Development of Guidelines and Specifications for Low Volume Sealed Roads through Back Analysis

Phase 3 Inception Report

TRL Ltd

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Cover photo: Field Testing in Mozambique / Francis Dangare

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Abstract

Development of Guidelines and Specifications for Low Volume Sealed Roads (LVSR) through Back Analysis is a project being carried out in three phases. Phase 1 and Phase 2 were completed whereas Phase 3 started in December 2018 and is scheduled for completion in June 2019.

Phase 1 involved the identification of data sources; collection of historical performance data from previous studies; processing of the data; and creation of a database for Low Volume Roads (LVRs).

Phase 2 involved refining of, and addition of more data into, the database; training of counterparts from the participating road agencies of the 12 Africa Community Access Partnership (AfCAP) partner countries on how to use the database; and identifying gaps for further studies to refine standards and design catalogues.

Phase 3 will involve field and laboratory investigations to fill the critical knowledge gaps that were identified in Phase 2; data analysis, corroboration or revision of existing specifications in guidelines and catalogues for pavement design for LVSRs; further population of the database; capacity building of participating road agencies counterpart staff who will be involved in the project activities; dissemination of findings; and production of a scientific paper.

This report describes the activities undertaken during the inception stage of Phase 3 including the pre-visit desk studies, the outcomes of the reconnaissance visits and recommends the way forward for the subsequent stages of Phase 3.

Key words


Acknowledgements

The authors are grateful to the individuals from the road agencies in Ghana, Mozambique, Uganda and Zambia for providing their support during the reconnaissance visits. These road agencies include: Ghana – Ministry of Roads and Highways (MRH), Ghana Highway Authority (GHA), and Department of Feeder Roads (DFR); Mozambique – National Road Administration (ANE); Uganda – Uganda National Roads Authority (UNRA); Zambia – Road Development Agency (RDA), and National Road Fund Agency (NRFA).

Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

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

www.research4cap.org
### Acronyms, Units and Currencies

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<td>Aggregate Crushing Value</td>
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<tr>
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<td>MESA</td>
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<td>TFV</td>
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Executive summary

This report covers the inception stage of Phase 3 of the project on Development of Guidelines and Specifications for Low Volume Sealed Roads (LVSRs) through Back Analysis. Phase 3 of this project commenced in December 2018 and is scheduled to be completed in June 2019.

Phase 3 will focus on bridging the knowledge gaps that were identified in Phase 2, through field and laboratory investigations in selected countries (Ghana, Mozambique, Uganda and Zambia). This will subsequently lead to analysis, update and/or corroboration of specifications in existing guidelines and catalogues for pavement design of LVSRs. The knowledge gaps that were identified include: knowledge on the use of non-conventional surfacings at higher traffic levels (> 0.5 Million Equivalent Standard Axles, MESA); the limiting strength of base layer material at higher levels of traffic (>0.5 MESA) in areas of high rainfall (> 1000 mm); the performance of very weak and moderate strength subgrades in areas of high rainfall (> 1000 mm); the impact of maintenance on the performance of LVSRs; and durability and expected age of pavements and surfacings.

A pre-visit desk study was undertaken to preliminarily identify possible roads that would be considered for detailed investigations during this phase of the project. Subsequently, reconnaissance visits were made to the countries in order to ascertain the suitability of the preliminary road selections as well as establish the willingness of the countries to collaborate on the project (drawing from the partnership between each of the countries and the Africa Community Access Partnership, AfCAP).

Overall, there was general acceptance and acknowledgement of the significance of this phase of the project in Ghana, Mozambique, Uganda and Zambia. The countries also offered to support the project through secondment and facilitation of their staff to co-execute the project activities with the consultant (TRL Limited); provision of all the available documentation on the selected roads including maintenance history and as-built records; authorisation to access the selected project roads during all stages of the project; deployment of their equipment for field surveys; and allowing testing of material samples in their laboratories, at their cost.

Following the reconnaissance visits, suitable roads for this study were selected in each of the countries as follows.

In Ghana:
- Cape Coast – Twifo Praso road.
- Mpataba Junction – Half Assini road.
- Koforidua – Adukrom road.

In Mozambique:
- Boane – Namacha road.
- Boane – Moamba road.
- Macia – Chokwe road.
- Pambara – Rio Save (targeted sampling)
- Rio Zambezi – Nicoadala (targeted sampling)
- Lindela – Inhambane road (targeted sampling)

In Uganda:
- Kikorongo – Mpondwe road.
- Ishaka – Kasese road.
- Matugga – Semuto – Kapeeka road.

In Zambia:
- Samfya – Musaila road (off the D451).
- Mansa – Bahati road (M3).
- Mukuku Bridge – Samfya road (D235).

The next stage of the project will involve field surveys on the selected roads and laboratory investigations.
1 Introduction

This report covers the inception stage of Phase 3 of the project entitled Development of Guidelines and Specifications for Low Volume Sealed Roads through Back Analysis (referred to as the 'Back Analysis' project throughout this report).

1.1 Background

The Back Analysis project is under the Africa Community Access Partnership (AfCAP), a research programme that is funded by the UKAID - Department for International Development (DFID) and managed by Cardno.

The overall objective of the project was to undertake a review of the performance of Low Volume Sealed Roads (LVSRs) constructed in the last four decades in order to achieve the following:

1. Provide a database of existing LVSRs that have been investigated in relation to pavement type and materials, performance and environmental conditions, and consequently:
   - Refine existing generic guidelines for selection of surfacing type as well as pavement design based on life-cycle costs.
   - Corroborate and refine existing catalogues for pavement design of LVSRs in order to ensure their applicability to a wider range of materials and geographic conditions.

2. Provide a base level for information on the performance of non-standard designs and material specifications in comparison with conventional designs and specifications for roads carrying high traffic volumes (>300 vehicles per day, vpd).

The project was divided into three phases. Phases 1 and 2 were completed whereas Phase 3 is ongoing. A summary of the activities for each of the phases is listed below.

- Phase 1 involved the identification of data sources; collection of historical performance data from previous studies; processing of the data; and the creation of a database for Low Volume Roads (LVRs). The link to the database that was developed is www.lvroadsdata.com
- Phase 2 involved refining of, and addition of more data into, the database; training of counterparts from the Road Research Centres (Participating road agencies) of the 12 AfCAP partner countries on how to use the database; and identifying knowledge gaps for further studies to refine standards and design catalogues.
- Phase 3 (current phase) will involve field and laboratory investigations to fill the critical gaps that were identified in Phase 2; analysis of the field and laboratory data; revision of specifications for guidelines and catalogues for pavement design; further population of the database; capacity building of participating road agencies counterpart staff who will be involved in the project activities; dissemination of findings; and production of a scientific paper.

1.2 Gaps to be addressed in phase 3 of the project

Critical knowledge gaps in regard to the performance of LVSRs were identified in Phase 2. These included:

- Insufficient data on durability and expected age of pavements and surfacings.
- Insufficient data on performance of LVSRs subjected to traffic loading ranging between 0.5 and 1 Million Equivalent Standard Axles (MESA).
- Insufficient data on the impact of high rainfall on the performance of the base and surfacing layers in LVSRs.
- Lack of data on maintenance and its impacts on performance of LVSRs – maintenance regime vs. type of surfacing vs. environment.
- Insufficient data on dealing with weak to moderate strength subgrades in LVSRs.
- Insufficient data on unconventional road bases in different environments.
- Insufficient data on locally-available materials (types and properties) and their performance under heavy traffic loading.
- Insufficient data on non-conventional surfacings (Otta seal, Sand seal, combinations seals, Road Mix, Cold Mix Asphalt – CMA, etc.).

In order to bridge the above knowledge gaps, the following investigation matrices were suggested:

- Non-conventional surfacing versus traffic, environment and age.
- Bases versus traffic loading and environment.
- Maintenance versus climate, traffic loading, age and type of surfacing.
- Weak subgrades versus traffic loading, climate and age.

A detailed description of the knowledge gaps and investigation matrices was provided in the Phase 2 Report. This phase (Phase 3) of the project will go a step towards bridging these gaps through studies in selected AfCAP partner countries.

### 1.3 Proposed countries of study in phase 3 of the project

During Phase 2 of the project, four countries were primarily identified as having prospective study areas that would be suitable for detailed investigations in Phase 3. Table 1 presents the countries that were proposed and the main reasons for their selection.

<table>
<thead>
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<th>Country</th>
<th>Reasons for selection</th>
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| Ghana     | - A Master's thesis by George Kodwo Addison compiled test results of natural gravels from 454 borrow pits used in the Ghana road network.  
                     - This strongly increases the possibility of finding suitable sections.  
                     - Rainfall of 1250 – 2000 mm/year in a large part of the country. |
| Mozambique| - A large percentage of the road network was constructed using marginal materials that have generally performed well after several years in service.  
                     - Highly varied climate.                                               |
| Uganda    | - A large variety of non-conventional surfacings were constructed in the eastern and northern part of the country between 2011 and 2014.  
                     - High quantity of rainfall with many areas receiving more than 1250 mm/year.  
                     - Large areas of swampy subgrades. The likelihood of finding weak subgrades is therefore high. |
| Zambia    | - Average rainfall conditions (750 – 1500 mm/year) in a large part of the country.  
                     - A large variety of subgrade soils. The likelihood of finding very weak to medium strength subgrades is therefore high. |

It was further proposed that in the event that Uganda and Zambia were found unsuitable for detailed investigations, they could be substituted with Tanzania and Malawi respectively. Reconnaissance visits to the 4 primary countries (Table 1) were scheduled for the second week of January 2019. However, pre-visit desk studies were undertaken for all the 6 countries including the 2 substitutes (Malawi and Tanzania).

### 1.4 Structure of this Report

The report is structured as follows:
Section 1 presents the project objectives, the knowledge gaps that were identified in Phase 2, and the countries that were selected for the Phase 3 investigations.

Section 2 describes the activities that were carried out in the pre-visit desk study including communication with the partner countries in which the Phase 3 detailed investigations had been proposed, definition of roles of parties on the project and identification of preliminary candidate roads.

Section 3 presents the key findings and outcome from the reconnaissance visits.

Section 4 outlines the summary and way forward.

