standardisation of protocols for establishment and monitoring the long-term performance of demonstration sections is needed to harmonise the various approaches being adopted and to address the inconsistencies as observed on the two demonstration projects in Tanzania and projects in other countries supported by AfCAP.

This project is to be closely linked to an AfCAP regional project[1]. The expected outcome of Task 2 of the project was standardised regional guidelines/protocols for the establishment of road trials and information collection from established road trials. The protocols/guidelines developed are aimed at supporting the future establishment of LTPP sections not only for Tanzania, but also for other sub-Saharan African countries. The project concept was therefore geared towards regional harmonisation of the practice.

1.2.2 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 guidance in terms of assessing the 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 meeting records, monitoring method reports, contract documents for routine maintenance of the sections and any failure investigation reports. A number of additional project reports were identified on the basis of the information gathered during the course of the deliberations. This provided the necessary background information about current practices and recent developments that took place in relation to AfCAP projects.

The review 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 the establishment and monitoring methodology that had been followed, as well as improvements required for similar projects in the future.

The key aspects that were considered during the information compilation phase included relevant information on design, construction and performance assessment, and methods of monitoring. Under this project, the pavement sections had several combinations of surfacing: concrete paving blocks, concrete slabs, geocells, concrete strips, double surface dressing, bituminous penetration macadam and a gravel wearing course. The project team also obtained the documentation on the methods used by the Roughton International who monitored the demonstration sections in Bagamoyo and Siha.

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[1] **Development of Guidelines and Specifications for Low Volume Sealed Roads through Back Analysis.** Africa Community Access Programme. Contract Reference: AfCAP RAF2069A.

The project team collected and reviewed international guidelines on establishing and monitoring experimental sections, including the draft Guideline for the monitoring of experimental and LTPP Sections in Mozambique, prepared under AfCAP Contract Project MOZ2093A. At the meeting of the Group of Experts on ReCAP's project - Development of Guidelines and Specifications for Low-Volume Sealed Roads through Back Analysis (AfCAP RAF2069A) - held on 6 February 2017 at the CSIR in Pretoria, it was agreed that this document should be the basis of the refined guideline on monitoring of trial sections to be prepared under this project. The review of relevant guidelines was an on-going activity throughout the project delivery.

1.2.3 Capacity building

The capacity building strategy, through a combination of workshops and field monitoring training in the project, was aimed at assisting in accelerating skills development for LTPP monitoring within LoGITReC. The content of the capacity building programme was informed by the training requirements considered and identified on the outset of the project and on the basis of relevant knowledge and required field skills for practical implementation of the long-term monitoring programme of the trial sections. The capacity building programme was delivered through four problem-based learning training workshops (involved both in-class presentations and field demonstrations) presented to participants and two on-site field training held at both demonstration sites in Siha and Bagamoyo. All in-class training sessions were delivered through PowerPoint presentations, group exercises, and discussions, which were planned to be interactive and allow more time for individual and group discussions. The on-site field training sessions were delivered through demonstration and hands-on activities by participants, individually and in groups depending on the type of activity.

The overall objective was to build capacity in the establishment and monitoring of trial and LTPP sections, inclusive of: planning, design and construction of trial sections; setting up of a monitoring programme; establishment of baseline data; performance monitoring of the sections (including the capturing of traffic and environmental data); data management (including capturing, validation and storage of data in a fit-for-purpose database); data processing and analysis; and reporting formats.

A technical report that provides detailed methodology, elements and outcomes of capacity building and skills development was submitted as a milestone deliverable of this project.

1.3 Objectives

The main objectives of the assignment was to:

- Conduct a 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 Tanzania, to evaluate the nature and quality of information available from these road trials.
- Refine and implement the existing regional protocols for establishment and monitoring of road trial sections during implementation of monitoring surveys to ensure that the establishment of road trials and collection of the information is standardised.
- Conduct field surveys on the two demonstration sites in order to collect performance data in accordance with the monitoring processes provided in the refined guidelines/protocols.
- Provide in-service training to the LoGITReC research staff on practical implementation of the harmonised protocols/guidelines.

1.4 Scope of work and methodology

The scope of work comprises three main tasks that were undertaken to achieve the goals of the project:

4. **Task 1** (**Review of existing trial sections):** To evaluate the nature and quality of information available from existing trial sections, and undertake in-depth review of the two selected existing road trials.
5. **Task 2 (Review and implementation of existing regional guidelines/protocols for establishing and monitoring trial sections):** To refine and implement existing regional guidelines/protocols to ensure

that the establishment of the trial sections and collection of the information is standardised across Tanzania and the African region.

6. **Task 3 (Monitoring of trial sections):** To conduct field surveys on the trial sections, and collect performance data in accordance with the monitoring processes provided in the refined guidelines/protocols developed as part of Task 2. This task involved the following key activities:
   - Assist personnel from TARURA including council managers, regional coordinators, district engineers in Siha and Bagamoyo and LoGITReC, and lecturers from academic institutions to carry out monitoring activities on the two project sites with the purpose of ensuring that they are fully conversant with the monitoring methods and equipment, and that they can carry out LTPP /trial section layout markings and measurement.
   - Conduct four problem-based learning training workshops to ensure that personnel involved in the programme are fully conversant with the monitoring methods and that they carry out the measurements of the identified parameters to the required standard and report on the results accordingly.
   - Conduct two monitoring training exercises. These exercises were used to assess the level of competency achieved by individuals who participated in the respective activities.
   - Provide training to the TARURA staff and representatives from the academic institutions on practical implementation of LTPP protocols. It was expected that the project team would participate in at least two monitoring rounds during the duration of this assignment.

All of the above scope of work successfully implemented except that only one full monitoring could be undertaken instead of two as planned. This was mainly due to the restructuring within PO-RALG followed by the establishment of the Tanzania Rural and Urban Roads Agency (TARURA), which affected the implementation of the timing of the monitoring rounds. However, two comprehensive and extensive field monitoring training programmes were implemented to capacitate LoGITReC/TARUARA engineers and technicians for future monitoring and sustainability of the LTPP programme in Tanzania.

1.5 Terms of reference

The assignment requires that all aspects of long-term performance assessments of experimental/trial sections, inclusive of: the planning, design and construction of sections; the setting up of a monitoring programme; the establishment of baseline data; performance monitoring of the sections (including the capturing of traffic and environmental data); data management (including capturing, validation and storage of data in a fit-for-purpose database); data processing and analysis; and reporting formats, be addressed through a review of the trial sections in the Bagamoyo District and the Siha District and refinement and implementation of the existing regional protocols. During the project implementation, knowledge and expertise should be transferred to engineers from PO-RALG, CML and especially staff from LoGITReC.

The terms of reference (ToR) for the project were well understood. There was no revision of the scope of works and technical deliverables of the project. However, the timelines for deliverables were adjusted to consider delays in the project. Following the restructuring within PO-RALG and related delays in decisions by TARURA to undertake the workshop training and field monitoring programmes, there was a need for revisions in the planned project activities and deliverable dates that necessitated two amendments in the original contract. The initial and revised time scales for project milestone deliverables are presented in table 1 (section 3).

Expected input from PO-RALG/TARURA

- Provide office facilities in Dodoma, Siha and Bagamoyo Districts for the service provider's key experts during their in-country visits;
- Provide service provider's road transport to and from the trial sites in Siha and Bagamoyo, and any other;

- Cover the cost of venue hire for the dissemination workshops; Note that ReCAP will not pay for any transport, accommodation and allowances for participants as this is the responsibility of the respective institutions.
- Cover the cost of materials sampling from the trial sites and respective laboratory testing at LoGITReC, as required; and
- Provide all existing reports and documentation pertaining to the trial sections under review. .

2 Project inception phase

The inception phase presented how subsequent tasks/activities of the project would be undertaken to achieve the objectives of the project. A revised programme plan was provided to guide the project team on the implementation of the project. An Inception Report was submitted to the AfCAP PMU and approved in March 2017. The report covered the preparatory activities; detailed methodology and programme for conducting the assignment including proposed time inputs for the experts; brief descriptions of trial sections to be assessed.

2.1 Project initiation

The project initiation meeting was held on 6 February 2017 at the CSIR offices in Pretoria between the project team and AfCAP Team Leader (Infrastructure, Mr Nkululeko Leta), following the Expert Group Meeting on ReCAP's Back-Analysis project (AfCAP RAF2069A). Mr Nkululeko Leta provided the background information to the project and clarified the Client's expectations that included, potential contact key persons in Bagamoyo and Siha, importance of capacity building component of the project, the key expectation regarding the linkage of the database to be developed for this project to the regional database being developed under the ReCAP's Back-Analysis project.

2.2 Project mobilisation

The main activities that were undertaken involved meetings with project staff at the Bagamoyo and Siha district Councils and site visits to the road trials, and project kick-off meeting. These activities took place between 13 and 17 February 2018. The project kick-off meeting was held at the offices of PO-RALG on 15 February 2017. The meeting was attended by members of the project team: Dr Martin B Mgangira, Dr Joseph Anochie-Boateng and Ms Adele van de Merwe (all from the CSIR), and Dr Fikiri Magafu (PO-RALG), representatives from LoGITReC and the district engineers.

A Project Mobilisation Report was submitted to the AfCAP PMU and approved in February 2017. The report highlighted activities to be undertaken to ensure an understanding of the expected project outcomes from the Client's point of view, working conditions, availability of support infrastructure, information sources and responsibilities in terms of facilities and services to be provided by PO-RALG and the CSIR.

2.3 Visit to project sites

Fact-finding site visits were undertaken at the project inception stage to better understand the project tasks and activities. The site visits were also aimed at gathering necessary information for the purpose of planning the field information compilation process. During the site visits, Engineer C Philip from Bagamoyo district offices and one technician (Mr V Kimaro) from Siha district offices were identified as the people with the longest institutional memory regarding demonstration sites in their respective districts. They provided essential information on the trial sections to the project team; i.e. details on problems encountered during construction of some sections, which have impacted on the performance of the sections. Another example was about a section on the Lawate to Kibongoto road in the Siha District—the section's post-mark indicates lightly reinforced concrete slab, but according to Mr Kimaro a portion of the section is unreinforced. Having someone who is familiar with the project from the early stages was invaluable.

2.4 Meetings with academic institutions

Meetings with academic institutions were identified as project activities during project inception. Subsequent to the training workshop, meetings were also held at two academic institutions (College of Engineering and Technology at the University of Dar es Salaam, and Dar es Salaam Institute of Technology) on 9th and 10th October 2017, respectively. The meetings were aimed at establishing formal arrangements for strengthening linkages between LoGITReC and the academic institutions to foster collaborative research and establish pathways for enhancing road research uptake in the academic institutions.

The project team was accompanied by TARURA representatives, namely Eng. Joseline Kagombora (Research Engineer) and Eng. Vincent Lwanda (Manager of LoGITReC Central Research Materials Laboratory) who also coordinated the project on behalf of TARURA, to meet Heads of Civil Engineering Departments at the two institutions. The meetings were led by Eng. Vincent Lwanda, who provided the background to how LoGITReC was establishment and its mandate as well objective of the meetings. The project team then provided the background to the project and the need for establishing mechanism to enhance road research uptake in academic institutions, such as *Problem-Based Learning* approach. The meeting at College of Engineering and Technology at the University of Dar es Salaam and Dar es Salaam was attended by Dr Eradius Rwakarehe and Dr Hannibal Bwire, whereas the meeting at Dar es Salaam Institute of Technology was attended by Dr Jubily Masagasa and Dr Anthony Kilimo (Head Civil Engineering Department).

2.5 Research collaboration

Potential areas of collaboration identified by the meeting between the project team and academic institutions include expert support to LoGITReC, development of research topics for postgraduate students and project topics for final year students, particularly students from Dar es Salaam Institute of Technology, and University of Dar es Salaam University. It was agreed at both meetings that the way forward was to establish formal agreements between the institutions and TARURA to develop Professional Services Agreements and Task Instructions to undertake joint research in specific areas.

Mr Joseph Mnkeni (a lecturer from Mbeya University of Science and Technology), indicated that his colleague, Dr Mwajuma Lingwanda who is doing post-doctoral research on moisture variation in low volume road pavements, was interested in visiting both project sites, to establish whether the sites can be incorporated in the study. Dr Lingwanda managed to visit the Siha site during the monitoring exercise in May 2018, but decided not to include the sites due to anticipated difficulties and expected costs in conducting the study.

2.6 Institutional partners

A number of identified partners were consulted for their involvement in the implementation of the project. The following agencies and institutions confirmed their participation in the training programmes at the initial stage of the project:

- Tanzania National Roads Agency (TANROADS)
- Tanzania Central Materials Laboratory (CML)
- Dar es Salaam Institute of Technology (DIT)
- Mbeya University of Science and Technology (MUST)
- Road Funds Board (RFB)
- Private sector (engineering consultants and contractors)
- University of Dar es Salaam (UDS)

It was the responsibility of LoGITReC/TARURA to extend the invitations for participation. However, because of other commitments, only staff from DIT and MUST fully participated in the project. CML contributed to the equipment selection aspect of the project.

2.7 Site evaluation

At the onset of the project, both the Bagamoyo and Siha sites were visited to evaluate the current state of all trial sections. The project team and engineers/technicians from TARURA conducted the site visits. The Bagamoyo site was visited on 19 April 2017 whilst the Siha site was visited on 21 April 2018. Inspection of the sites was conducted on the surfacings and to establish maintenance programmes that were followed after TARURA took over monitoring from the Roughton International. Detailed observations and photographs showing the state of the trial sections were presented in the Task 1 Report of this project.

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

- Some demonstration sections performed well, in particular the concrete paving blocks and concrete strips at the 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 at Siha also performed well, however the unreinforced concrete slab sections exhibited extensive cracking.
- In Siha, only double seal and penetration macadam were built. These two bituminous surfacing options performed reasonably well.
- 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 did not work as expected, and requires regular maintenance. The stones did not provide a surface that motorcycles and small vehicles can comfortably drive over, as there was severe erosion between hand-packed stone with some stones completely dislodged, resulting in increased roughness that caused motorists to avoid the section.
- At the Bagamoyo site, geocell pavements have exhibited cracks and depressions across significant areas of the sections. However, the geocell sections in Siha performed 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 at both sites. This may explain the better construction quality, as some experience had been gained on construction methodology of the relatively new surfacing type..
- The cracking that occurred in the unreinforced slabs at Siha did not occur 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 severely eroded and created a “step” between the gravel and the concrete, causing a road safety issue. This was believed to be caused by the lack of maintenance.
- Greater increases in the average rut depths in bituminous surfacings were observed in the Bagamoyo sites compared to the Siha sites.
- The lightly reinforced concrete slabs at Siha performed well, with only minor cracks visible. The unreinforced concrete slabs were problematic, due to the extensive cracking that had occurred.

Generally, there was a difference in the level of maintenance between the two demonstration sites. The indication was that trial sections in Siha were well maintained when compared to the trial sections in Bagamoyo district, where there were more areas with deterioration. Typical forms of deterioration included severely eroded engineered natural surfacing, eroded concrete strips edges, and erosion between hand-packed stone with some stones completely dislodged, resulting in increased roughness that causes motorists to avoid the section. However it was observed that motorists are forced to drive on the section during the rainy season as the sides become unpassable due to flooding. The sections in Siha have post marks giving the details of the type of surfacing and chainage, unlike Bagamoyo. Selected photographs to illustrate conditions of the trial sections from the two sites are presented in Annex 2.

2.8 Challenges

The restructuring within PO-RALG followed the establishment of the Tanzania Rural and Urban Roads Agency (TARURA) was the main challenge faced by the project team. TARURA was established under the Executive Agencies Act Cap 245 in May 2017, and took over the operational roles and functions related to development and maintenance of rural and urban roads network. All operational work related to rural and urban roads network performed under the PO-RALG now falls under TARURA, while the role of policy formulation and monitoring of development and maintenance of rural and urban roads network, implemented through the Division of Infrastructure Development (DID), remains with PO-RALG. As a result, LoGITReC was moved to TARURA. This affected administrative arrangements at LoGITReC during the transition period.

The transition period impacted on the training programme schedules of the project, and contributed to the delays in the project implementation. For instance, the first training workshop was held in September/ October 2017 instead of August 2017. Accordingly, there was five months delay in project deliverables at the initial stages of the project. The transition period created a void, and the project team had to wait until normality in the administrative arrangements at TARURA was established.

3 Project plan and deliverables

The formal outputs of the project are milestone deliverable reports including at least one technical paper to be developed from the Final Report. A refined *Guideline for Establishing and Monitoring Trial and Long Term Pavement Performance Sections in Tanzania* (Interim) is also submitted separately as an output of the project. The planned and actual project deliverable dates are presented in Table 1. The project outputs will be available on the ReCAP website (http://www.research4cap.org/SitePages/Rural%20access%20library.aspx).

Table 1 Timescale and deliverables

No	Milestone deliverable	Content	Due date (planned)	Due date (actual)[1]
1	Mobilisation	Report covers project team mobilisation, and start-up meeting held with PMU	24 February 2017	24 February 2017
2	Inception Report	Report covers the preparatory activities, detail methodology and programme for conducting the assignment including proposed timelines and a brief description of the trial sections to be assessed in this project.	27 March 2017	27 March 2017
3	Task 1 Report	Report provides detail review on available information and data on the two trial sections, including recommendations on data storage, a plan for capacity building, and recommendations for presentation to the Roads Research Steering Committee.	24 April 2017	24 August 2017
4	Technical progress report 1	Brief report, presenting activities and outcomes of the first training workshop and the first field monitoring training exercise that was carried out at Bagamoyo and Siha project sites.	15 May 2017	15 December 2017

5	Task 2 Report	Report covers the outcome of the review of existing regional LTPP protocols/guidelines for establishment and monitoring of road trial sections, and a refined guideline for managing pavement performance monitoring programme of trial sections.	19 June 2017	29 December 2017
6	Technical progress report 2	Brief report, presenting activities and outcomes of the second training workshop	30 June 2017	15 February 2018
7	Technical progress report 3	Brief report, presenting activities and outcomes of the third training workshop	21 August 2017	30 April 2018
8	Technical progress report 4	Brief report, presenting activities and outcomes of the fourth and last training workshop	13 October 2017	6 July 2018
9	Technical Progress report 5	Brief report, presenting activities and outcomes of the first and second monitoring field training exercise that was carried out at Bagamoyo and Siha project sites.		13 August 2018
10	Capacity Building and Skills Development Report	This is a follow-on report that provides much detail information and analysis of the information presented in the five technical progress reports. A detail information on the training of RRC personnel and an assessment of competence/capacity levels of each researcher in specific areas and aspects requiring further training are presented.	16 April 2018	24 December 2018
11	Draft Final Report	This is the current report that consolidates a draft of up-to-date activities of the project, and presents a draft summary of project outcomes, challenges, conclusions and preliminary recommendations. The information presented in this report constitutes the focal point of discussion during the project's dissemination workshop preceding the Final Project Report.	21 May 2018	07 January 2019
12	Final Report and at least 1 technical paper	The final report will incorporate valid stakeholder comments emanating from the dissemination workshop that will be held in Dodoma on 30 January 2019. Two technical papers will be submitted to the T2 conference in Mozambique.	28 May 2018	28 February 2019

[1]Based on contract amendments (2)

4 Project key activity (Task 1): Review of existing trial sections

This was the first major task of the project. The objective was to review available information and data on Bagamoyo and Siha trial sections, including recommendations on data storage, and present observations made from site inspection as well as provide a plan for capacity building. A milestone report (Task 1 Report) was submitted and approved by the PMU in August 2017.

Task 1 Report summarised the initial findings of the project team on the review of the two trial sections in terms of the validation of available information, visual inspection of the condition of the trial sections, scoping of a training programme and the implementation of capacity building. The findings and recommendations were presented and discussed with the Road Research Steering Committee during the first training workshop. Detailed outcomes of this task are presented in Project Report 1.

The key findings of the project team 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, which leads to problems in accessing information. The aim of this project was to assist in establishing an information management system that will be linked to the regional AfCAP project (RAF 2096A— Development of Guidelines and Specifications for Low-Volume Sealed Roads through Back Analysis). A pilot information management system will be demonstrated during the project closure workshop.
- Defects were observed on some parts of the trial sections in the form of 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 the engineered gravel section; and the occurrence of sedimentation build up in drains.
- The lack of a proper maintenance programme is the most likely contributing factor to the observed poor performance of some of the road sections. However, the inspection of road sections on the Siha site showed that they were in a better condition than the Bagamoyo site, where there were more areas with moderate to severe deterioration as indicated above.
- Connected to the above, there seems to have been a lack of proper handover of project documentation between the Roughton International, Contractor and PMO-RALG who were involved in the project at the time of project completion.
- The quality of the available information is of a twofold nature. Data collection prior to 2014 was undertaken by Roughton International (Project Consultant) and is considered reliable, while data gathered after 2014 by PMO-RALG with support from CML is considered uncertain, as no analysis was conducted and the data is substantially incomplete.
- The monitoring process of road trials was informed by the expected outcomes of the LTPP study. The sections constructed on the Bago to Talawanda road in the Bagamoyo district and on the Lawate to Kibongoto road in the Siha district were designed to demonstrate and verify different options in design, material utilisation (for both pavement and surfacing) and construction methods for low-volume roads. The best design concepts in terms of performance and life-cycle costs will then be incorporated as part of the Tanzanian Pavement and Materials Design Manual. In addition, data collected should facilitate the development of a reliable national database which can be linked to the regional database.
- In spite of the benefits to be gained in improved designs, construction methodologies and maintenance practices, on the basis of information collected during the monitoring of the road trials, the challenge is in ensuring consistency in the timing and most of all, continuity of the monitoring survey, once donor funded projects are handed over to the beneficiary organisations.
- Existing project reports showed 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. However, it was reported that an additional year of monitoring was carried out by the consultant, following an extension of the original contract. PO-RALG was therefore expected to monitor the sections and collect data for analysis in the following eight years. This means

that monitoring was to continue for a period of ten years following the construction completion date. It was expected that throughout the various monitoring stages engineers and technicians from the two districts (Bagamoyo and Siha) would 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. As indicated previously in this report, all monitoring data collected during the project implementation was recorded digitally and can be accessed on the ReCAP website.

- PO-RALG and TANROADS-CML, with the involvement of district engineers, carried out one additional monitoring visit to both demonstration sites. The raw data from the baseline study until the 2014 monitoring of the two sites were made available. However, due to the fact that only partial data of the last monitoring (2014) was available to the project team, it categorised the data, from a quality point of view, as uncertain.

Table 2 and Table 3 present details of the trial sections in Bagamoyo and Siha districts, respectively.

Table 2 Selected sites for the monitoring exercise – Bagamoyo trial sections

Trial Section	Chainage		Length (km)	Gradient (%)	Surfacing Type
	Start	End			
1	0.030	0.230	0.200	2.1	Single Otta seal with a sand seal (26 mm)
2	5.340	5.520	0.180	3.0	Hand packed stone (150 mm)
3	5.560	6.080	0.520	3.0	Concrete strips (100 mm - Reinforced)
4	6.080	6.740	0.660	6.0	Geocells (75 mm)
5	8.000	8.240	0.240	6.0	Double surface dressing (20 mm)
6	9.980	10.670	0.690	6.0	Concrete strips (100 mm - Unreinforced)
7	11.200	11.400	0.200	4.0	Double sand seal (20 mm)
8	12.200	12.580	0.380	3.0	Gravel wearing course
9	16.240	17.100	0.860	3.5	Concrete strips (100 mm - Reinforced)
10	18.480	18.740	0.260	3.2	Concrete strips (100 mm - Reinforced)
11	19.000	19.200	0.200	3.0	Gravel wearing course
12	20.040	20.260	0.220	3.0	Slurry Seal (8 mm)

Table 3 Selected sites for the monitoring exercise – Siha trial sections

Trial Section	Chainage		Length (km)	Gradient (%)	Surfacing Type
	Start	End			
1	0.000	0.200	0.200	1.4	Concrete paving blocks
2	1.360	1.500	0.140	1.4	Unreinforced concrete slab (100mm)
3	1.960	2.180	0.220	14.2	Flexible geocells (75mm)
4	2.180	2.580	0.400	19.9	Unreinforced concrete slab (75mm)
5	2.580	2.780	0.200	19.9	Gravel wearing course
6	2.780	3.640	0.860	19.4	Concrete strips
7	4.340	4.540	0.200	20.8	Double surface dressing
8	4.540	4.780	0.240	20.8	Concrete strips

9	4.780	5.000	0.220	20.8	Unreinforced concrete slab (100mm)
10	5.000	6.100	1.100	19.4	Concrete strips
11	6.340	6.620	0.280	28.5	Unreinforced concrete (100mm)
12	7.720	8.260	0.540	14.7	Concrete strips
13	9.670	9.900	0.230	23.8	Unreinforced concrete (75mm)
14	10.100	10.300	0.200	16.8	Concrete strips
15	10.680	11.200	0.520	17.4	Concrete strips
16	11.620	11.820	0.200	19.6	Bituminous penetration macadam
17	11.820	12.120	0.300	19.3	Lightly reinforced concrete slab (100mm)
18	12.280	12.560	0.280	19.3	Lightly reinforced concrete slab (75mm)
19	12.640	13.070	0.430	30.0	Lightly reinforced concrete slab (100mm)
20	13.070	13.480	0.410	30.0	Gravel wearing course

[1]Approximatle, average values

5 Project key activity (Task 2): Review and implementation of regional guidelines

One of the key components of the project activities was to refine and implement existing guideline/protocols for establishment and monitoring of road trial sections, and to ensure that data collected from demonstration sections are consistent with regional protocols. Revision of the AfCAP *Guideline for Monitoring Experimental and LTPP sections in Mozambique (Paige-Green, 2016)* was accomplished under Task 2 of this project and updated as refined Guideline for Tanzania (will be discussed at the workshop and attached to the Project Final Report). The goal was to develop refined guidelines for LTPP establishment and monitoring in the country.

The information gathered from the task was to be utilised by the project team to understand how adaptable the refined guideline is, and to identify required measures to further refine it, so that it provides clear guidance on best practices that could be standardised and adapted for LTPP establishment and monitoring across the country. The concepts in the preliminary version of the guideline was used to carry out the two monitoring exercises of this project, mostly on the basis of the draft Guideline for Monitoring Experimental and LTPP sections in Mozambique (Paige-Green, 2016). A total of 13 documents formed the core for the review and consolidation of information to prepare the refined LTPP guideline on establishment and monitoring of trial sections and data collection for Tanzania. These are:

i. Guideline for the Monitoring of Experimental and LTPP Sections in Mozambique (First Draft) – Project Reference: MOZ2093A (January 2016).
ii. Development of Pavement Design Standards for Low-Volume Roads in Ethiopia – A Guideline for the establishment and monitoring of sections on the road network to measure Long-Term Pavement Performance (LTPP) (2014).
iii. Design and construction of demonstration sites for district road improvement in Tanzania – Final Report, Roughton International (2013).
iv. Design, construction and monitoring of demonstration sites for district road improvements in Tanzania – Quarterly Report during the Monitoring Phase (April 2012).
v. Back analysis of previously constructed low-volume roads in Mozambique, AFCAP/MOZ/001/G – Final Report, CPR1612, June 2013.
vi. Low-Volume Rural Road Surfacing and Pavements. A Guide to Good Practice (Cook et al., 2013).
vii. Design Manual for Low-Volume Sealed Roads – Malawi Ministry of Transport and Public Works (2013).
viii. Low-Volume Roads Manual – Tanzania Ministry of Works, Transport and Communication (2016).

ix. Labour-enhanced construction for bituminous surfacings – Southern African Bitumen Association (Sabita Manual 11, 1993).
x. Appropriate bituminous surfacings for low-volume roads and temporary deviations – Southern African Bitumen Association (Sabita Manual 10, 2012).
xi. Comparison of the US and Australian Long-Term Pavement Performance (LTPP) Data on Asphalt Pavements (February 2009).
xii. Long-Term Pavement Performance Inventory Data Collection Guide – Publication No.: FHWA-HRT-06-066 (March 2006).
xiii. Recommendations on the use of marginal base course materials in low-volume roads in South Africa. – South African Dept. of Transport, Research Report RR 91/201 (November 1996).

A detail review of these documents was provided in Task 2 report of this project. The main focus was on the review and analysis of available national and international guidelines/protocols on the establishment and monitoring of trial sections. Highlights and key findings are provided in Table 3.