2 Pre-visit desk study

There are certain parameters that cannot be recreated in a laboratory and can only be determined in-situ. Such parameters include climate and subgrade soils. A preliminary analysis of the climatic and soil maps of the AfCAP countries showed that the climatic and subgrade gaps identified in Phase 2 could be found in Ghana, Malawi, Mozambique, Tanzania, Uganda and Zambia. Further detailed study of these maps and consultation with the countries was carried out to identify the potentially suitable study roads in the right climatic zone and subgrade zones. The initial criteria for screening of roads to establish potentially suitable roads were roads sealed with a thin bituminous surfacing, constructed with natural gravels or moderately modified natural gravels, and that have been in existence for at least 10 years.

2.1 Communication with the partner countries

Email communication was sent to the AfCAP national coordinators of the 6 countries, notifying them of the proposed reconnaissance visits that were scheduled starting the second week of January 2019. In addition, the preliminary scope of investigations and the characteristics of the roads and sections that would be ideal for the study, as well as the need for collaboration from the countries, were highlighted. The email communication was followed up by phone calls to the respective national coordinators.

Following the communication that was made, Ghana, Mozambique, Uganda and Zambia all responded positively to the proposed reconnaissance visits. It was therefore decided to do the reconnaissance in these four countries first and only carryout reconnaissance in Malawi and Tanzania if no suitable sites were found in the four countries. Using the soils and climatic maps, partner countries were advised on what regions to carry out a preliminary search of the roads. The parameters used for preliminary search were:

- Roads generally in a good to fair condition that have existed for more than 10 years without periodic maintenance of rehabilitation.
- Mean annual rainfall of the area (> 1000 mm/yr).
- Surfacing type (thin surfacings).
- Surfacing age (> 7 years without periodic maintenance).
- Pavement materials (natural gravels or moderately modified natural gravels).
- Constructed with thin or simple pavements (thin surfacing, base – 1 layer, sub-base – maximum 1 layer, capping –optional)
- Subgrade types (weak to medium).
- Traffic volume (50 to 100 trucks per day and therefore likely to have carried more than 0.5 MESA over its existence to date).

2.2 Definition of roles for the project parties

As stated in the Phase 2 completion report, a Memorandum of Understanding (MoU) outlining the scope of collaboration between TRL and the rest of the project parties was drafted. The roles of each of the parties were also defined. This MoU was premised on the agreement between AfCAP and each of the partner countries. However, because of the tight project timelines and bearing in mind the often lengthy procedure associated with functionalising MoUs, the MoUs were not initiated. Instead, a brief write-up stipulating the form of collaboration and roles of the project parties was prepared for elaboration to the countries during the reconnaissance visits. This write-up is presented in Annex 1.
2.3 Preliminary identification of candidate roads

Prior to the preliminary selection of the LVSRs that would be investigated in Phase 3, road network maps from each of the countries were studied alongside their respective soil and climatic maps. Care was taken to ensure that the roads were adequate for addressing the data gaps identified in Phase 2 (see Section 1.2 of this report).

The road network maps were obtained from the websites of the road agencies of the respective countries. Where these were not readily accessible, counterparts in the countries were contacted to assist with acquiring them. Soil maps of Ghana, Malawi, Mozambique, Uganda and Zambia were obtained from the European Soil Data Centre (ESDAC); the soil map of Tanzania was obtained from the Intergovernmental Authority for Development (IGAD) Climate Prediction and Applications Centre GeoPortal. Climate data for all the 6 countries was obtained from Earthwise. The road network, soil and climatic maps for Ghana, Malawi, Mozambique, Tanzania, Uganda and Zambia are appended in Annex 2.

In addition, counterparts in some of the road agencies of the prospective study countries were contacted to gain further insight on the suitability of the preliminary candidate roads. Previous reports on LVSRs were also studied. The sub-sections that follow present a brief outline of the roads that were selected in each of the countries. A summary of the characteristics of the roads and the corresponding proposed investigation matrices is presented in Annex 3.

2.3.1 Ghana

From a study of the soil maps, climate maps and the road network maps of Ghana, the first preliminary selection of candidate roads was made. This selection had 6 roads which included:

- Hamale – Lawra road.
- Half Assini – Axim road.
- Twifo Praso – Cape Coast road.
- Twifo Praso – Dunkwa road.
- Winneba – Swedru road.
- Tema – Ho road.

However, after consultation with in-country partners in Ghana, it was established that all the above 6 roads were being managed by the Ghana Highway Authority (GHA). GHA is the road agency that is responsible for delivering the trunk road network in Ghana. In the absence of any immediate additional information on the road characteristics, it was suspected that the 6 roads were likely to be heavily trafficked. Consequently, a new selection of candidate roads was made. This included 3 roads namely:

- Twifo Hemang – Baakondzidzi road (Central region).
- Obomofo Densua – Akote road (Eastern region).
- Allowule – Kengen road (Western region).

Twifo Hemang Hemang – Baakondzidzi road, Obomofo Densua – Akote road, and Allowule – Kengen road were chosen from the high rainfall (>1200 mm/year) areas of Ghana. Their traffic data was not readily available at the time of the desk study.

Allowule – Kengen road is located in an area with weak and wet unconsolidated soil, and the other two roads have non-conventional surfacing over them. Twifo Hemang – Baakondzidzi has Otta seal trials whereas Obomofo Densua – Akote road has chip seal trials of variable binder content and CMA. According to the Ghanaian soil map, Obomofo Densua – Akote road is overlaying a strong lateritic subgrade. With such strong subgrade material, it was thought that the likelihood of finding imported material in the base layer was unlikely. This increased the possibility that the base was constructed using natural gravel. It was also established that the road provides access to a sand borrow area. This implied that the traffic loading on the road was likely to be more than 0.5 MESA.

The following investigation matrices were therefore proposed for Ghana:
2.3.2 Malawi

In the high rainfall areas of Malawi, the Rumphi road (Northern region) was identified as a candidate for investigation. According to a traffic survey conducted in 2010, its motorised traffic volume was 790 vpd. The road was built in 2004 over a well-drained clayey lateritic subgrade with a road base from naturally occurring weathered granite.

In the low rainfall areas, Lilongwe ABC road, Central region (constructed in 1985) and Dowa Boma road, Central region (constructed in 2004) were identified. Lilongwe ABC road can be considered as a ‘typical’ LVSR. It has cape seal surfacing overlaying a natural gravel base and a sandy clay subbase/subgrade. Dowa Boma road was built in an area with sandy clay and gravelly subgrade soil, with a base layer similar to that of Rumphi road.

Based on the available information, the following investigation matrices were proposed for Malawi:

- Non-conventional surfacing versus age and environment.
- Natural gravel bases versus environment and traffic.
- Durability and age of pavements and surfacing.

2.3.3 Mozambique

From the climate map of Mozambique, it was noted that the Southern and Western parts of the country experienced mean annual rainfall of less than 1000 mm compared to the rest of the country which had more than 1000 mm. From the higher rainfall areas, two roads were selected namely:

- Rio Zambezi – Nicoadala road (Central region).
- Metoro-Macomia road (North-eastern region).

From the lower rainfall areas, three (3) roads were selected namely:

- Macia – Chokwe road (Southern region).
- Pambarra – Rio Save road (Central region).
- Xai-Xai – Chissibuca road (Southern region).

Some of these candidate roads were investigated in a previous back analysis study that was undertaken in Mozambique. This included roads in high rainfall areas like Nampula and Niassa. The data from these roads will be combined in the analysis.

Macia – Chokwe road was constructed over 20 years ago in an area with brownish-grey sandy soil. During the course of its maintenance, a section of the road was resealed leaving the remaining section of the road with its original surfacing. Pambarra – Rio Save road, Xai-Xai – Chissibuca road, and Rio Zambezi – Nicoadala road have Hot Sand Asphalt (HSA) surfacing and were constructed over weak subgrade material. In addition, the base layers of Pambarra – Rio Save road and Rio Zambezi – Nicoadala road were constructed using material that was naturally occurring along the roads. Metoro – Macmia road has Single Surface Dressing (SSD) in its surfacing layer and was constructed in an area with greyish-brown clay and sandy subgrade soil.

The following investigation matrices were proposed for Mozambique:

- Maintenance versus age and traffic loading.
- Non-conventional surfacing versus traffic loading and environment.
- Natural gravel bases versus environment and traffic loading.
- Weak subgrades versus environment and traffic loading.
- Durability of pavements.
2.3.4 Tanzania

According to the 2010 data that was obtained from the Tanzanian Prime Minister’s Office-Regional Administration and Local Government (PMO-RALG), less than 6% of the LVRs in Tanzania were surfaced. Two LVSRs with surfacing trials were initially identified for consideration in the phase 3 investigations. These included:

- Lawate – Kibongoto (Siha district).
- Bago – Talawanda (Bagamoyo district).

However, after computation of the likely traffic loading on both roads, it was found that these roads had undergone traffic loading of less than 0.1 MESA. This loading was not adequate to bridge the knowledge gaps identified for this study. Subsequently, another candidate road (Babati – Singida road) was selected.

Babati – Singida road is located in the North-eastern part of Tanzania with a mean annual rainfall of less than 1000 mm in a region with clay subgrade material. Based on its proximity to Dodoma and Tarangire National Park, it was anticipated that the traffic loading on the road would be reasonably high.

It was therefore proposed that the performance of weak subgrades under heavy traffic in low rainfall areas would be investigated in Tanzania.

Partners from Tanzania proposed the following roads for detailed study:

- Kituru – Itulituli about 15 km from Mufindi District Council around Iringa.
- Kising’a – Ilambilele – Isimani Tarafani about 34 km from Iringa District Council between Iringa and Dodoma – rainfall.
- Mbenga – Kipololo from Mbenga District Council, Ruvuma near Lake Malawi – rainfall.
- Peramiho – Lundusi from Songea District Council, Ruvuma – rainfall.
- Peramiho – Morogoro village from Songea District Council, Ruvuma – rainfall.

The roads would add significant value to bridging the gaps identified in Phase 2. Consideration may have to be given to the inclusion of some of these roads in the detailed study.

2.3.5 Uganda

The Matugga – Semuto – Kapeeka (M-S-K) road (Central region) was selected for investigation in Uganda owing to its location in a high rainfall area and the heavy traffic arising from the factories and quarries along the road. The construction of this road was completed in 2010 with a design life of 15 years. The 2010 traffic survey data from the traffic count station nearest to proposed study sections indicated a maximum traffic volume of about 750 vpd on this road. This was significantly higher than the 400 vpd that had been projected at the time of designing the road in 2008. According to Uganda’s soil map, the subgrade composition in the area in which the road lies is sandy loams with traces of clay. The road is made up of several sections with different base and surfacing configurations. For this study, 6 sections were identified as suitable for investigation. One section, M-S-K 21+550 – 21+900, had a conventional surfacing (Double Surface Dressing, DSD) but its base was constructed using cement-stabilised clayey natural sand. The rest of the 5 sections had different non-conventional surfacing over them. Table 2 outlines the surfacing types on the 5 sections.