Table 4 Summary of reviewed LTPP guideline/protocols

Highlights	Key findings / outcomes
Planning and design of a monitoring programme	– The planning and coordination relates to design process and management of a long-term monitoring programme to ensure that the maximum benefit is obtained from the studies. The following documents adequately cover planning and design of an LTPP programme for monitoring existing trial sections: ▪ the draft **Guideline for the Monitoring of Experimental and LTPP Sections in Mozambique**, ▪ **Appropriate bituminous surfacings for low-volume roads and temporary deviation, Southern African Bitumen Association** and ▪ **Low-Volume Rural Road Surfacing and Pavements. A Guide to Good Practice**.
Monitoring techniques and equipment	– Relevant field and laboratory measurements during monitoring include transverse and longitudinal profile measurements, riding quality, in-situ strength with DCP method, skid resistance and laboratory testing of materials (subgrade soils and gravels, natural borrow materials, processed layer aggregates, surfacing chippings and bitumen, aggregates and binders, cemented materials and cementing agents, etc.). – Detailed guidelines for the measurements of density and moisture content of individual layers using a dual-probe hydro density meter are presented in most of the documents reviewed, in particular the following documents: ▪ the draft **Guideline for the Monitoring of Experimental and LTPP Sections in Mozambique**, ▪ **Low-volume Rural Road Surfacing and Pavements. A Guide to Good Practice**, **Development of Pavement Design Standards for Low-Volume Roads in Ethiopia: A Guideline for the establishment and monitoring of sections on the road network to measure Long-Term Pavement Performance.**
Sampling and testing	– Field and laboratory testing guidance is essential as part of the assessment of LTPP as it will provide information on any changes in properties over the monitoring period. This aspect is adequately covered in ▪ the draft **Guideline for the Monitoring of Experimental and LTPP Sections in Mozambique,** and ▪ the **Development of Pavement Design Standards for Low-Volume Roads in Ethiopia**: **A Guideline for the establishment and monitoring of sections on the road network to measure Long-Term Pavement Performance**.
Data management	▪ Collected data form the basis for the refined guideline and it is essential that the collected data is accurate, consistent and appropriate. A detailed approach for

	data capturing and analysis is recommended for LTPP monitoring. For example, each time a section is monitored, the data should be fully captured in the field on field forms. This data should then be entered into a spreadsheet or database as soon as possible and the field forms should be digitally scanned and saved to a reliable storage medium. Reporting of the data should be reviewed, checked and analysed in terms of its basic properties and statistics. Temperature, rainfall and wind data of the LTPP sections is to be collected daily during monitoring that may be done using a small portable weather station. Temperature button loggers are recommended to monitor temperature. The loggers are designed to continuously monitor the temperature and to store this information in their memory. – Manual traffic counts are appropriate for situations where automatic traffic count equipment is not available or the cost of the equipment is very high. Manual traffic counts are usually used for short-term traffic counts – typically less than one week (24 hours a day for 7 days). Each passing vehicle is recorded on a survey form in terms of the vehicle type and the time it was observed (see Appendix G: Traffic Tallying Form). Traffic is counted in both directions for the duration of the survey. ▪ This aspect is adequately covered in **Long-Term Pavement Performance Inventory Data Collection Guide. Publication No.: FHWA-HRT-06-066. March 2006**
Maintenance	– The monitoring of the response of the pavement to the required maintenance other than the scheduled maintenance is essential. This will provide the information required on the impact of maintenance operations on rate of deterioration and therefore the impact on in-service performance/serviceability of the trial sections. The resources allocated for the unscheduled maintenance will provide the data for quantifying the performance. The document, **Appropriate Bituminous Surfacings for Low-Volume Roads and Temporary Deviation published by the Southern African Bitumen Association** covers this aspect in more detail.
Whole life-cycle costs	– The analysis of the whole life-cycle costs of LTPP sections is important to any LTPP monitoring programme that compares performance of alternative pavement surfacing options (as is the case in this project). The cost analysis involves comparison of the discounted total cost of the pavement option with that of a conventional or alternative design. Included in this analysis are the full construction cost, maintenance and rehabilitation costs, operating costs and benefits, and the salvage value of the option at the end of the analysis period. The objective of the assessment is to determine the design concept that minimises whole life-cycle costs. The latter aspect is adequately covered in ▪ **Design and Construction of Demonstration Sites for District Road Improvement in Tanzania (Final Report)** and ▪ **Design Manual for Low-Volume Sealed Roads (Malawi Ministry of Transport and Public Works).**
Capacity building	– Although training is not emphasised in most of the documents reviewed, it is considered an important component of LTPP monitoring to ensure that the team is capable of taking measurements on site and collecting information that is reliable and accurate during the monitoring period. Capacity building is the key objective of this project and a measure of the successful implementation of the project. Sections on capacity building and training are presented in ▪ the **Establishment of a Road Research Centre in Mozambique: Short-Term Technical Assistance Programme** by Verhaeghe et al. (2014) and ▪ Development of Pavement Design Standards for Low-Volume Roads in Ethiopia: **A Guideline for the establishment and monitoring of sections on the road network to measure Long-Term Pavement Performance** by Otto et al. (2014).

	– Considering the importance of collecting reliable and accurate information during the monitoring period, it seems appropriate to consider elevating human resources development to a core component of LTPP monitoring programme and therefore to be included as one of the main sections in the refined guideline.

6 Project key activity (Task 3): Monitoring of trial sections

This project primarily deals with post-construction monitoring of selected trials sections. The key objectives of Task 3 were to train and assist staff from TARURA /LoGITReC in carrying out monitoring activities on the two trial sections. The following sub-sections present details of the approach followed to achieve the objectives of Task 3.

6.1 Training needs assessment

At the project inception phase, a preliminary discussion on capacity needs was held through engagement with TARURA for the project team to gather information about the areas that required additional training, areas to prioritise, and how capacity building could be incorporated into TARURA current and future strategies.

It was appreciated that capacity building in post-construction monitoring of LTPP/trial sections should focus on the engineers, technicians, council managers from TARURA, who are responsible for the management and implementation of any methods or equipment for the monitoring of LTPP/trial sections on low-volume roads in Tanzania. However, their capacity to independently monitor the existing trial sections was assessed at the inception stage as being limited and in need of a more detailed training programme. The additional responsibility of becoming conversant with use of a new LTPP Guideline for the establishment and monitoring of LTPP sections in Tanzania places a more challenge on TARURA and it was important for the project team to consider the essential training needs. The training programmes were to:

- Explain the background of concepts behind LTPP establishment and monitoring.
- Lay out the key aspects and requirements of the LTPP guidelines to be used in Tanzania
- Fully describe the necessary procedures required to practically implement the LTPP Guideline
- Include an in-class and practical hands-on elements.
- Address LTPP project-specific training needs assessment of PO-RALG.
- Develop training materials necessary for monitoring trial sections
- Incorporate an element of feed-back and course assessment.

Generally, the approach implemented for achieving the objectives and outcomes of the capacity building programme was based on an integrated and hands-on approach to ensure effectiveness of the capability development, including a combination of workshops and mentoring. PO-RALG provided facilities and logistics for the training programmes, while the project team provided the training services.

6.2 Implementation of monitoring programme

As mentioned previously, the implementation of Task 3 was achieved through four problem-based learning workshops and two field monitoring exercises. The workshops were made of 16 Modules while the field monitoring exercise had eight modules. A detailed monitoring training programme and a road map (13 stages) to the implementation of Task 3 is summarised in Figure 1.

Figure 1 Road map to the implementation of monitoring training programme

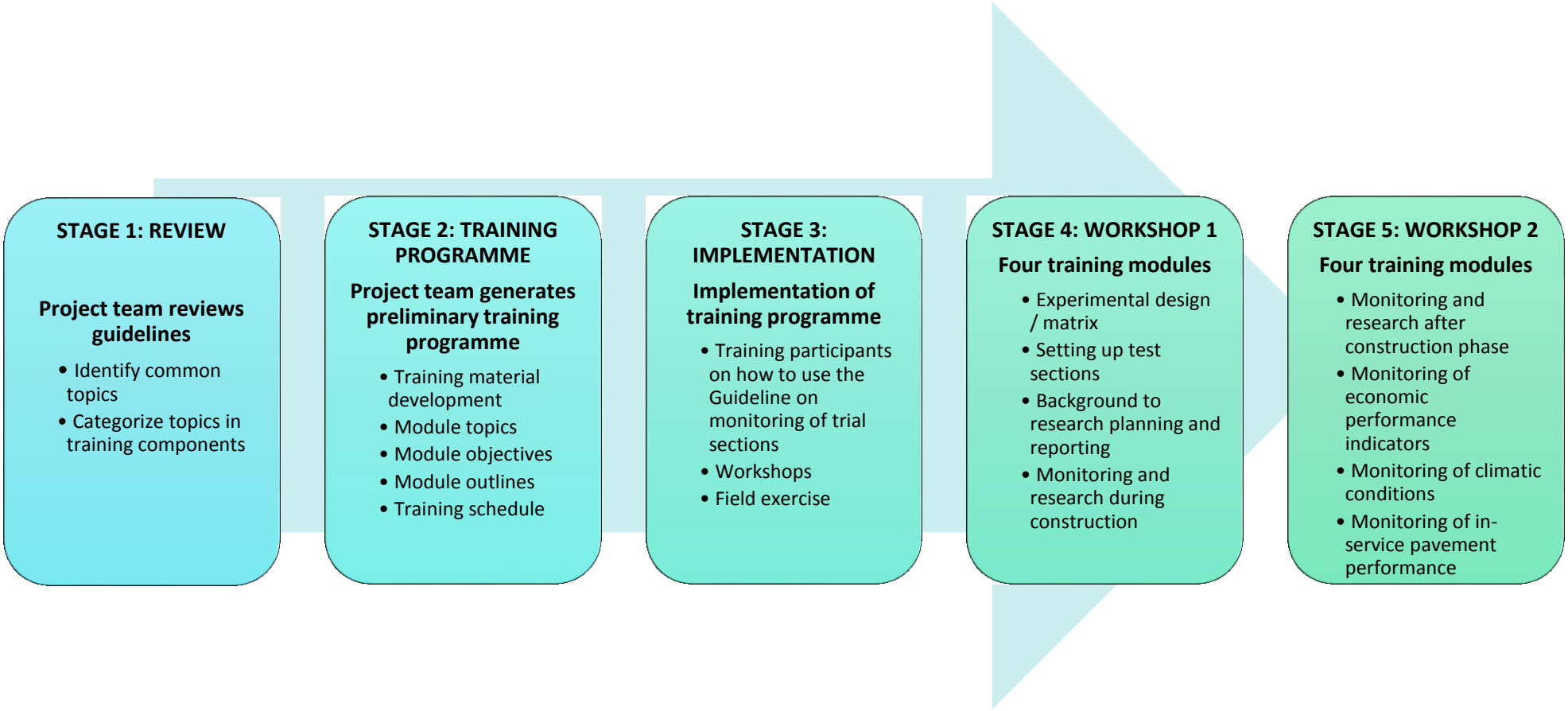
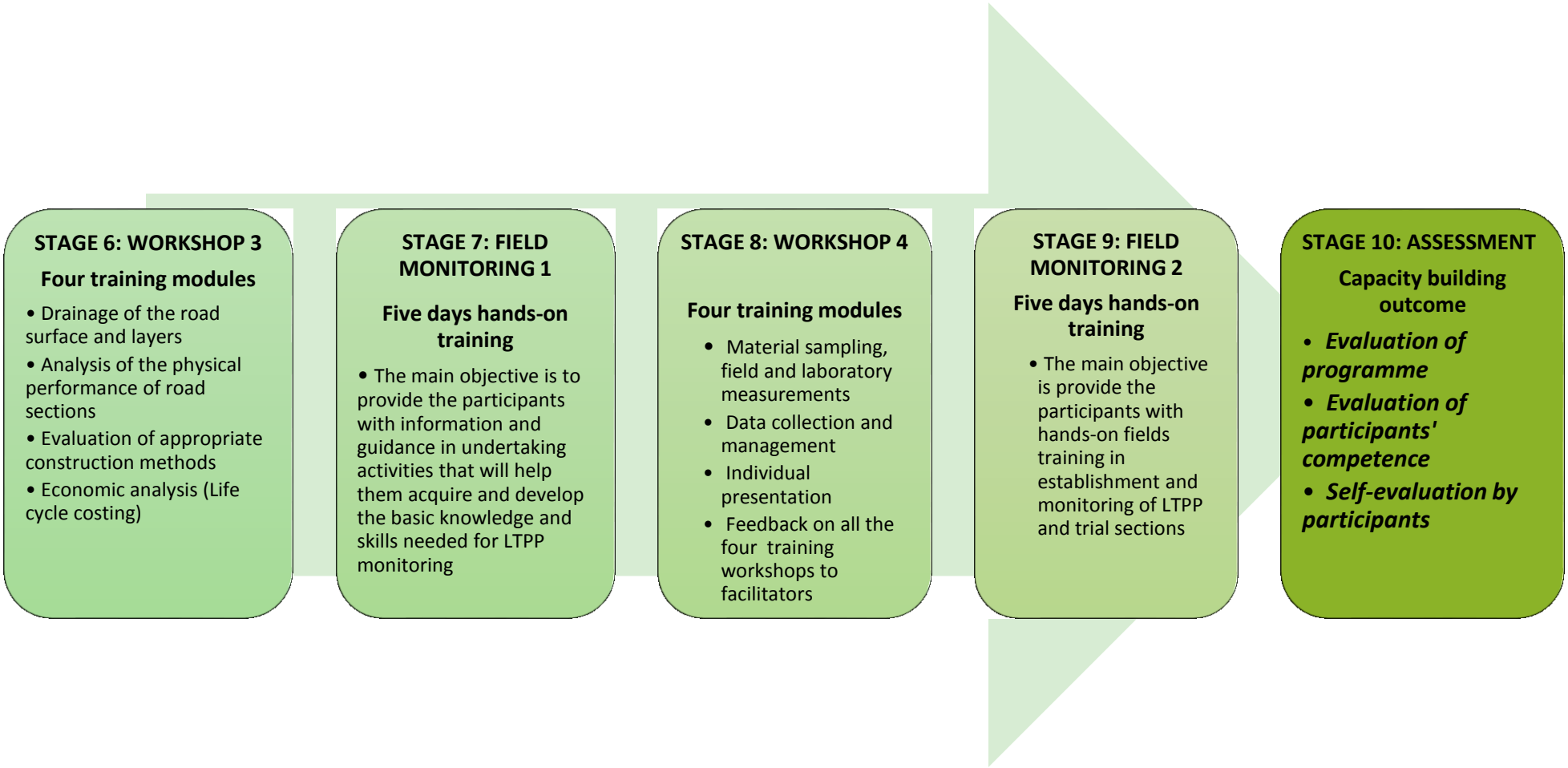


Figure 1 (Cont'd) Road map to the implementation of monitoring training programme



6.3 Development of training programme

The training programme was developed in consultation with LoGITReC /TARURA. One of the main activities undertaken by the project team was the review of available reports on the two demonstration sites on the Bago to Talawanda road and Lawate to Kibongoto road. Information gathered from the reports indicated that during the construction of the two trial sections some training was provided to local technicians and engineers from PMO-RALG and CML on the project. Part of the training evaluation focused on the ability of the technicians/engineers to accurately collect data on visuals, photo logs, surface profile measurement, rut depth measurement, surface roughness, DCP, traffic counts, concrete coring, etc. However, an overall assessment of the competence of these trainees in terms of data collection techniques indicated a lack of complete understanding of data analysis and management. This implied that further training should put emphasis on these important components of LTPP monitoring. The following were incorporated in the training programme for capacity building:

- Visual inspection of roads, identification of defects, methods of recording and taking photographs of defects;
- Demonstration of five key equipment used to measure rut depth, surface roughness, surface texture, surface profile, and pavement strength (DCP), and at which point on the road should these measurements be taken, and how data collected are analysed. This included methods required for taking these measurements, the types of surface that the measurements are taken on, how changes in these parameters can be monitored over time, and the possible causes of these defects;
- Methods of carrying out rut depth, surface roughness, surface texture, surface profile, and pavement strength (DCP) measurements, advantages/disadvantages of each method, the time intervals at which measurements are taken.;
- 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;
- 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;
- Data collection and extraction of relevant information as input to pavement performance analysis.