<table>
<thead>
<tr>
<th>Section Chainage (km)</th>
<th>Surfacing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-S-K 22+600 – 22+850</td>
<td>SSD + crusher dust sand seal</td>
</tr>
<tr>
<td>M-S-K 22+850 – 22+950</td>
<td>SSD + natural sand seal</td>
</tr>
<tr>
<td>M-S-K 22+950 – 23+200</td>
<td>Double Sand Seal (DSS) with crusher dust</td>
</tr>
</tbody>
</table>
The following investigation matrices were proposed for the sections along M-S-K road:

- Natural gravel bases versus environment and traffic.
- Non-conventional surfacing versus traffic, age and environment.

Additional roads were proposed by the counterparts in Uganda following the email communication that was sent to them alerting them of the reconnaissance visits. These roads included:

- Kikorongo – Mpondwe road.
- Kilembe – Kasese road.
- Ntungamo – Katunguru – Rukungiri road.
- Ishaka – Kasese road.

### 2.3.6 Zambia

According to the soil map of Zambia, the country has a widespread coverage of soils that resulted from the weathering of the underlying igneous and sedimentary rocks – with patches of alluvial soils. The country’s precipitation map revealed a mean annual rainfall ranging between 600 and 1300 mm, with the Northern region experiencing the highest rainfall intensity. From comparison of the available desk study data, 5 candidate roads covering a wide range of variables were initially identified. These included:

- Seshek – Mulobezi road.
- Mumbwa – Kasempa road.
- Kasempa – Kaoma road.
- Mayuka – Mpika road.
- Mwinilunga – Kabompo road.

However, after consultation with the national counterparts in Zambia, it was found that all the potentially suitable roads were not surfaced. This initial list of candidate roads was therefore disregarded and a new list of 6 prospective study roads was selected. These included:

- Luwingu – Kasama road (Northern region).
- Kasama – Mbesuma – Isoka road (Northern region).
- Mbala – Nakonde road (Northern region).
- Kalulushi – Lufwanyama road (Central region).
- T002 – Siavonga road (Southern region).
- Maamba – Batoka road (Southern region).

T002 – Siavonga road and Maamba – Batoka road are in the dry zone while the rest of the 4 roads are in the country’s wet zone. The subgrade material of T002 – Siavonga road and Maamba – Batoka road is made up of a complex of grey-brown alluvial soils and dark grey clays. On the other hand, Luwingu – Kasama road, Kasama – Mbesuma – Isoka road, Mbala – Nakonde road, and Kalulushi – Lufwanyama road have underlying subgrade material that is made of sandy loams and loamy sands. In addition, there is record showing that T002 – Siavonga road and Maamba – Batoka road have undergone some maintenance following their construction over 20 years ago. Furthermore, high traffic is expected over Maamba – Batoka road owing to the recent opening of a coal mine in the area. Traffic projection undertaken in 2015 indicated that the road will have traffic loading of about 6 MESA over a period 15 years.

Based on the available information, the following investigation matrices were proposed for Zambia:

- Weak subgrades versus environment and traffic loading.
- Maintenance versus age and traffic loading.
- Durability of pavements.

3 Reconnaissance Visits

Site reconnaissance visits were undertaken in Ghana, Mozambique, Uganda and Zambia. The full programme for the visits in the 4 countries is presented in Annex 4.

The purpose of these visits was to:

- Discuss with the in-country partners the possibility of participating in Phase 3 of the project.
- Select at least 3 candidate roads to visit and carry out reconnaissance survey on.
- Select roads for detailed study in phase 3.
- Gather and collate any data available on the selected roads.
- Plan for further joint detailed fieldwork and data analysis.

During the visits, initial meetings were held with the road agencies; followed by site reconnaissance visits and wrap-up meetings. The opinion of the in-country partners on the proposed roads was sought prior to the field visits. This was done based on a list of preferred characteristics for the targeted roads in line with the knowledge gaps that were identified in phase 2 of the study. These key characteristics included:

- Simple structure (thin surfacing, granular base, granular sub-base, optional capping layer and subgrade).
- Thin bituminous surfacing (not asphalt concrete) such as surface dressing, Otta Seal, slurry seal, CMA (< 25 mm thick), etc.
- Natural gravel base (laterite, quartz, etc.) or weak gravel (California Bearing Ratio, CBR < 40) improved by mechanical or cement stabilisation and not crushed stone material.
- Age of road since first bituminous surfacing; preferably more than 10 years.
- Traffic volume of about 500 vpd (with approximately 50 – 100 trucks/day) – likely to have carried traffic loading in the range of 0.7 – 1.5 MESA.
- High rainfall conditions (> 1000 mm/year).
- Weak to medium strength subgrades (clays, silts and loams).

The details of the reconnaissance visits for the 4 countries are discussed in the sections that follow.

3.1 Ghana

Ghana was visited between the 21st and 25th January 2019. The key activities included meetings with the in-country partners and site reconnaissance visits.

3.1.1 Initial meeting with in-country partners in Ghana

The initial meeting was attended by staff from GHA, the Department of Feeder Roads (DFR) and the Ministry of Roads and Highways (MRH). The full list of participants is presented in Annex 5.

The in-country partners in Ghana communicated that the Back Analysis project would be hosted by GHA and MRH, with GHA as the lead agency. DFR would provide the necessary support as required. The need for commitment of all parties was emphasised. In this regard, a team comprising representatives from all 3 agencies was seconded to participate in the site reconnaissance visits. Additionally, it was noted that a similar project involving the development of manuals for LVRs was being undertaken in Ghana. It is expected that this similar project will be completed in March 2019.

In discussing the suitability of the proposed candidate roads, the in-country partners in Ghana proposed amendment of the list of candidate roads. Given that the desired roads were expected to be surfaced with a traffic loading of 0.7 – 1.5 MESA, it was found that DFR, which is mandated with LVRs, did not have any roads that met the selection criteria. As such, roads under GHA were proposed.
After intensive discussions between DFR, GHA, MRH and TRL, two of the roads that had been identified in the first preliminary selection of candidate roads (according to criteria in Section 2.1) were endorsed. These included:

- Cape Coast – Twifo Praso road (Central region).
- Twifo Praso – Dunkwa road (Central region).

Furthermore, additional roads were proposed:

- Mpataba junction – Half Assini road (Western region).
- Daboase – Atieku road (Western region).
- Koforidua – Adukrom road (Eastern region).
- Koforidua – Suhum road (Eastern region).

The second selection of roads that was done at the pre-visit desk study was not found suitable because of the reasons summarised in Table 3.

<table>
<thead>
<tr>
<th>Name of road</th>
<th>Reason(s) for unsuitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twifo Hemang – Baakondzidzi</td>
<td>• The road was surfaced less than 2 years ago</td>
</tr>
<tr>
<td></td>
<td>• The traffic volumes on the road were far below 500 vpd</td>
</tr>
<tr>
<td>Obomofo Densua – Akote</td>
<td>• The road was very lightly trafficked</td>
</tr>
<tr>
<td>Allowule – Kengen</td>
<td>• Little/no information was available on the road</td>
</tr>
</tbody>
</table>

Site reconnaissance visits were undertaken on the new set of roads to ascertain their suitability for detailed investigations.

### 3.1.2 Site visits in Ghana

The roads that were agreed on during the initial meeting were visited by region in the order of Central, Western, and finally Eastern region. The TRL team was accompanied by a team comprising members from GHA, DFR and MRH. The GHA representatives were from the respective GHA regional offices. Possible study sections on the roads were categorised and identified based on their gradient, sub-surface drainage, surfacing type, surface condition, estimate of crack intensity, maximum rut depth, potholes, state of shoulders and side drain condition. The carriageway width and base material (as observed from edge of the road or within potholes) were also recorded. It was noted that all the proposed roads had DSD as surfacing.

In the Central region, Cape Coast – Twifo Praso road and Twifo Praso – Dunkwa road were visited. For a continuous period of 1 hour, the number of trucks encountered on Cape Coast – Twifo Praso road and Twifo Praso – Dunkwa road was 15 and 13, respectively.

### Cape Coast – Twifo Praso Road

On Cape Coast – Twifo Praso road (71 km), two possible study sections whose surface condition was fairly good were identified between km 35+000 and 60+000 of the road. On one of the identified sections, signs of a rising water table during the rainy season were observed. Therefore, this section had the potential of deteriorating to a poor state and yet it has defied this adverse condition and continued to perform well. It was also established that if the need arises, this section will be supplemented with a few hundred metres towards the Cape Coast side. On the other hand, the second section was considered as a 2-in-1 section (part of it would serve as a “good” section and the other part would serve as a “fair” section). The start of the section had no rutting but the middle part had rutting and cracking in the outer wheel track of the Left
Hand Side (LHS). Additionally, on one of the sections of the road, the base material (as seen from the pavement edge) had very coarse material (Figure 1) which is usually marginalised for use in the base layer. Investigations of the performance of this marginalised base material would be vital.

Figure 1 Marginalised base material along Cape Coast – Twifo Praso road

Possible study sections were not selected from the rest of the road because km 0+000 – 5+400 was part of urban roads, and the sections between km 5+400 – 35+000 and km 60+000 – 71+000 had on-going construction works.

Twifo Praso – Dunkwa Road

According to the GHA maintenance manager of the Central region, construction of Twifo Praso – Dunkwa road was completed in the late 1990s. Given the on-going resealing activities on some sections of the road, it was recommended that only the first 11 km of the road be considered for this study. Neither the shoulders nor the pavement edge exposed the base material of the pavement. However, the maintenance manager intimated that the base material of this road was made of natural gravel. Two sections were identified on this road – one with “poor” and another with “fair” surface condition. On the “poor” section, there was evidence of clayey subgrade as seen from the soil adjacent to the road (Figure 2). On the “fair” section, although the sub-surface drainage condition was dry at the time of the reconnaissance survey, the GHA maintenance manager mentioned that ponding occurs along this section during the rainy season.

Figure 2 Clayey subgrade on “poor” section identified on Twifo Praso – Dunkwa road

Daboase – Atieku Road

In the Western region, no suitable study section could be identified on Daboase – Atieku road because of the extremely windy nature of the road as well as high volume and speed of the traffic (safety concern during field study). Therefore, this road will not be considered for further investigations in this study.

Mpataba junction – Half Assini Road
According to the staff at the GHA western regional offices, the Mpataba junction – Half Assini road was constructed around 2006 – 2007. On this road, one study section was identified. Although this identified section was in an area of high water table, the condition of the pavement surface was good (Figure 3). Additionally, 8 trucks were encountered on this road in a period of 1 hour.

Figure 3 Section with good surface condition along Mpataba Junction – Half Assini road

Koforidua – Suhum Road

In the Eastern region, no suitable study section was found on Koforidua – Suhum road. This was because the base layer of the entire road was made of crushed stone as observed from the exposed edge of the road (Figure 4).

Figure 4 Crushed stone base on Koforidua – Suhum road

Koforidua – Adukrom Road

On Koforidua – Adukrom road, two study sections – one highly deteriorated (Figure 5) and another in a fair condition were identified. On the highly deteriorated section, a lot of the traffic was being diverted to the unsealed shoulders. From the exposed sections of the road, it was observed that the base material was made of laterites. The road is said to be over 20 years old and has undergone routine maintenance. 7 trucks were counted in a continuous period of 1 hour on this road.
Figure 5 Highly deteriorated section along Koforidua – Adukrom road

The detailed information sheets for all the sections that were identified in Ghana are provided in Annex 5.

3.1.3 Wrap-up meeting in Ghana

The following points were brought forward by the in-country partners in the wrap-up meeting:

- The Ghana partners acknowledged the significance of the project in regard to provision of LVSRs.
- MRH, GHA and DFR expressed their commitment to facilitate and fully engage in the project.
- GHA confirmed availability of equipment for laboratory investigations and their willingness to deploy it on the project. The MRH Director, Research Statistics and Information Management confirmed that the cost of laboratory testing as well as the allowances of seconded staff from the Ghana agencies would be borne by Ghana – as part of their counterpart contribution to the project. MRH will coordinate the logistical arrangements amongst the Ghana partners.
- When the report from the reconnaissance visits is shared with Ghana, MRH will constitute a project team comprising members from GHA and DFR, who will be fully briefed on the project requirements.
- For this study, Cape Coast – Twifo Praso road, Mpataba Junction – Half Assini road, and Koforidua – Adukrom road would be considered.
- GHA would provide all the available documentation on the selected roads including maintenance records, as-built data, among others.

3.2 Mozambique

3.2.1 Background

The Mozambique component study is following on from the previous project ‘Back Analysis of Previously Constructed Low Volume Roads in Mozambique’ conducted under AfCAP 1. The reconnaissance visit therefore was carried out with the intention of expanding on the knowledge gained in the previous project.

Very important research outputs were obtained from the previous study and these were used to review specifications for the provision of low volume roads in Mozambique and beyond and are contained in the Work Standards Manual for Mozambique, which was published in 2014 and the Manual for the Provision of Low Volume Roads in Mozambique which has been produced recently.

During the ‘Back Analysis of Previously Constructed Low Volume Roads in Mozambique’ conducted under AfCAP 1 in Mozambique, materials test results from two sections that were performing well were exceptionally below existing specifications. For this reason, we propose to take samples from these sections again for further testing. If indeed the results are exceptionally below existing specifications, then these could be used to revise specifications significantly. A brief description of the two sections is presented as follows:

Pambara-Rio Save Road N1 (Inhambane Province)
This is a section of trunk road which has been in service for more than 30 years but the grey sand road base shows no signs of failure. The tests for the presence of cement for stabilisation came out negative indicating that the sand was not stabilised or the cement had completely carbonated. These unexpected results suggest that this road requires additional study.

The AADT is 538 vpd. The average annual rainfall is 518 – 658 mm.

**Rio Zambezi-Nicoadala Road N1 (Zambezia Province)**

There was a laterite base with a soaked CBR of 5% and PI of 19, which had performed exceptionally well and had carried more than 2 MESA cumulative traffic loading on a trunk road with very heavy trucks without failing. The AADT is 864 vpd. The average annual rainfall is 855 – 965 mm.

Several research objectives were considered in the targeting of roads and road sections for reconnaissance visits.

1. To focus on higher trafficked low volume roads, which may have carried 0.5 MESA to 1.0 MESA. This implies that the AADT would be greater than 300 vpd in most circumstances.

2. To include roads which have pavement design structures which conform to LVR standards but may have carried more than 1.0 MESA. This is intended to identify the pavements that have performed particularly well, to study their performance in detail and to perhaps use this research evidence to break the current specification boundaries/limits.

3. To target critical climatic conditions which may impact on performance of LVRs positively or negatively. This implied targeting dryer and wetter climates while also taking account of the local climate and moisture conditions.

4. To target sites studied during the previous project where unique results were obtained and no sufficient scientific explanations for the exceptional performance could be developed and thus warranted further investigations.

**3.2.2 Initial Meetings with ANE Engineers**

A meeting was held on the 31st January 2019 at ANE prior to the site reconnaissance visits. The following issues were discussed. The full list of participants in this meeting has been provided in Annex 6.

1. Purpose of the project – It was explained by TRL that the purpose of the project was to investigate the performance of previously constructed LVRs in 4 countries in Africa and the data and information will supplement the data already entered in the LVR database.

2. Scope of the project – TRL explained the scope of the project, that it involves 3 other countries in Africa and that this is the 3rd and final phase of the project. The activities involved in the reconnaissance visits and the subsequent field work were also explained.

3. Participation of ANE – ANE had received communication from TRL regarding the project and reconnaissance visits and had made arrangements for the TRL team to be accompanied by the Head of Research and provincial engineers on reconnaissance surveys.

4. It was discussed and agreed that ANE would fully participate in the project and be mandated with the following key responsibilities:
   
   a. Participation in the reconnaissance visits.
   b. Provide all the necessary records and information necessary for the execution of the Mozambique component of the study.
   c. Provide equipment for the field testing as necessary.
   d. Assist in carrying out materials testing except specialised tests to be carried out in UK.
3.2.3 Site visits in Mozambique

The reconnaissance visits were conducted in Maputo, Gaza and Inhambane Provinces. The list of those who participated in the visit is presented in Annex 6.

On each road that was visited during the reconnaissance, two to four sections that could be studied in detail were identified. The sections were identified such that the visual appearance of the surface conditions (Good, Fair and Poor) were represented. The sections vary in length between 200 and 500 m. Details of the roads and the sections, which were selected for possible inclusion into the study, are given in the Site Reconnaissance Form in Annex 6 and additional information is given below.

Boane-Namaacha Road

This is a national road by virtue of it connecting to the border with Swaziland. However, in terms of traffic and the pavement design structure it is a secondary road and can also be regarded as a low volume road with relatively high traffic loading. The AADT from traffic counts (traffic count post 106) is 2794 of which 650 are heavy vehicles. However, locally available materials were used in the construction of the bases (unstabilised) and surfacings. Average annual rainfall is 518 – 658 mm. Four sections for possible further study were identified on this road.

Section 1

Observations:

1. The first part of the section is situated within the flood plain and is probably occasionally flooded during rainy seasons. There are patches in this section which signify failures related to poor drainage.

2. The subgrade is black cotton soil and the normal treatment either by structural design (Treatment for Expansive Clays) or chemical treatment of the black cotton soil is not immediately evident.

3. Natural rhyolite was used for the construction of base course which could be crusher run or unprocessed but it appears as though it is unprocessed judging by the high content of fines.

4. The surfacing looks old and brittle and it has exceeded its service life.

5. The 2nd part of the section, which is outside the flood plain, appears to be very sound structurally but the surfacing is also old and brittle.
Section 1: Showing the extensive patching in the part that is in the flood plain

Extensive patching, cracking and Spalling

Section 2
Observations:
1. The middle of the section is located at the boundary of a river flood plain hence the high embankment (approx. 2 m).
2. Subgrade is black cotton soil.
3. Some periodic intervention had been carried out on the section that is within the flood plain and it involved repairs on the base and resealing.
4. Cracks are predominantly longitudinal but there are also crocodile cracks in some parts of the section.

Section 3
Observations:
1. Traffic is lower than that of Sections 1 and 2 because it is located after the quarry at 10+200.
2. Subgrade is silty-loam soil and non-expansive.
3. Gradient is steep.
4. Drainage is good. Though it has shallow drains, drainage is generally good due to the steep gradient.

**Figure 8 Section 3 Boane-Namaacha Road**

<table>
<thead>
<tr>
<th>Section 3: Showing steep gradient and road in good condition</th>
<th>Longitudinal cracks</th>
</tr>
</thead>
</table>

**Section 4**

Observations:
1. Traffic on this section is the same as that of Section 3.
2. The subgrade is silty-loam soil and non-expansive.
3. This section is flat.
4. Drainage is good.

Selection of sections for the study:
Sections 1, 2 and 3 were selected for the study. The research considerations are:
1. The climate is the same for all – generally drier but very heavy rains usually occur for short periods of time.
2. Unstabilised granular rhyolite base was used on all sections.
3. Sections 1 and 2 are founded on expansive black cotton soil and partly in flood plains of defined water courses.
4. Traffic is heavy on Section 1 and 2 and lighter on Section 3. Section 3 can be considered as a control section with ideal conditions for good performance of a typical LVR.

**Boane – Moamba Road**

This is an old road with a very old surfacing. The road was targeted due to its unique design and exceptional performance. This is not a typical LVR but there are good engineering and scientific aspects which will contribute significantly to the research results.
The road was the main route to the South African border for many years before the construction of the new highway (N4). N4 has a weigh bridge and a significant proportion of the heavily loaded and overloaded trucks use this route to date in order to avoid the weighbridge. In addition, there are big quarry sites on the section from 20+000 to 27+000 and there are also heavily laden trucks carrying wet river sand from Incomati River.

The base course is a layer of very coarse natural gravel with nominal maximum size of 75 mm. The majority of the road has failed as expected but there are sections which are still performing well with very little rutting (< 10 mm) and no deformation. Only routine maintenance has ever been carried out on this road and it is puzzling how these sections could have survived this long with such extreme traffic loading.

This is a high volume road in terms of the traffic loading with a LVR pavement structure hence the need to study the pavement and traffic loading characteristics. The grading of the base course is certainly out of specifications for LVR and HVR because of the oversize stone in the gravel but the performance is certainly much better than the recommended standard gravel (≤ 37.5 mm nominal maximum size).