A full report on capacity building and knowledge transfer was submitted to Cardno as a milestone deliverable of the project. The report detailed a record of the capacity building activities achieved through a combination of four workshops and two field monitoring training exercises. The report also examines participants' perceptions of capacity building issues addressed during the implementation of the project. It also covers lessons learnt and recommendations to enhance effective implementation of the monitoring of the trial sections, analysis and interpretation of the collected data.

6.4 Training workshops

Four structured problem-based learning training workshops constituted an important component of capacity building strategy of this project. Structured classroom presentations and field exercises on monitoring of trial and LTPP sections were covered in these workshops. All four training workshops were attended by participants comprising technicians, council managers, regional coordinators, engineers and managers from TARURA and lecturers from DIT and MUST. The main topics covered were:

- Monitoring of in-service pavement performance
- Monitoring of traffic and climatic conditions
- Monitoring during construction
- Implementation of monitoring plan – identify monitoring methods
- Review of equipment required for post construction monitoring
- Post construction laboratory testing for monitoring

- Data collection forms for monitoring

Generally, the workshops were undertaken to systematically take participants through all processes and activities required for LTPP establishment and monitoring of sections. The long-term expected result of the training workshops is development of sustainable capacity with the required skills and necessary knowledge to effectively implement a monitoring programme on long term performance of trial sections. Four separate project reports (see Table 1) on these workshops were submitted to Cardno as project technical deliverables.

6.4.1 Key activities and outcomes of workshops

Table 5 summaries the main activities and outcomes of the four training workshops. Annex 1 is an aggregate compilation of the responses of participants on their observation with respect to what they liked the most about the respective training workshops, what aspects of the training could be improved and any other general comments. These were responses to a prepared questionnaire with brief structured questions on various aspects of the training including workshop venues. The same questionnaire was used for all the training workshops, and can be found in Project Progress Reports 1, 2, 3 and 4).

Table 5 Summary of activities and outcomes of training workshops

No.	Key activities	Main outcomes
Training workshop 1	– LTPP experimental programme design, construction and monitoring of trial sections. – Differences between trial and test sections in terms of the setting up criteria and expected data from these sections. – Research objectives, activities and stages that are expected to be undertaken during construction and monitoring stages. – Baseline monitoring data collection during and immediately after construction. – Characteristics and materials properties to be determined from experimental sections.	– Participants gained knowledge in the processes involved in the development of experimental matrix and the monitoring of experimental sections. – There was an appreciation of the importance of linkage between research process and monitoring of trial sections. – Improved knowledge was gained by participants on recording of field observations for visual assessment. – Participants became conversant with the information to be collected during construction of trial sections.
Training workshop 2	– Involved both classroom training and on-site training that mainly focused on demonstration of monitoring equipment. – In-class presentation and field demonstration of five types of equipment/tools used for monitoring. – Introduction of participants to activities involved in monitoring and research after construction of trial sections.	– Participants demonstrated ability to use five key equipment/ tools commonly used for LTPP monitoring (i.e. DCP, MERLIN, dumpy level, tripod and levelling staff, Straight edge and Sand patch). – Participants learnt basic concepts of monitoring and research after construction of trial sections. – Participants became familiar with data collection sheets/forms for monitoring LTPP sections. – Majority of the participants were declared competent in the use all five equipment demonstrated in this training.

Training workshop 3	– Road drainage system and monitoring of drainage conditions. – Visual assessment of trial sections. – Discussions and in-class exercise on plotting of profiles from the survey data, cumulative sum method using DCP data. – Economic analysis, data analysis and data interpretation of economic cost indicators. – Preparation for monitoring including formation of teams and allocation of responsibilities.	– Participants gained knowledge in fundamental principles of drainage systems – Participants learnt that monitoring programme has to be properly linked to the proposed initiative and has implication on the future role of LoGITReC within TARURA. – Participants demonstrated a general understanding of the material covered during the training workshop 3. – Participants gained basic knowledge in data analysis and interpretation.
Training workshop 4	– Sampling and testing of materials during LTPP monitoring. – Procedures for data collection and management as well as introduction to link of material properties with pavement design. – Individual technical presentation to assess presentation skills and ability of participants to potentially disseminate research/technical information. – Assessment of a presentation and evaluation of training workshops.	– Participants gained knowledge learned to undertake the second monitoring exercise. – Gaps in presentation skills of both engineers and technicians from TARURA were identified. – It was agreed that Problem Based Learning should be emphasised in technical institutions in Tanzania. – Participants were of the opinion that TARURA and the academia should assume a lead role in the establishment and monitoring of LTPP sections on rural roads in the country.

6.5 Monitoring training

6.5.1 Monitoring exercise

Two monitoring exercises on the trial sections formed part of training and capacity building activities of the project. The goal was to build capacity in the area of establishment and monitoring of LTPP sections using the refined LTPP Guideline developed as part of this project. Monitoring of a trial section is usually aimed at recording the baseline data and in-service performance of the pavement over time, as well as changes in the environment that may influence the performance of the road. Two separate reports were submitted as project deliverables on the monitoring exercises (Progress Report and 5).

For this project, it was expected that the monitoring exercises provide participants with the requisite knowledge and understanding to address competence gaps in data collection and analysis as well as ability to extract relevant information from LTPP monitoring for decision making by the road agencies and authorities in Tanzania. The first exercise was undertaken from 10 to 30 May 2018, whilst the second exercise was carried out from 3 to 11 October 2018.

The monitoring exercises was based on a hands-on skills development approach and aimed at imparting knowledge in long-term pavement performance monitoring of trial sections to participants, and understanding of;

- how monitoring programme is designed,
- the differences between data collected from trial and LTPP sections,
- the various monitoring objectives, activities to be carried out during monitoring stages, and
- measurements and marking out of trial and LTPP monitoring sections

Key highlights of the monitoring training exercises were as follows:

- First days of each session were devoted to planning and overview of the task at hand, as well as discussion on the approach to be used for the two exercises. During the planning meeting, participants

were divided into two groups for the exercise. Groups were formed to ensure professional/academic backgrounds mix; e.g. engineers, technicians and participants from academia were split between groups.
- Constraints associated with marking out of trial and LTPP sections using the AfCAP LTPP Guideline.
- Observation and assessment of individual participant's needs.
- Discussion on key issues related to monitoring of trial sections.
- Views of participants about the monitoring training exercise.

A total of 14 council managers, and regional coordinators, engineers and technicians from Tanzania Rural and Urban Roads Agency (TARURA) and lecturers from two academic institutions fully participated in the first exercise. This number was reduced to 11 during the second monitoring exercise due to the fact that some of the TARURA engineers and technicians had other commitments. Part of the last day of the two monitoring training exercises was used for open discussions and contributions from participants on issues of general concern and lessons learnt from the exercise.

It was generally targeted that individual participants demonstrate competence in all activities with the necessary knowledge and required skills, to effectively implement a monitoring programme on long term performance of trial sections. The refined Guideline was used to conduct the monitoring exercise at the two project sites, to ensure that the establishment of LTPP trial sections and monitoring is standardised in Tanzania.

6.5.2 Monitoring methods

Six monitoring methods and relevant low-cost equipment were demonstrated in detail to participants. These are presented in table 6.

Table 6 Monitoring methods and equipment

Method	Approach	Equipment
Visual Assessment/Photographic Logging	Visual condition assessment was conducted using visual inspection field sheets. The road section was divided into blocks ranging from 10 m to 40 m whereby detailed visual assessment was conducted on each side of the centreline. The visual assessment focused on the type, extent, severity and position of the defects. In this exercise, visual assessments were combined with photographic logging. Modes of surface distress recorded include depressions, pot holing, erosion and drainage defect.	None, but linked to basic measuring tape or the steel straight edge
Surface Profile Measurements	Surface profile measurements were conducted using dumpy level at selected locations within the road segments. Attempts were made to collect data in locations used during the 2014 monitoring exercises. Starting from the edge of the road, levels were taken at 10 m intervals across the section so that surface profile levels and approximate cross fall can be determined. The recorded data from dumpy level were then used to compute the reduced levels across the section which were then use to plot the profiles.	

Surface ruts measurements using standard straight edge	Rut depths were measured using a 2 m straight edge and a wedge. Rut depth measurements were taken across wheel paths from either side of the centreline. The straight-edge was placed across the wheel-path, at right angles to the direction of traffic, and three rut depth measurements were recorded. The ruts depths were measured at a distance of 10m intervals starting from the beginning of the trial section.	
Dynamic Cone Penetration (DCP)	TRL DCP instrument was used to assess strength of existing pavement layers. The standard instrument that uses an 8 kg hammer dropping through a height of 575mm and a 60° cone with a diameter of 20mm was used for this exercise. The depth of penetration was recorded after every five hammer blows to a depth of at least 800 mm. DCP test points were selected to tally with the test points used during the 2014 monitoring.	
Surface roughness	Surface roughness measurements were carried out by using Machine for Evaluating Roughness using Low-cost Instrumentation (MERLIN) equipment. The equipment was first calibrated using the standard procedure before any measurement was taken. Measurements were done along the wheel path and covered a total of 200 data points. International roughness indices were then calculated based on the recorded measurements.	
Surface texture	The sand patch method (volumetric) was used to measure surface texture along the demonstration sections. Sand patch testing were done at 100 m intervals between each set of monitoring beacons to provide consistency in future monitoring phases. Sand patch testing can be used to monitor the surface texture of all concrete and bituminous surfacing options of the trial sections.	
Traffic count	Manual traffic counts for Bago – Talawanda road were carried out at two observation points. Traffic counts were performed at CH: 0 + 040 - Bago and CH: 19 + 060 - Talawanda. Twelve-hour counts were carried out for three consecutive days from 21/05/2018 to 23/05/2018. Classified traffic count approach was used where different categories of motorized and non-motorized traffic were recorded. Traffic count was also conducted in Siha. Results were compared with previous monitoring ending in 2014.	None, but linked to standard clipboard with traffic count forms

6.5.3 Outcomes of monitoring training exercises

Based on the outcomes of the two monitoring training exercises, the following observations and concluding remarks were made:

- The objectives of the monitoring exercise were achieved, based on the assessments and the general consensus from the evaluations by the participants that the two exercises were beneficial to participants and particularly, TARURA as it is through these exercises they became aware of the advantages of establishing and monitoring trial sections, as well as maintenance activities that should be incorporated in the programme.
- During monitoring, the level of competence of the newly trained researchers and the technicians were assessed. The LoGITReC research team and others from stakeholder institutions accompanied the project team on its visits to the two sites during each round of monitoring and were required to write individual reports in order to develop skills for reporting on results of the monitoring based on the revised regional guideline.
- There was evidence that most of the personnel who participated in the two exercises have acquired basic knowledge and understanding of monitoring activities of trial sections. Ten (10) participants who were closely observed during the second exercise are proficient in measurement and marking out of trial sections. However, there is a need to carry out monitoring activities on a continuous basis with the purpose of ensuring that they become fully conversant with monitoring methods and guidelines. It is expected they will further build confidence and become fully conversant with monitoring methods and guidelines as they carry out further monitoring activities.
- Transfer of knowledge and expertise to technicians, engineers and staff from academia was successful through the exercise. This was accomplished through a combination of four training workshops and two field monitoring training and addressing the needs of participants in terms of challenges of monitoring and data analysis. Participants demonstrated a measure of understanding of the information to be collected during monitoring and recording of field observations.
- Similar to the training workshops of the project, participants indicated that the skills and knowledge acquired from the two exercises will be shared with regional coordinators and council managers through coordinated visits to trial sections of the two sites. They however, noted that logistics /budget may be a risk to the full implementation of knowledge acquired through the monitoring exercise.
- Full assessments of competency of each participant including proficiency in data management was incorporated in the Capacity Building Report of this project.

7 Analysis of LTPP monitoring data

For this project, the long-term performance of the trial sections was evaluated in relation to the baseline data collected during the construction period, the research data (post-construction), and the project reports. The objective was to analyse the existing data based on the available information from the two demonstration sites, and subsequently use the current data collected through the monitoring exercise to update the existing information. As indicated in Project Task 1 Report, limited data were available to the project team for a full analysis. Only surface roughness and rut depth were consistently measured from the baseline study and monitoring periods up to April 2014.

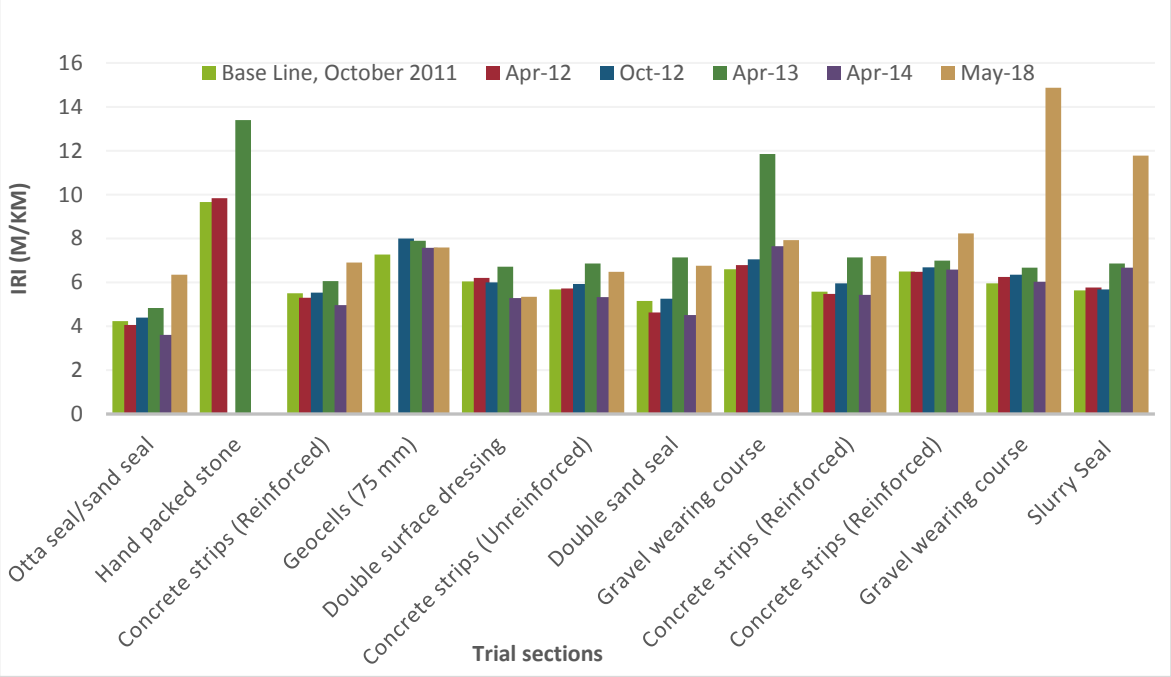
The first field monitoring exercise was used to collect data on all sections. However, the single Otta seal with a sand seal trial section on the Bagamoyo site was used to demonstrate analysis and interpretation of data by the participants through a report writing exercise. For consistency of data presentation and reporting purposes, only rut depth and surface roughness data are presented in this section. Generally, the data collected were processed and analysed by participants using Microsoft Excel and AfCAP DCP-DN software). Data processing and analysis was an integral part of the first field monitoring training exercise. ,.

7.1 Surface roughness – Bagamoyo site

Figure 2 shows minimal increases and decreases in the International Roughness Index (IRI) values during the monitoring periods. The results show that the single Otta seal with a sand seal is generally the smoothest surfacing of all demonstration sections. Significant increases in IRI values were obtained for the hand-packed stone, gravel wearing courses and the slurry seal. These high values are an indication of excessive roughness on these trial sections.

A comparison was made in the IRI values of the single Otta seal with sand seal during the monitoring periods, including the value determined in May 2018. Generally, the IRI increased during the monitoring periods. The rate of increase of IRI was about 0.4 per year for the first three monitoring periods. The results further indicate that IRI increased from 4.8 in April 2013 to 6.8 in May 2018 with approximately the same annual rate of 0.4. A decrease in IRI was however, observed between April 2013 and April 2014. This is probably due to stone polishing and excess binder on the surface, emanating from stone loss.

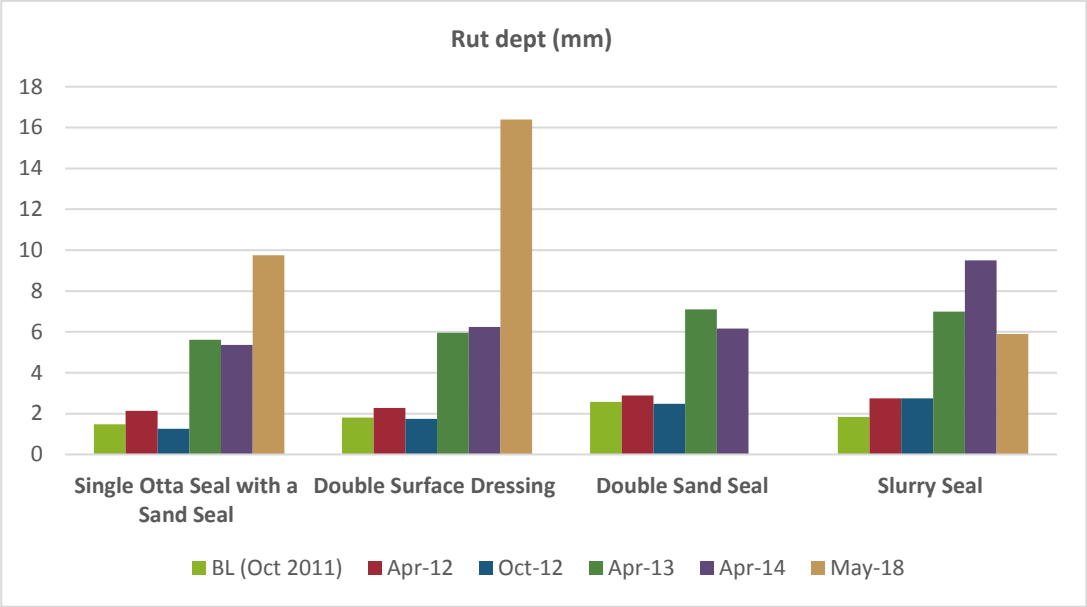
Figure 2 IRI monitoring results – Bagamoyo trial sections



7.2 Rut depth – Bagamoyo site

Rut depth measurements were undertaken in the four bituminous surfacing sections. Figure 3 shows the rut depth results from the baseline study to April 2014 and compared with the rut depth measurements in May 2018. Generally, the rut depth values for the Otta seal and double surface dressing trial sections increased during the monitoring periods. The consistently gradual increase in rut depth suggests that the underlying road base layers may be intact. A decrease in rut depth was however, observed in the double sand and slurry seal trial sections during the last two monitoring periods. Formation of rut is mainly attributed to the consolidation of one or more layers of the pavement. The measurement could not necessarily have been done on the exact same position on the road as there were previously no permanent markings for reference. The issue of road marking was dealt with during the second monitoring training exercise.

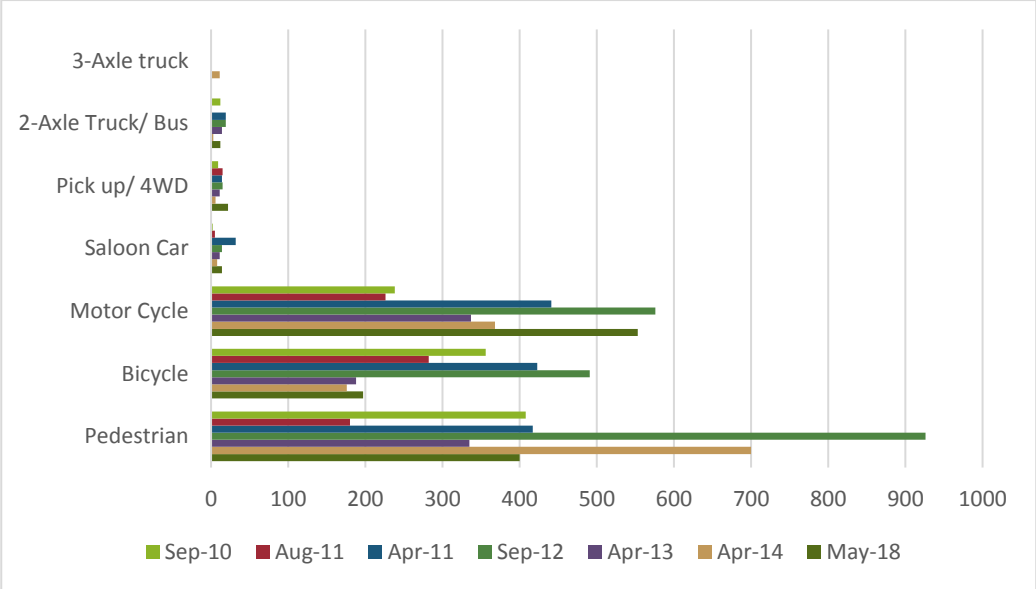
Figure 3 Max rut depths monitoring results - Bagamoyo



7.3 Traffic count – Bagamoyo site

Traffic counting was carried out on the Bagamoyo site during the monitoring exercise. The counting was carried out at Bago village. Figure 4 shows the updated results with the May 2018 traffic count. The traffic data indicate that the traffic on this site is predominantly pedestrian, bicycle and motorcycle. Only few vehicles (i.e. passenger cars, minibuses, light to medium goods trucks) were observed during the traffic monitoring. Traffic count was conducted for for 12 hours (6 am to 6 pm) and over three consecutive days (17 – 19 May 2018). It is noted that for pavement design, 12 hours data needs to be adjusted, to obtain the average daily traffic and the annual average daily traffic. The increase in the 2-Axle and Truck traffic in May 2018 compared to the last monitoring in April 2014 was attributed to harvesting season during the traffic count. An increase in in motor bicycle and bicycle traffic is also observed during April 2014 and May 2018 monitoring periods.

Figure 4 Traffic count/monitoring in Bagamoyo

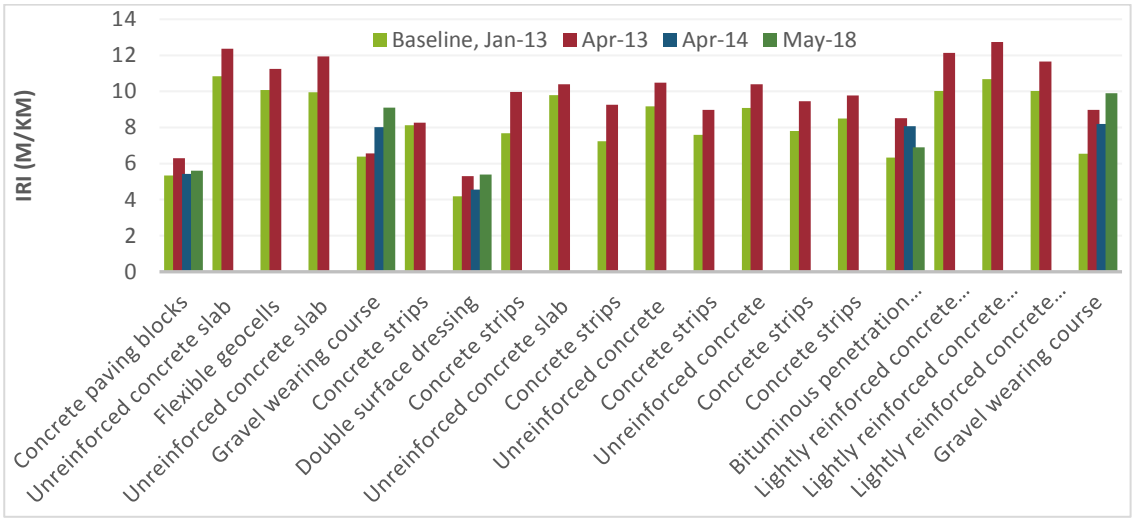


7.4 Surface roughness – Siha

Figure 5 shows that the IRI value increased on all sections between the baseline monitoring in January 2013 and that in April 2013. The IRI values were obtained for five trial sections during the May 2018 monitoring. These section were; concrete paving blocks, double surface dressing, two gravel wearing course surfaces and bituminous penetration macadam. Apart from the bituminous penetration macadam, there was an increase in IRI values for all the surfaces since the last monitoring period in April 2014.

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.

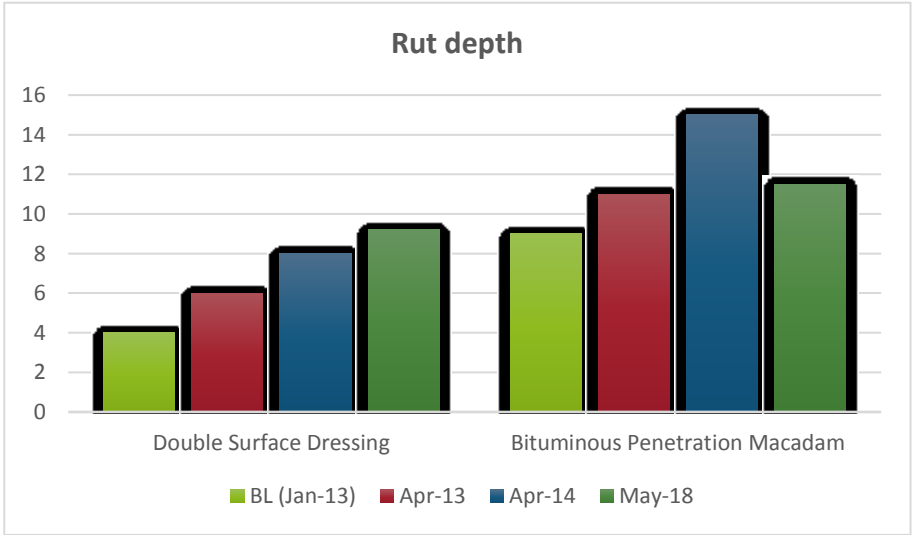
Figure 5 IRI monitoring results – Siha trial sections



7.5 Rut depth – Siha

Rut depth measurements at the Siha sites were carried out on the double surfacing and bituminous penetration macadam surfacings. Figure 6 shows the maximum rut depths for the two trial sections during the baseline study, April 2013 and April 2014, and compared with the rut depths in May 2018. Apart from rut depth for bituminous penetration macadam in May 2018, there is a steady increase in the maximum rut depths on both trial sections.