The AADT obtained from traffic counts (station 116) is 505 of which 436 are heavy vehicles. Average annual rainfall is 518 – 658 mm. Three sections for possible further study were identified on this road.

**Sections 1 and 2**

Observations:
1. Subgrade consists of very coarse gravel which is gap graded.
2. There is 1 base layer of very coarse and gap graded natural gravel.
3. Double surface dressing is still intact in some isolated sections.
4. Drainage is good in some parts and very poor in other parts
**Figure 9 Section 1 and 2 Boane-Moamba Road**

| Sections 1 and 2: Showing the condition of the sections and the surfacing after more than 20yrs of service | Typical trucks plying this road and Very coarse base coarse carrying heavy loads |

**Section 3**

Observations:

1. Subgrade is expansive black cotton soil.
2. Drainage of the area is generally poor and flooding occurs occasionally.
3. Traffic is slightly lower because this is after the main quarries in the area.
Selection of sections for the study:
Sections 1 and 3 shall be considered for the study since Sections 1 and 2 are similar in all aspects. The challenge arising from the study of these sections would be on quantifying the strength of the base and subgrade because the common methods such as DCP and laboratory CBR cannot apply due to the coarse nature of the base material.

Xinavane-Magude Road
This road is in the sugar cane plantations and services the processing plant at chainage 7+900 and Magude District. The vehicles for the plantation are super-heavy tractor type trucks. The axle loads are yet to be measured. The road is founded on perpetually wet foundations due to the swampy conditions in the plantation. The base is fine red sand applied with and without chemical stabilisation, macadam base and red sand mechanically stabilised with oversized aggregate.

The road was constructed in 2002.

The AADT from traffic counts (station 122) is 1149 of which 278 are heavy vehicles. The average annual rainfall is 768 – 855 mm. Three sections for possible further study were identified on this road.

Section 1
Observations:
1. The road is generally in good condition.
2. Red sand was used on this section and appears to be stabilised though the information obtained from ANE appears to indicate that the base was not stabilised. If indeed the red sand is not stabilised then the performance would be considered exceptional and must be investigated due to potential cost savings from the applications of outcomes of studying this section.
3. The surfacing is double surface dressing and a reseal of slurry was applied in period from 2015-2016.
4. The double surface dressing was constructed in 2002 so it was 13 years old when the reseal was applied and this good performance considering the traffic and the prevailing road environment needs to be investigated.
Section 2
Observations:
1. Base course – there is what appears to be macadam or armoured base course in the first 150m and red sand base in the remaining 150m.
2. Drainage is poor.
3. The road is in good condition.

Section 3
Observations:
1. Road base is a mechanically stabilised red sand base and it is a mixture of fine sand and very coarse aggregate.
2. Embankment is high.
3. The section is badly cracked and potholed and it could be a combination of both surfacing and base failure. This was unexpected because the traffic on this section is expected to be lower than of Sections 1 and 2 which are before the factory.

Sections selected for the study:
All 3 sections would yield vital information for further review and development of the specifications for LVRs.

Macia-Chokwe Road
This road connects the national road N1 in Gaza Province to the border with Zimbabwe at Chicualacuala Border Post. The road was chosen in order to investigate the impact of timely maintenance on the performance of LVRs. Five years ago routine maintenance involving crack sealing was carried out on the section from 0+000 for 24-25km along the road. No crack sealing was carried out on the remaining sections. The section which received crack sealing is still in fair to good condition whereas the remaining sections are either in poor condition or have completely failed thus requiring heavy maintenance or rehabilitation. All sections have double surface dressing. The surfacing is old and no reseal has ever been applied.

The road is over 20 yrs old and the AADT from traffic counts is 1692 of which 120 are heavy vehicles. The average annual rainfall is 658 – 758 mm. Three sections for possible further study were identified on this road.

Section 1
Observations:
1. The base is cement stabilised white sand and there is evidence of block cracking.
2. There is no evidence of structural failure but longitudinal and transverse cracking is pronounced and could be a reflection of the block cracking in the based course.

Section 2
Observations:
1. There is a macadam or crushed stone base and there is no deformation at all.
2. Rutting is very minimal showing good performance of the pavement.
Section 3

Observations:

1. This section has failed and requires rehabilitation, replacing the surfacing.
2. The base is cement stabilised white sand similar to Section 1.
3. The numerous potholes are shallow showing that this is a surfacing failure.

Sections selected for the study:

All 3 Sections would yield good information on performance of LVRs, use of alternative designs and most of all the impact of timely maintenance on the performance of LVRs.

Macaritane-Massingir Road

This road is located in a dry area but suffers from high flooding from occasional tropical storms and sometimes cyclones. The traffic is low so it is a typical LVR. The road was targeted to understand the behaviour of river gravel in road pavements in this type of environment and traffic loading.
The road is expected to perform very well under these circumstances but significant deformation has been observed. It is not clear whether this is caused by the weakness of river gravel, which of course has rounded soil particles and may have high PI, or the settlement of the embankment or quality of construction or a combination of the above factors.

The road is over 20 years old and the AADT from traffic counts is 643 of which 33 are heavy vehicles. The average annual rainfall is 518 – 658 mm. Two sections for possible further study were identified on this road.

**Sections 1 and 2**

Observations:
1. The river gravel which was used consists of coarse and gap graded rounded particles with a high content of fines.
2. High plasticity is suspected but clay was not observed.
3. Deformation is mainly in the wheel paths but the number of heavy vehicles is relatively low.

Sections selected for the study:
Studying at least one of these sections would give an indication of the lower limit of specification for river gravels which in some cases, and areas, would be the only locally available material for construction of LVRs.

**Lindela-Mutamba Road**

This road links the town of Inhambane to the main road (N1). The road passes through flat terrain, a swampy area, undulating landscape and a steep climb. The base course is cement stabilised red and white sand. There is an old double surface dressing constructed using locally available calcrite aggregate. In 2015 - 2016, maintenance consisting of application of slurry seal was carried out. Quarry sand from Maputo was used in the slurry and the haulage distance is 500 km. Other parts have single surface dressing consisting of rhyolite aggregates also transported from quarries in Maputo. The average annual rainfall is 855 – 965 mm. Four sections for possible further study were identified on this road.

**Section 1**

Observations:
1. Some of the slurry seal is wearing away.
2. Exposed old double surface dressing shows that the calcrite had low abrasion strength judging from the wearing and polishing of the calcrite aggregate.
3. The old calcrite surface dressing seems to be in a fair condition still and this is an indication of good performance.
4. There is a low embankment from the middle of the section to the end and none from the beginning to the middle.

**Section 2**

Observations:
1. This section is founded in a swamp, which is perpetually waterlogged.
2. The embankment is high (2-3 m).
Section 3
Observations:
1. The gradient is very steep.
2. Cracking is severe and unsightly. The slurry seal has cracked badly. The cracks are longitudinal and transverse and connected, and some areas have crocodile cracks. It was not clear whether these are reflective cracks form the base or they only occur in the slurry seal but the latter is suspected.

Section 4
Observations:
1. Similar observations were made on this section as listed for Section 1 with the exception that the reseal was not slurry but single surface dressing and rhyolite aggregate was used.
2. Very little cracking was observed compared with the slurry seal.

Mutamba-Inhambane Road
This road is built on loose, self-draining white sands and carries more traffic than Lindela-Mutamba Road. The bases are cement stabilised white sand and cement stabilised red sand. The performance is generally fair to good. The average annual rainfall is 855 – 965 mm. Three sections for possible further study were identified on this road.

Sections 1 and 3
Observations
1. The base is white sand stabilised with cement.
2. The original surfacing was double surface dressing with calcrete aggregate.
3. Slurry seal was used for resealing
4. There are no side drains

Section 2
1. There are no side drains the road is generally level with the ground.
2. Reseal was done using single surface dressing with rhyolite aggregate form Maputo (500 km).

Based on the above, the following roads and sections have been selected for detailed fieldwork and lab testing:
- Boane – Namaacha road
- Boane – Moamba road
- Macia – Chokwe road

To confirm findings from the previous back analysis study carried out in Mozambique in 2012 under AFCAP 1, samples will be taken from the following sections for further laboratory testing:
- Pambarra – Rio Save (targeted sampling)
- Rio Zambezi – Nicoadala (targeted sampling)
- Lindela – Inhambane road (targeted sampling)
3.3 Uganda

During the visit in Uganda, an initial meeting was held, following which the selected candidate roads were visited. A wrap-up meeting was also held.

3.3.1 Initial meeting with counterparts in Uganda

The initial meeting was held with the Uganda National Road Authority (UNRA) on 28th January 2019 at the UNRA head office. The full list of participants in this meeting has been provided in Annex 7.

From the discussion, the following points arose:

- UNRA expressed their willingness to support the project and provide resources where required. Counterpart staff were seconded to undertake the site reconnaissance visits with TRL.
- The need for involvement of the Ministry of Works and Transport (who are mandated with the development of standards and specifications for roads in Uganda) was emphasised by the Head of the Research and Development Unit - UNRA.
- It was communicated by UNRA that finding maintenance records of the candidate roads would not be a problem since the roads have not undergone any periodic maintenance.
- UNRA committed to assisting with collation of all available information on the candidate roads. It was also noted that the proposed candidate roads were constructed under the Road Agency Formulation Unit (RAFU). As such, some of the information on the roads might have been lost during the phases of transition that UNRA has undergone.
- No reliable data on traffic loading was available for the candidate roads. UNRA committed to mobilising their mobile weighbridge on the project whenever required.
- TRL was tasked with drafting a high level capacity building strategy (1-2 pages) clearly highlighting how the skills of key staff would be advanced during each stage of the project. A draft was prepared and will be used in all the four study countries.
- TRL would share with UNRA the detailed scope of activities (dates of site investigations, timelines, plant/resources required, staff requirements, material/quantities required for reinstatements) as soon as possible to allow UNRA adequate time for completing the internal approval processes.

3.3.2 Site visits in Uganda

Site visits were conducted, by region, to the candidate roads. In the Western region,

- Ntungamo – Katunguru – Rukugiri road,
- Kikorongo – Mpondwe road,
- Ishaka – Kasese road, and
- Kilembe – Kasese road were visited.

In the Central region, Gayaza – Kalagi road and Matugga – Semuto – Kapeeka road were visited.

Ntungamo – Katunguru – Rukugiri road and Gayaza – Kalagi road were found unsuitable for consideration in this study because their base layers were made of crushed stone. In addition, the traffic encountered on Kilembe – Kasese road (road to the former copper/cobalt mines) was not adequate for this study following the closure of the mines in the mid-1980s.

Kikorongo – Mpondwe Road

Kikorongo – Mpondwe road, which is said to have been constructed 15 – 20 years ago, was found to be ideal for consideration in this study. 19 trucks (mostly overloaded 6 – 9 axle) were observed in a traffic count that was done for a continuous period of approximately 1 hour. The road had overgrown side drains and its base material was made of natural gravel which appeared to be modified. The pavement surfacing was DSD. 3 study sections were selected from this road, 2 of which were performing well and 1, fairly well. The first “good” section had no cracking, few potholes and minimum rutting whereas the second one had no potholes, no rutting and low cracking intensity. On the “fair” section, the maximum rutting was estimated at 30 mm, the crack intensity was low and few potholes (mostly along the centreline) were
observed. It was also observed that most of the previously existing potholes on this road had been patched (Figure 13). These patches were in a good condition at the time of the site reconnaissance visits. Kikorongo – Mpondwe road would be considered for investigating the impact of age of pavement, the performance of natural gravels in LVSRs and the impact of maintenance on the performance of LVSRs.

**Figure 13 Pothole patches on Kikorongo – Mpondwe road**

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**Ishaka – Kasese Road**

On Ishaka – Kasese road, the inspected sections appeared to be 20 – 30 years old. Although the ground adjacent to the road was swampy, the road was in a relatively good condition. 10 trucks (many appearing overloaded) were observed in a continuous period of 1 hour. Two study sections were identified on this road. One of the identified sections had a good surface condition with no cracks, no potholes and maximum rutting of 20 mm. The second section had low crack intensity, few potholes and estimated maximum rutting of 10 mm. Localised block cracking (Figure 14) was also observed on this section. Sections of this road are currently undergoing rehabilitation. The rehabilitation team has already acquired relevant data on the section, which TRL will study during the execution of this project.

**Figure 14 Localised block cracking on Ishaka – Kasese road**

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**Matugga – Semuto – Kapeeka Road**

Matugga – Semuto – Kapeeka road (constructed around 2010) is made up of a number of trial sections with varying types of surfacing. 25 trucks (mainly 2-axle trucks) ferrying sand were recorded in a continuous period of 1 hour. This road is currently being studied in an on-going Long-term Pavement Performance (LTPP) monitoring project under AfCAP (GEN2132A). The study sections selected along this road included 4 with “good” surface condition, 1 with “fair” surface condition and 1 highly deteriorated section. The sections that were performing well were those with single Otta seal + sand, double sand seal, SSD + sand seal, and inverted DSD in their surfacing layers. The surfacing layer of the “fair” section was made of double Otta seal, whereas that of the highly deteriorated section was made of single Otta seal. The sections
identified on this road will be suitable for investigating the performance of unconventional surfacing in LVSRs under high rainfall and heavy traffic.

The detailed information sheets for all the sections that were identified in Uganda are provided in Annex 7.

Based on the above, the following roads were selected for detailed fieldwork and laboratory testing:

- Kikorongo – Mpondwe road
- Ishaka – Kasese road
- Matugga – Semuto – Kapeeka road

3.3.3 Wrap-up meeting in Uganda

The following points of consensus were reached in the wrap-up meeting that was held on 1st February 2019 at the UNRA offices in Nakawa, Uganda:

- Generally, UNRA was willing to support the project as far as possible. They requested TRL to provide them with a detailed activity schedule to guide them in allocation of resources.
- TRL would consult with ReCAP on covering the cost of reinstatement of test pits, in conjunction with the UNRA regional maintenance managers.
- Kikorongo – Mpondwe road, Ishaka – Kasese road and Matugga – Semuto – Kapeeka road will be suitable for detailed study to fill some of the gaps identified in Phase 2 of this project (and listed section 1.2 of this report).
- UNRA had already started collecting the required data (maintenance records, traffic data, axle loads, and construction records) on the selected study sections.

3.4 Zambia

Similar to all the other countries, an initial meeting was held, which was followed by site reconnaissance visits to the candidate roads in Zambia. Due to time constraints, the wrap-up meeting could not be held in an official meeting setting.

3.4.1 Meeting with Zambian counterparts

A meeting was held on 15th January 2019. On the side of the Zambian counterparts, the meeting participants included representatives from the Road Development Agency (RDA) and the National Road Fund Agency (NRFA). A full list of participants is provided in Annex 8.

The key points from the meeting included:

- RDA was committed to fully supporting the project and fulfilling all their roles in the collaboration.
- Laboratory testing for the project would be done in the RDA laboratories at their cost.
- RDA staff would be seconded to co-execute the project with TRL. NRFA staff would also participate whenever possible.

During the discussions on the suitability of the candidate roads identified at the pre-visit desk study, RDA and NRFA recommended a new list of potential roads based on the selection criteria that had been presented by the TRL team. The RDA Highway Management System (HMS) was used as a tool to filter candidate roads that met the traffic requirements for the project. From the HMS, a list of potential roads was provided from which 3 were selected for site reconnaissance visits. These 3 roads included:

- Samfya – Musaila road (off the D451).
- Mansa – Chembe and Mansa – Bahati road (M3).
- Mukuku Bridge – Samfya road (D235).

All the selected roads were in the Northern region, which experiences the highest rainfall in the country. All roads had DSD as the surfacing material.
3.4.2 Site visits in Zambia

The TRL team was accompanied by a seconded RDA staff member for the site reconnaissance visits.

**Samfya – Musaila Road**

On Samfya – Musaila road (off the D451), 5 trucks were seen on the road in a continuous period of 1 hour. Two suitable sections were selected – one with a good surface condition, and another was fairly good. On both sections, the rutting was negligible. For the “good” section, the estimated crack intensity was very low whereas that of the “fairly good” section was high. Both sections, however, had few potholes. The material which was exposed on the 0.5 m wide unsealed shoulders appeared to be chemically-modified laterite. Although the chemical content could not be ascertained at the time of the reconnaissance visits, the RDA engineer postulated that cement content of most chemically stabilised roads in Zambia was about 3%. This will be confirmed during the detailed site investigations. This road will be suitable for investigating the performance of natural gravel bases in high rainfall areas.

**Mansa – Chembe, and Mansa – Bahati Road**

On the M3 (Mansa – Chembe, and Mansa – Bahati road), one section was identified along Mansa – Chembe road; and 2 sections along Mansa – Bahati road. For a continuous period of 1 hour, 13 trucks were recorded. Locals stated that the Mansa – Bahati stretch was the main route between the Democratic Republic of Congo and Zambia (through Mansa) and had “far too many trucks all year round, especially during the harvest season between April and May.” This was evidently reflected in the condition of the road as only a highly deteriorated section and fairly performing section could be identified on this road. On the “fair” section, the maximum rutting depth was estimated at 22 mm, whereas the cracking intensity and the frequency of potholes were low. Conversely, the highly deteriorated section had numerous potholes (Figure 15). Owing to the poor state of this section of the road, motorists were using the shoulder, which had become severely rutted from the diverted traffic. The pavement had lost its camber, and water from the pavement could not make it to the verge. It was observed from the exposed sections of the road that the base layer was made of lateritic gravel material. This road will therefore be a good candidate for investigating the performance of natural gravels under high rainfall and heavy traffic.

*Figure 15 Highly deteriorated section on Mansa – Bahati road*

The “good” section along the Mansa – Chembe stretch had an estimated maximum rutting depth of 8 mm, few potholes and no cracking. The aggregates in the surfacing were coarse in nature with resemblance to inverted DSD (Figure 16). This could be considered as a non-conventional surfacing. The Right Hand Side (RHS) of the section had poor drainage in parts coinciding with overgrown grass at the carriageway edge, and the LHS had good drainage for the most part. From the adjacent ground, the subgrade on the RHS was silty loam and that on the LHS was clayey sand.
Mukuku Bridge – Samfya Road

The Mukuku Bridge – Samfya road (D235) is located in a swampy/marshy area with a high water table (less than 1m below the surface of the road). Accordingly, the side drains had overgrown grass which impeded the water from flowing off the pavement in most of the sections (Figure 17). 3 adjacent sections with varying surface condition of “good”, “fair” and “poor” were selected from this road. The “good” section had no cracking, no potholes and minor rutting (Figure 18). A few localised, but deep, potholes were observed on the “fair” section. The “poor” section had numerous potholes. This road will be suitable for understanding the variation in performance of adjacent sections subjected to the same traffic and environmental conditions as well as the performance of weak subgrades in LVSRs.

The detailed information sheets for all the sections that were identified in Zambia are provided in Annex 8.
Based on the above preliminary observations, the following roads were selected for detailed fieldwork and laboratory testing:

- Samfya – Musaila road (off the D451)
- Mansa – Bahati road (M3)
- Mukuku Bridge – Samfya road (D235)

3.4.3 On-site wrap-up in Zambia

A brief wrap-up was held with the RDA engineer on site. The following key points of agreement emerged:

- Of the roads visited, Samfya – Musaila road (off the D451), Mansa – Bahati road (M3) and Mukuku Bridge – Samfya road (D235) would be considered for detailed investigations.
- Field equipment belonging to RDA (such as the Falling Weight Deflectometer (FWD) and bump integrators, among others) was readily available for deployment on the project. RDA would confirm the status of their calibration prior to commencement of the field investigations.
- RDA staff would be available to undertake the field and laboratory investigations, with TRL.
- Axle load surveys will be undertaken by the RDA sponsored by ReCAP.
4 Summary and way forward

This section presents a summary of the recommended roads for detailed field investigations based on the findings from the pre-visit desk study and the reconnaissance visits, as well as the activity schedule.

4.1 General

Overall, there was acceptance of this phase of the project in Ghana, Mozambique, Uganda and Zambia. The participating road agencies in all the above countries acknowledged the significance of the project in regard to improved provision and delivery of LVSRs.

The countries committed to supporting the project through:

- Secondment and facilitation of their staff to co-execute the project activities with TRL.
- Provision of all the available documentation on the selected roads including maintenance history and as-built records.
- Providing authorisation for access to the selected project roads during all the stages of the project.
- Deployment of their equipment (in kind) for field surveys.
- Assisting in the reinstatement of test pits.
- Allowing testing of material samples in their laboratories, at their cost.