Figure 6 Rut depth on two trial sections in Siha

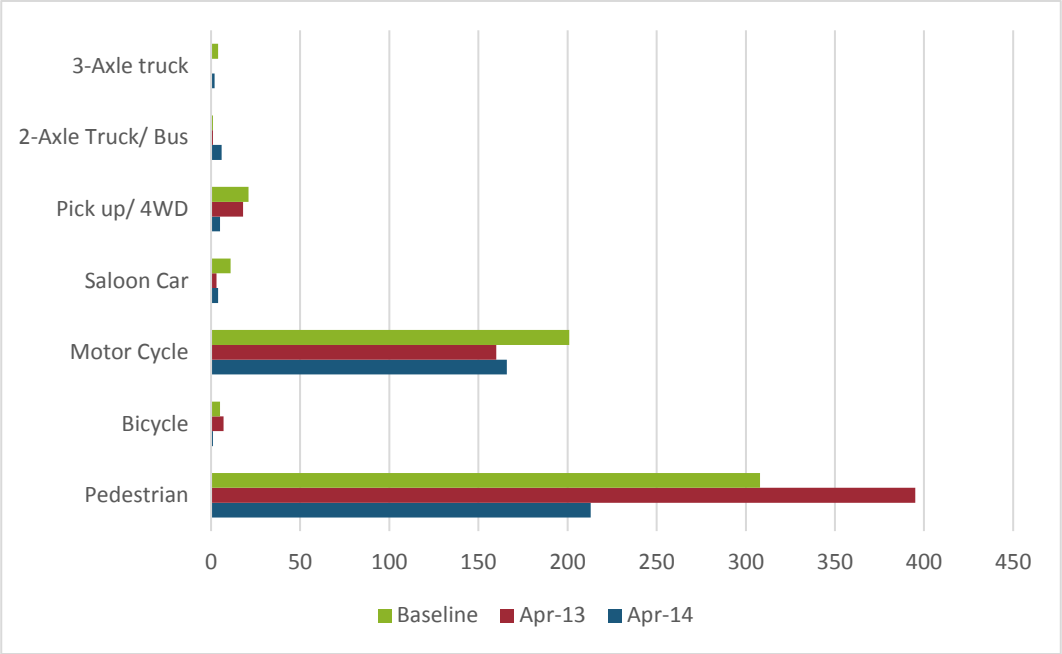


7.6 Traffic count – Siha site

Traffic count results of the Siha site in May 2018 were not available for this report. When they become available, the results will be used to update the Final Project Report.

The results of traffic count carried out at Lawate Market on the Siha site in April 2013 and April 2014 are however, presented in Figure 7. Similar to the Bagamoyo site, traffic travelling on the road was counted for for 12 hours 6 am to 6 pm and over three consecutive days (11-13 May 2018). No trend can be observed in traffic during the monitoring periods.

Figure 7 Traffic count/monitoring in Siha



8 Whole life cost analysis

8.1 Life-cycle cost

Life-cycle cost is commonly used to determine the most cost-effective options for road construction projects. A basic method utilised by many transportation agencies, and selected for this project is the present worth of cost. This method discounts all future sums to the present using an appropriate discount rate. The alternative pavement designs for the trial sections at Bagamoyo and Siha sites were compared on the basis of the present worth of the life-cycle costs. The main economic factors known to determine the cost of a road include the analysis period, the construction cost, the maintenance costs and the real discount rate. The empirical relationship to determine the present worth of cost is presented in Equation 1.

$$PWOC = C + M_1(1+r)^{-x_1} + \cdots + M_j(1+r)^{-x_j}) - S(1+r)^{-z} \quad \text{Equation 1)}$$

where, PWOC = present worth of costs; C = present cost of initial construction; M_j = cost of the j^{th} maintenance measure expressed in terms of current costs; r = real discount rate; x_j = number of years from the present to the j^{th} maintenance measure, within the analysis period (where x_j = 1 to z); z = analysis period; S = salvage value of pavement at the end of the analysis period expressed in terms of present values.

The following assumptions were made:

- The pavement structures selected for this study are in the same road category (i.e. low-volume roads).

- The suggested analysis period for rural access roads is 20 years and that of lightly trafficked rural roads is 30 years (Technical Recommendations for Highways—TRH4, 1996).
- The salvage values were assumed to be zero for all pavement options, even though there would still be some value regained in most pavements and especially for the concrete surfacings and the interlocking concrete block pavements.
- All pavements options for the same district are subject to similar traffic and climate, and are assumed to have the same equivalent standard axle loads.
- The discount rate of 6 and 10 % (Tanzania discount rates, Roughton International Final Report) was used for the analysis.

Typical maintenance measures are based on known performance of the pavement options at the Bagamoyo and Siha sites. The pavement design method of the Bagamoyo site was based on Tanzania pavement design method while the design of the pavements in Siha district was based on Malawi DCP method.

8.2 Initial construction cost

The initial construction costs were computed based on the current construction rates used in Tanzania. Construction work activities and current rates of local labour and equipment have been considered in the cost. Costing was mainly based on the pavement structures, as well as on variables such as materials, production, haulage distance, labour, construction and equipment.

It is assumed that provisional sums for general items and initial preparation of road formation, as well as drainage systems will be the same for all pavement options. This may not necessarily be true, however, it is expected that cost variations would be minimal.

8.3 Future maintenance

When different pavement types are compared on the basis of cost, the future maintenance costs should be included in the analysis to ensure that a reasonable comparison is made TRH4 (1996). For this report, maintenance (routine and periodic) costs for the demonstration sites from 2013 to 2018 were used in the analysis. The road widths were normalized to 3.5 metres (Roughton International Final Design Report).

8.4 Total life cycle cost

The result of the present worth of cost analysis with the initial construction and future maintenance is presented in table 7 and graphically presented in figure 8 (Bagamoyo) and figure 9 (Siha) for the pavement options. These results are preliminary and will be updated for the Final Report when all maintenance activities and costs for the trial sections are provided by TARURA.

A sensitivity analysis was conducted on the life-cycle costs at discount rates of 6% and 10% (Tanzania rates). The sensitivity analysis shows that the discount rate can vary from 6% to 10% with no significant influence on the present worth of costs for the pavement options, and also indicates that all alternative surfacings are economically feasible with an average life-cycle cost of less than GBP 25/m² at a real discount rate of 6 and 10%. The single Otta seal and the double surface dressing were the most cost-efficient for Bagamoyo and Siha sites, respectively. Usually, if the difference in present worth of costs between two alternatives is 10% or less, then the present worth of costs of the two alternatives is taken to be the same (TRH4, 1996). For instance, the life-cycle cost for the concrete paving blocks and unreinforced concrete slab (100mm) can be taken as the same. The life-cycle cost of the double sand seal and double surface dressing is also comparable.

Table 7 Whole life cycle analysis of Bagamoyo and Siha trial sections

	Surfacing	Surfacing life	Periodic maintenance (x yrs)	Maintenace (USD/km)	Maintenance (GBP/m^2)	Routine Maintenance		Maintenance cost USD/km	Maintenance cost GBP/m^2	Initial Cost (USD/km)	Initial Cost / m^2 (GBP)	Life Cycle Cost / m^2 (GBP)	
						Strategy	After x years					r = 6%	r = 10%
Bagamoyo Trial Section	Single otta seal [sand seal] [26mm]	20 years	10	4100	0.91	pothole repair	1	116	0.03	34500.00	7.69	8.78	8.40
	Hand packed stone [150mm]		0	0	0.00	pothole repair	1	1397	0.31	49000.00	10.92	14.49	13.57
	Concrete strips [100mm reinforce]		10	2195	0.49	regravel	1	1164	0.26	63300.00	14.11	17.51	16.58
	Geocells [75mm]		0	0	0.00	repair	1	47	0.01	84700.00	18.88	19.00	18.97
	Double surface dressing [20mm]		10	5700	1.27	pothole repair	1	116	0.03	57100.00	12.73	14.13	13.62
	Concrete strips [100mm un-reinforce]		10	2055	0.46	regravel	1	1164	0.26	50700.00	11.30	14.67	13.75
	Double sand seal [20mm]		3	6300	1.40	pothole repair	1	233	0.05	36000.00	8.02	13.39	11.94
	Gravel wearing course		5	5700	1.27	grading	1	815	0.18	23200.00	5.17	9.84	8.49
	Concrete strips [100mm reinforce]		10	2195	0.49	regravel	1	1164	0.26	63300.00	14.11	17.51	16.58
	Concrete strips [100mm reinforce]		10	2195	0.49	regravel	1	1164	0.26	63300.00	14.11	17.51	16.58
	Gravel wearing course		5	5700	1.27	grading	1	815	0.18	23200.00	5.17	9.84	8.49
	Slurry seal [8mm]		6	6300	1.40	pothole repair	1	698	0.16	34200.00	7.62	11.59	10.44
Siha Trial Section	Concrete paving blocks		20	0	8.71	pothole repair	1	62	0.01	91100.00	20.30	23.18	21.71
	Unreinforced concrete slab [100mm]		20	0	6.27	repair	1	124	0.03	94300.00	21.02	23.29	22.18
	Flexible geo-cells [75mm]		20	0	2.09	repair	1	62	0.01	93500.00	20.84	21.65	21.27
	Unreinforced concrete slab [75mm]		0	0	0.00	repair	1	155	0.03	81300.00	18.12	18.51	18.41
	Gravel wearing course		3	5700	1.27	grading	0.25	3948	0.88	33900.00	7.55	21.97	18.19
	Concrete strips (reinforce)		10	2400	0.53	regravel	1	1551	0.35	76200.00	16.98	21.41	20.21
	Double surface dressing		10	5700	1.27	pothole repair	1	155	0.03	61600.00	13.73	15.23	14.58
	Concrete strips (un-reinforce)		10	1990	0.44	regravel	1	1551	0.35	68000.00	15.15	19.50	18.33
	Unreinforced concrete slab [100mm]		20	0	6.27	repair	1	124	0.03	94300.00	21.02	23.29	22.18
	Concrete strips (reinforce)		10	2400	0.53	regravel	1	1551	0.35	76200.00	16.98	21.41	20.21
	Unreinforced concrete [100mm]		20	0	6.27	repair	1	124	0.03	94300.00	21.02	23.29	22.18
	Concrete strips (unreinforce)		10	1990	0.44	regravel	1	1551	0.35	68000.00	15.15	19.50	18.33
	Unreinforced concrete [75mm]		0	0	0.00	repair	1	155	0.03	81300.00	18.12	18.51	18.41
	Concrete strips (reinforce)		10	2400	0.53	regravel	1	1551	0.35	76200.00	16.98	21.41	20.21
	Concrete strips (unreinforce)		10	1990	0.44	regravel	1	1551	0.35	68000.00	15.15	19.50	18.33
	Bituminous penetration macadam		20	0	6.97	pothole repair	1	62	0.01	66900.00	14.91	17.24	16.06
	Lightly reinforced concrete slab [100mm]		20	0	6.27	repair	1	62	0.01	96800.00	21.57	23.69	22.62
	Lightly reinforced concrete slab [75mm]		20	0	6.27	repair	1	93	0.02	83800.00	18.68	20.87	19.78
	Lightly reinforced concrete slab [100mm]		20	0	6.27	repair	1	62	0.01	96800.00	21.57	23.69	22.62
	Gravel wearing course		3	5700	1.27	grading	0.25	3948	0.88	33900.00	7.55	21.97	18.19

Figure 8 Whole life cycle analysis (Bagamoyo- TPDM design)