4.2 Summary of the roads visited

4.2.1 Roads selected for the detailed study stage

During the reconnaissance visits, study sections were identified on selected roads on which the detailed investigations would be undertaken in Ghana, Mozambique, Uganda and Zambia. The factors that influenced the selection of these roads included:

- The suitability of the roads to bridge the knowledge gaps that were identified in phase 2 of the project (section 1.2 of this report). Roads which exhibited the potential to meet more than one knowledge gap were given preference.
- The availability of feasible test sections (equivalent to study sections) on the roads. Some of the crucial aspects considered during identification of feasible study sections included:
  - Availability of sections of varying conditions (Good, Fair, Poor).
  - Safety of personnel during the site investigations. Adequate sight distance from both the start and end of the study section was a requirement.
  - Similarity of the section’s “subgrade” layer to the actual ground conditions of the adjacent native soil. As far as possible, sections on high embankments were avoided.
  - Affordability of the pavement. Sections which were constructed using crushed rock/stone in their base layers were not selected.

A summary of the suitable roads that were selected in each country, together with the targeted investigation matrices is presented in Table 4. The investigation matrices are in line with those proposed in the Phase 2 Report.
### Table 4 Summary of selected roads and the corresponding investigation matrices

<table>
<thead>
<tr>
<th>Country</th>
<th>Selected roads</th>
<th>Targeted investigation matrices</th>
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<tbody>
<tr>
<td>Ghana</td>
<td>Cape Coast – Twifo Praso road</td>
<td>• Bases versus traffic loading and environment</td>
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<tr>
<td></td>
<td>Mpataba Junction – Half Assini road</td>
<td>• Weak subgrades versus traffic loading, climate and age</td>
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<td></td>
<td>Koforidua – Adukrom road</td>
<td>• Bases versus traffic loading and environment</td>
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<tr>
<td></td>
<td></td>
<td>• Maintenance versus climate, traffic loading and age</td>
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<tr>
<td>Mozambique</td>
<td>Boane – Namaacha road</td>
<td>• Bases versus traffic loading , Weak bases versus traffic loading</td>
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<td>• Weak subgrades versus traffic loading, Weak subgrades versus traffic loading</td>
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<td>• Drainage versus traffic , Bases versus gradient</td>
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<td></td>
<td>Boane – Moamba road</td>
<td>• Coarse bases versus traffic loading</td>
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<td>• Weak subgrades versus traffic loading, Drainage versus traffic loading</td>
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<tr>
<td></td>
<td></td>
<td>• Weak subgrades versus drainage, Surfacings versus age</td>
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<tr>
<td></td>
<td>Macia – Chokwe road</td>
<td>• Surfacings versus age</td>
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<td>• Surfacings versus maintenance, Surfacings versus traffic loading</td>
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<td>Pambara-Rio Save road(^1)</td>
<td>• Weak bases versus traffic loading, Stabilisation versus traffic loading</td>
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<td>Rio Zambezi – Nicoadala road(^1)</td>
<td>• Very weak bases versus traffic, Pavement drainage versus traffic loading</td>
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<td>Lindela – Inhambane road(^1)</td>
<td>• Weak surfacing aggregate versus traffic loading</td>
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<td>Uganda</td>
<td>Kikorongo – Mpondwe road</td>
<td>• Bases versus traffic loading and environment</td>
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<td>• Weak subgrades versus traffic loading, climate and age</td>
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<td></td>
<td>Matugga – Semuto – Kapeeka road</td>
<td>• Non-conventional surfacing versus traffic and environment</td>
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<td>Zambia</td>
<td>Samfya – Musaila road (off the D451)</td>
<td>• Bases versus traffic loading and environment</td>
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<td>Mansa – Bahati road (M3)</td>
<td>• Bases versus traffic loading and environment</td>
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<td></td>
<td>Mukuku Bridge – Samfya road (D235)</td>
<td>• Weak subgrades versus traffic loading, climate and age</td>
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</table>

Note 1: These represent sections for which only limited study to confirm findings from the previous back analysis study will be done. This may involve only materials sampling and testing.

In order to investigate the matrices listed in Table 4, field surveys and laboratory testing on samples extracted from the sites will be done.

#### 4.2.2 Roads for future follow-on study

Several roads and study sections visited in Mozambique and described in section 3.2.3 of this document would yield invaluable information, which would contribute significantly to the revision of specifications for LVSRs. However, due to inadequate finances and the limited timescale for this study, the number of sections proposed for the detailed study stage has been reduced to be in line with the limitations. The following research areas and sections, amongst many others, will be regrettably excluded from the study:
1. Low embankment with very coarse base course on coarse subgrade for heavy traffic on Boane-Moamba Road (Section 2)
2. Hot sand asphalt and unstabilised laterite base on Pambara – Rio Save Road
3. Performance of river gravel on Macaretane-Massingir Road (Sections 1 and 2)
4. Mechanical stabilisation of weak sand bases, neat sand bases and macadam layer of red sand on Xinavane-Magude Road
5. ETB on a secondary road – Chibuto-Chongoene Road
6. Rubber modified bitumen on Muxungue-Inchope Road.
7. Exceptional performance of blended wearing courses on Marracuene-Macaneta Road. Exceptional performance of ETB on Marracuene-macaneta Road and failure of thin slurry seal after abnormal loads of rigging equipment, precast bridge elements and construction materials and equipment were transported through the section for the construction of the Incomati Bridge.

4.3 Field measurements and laboratory testing

The following activities are proposed for the field surveys on the selected roads:

- Deflection measurements.
- Roughness measurements.
- Visual condition assessment (rutting, cracking, potholing and patching).
- Determination of cross-section levels.
- Dynamic Cone Penetrometer (DCP) tests.
- Field density test.
- Test pits/ layer thicknesses/ sampling.
- Traffic counts.
- Axle load surveys.

The tests will vary according to the data already available on some of the sections and the intensity of testing may vary depending on the extent of deterioration observed on the sections.

It is anticipated that the laboratory testing will involve:

- Soils related tests
  - CBR.
  - Maximum Dry Density (MDD) / Optimum Moisture Content (OMC).
  - Moisture contents.
  - Atterberg Limits.
  - Particle Size Distribution (PSD).
  - Unconfined Compressive Strength.
- Aggregate related tests
  - PSD.
  - Aggregate Crushing Value (ACV) / Ten per cent Fines Value (TFV) / Aggregate Impact Value (AIV).
  - Los Angeles Abrasion (LAA).
  - Average Least Dimension (ALD).
  - Flakiness Index (FI).
  - Specific gravity and water absorption.
- Bitumen recovery
  - Penetration.
  - Softening point.
  - Ductility.
The tests will vary according to the data already available on some of the sections and the intensity of testing may vary depending on the extent of deterioration observed on the sections.

4.4 Activity schedule

The activity schedule for Phase 3 of this project is provided in Figure 19. Phase 3 commenced in December 2018 and is scheduled for completion in June 2019.

**Figure 19 Activity schedule for Phase 3**

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<td>Inception Report for Phase 3</td>
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<td>John Rolt</td>
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<td>Kevin McPherson</td>
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<td>James Zihni</td>
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<td>Francis Dangare</td>
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<td>Dominic Leal</td>
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<td>Michael Mayanja</td>
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Bibliography


http://www.ra.org.mw/maps/Malawi_Road_Network_All_Roads.pdf
http://geoportal.icpac.net/layers/geonode%3Atza_tanzania_soil#more
https://www.bgs.ac.uk/data/earthwise.html


Annex 1  Definition of roles for Phase 3 of the Back Analysis project

Form of Collaboration

TRL Limited (hereinafter referred to as TRL) was appointed by Cardno Emerging Markets, UK through the Africa Community Access Partnership (AfCAP) programme to execute the project of ‘Development of Guidelines and Specifications of Low Volume Sealed Roads (LVSRs) through Back Analysis’ (hereinafter referred to as the “project”). Phases 1 and 2 of the project have already been completed and Phase 3 is expected to be completed by June 2019. Phase 3 will involve detailed investigations, which will subsequently lead to the update and/or corroboration of the existing guidelines and catalogues for pavement design of LVSRs. Six (6) AfCAP partner countries – Ghana, Malawi, Mozambique, Tanzania, Uganda, and Zambia – have been identified as prospective study areas. Drawing from the partnership between AfCAP and the 6 countries, TRL will execute this project in close collaboration with the participating road agencies through their Road Research Centres (RRCs) through which the AfCAP programme is delivered in the respective countries. The parties of the project will therefore be AfCAP, TRL and the participating road agencies of the selected AfCAP partner countries.

Roles of the Parties

AfCAP, will:

- Pay for consultancy services in accordance with contract signed with TRL.
- Liaise with the participating road agencies to ensure their needs within the project scope are met.
- Oversee and manage the activity of the Consultant (TRL Limited).
- Carry out quality review of the Consultant’s outputs.

The obligations of TRL and the participating road agencies are defined below:

TRL shall:

- Execute the project in tandem with the partnership between the participating road agencies and AfCAP.
- Manage the execution of the project activities to ensure that the project objectives are met, including preparation of progress reports and final documents.
- Involve seconded participating road agency staff in the execution of the project activities for capacity building purposes. This will involve working with the participating road agency staff during the field surveys, laboratory investigations, compilation, analysis and interpretation of data.
- Hand over all work products generated solely or jointly with the participating road agency teams in the execution of this phase of the project to the participating road agencies at the earliest reasonable time. Work products shall include all raw and processed data, notes, ideas, processes, drawings, and formulae, among others.
- Carry out any specialised testing of selected samples outside the country in case it is deemed necessary to enhance the findings and it is agreed by AfCAP.