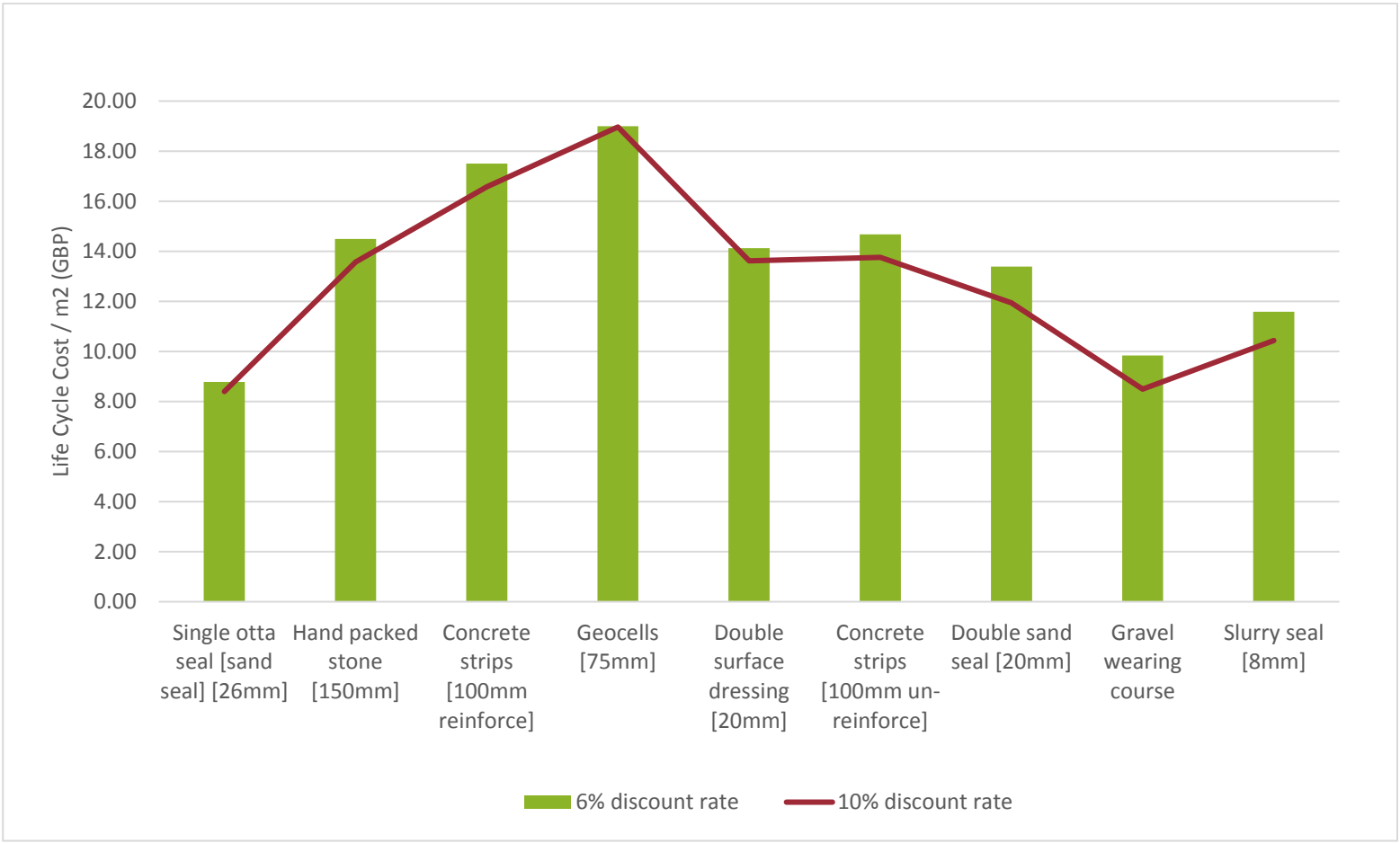
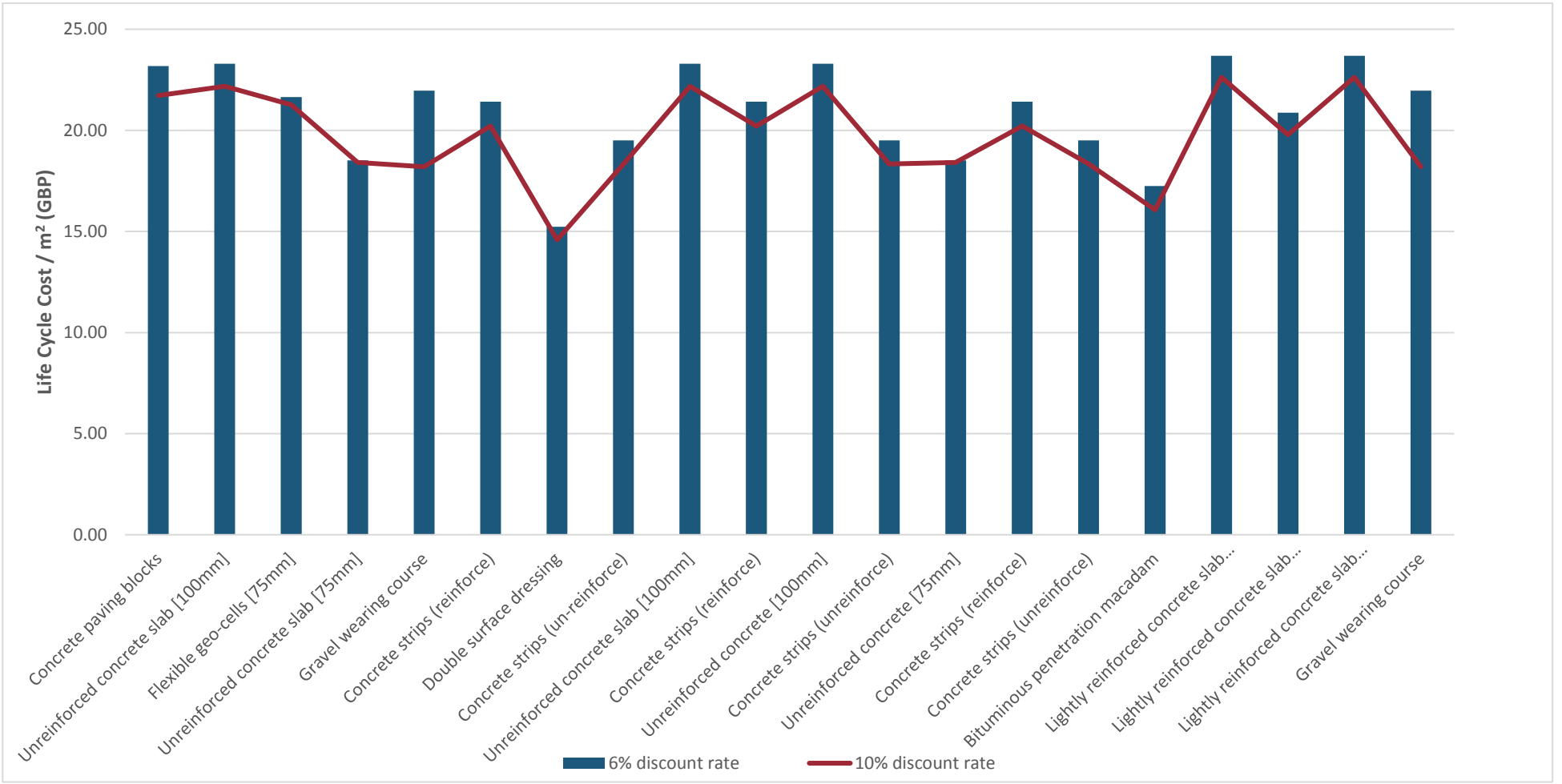


Figure 9 Whole life cycle analysis (Siha – DCP design)



9 Data management

9.1 Database structure for knowledge management system

In order to develop a proper knowledge management system it is important to understand all the elements in context. Furthermore it is important to determine the links between the different elements prior to the development of a knowledge management system as duplication of information and work should be avoided as far as possible. The recommendations made in this document is therefore focussed on the needs of LoGITReC for long term pavement performance monitoring of trial sections.

The following key statements were considered during the planning and design of the system:

- The recorded data from the existing trial sections are to be stored into a formal database.
- The centralized knowledge database should be capable of capturing, storage, and dissemination of findings and knowledge of research undertakings.
- It will be a tool for assessing the quality, utilisation, and performance of non-conventional materials used in trial sections, leading to improvements to standards and specifications as well as road construction techniques.
- The database is to closely be linked to the regional database under AfCAP's regional project.
- Data management, e.g. the way that the data is captured, stored and managed, and disseminated.

Knowledge Management System will be compiled by harvesting relevant linked information from the groups mentioned in the above key statements. Using a linked / relational approach, provides a logical framework within which to operate and expand information. A single database will be more complex to manage should needs change in the future. A relational approach will also support future migration to a different environment based on the same criteria but within a different environment.

For the purpose of the suggested structure, a simple relational Structured Query Language (SQL)-type approach is followed as the approach relates to the majority of commercial software available for the use within Knowledge Management, such as the InMagic DBTextworks[2]. The advantage of commercial software is mainly that no specialised skills are required and non-IT staff can easily manage, develop, and maintain the system. However, in an environment of limited resources, Microsoft Excel and Access, or any open source software can be utilized. Well developed and tested products save development and testing time and due to the support of the distributers, set-up can be done very quickly. A well-established client base will further contribute towards shortening the learning process. The majority of commercial products provide a web interface for dissemination and sharing purposes and customisation functionalities. It is however important when selecting a commercial product that the customisation functionalities be investigated in-depth to ensure that modifications can be done with ease and without costly consulting fees.

9.2 Suggested structure

There are four main groups to be considered. These are:

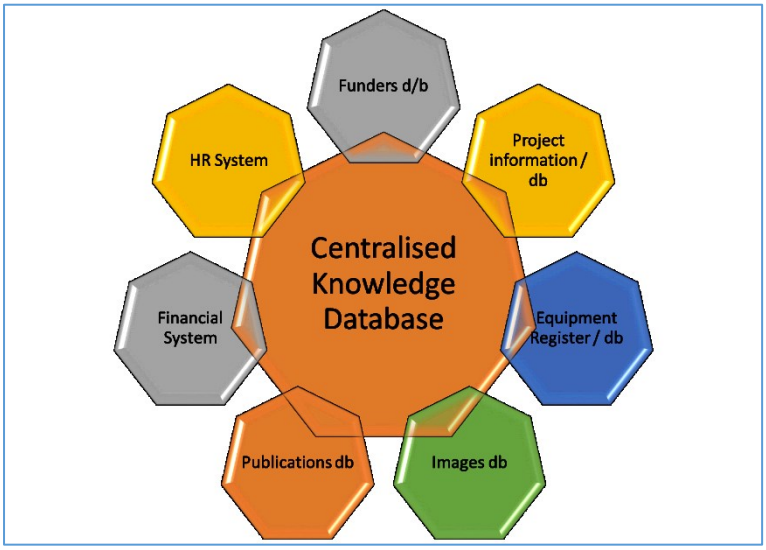
- **Publications:** outputs such as reports, articles, conference papers, final shared datasets, etc.
- **Project:** information regarding the project itself, e.g. the site, equipment used and/or required, funding agency information, and project team, etc.
- **Human Resources**: details of the employees including qualifications, experiences, earlier projects, etc.
- **Financial** (peripheral and not for sharing): budgets, contracts, funds.

[2] https://lucidea.com/inmagic/dbtextworks/

These are enhanced by linked / relational database containing information regarding:

- **Funder:** information regarding the requirements of the Funders, e.g. availability of research / project datasets
- **Images:** metadata as it relates to proving the provenance of the image, irrelevant of format
- **Equipment / Apparatus:** specification of the equipment plus calibration records

Figure 10 Connection between databases feeding into the central knowledge database



The centralized knowledge database presented in table 8 should be for capturing, storage, and dissemination of findings and knowledge of research undertakings must be developed.

Based on the above, the following assumptions are made:

i. There is an existing HR system/database that can be harvested. Alternatively, a trusted validation (lookup) functionality can be used that will contain the information required accessed via staff identification number or alternatively a primary key.
ii. There is an existing financial system that can be harvested by using a unique or primary key.
iii. Project information: information is available regarding contracts and project definitions. The information should be harvestable. Alternatively, a primary key / identifier can be used that will redirect the user to the additional information.
iv. Equipment / Apparatus register or database containing the specifications and calibration records needs to be developed if not yet available. If an existing system is in place, investigations into the harvesting of the information is required.
v. Funder's database is available. A trusted validation (lookup) functionality can be used that will contain the information required if a register or database of some sort isn't available.
vi. Images: it is assumed that images are currently not managed effectively. A repository or register should be developed, adhering to international standards.
vii. A register or database for providing access to raw datasets has already been and must be linked with the publications database. Ideally this should form part of the project information
viii. Optional (Add-on): a publications database should publication equivalents be required. Alternatively, trusted validation (lookup) functionality can be used that will contain the information required.

Table 8 describes the basic metadata fields required, based on the Dublin Core Metadata Element Set[3] and is applicable to all format, including datasets.

Table 8 Structure for the centralised knowledge database

Item	Field label	Description
PK	Unique identifier	Similar to the primary key in relational databases. A chronological number assigned by the system
1	Author(s)	Equals to the Dublin Core Metadata Initiative (**DCMI**) contributor and creator fields and referring to those who contributed towards the content in the artefact / resource being described. Data should be linked to / extracted from the HR database but should also be editable to contain the information from external contributors.
2	Title	The name by which the resource is known, normally formal.
3	Subject	Controlled vocabulary providing the broader terms, e.g. Concrete paving blocks; Reinforced concrete slabs; Unreinforced concrete slabs, etc.
4	Keywords	Natural language phrases providing more information, e.g. MERLIN Apparatus, dark brown silty soil; dark reddish brown clay, etc. Strict use of singular and plural should be implemented
5	Description	May include but is not limited to an abstract or a table of contents, or any other free-text providing additional information.
6	Year [of publication]	The year in which the information, dataset, resource, etc. was released to the public. This field is different to the date range of a project that is included in the project database.
7	Month of publication	The month in which the information, dataset, resource, etc. was released to the public.
8	Format	The file format, physical medium, or dimensions of the resource. Recommended best practice is to use a controlled vocabulary such as the list of Internet Media Types.
9	Publication number	An unambiguous reference to the resource within a given context by means of a string conforming to a formal identification system. (System created)
10	Language	Although optional, it is recommended that the field be used should records in various languages be accepted. The ISO 639.2 Codes for the Representation of Names of Languages should be used.
11	Source	Only used when there is an explicit recorded published by an external entity, e.g. journal article, conference paper. It is recommended that the Harvard Reference style is used. However, any other style may be used on the condition that standardisation is implemented. Generally, Harvard Reference List citations follow this format:

[3] http://dublincore.org/documents/2012/06/14/dces/

Item	Field label	Description
		– Last name, First Initial. (Year published). Title. City: Publisher, Page(s). – Last name, First initial. (Year published). Article Title. Journal, [online] Volume (Issue), pages. Available at: URL [Accessed Day Mo. Year]. There are several free online resources that may be used to provide guidelines, e.g. "Ultimate Guide to Harvard Referencing - Cite This For Me"
12	Type	Based on the assumption that a single access point for all information will be used, the "Type" field is required to identify the resource, using a validation / look-up list for standardisation. Care should be taken not to 'over-indulge' when selecting the publication types. It is recommended that the following broad categories be used: – Journal article – Conference paper – Research Report – Dataset
13	[Security] Access control	If needed, and making use of a validation / look-up list, e.g. Open, Restricted/Participants only, Organisational only, Request access, etc.
14	Funder	Provide a link / redirect to where more information to the funder can be obtained, e.g. PK in Funders database
15	Project information	Provide the project number / identification information for cross referencing purposes, e.g. PK in Project Information database or Financial system
16	Image	PK or unique file name with mapping to the storage area. Images includes photographs, charts, figures etc. not embedded in the document / record.
17	Equipment / apparatus / monitoring	PK – refer to the asset number. The assumption is that accurate record keeping of calibration records is in place. If not, this needs to be develop.
18	Monitoring Methods	PK – alternatively a validation list or look-up field, e.g. Visual inspection; photographic logging (link to Image database), surface profile measurement, Dynamic Cone Penetrometer, etc.
19	Datasets	Raw, transcribed or interpreted datasets generated during the project, e.g. DCP testing results, IRI values etc.
20	Supporting documents	Links to any additional 'soft' copies that can provide additional context and information, e.g. file sizes, formats, modification to approaches, etc.

Image metadata can be embedded in the image file or provided separately in an associated file(s) as described in table 9. The metadata provides information relevant to the image itself. There are three categories of metadata, namely

- technical (generated by the equipment),
- descriptive (added manually), and
- administrative (added manually or part of the set-up information).

Table 9 Description of Images/recordings

Item	Field label	Description
PK	Primary key	Any unique identifier
1	"Creator"	Photographer, artisan, artists, etc.
2	File format	Jpg, mpg, png etc.
3	File size	Electronic file
4	Location	Where the photograph, moving image (video), audio recording (e.g. interviews that were not videoed) were taken.
5	Date/Time stamp	Date and time, normally assigned by digital equipment but steps must be taken to ensure that the setting on the equipment is correct prior to using the equipment.
6	Description	The why, what, etc.
7	File name	Short, unique
8	Approval	When individuals are photographed or interview, permission (as per individual country legislation) may be required. Authorisation to use must be stored together with the image / recording. Capture names, location etc.
9	Copyright / License	If applicable
10	Embedded	Type of equipment, photographic settings
11	Image type	Still image, digital image, electronic image, video, audio
12	Keywords	If applicable
13	Supporting documents	Links to any additional 'soft' copies that can provide additional context and information, e.g. file sizes, formats, modification to approaches, etc.

10 Conclusions

This project provided an opportunity for LoGITReC/ TARURA staff and lecturers from technical universities to develop new knowledge and skills. Based on the outcomes of the project, the following preliminary conclusions are made:

- The project has provided technical assistance to LoGITReC, which is a research entity of TARURA. The process of capacity building on all aspects of long-term pavement performance assessments was achieved through a mentoring programme, undertaken by the project team. Hence the required capacity to establish, monitor and evaluate the performance of trial sections was created within TARURA and LoGITReC in particular. . The opportunity for training was extended to engineers in academia in Tanzania.
- Based on the assessments undertaken during the training sessions, participants achieved satisfactory level of competence to establish and going forward able to undertake monitoring of the trial and LTPP sections without a support of the service provider. However, the collaboration between TARURA and the lecturers from the DIT and MUST, who participated in this project should be strengthened. This is crucial for the future success of the establishment and monitoring of trial and LTPP sections in Tanzania.

- There are merits and demerits of the five key monitoring equipment demonstrated in this project. Personnel who participated in the training programmes of the project found three equipment, i.e. straight edge, sand patch apparatus and DCP convenient to use for monitoring, whereas two equipment, i.e. MERLIN and dumpy level instruments were found to be laborious. There is a need to carry out monitoring activities on a continuous basis with the purpose of ensuring that staff from TARURA and LoGITReC in particular become fully conversant with monitoring methods and all prescribed equipment.
- The training workshops and monitoring exercises of the project progressively built the required knowledge foundation and the capacity for establishing and monitoring trial sections in Tanzania. These activities generally linked aspects of establishing trial sections and how monitoring programme should be planned and implemented.
- The general consensus is that some of the equipment proposed in the AfCAP LTPP draft Guideline are more applicable to high-volume roads than traditional low-volume roads. It was however, agreed that budget and expertise of the district and regional road agencies would be the determining factor for any option of equipment for LTPP monitoring.
- It is important that further steps and developments are taken to enhance confidence in the implementation of the project outcomes.

11 General recommendations

A number of general recommendations are made for the benefit of TARURA regarding future projects:

- The current staff composition of LoGITReC shows that there is a need to recruit at least one researcher to provide in-depth data analysis capability to effectively contribute to future LTPP projects.
- LoGITReC does not currently have most of the equipment for LTPP monitoring. In addition, some of the available equipment appear to have manufacturing (available MERLIN, not to standard) issues when compared with standardised equipment for monitoring.
- 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 shoulders is ensured.
- Use of hand-packed stone surfacing is only recommended where adequate maintenance can be assured, with appropriate treatment of problematic subgrades.
- Use of unreinforced concrete slabs should be discouraged especially on the steep sections such as those in Siha district. The performance of both the 75 mm and 100 mm thick slabs is poor, as evidenced by the development of cracks. However, it is worth noting that the Final Report (Roughton International) on the demonstration sites pointed out that some cracking were suspected to have been caused by poor construction techniques used by the contractor. Quality control and assurance procedures should therefore, be enforced during construction.
- On the steeper sections (Siha site, gradients more than 12%), it is recommended that thin mesh-reinforced concrete or asphalt surfacings should be considered for future demonstration sections. there is generally potential gain in whole life cycle cost using these alternative surfacing .
- The rapidly deteriorating seal surfacing requires that timely maintenance interventions be carried out. Crack sealing or resealing should be carried out before the start of the rainy season or fog spray be applied to rejuvenate the surfacing, to avoid the existing surfacing prematurely reaching the end of its service life.
- For LTPP projects, it is recommended that greater emphasis should be placed on medium to long-terms benefits including research outputs and capacity building, otherwise allocation of budget could become a problem since generally, most road agencies are looking for short-term gains in their annual budgets.
- The range of pavement materials options for the construction of trial sections should be extended to include the use of construction waste materials such as recycled concrete and asphalt (depending on distance from available source) as well stabilised material for areas that experience high amount of annual rainfall.

- TARURA should seek to integrate the refined *LTPP Guideline* into a national standards for low-volume roads in the country.
- Road markings should form part of TARURA's contracts, and maintenance activities on trial sections.

Annex 1 Participants observation on training workshops

Participants' general observation on training workshop 1

Item	Observations
What did the participant like the most about this training?	– The inclusion of on-site training – The technics used by trainer during field exercises to make sure the trainee understand – The presentation of the trainer towards all topics – Knowledge attained throughout the training and the formulation of LoGITReC – Knowledge on some new technologies used for road construction and steps to be taken during monitoring – The interpretation of the trainer during trial sections condition assessment – Site visits at Siha and Bagamoyo – The objective of the training – Physical monitoring and visual assessment of the trial sections performance – Participatory mode of assignment in group form – Knowing the duties of technicians which I never thought of them – Potential of Trial Sections at SIHA
What aspects of the training could be improved?	– Video presentation showing construction of SIHA and BAGAMOYO trial sections – Mode of delivering lectures and answering of assignment should be in contribution and participatory fully – Monitoring tools to be provided where necessary – Time allocated for the training – The trainees should be given an introduction of the features for each section before going to the site – Location of the training should be away from working offices especially to TARURA HQ staff – Field exercises and modalities of data collections – More practical oriented training
Please share other comments or expand on other responses here	– Look at possible ways to encourage decision makers to collaborate with local colleges during implementation of such research activities – Need of getting information of the trial sections from previous involved LGA's and PORALG staff so as to give the background – The training was so constructive – Strong supervision as to be taken into consideration during project implementation to avoid substandard outcomes

Participants' general observation on training workshop 2

Item	Observations
What did the trainee like the most about this training?	– The inclusion of onsite training – The technics used by trainer during field exercises to make sure the trainee understand – The presentation of the trainer towards all topics – Knowledge attained throughout the training – The interpretation of the trainer during field practicals – The objective of the training – Participatory mode of assignment in group form

What aspects of the training could be improved?	– More detailed training materials could have been provided – Software should be provided for consistency (such as DCP Software) – Handouts should be prepared earlier – Time allocated for the training was too short – Computer based demonstrations – More practical oriented training
Please share other comments or expand on other responses here	– Participants should be trained on how to develop data base by using Microsoft access or other programmes – The training was so constructive – Strong supervision as to be taken into consideration during project implementation to avoid substandard outcomes

Participants' general observation on training workshop 3

Item	Observations
What did the trainee like the most about this training?	– The practical oriented training which encourages participation and require action on the part of trainees – The preparedness of the trainer – The presentation of the trainer towards all topics – Knowledge attained throughout the training – The interpretation of the trainers about DCP-DN design method – The objective of the training – Participatory mode of assignment in group form – Economic analysis of alternative materials to be used in LVR
What aspects of the training could be improved?	– More detailed training on designing using DCP- DN Method – Handouts should be prepared earlier – Time allocated for the training was too short – Skills on report writing after data collection and analysis could add more value – More practical oriented training
Please share other comments or expand on other responses here	– Participants should be trained on how to develop data base by using Microsoft access or other programmes – The training was so constructive – Need for further training on AfCAP DCP – DN design method

Participants' general observations on training workshop 4

Item	Response from participants
What did the trainee like the most about this training?	– Laboratory testing for the purpose of materials selection for design using the DCP-DN method – Individual presentations, overwhelming number of participants liked the individual presentations, they indicated gaining experience and learning a lot of new things – Some participants indicated that the workshop objectives were clear and they liked the way the presentation was organised to meet all objectives – Guidelines provided by the three-member evaluation panel on how to effectively make technical presentation. – Q&A time asking after each presentation provided further understanding of the training workshops of the project.

	– Involvement of participants in questioning fellow participants during individual presentations – Trainer was well prepared for topic presented. Knowledge obtained from training topics massive – The overview of the DCP-DN pavement design and laboratory data analysis to calculate DN number – The skills and techniques used by the facilitator in explaining different types of tests and the parameters to be accessed/checked. – The whole presentation of the presenter/facilitator
What aspects of the training could be improved	– Case studies in establishing trial sections and monitoring could be added in the training workshop presentations – Planning and logistics for the training programme should be improved for future training programmes – Time table / number of days allocated to the training is too short for such an extensive information provided in the workshop training programmes – Interpretation of graphs from the DCP software. – Interpretation on the database on the monitoring method used in pavement road like rut depth measurement, DCP, profile measurement, etc. – Training notes/materials should be available to participants much earlier. The materials should be provided to participants via email before meetings – More interaction, and more examples – Include laboratory testing in the training programme (similar to training in field testing) – Practical aspects of testing materials using laboratory DCP needed further elaboration
Please share other comments or expand on other responses here	– Further training on laboratory DCP testing as it is an essential component of LVR design – No comment but to congratulate you for being well prepared for this – Only time frame is limited related to field works – I would like to thank the trainer for the good topic and experience which they gave to us – Monitoring time was not enough, is better to get enough time. The data collection on site (monitoring programme) is better to sit together one day before leaving to process the data collected. – Workshop training should be more based on photograph to enhance understanding – I propose group discussions based on levels of education / qualification e.g. Technician, engineers, technicians. – Hardcopy of materials should be provided – Need for laboratory demonstration tests to enable participants to gain more experience in laboratory tests.

Annex 2 Conditions evaluation of trial sections

Bagamoyo project site

Sand seal section: Lime slurry seal (LHS) vs. Cement slurry seal (RHS)

Good performing concrete, but severely eroded gravel shoulders

Hand-packed stone section: Surface deformations and loss of stones

Gravel wearing course sections: Severe rutting in wheel paths

Geocell sections : Severe rutting in one wheel path

Good performing double seal section, but drains are covered by shrubs, tall grass – lack of maintenance

Siha project site

Unreinforced concrete slab (75mm) section: Dominance of both longitudinal and transverse cracks (block cracking)

Good performing Geo-cell section, poor maintenance in side drains

Gravel wearing course section: Large potholes and associated water ponding

Good performing block paving section, and typical traffic

Unreinforced concrete slab (100 mm) section: Severe longitudinal cracks

Good performing lightly reinforced concrete (75 mm) section, but severe sedimentation build-up

Annex 3 Capacity building programme

Overall training programme

Phase	Module	Location	Date	Actual Date
Phase 1	Module1: Experimental design/Experimental matrix	Dodoma	26 September 2017	26 September 2017
	Module 2: Setting up test sections – control section	Dodoma	27 September 2017	27 September 2017
	Module 3: Background to research planning and reporting	Dodoma	28 September 2017	28 September 2017
	Module 4: Monitoring and research during the construction phase	Dodoma	29 September 2017	29 September 2017
	Understanding monitoring of demonstration sites: Site visits	Siha Bagamoyo	2 – 3 October 2017 5 – 6 October 2017	2 – 3 October 2017 5 – 6 October 2017
Phase 2	Module 5: Monitoring and research after the construction phase Module 6: Monitoring of economic performance indicators	Siha	16 January 2018	16 January 2018
	Module 7: Monitoring of climatic conditions Module 8: Monitoring of in-service pavement performance	Siha	17 January 2018	17 January 2018
	Demonstrations: Use of DCP and data analysis	Siha	18 January 2018	18 January 2018
	Demonstrations: Use of the Merlin Sand patch testing	Siha	19 January 2018	19 January 2018
Phase 3	Module 9: Drainage of the road surface, pavement layers	Siha	4 April 2018	11 April 2018
	Module 10: Analysis of the physical performance of road sections (using collected data in Phase 2)	Siha	5 April 2018	12 April 2018
	Module 11: Evaluation of appropriate construction methods Module 12: Economic analysis (life-cycle cost analysis)	Siha	6 April 2018	13 April 2018
Monitoring 1 (Siha and Bagamoyo)			7 – 11 May 2018	9 – 24 May 2018
Phase 4	Module 13: Materials sampling, field and laboratory measurements	Siha	12 June 2018	3 July 2018
	Module 14: Data collection management & linkage to pavement design	Siha	13 June 2018	4 July 2018
	Module 15: Individual presentation	Siha	14 June 2018	5 July 2018
	Module 16: Feedback and evaluation	Siha	15 June 2018	6 July 2018
Monitoring 2 (Siha & Bagamoyo)			3 – 7 September 2018	3 – 11 October 2018

List of trainees

S.No	Name	Designation	Organisation
1	Eng. Vincent Lwanda	Laboratory Manager	TARURA HQ
2	Eng. Joseline Kagombora	Research Engineer	TARURA HQ
3	Eng. Joseph Matolo	Laboratory Engineer	TARURA HQ
4	Ahsante Kamba	Senior Laboratory Technician	TARURA HQ
5	Geofrey Mbunda	Laboratory Technician	TARURA HQ
6	Jacob Manguye	Senior Laboratory Technician	TARURA HQ
7	Peter Mkumbo	Senior Laboratory Technician	TARURA HQ
8	Eng. Mohamed M. Mkwata	Regional Coordinator	Dodoma Region
9	Eng Meleck Silaa	Regional Coordinator	Kilimanjaro Region
10	Eng. Edwin Kabwoto	Regional Coordinator	Pwani Region
11	Eng Juliana Masaro	Council Manager	Bagamoyo District
12	Eng. Protas Kawishe	Council Manager	Siha District
13	Eng. Joseph Mnkeni	Lecturer	MUST University
14	Dr. Jubily Musagasa	Lecturer	DIT University

Annex 4 Photographs of in-class training sessions

and seal section: Lime slurry seal (LHS); Cement slurry seal (RHS)

Participants in a group discussion

Participant presenting during individual presentations

Participant presenting during individual presentations

Group discussion on field data

Participants in a group discussion

Annex 5 Photographs of field monitoring training sessions

Information session before field monitoring training

Training in rut depth measurement

Participant marking LTPP section

Training in DCP testing

Traffic count on the project road

Training in roughness measurement using MERLIN