The participating road agencies shall:

- Appoint and second their staff who will co-execute the project with TRL.
- Jointly undertake field and laboratory investigations with TRL.
- Pay wages to labourers, and allowances for their seconded staff.
- Allow testing of materials in their laboratories at no cost to the project.
- Provide (in kind) available equipment for field testing.
- Assist in reinstatement of test pits excavated in sampling pavement materials.
- Provide available information/data on existing LVSRs to aid in selection of the project road(s) as well as project execution.
- Provide authorisation for access to the selected project road(s) during all the stages of the project.
- Facilitate duty and tax exemption for all items procured during this phase of the project.
• Facilitate the execution of the project through the provision of relevant supporting documentation and letters as may be required by relevant authorities – this includes materials export permits where necessary.
Annex 2  Road network, soil and climatic maps for Ghana, Malawi, Mozambique, Tanzania, Uganda and Zambia

Figures A.1 – A.17 show the climatic, road network and soil maps of Ghana, Malawi, Mozambique, Tanzania, Uganda and Zambia in the order below:

<table>
<thead>
<tr>
<th>Figure numbers</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1 – A.3</td>
<td>Ghana</td>
</tr>
<tr>
<td>A.4 – A.6</td>
<td>Malawi</td>
</tr>
<tr>
<td>A.7 – A.8</td>
<td>Mozambique</td>
</tr>
<tr>
<td>A.9 – A.11</td>
<td>Tanzania</td>
</tr>
<tr>
<td>A.12 – A.14</td>
<td>Uganda</td>
</tr>
<tr>
<td>A.15 – A.17</td>
<td>Zambia</td>
</tr>
</tbody>
</table>
Figure A.3 Soil map of Ghana
Figure A.8 Soil map with super-imposed road network of Mozambique
Figure A.11 Soil map of Tanzania

Figure A.12 Climate map of Uganda
Figure A.13 Road network map of Uganda

Figure A.14 Soil Map of Uganda
Figure A.15 Climate map of Zambia

Figure A.16 Road network map of Zambia
Figure A.17 Soil Map of Zambia
Annex 3  Characteristics of the proposed candidate roads from the pre-visit desk study and their corresponding investigation matrices

<table>
<thead>
<tr>
<th>Country</th>
<th>Rainfall</th>
<th>Proposed Road(s)</th>
<th>Surfacing type</th>
<th>MESA &gt;0.5</th>
<th>ADT</th>
<th>Year of last maintenance</th>
<th>Base from locally available material</th>
<th>Weak/ moderate subgrade</th>
<th>Subgrade material type</th>
<th>Year of road construction</th>
<th>Proposed Investigation Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>Rainfall &gt;1000 mm</td>
<td>Twifo Hemang-Baakondzidzi</td>
<td>Otta seal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>Pseudo sand and clayey soil</td>
<td>2006</td>
<td>• Non-conventional surfacing in high rainfall areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obomofo Densua-Akote</td>
<td>Chip seal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>( Likely that strong subgrade material was used )</td>
<td>x</td>
<td>Laterites</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allowule-Kengen</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>Wet unconsolidated soil</td>
<td>-</td>
<td>-</td>
<td>• Weak subgrades in high rainfall areas</td>
</tr>
<tr>
<td>Malawi</td>
<td>Rainfall &lt;1000 mm</td>
<td>Lilongwe ABC Road</td>
<td>Cape seal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>Quartzitic gravel</td>
<td>x</td>
<td>Sandy clay</td>
<td>1985</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dowa Boma</td>
<td>-</td>
<td>x</td>
<td>475</td>
<td>-</td>
<td>✓</td>
<td>Weathered granite</td>
<td>x</td>
<td>Sandy clay with zones of gravelly soils</td>
<td>2004</td>
</tr>
<tr>
<td></td>
<td>Rainfall &gt;1000 mm</td>
<td>Rumphi</td>
<td>-</td>
<td>x</td>
<td>790</td>
<td>-</td>
<td>✓</td>
<td>Weathered granite</td>
<td>x</td>
<td>Well-drained clayey laterites</td>
<td>2004</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Rainfall &lt;1000 mm</td>
<td>Macia-Chokwe</td>
<td>Double Surface Dressing (DSD)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>Section of the road maintained</td>
<td>-</td>
<td>Brownish-grey sandy soil</td>
<td>&gt;20 years ago</td>
</tr>
<tr>
<td>Road Location</td>
<td>Region</td>
<td>Rainfall</td>
<td>Surface Material</td>
<td>Traffic Loading</td>
<td>Base Material</td>
<td>Subgrade Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>Pambarra-Rio Save</td>
<td>Tanzania</td>
<td>&gt;1000 mm</td>
<td>Hot Sand Asphalt (HSA)</td>
<td>✓</td>
<td>Red silt</td>
<td>-</td>
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<tr>
<td>Xai-Xai – Chissibuca</td>
<td>Tanzania</td>
<td></td>
<td>HSA</td>
<td></td>
<td>Sandy soil</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rio Zambezi-Nicoadala</td>
<td>Tanzania</td>
<td>&gt;1000 mm</td>
<td>HSA</td>
<td></td>
<td>Sandy sedimentary</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Metoro-Macomia</td>
<td>Tanzania</td>
<td></td>
<td>Single Surface Dressing (SSD)</td>
<td></td>
<td>Greyish-brown clay and sandy soils</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babati-Singida</td>
<td>Uganda</td>
<td>&lt;1000 mm</td>
<td>-</td>
<td></td>
<td>Clay</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>M-S-K 22+600 – 22+850</td>
<td></td>
<td></td>
<td>SSD + crusher dust sand seal</td>
<td></td>
<td>Clayey natural sand (stabilised)</td>
<td>-</td>
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<td></td>
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<tr>
<td>M-S-K 22+850 – 22+950</td>
<td></td>
<td></td>
<td>SSD + natural sand seal</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>M-S-K 22+950 – 23+200</td>
<td></td>
<td></td>
<td>Double Sand Seal (DSS) with</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
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</tbody>
</table>

- High traffic loading vs. non-conventional surfacing, base material, and subgrade strength
- Non-conventional surfacing vs. traffic loading
- Weak subgrades vs. traffic loading
- Non-conventional surfacing in very wet climates
- Natural base in wet climate
- Durability of surfacing in wet zones
- Weak subgrades in high rainfall areas
- Weak subgrades vs. traffic and environment
- Natural gravel bases and weak subgrades in high rainfall areas under high traffic
- Heavy traffic loading on non-conventional surfacing in high rainfall areas
<table>
<thead>
<tr>
<th>Rainfall Category</th>
<th>Road Name</th>
<th>Maintenance Type</th>
<th>Subgrade Material</th>
<th>Maintenance Details</th>
<th>Impact of Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000 mm</td>
<td>T002 Siavonga</td>
<td>DSS</td>
<td>Complex of grey-brown alluvial soils and dark grey clays</td>
<td>2003</td>
<td>Impact of maintenance</td>
</tr>
<tr>
<td></td>
<td>Maamba-Batoka</td>
<td>DSS</td>
<td>6 MESA (estimated over 15 years starting 2015)</td>
<td>2011</td>
<td>Impact of maintenance</td>
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<tr>
<td></td>
<td>Kasama-Mbesuma-Isoka</td>
<td>DSS</td>
<td>Sandy loams and loamy sands</td>
<td>n/a</td>
<td>Weak/moderate subgrades in areas of high rainfall</td>
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<td>Luwingu-Kasama</td>
<td>DSS</td>
<td></td>
<td>n/a</td>
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<td>Mbala-Nakonde</td>
<td>DSS</td>
<td></td>
<td>n/a</td>
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<tr>
<td></td>
<td>Kalulushi-Lufwanyama</td>
<td>DSS</td>
<td></td>
<td>n/a</td>
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**Key:**
- DSS: Dust Sealed Surface
- DSS with natural sand
- Double Otta seal
- MESA: Maintenance Estimated Sealing Alternatives
- x: Crossed out, indicating no maintenance required.
- ✓: Checkmark, indicating maintenance required.
### Annex 4  Programme of the Reconnaissance Visits

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Activity</th>
<th>Participants</th>
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<tbody>
<tr>
<td>14 January 2019</td>
<td>-</td>
<td>Arrival in Zambia</td>
<td>TRL</td>
</tr>
<tr>
<td>15 January 2019</td>
<td>10:00 - 13:00</td>
<td>Meeting with RDA</td>
<td>RDA, TRL</td>
</tr>
<tr>
<td>16 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>RDA, TRL</td>
</tr>
<tr>
<td>17 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>RDA, TRL</td>
</tr>
<tr>
<td>18 January 2019</td>
<td>All day</td>
<td>Site visits/ wrap-up</td>
<td>RDA, TRL</td>
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<tr>
<td>21 January 2019</td>
<td>10:00 - 13:00</td>
<td>Meeting with DFR, GHA</td>
<td>TRL, DFR, GHA</td>
</tr>
<tr>
<td>22 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>TRL, DFR, GHA</td>
</tr>
<tr>
<td>23 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>TRL, DFR, GHA</td>
</tr>
<tr>
<td>24 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>TRL, DFR, GHA</td>
</tr>
<tr>
<td>25 January 2019</td>
<td>11:00 - 12:00</td>
<td>Wrap-up meeting</td>
<td>TRL, DFR, GHA</td>
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<tr>
<td>28 January 2019</td>
<td>10:00 - 13:00</td>
<td>Meeting with UNRA</td>
<td>TRL, UNRA</td>
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<tr>
<td>29 January 2019</td>
<td>All day</td>
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<td>TRL, UNRA</td>
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<td>30 January 2019</td>
<td>All day</td>
<td>Site visits</td>
<td>TRL, UNRA</td>
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<td>31 January 2019</td>
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<td>Wrap-up meeting</td>
<td>TRL, UNRA</td>
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<tr>
<td>01 February 2019</td>
<td>-</td>
<td>Departure from Uganda</td>
<td>TRL</td>
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Points of discussions during the initial meetings with the road agencies:

- Background of the Back Analysis project
- Project parties, their roles and responsibilities
- Discussion of proposed project roads
- Collation of available documentation on the prospective roads
Annex 5  Ghana

This section presents the:

- Attendance lists for the initial meeting
- Attendance list for the wrap-up meeting
- Field notes from the site reconnaissance visits

Attendance list for the initial meeting held on 21st January 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Ing. Ernest K. Obeng (Chair of the meeting)</td>
<td>MRH</td>
</tr>
<tr>
<td>2.</td>
<td>Dr. Patrick Bekoe</td>
<td>DFR</td>
</tr>
<tr>
<td>3.</td>
<td>Akwasi A.</td>
<td>DFR</td>
</tr>
<tr>
<td>4.</td>
<td>Peter K. Yawson</td>
<td>DFR</td>
</tr>
<tr>
<td>5.</td>
<td>Mawusi Joseph</td>
<td>DFR</td>
</tr>
<tr>
<td>6.</td>
<td>Richmond Ankrah</td>
<td>DFR</td>
</tr>
<tr>
<td>7.</td>
<td>Nana Achids B. Prempeh</td>
<td>DFR</td>
</tr>
<tr>
<td>8.</td>
<td>Mercy A. Payne</td>
<td>GHA</td>
</tr>
<tr>
<td>9.</td>
<td>Mark Okyeke</td>
<td>GHA</td>
</tr>
<tr>
<td>10.</td>
<td>Botchway Samuel</td>
<td>MRH</td>
</tr>
<tr>
<td>11.</td>
<td>Edmond Balika</td>
<td>MRH</td>
</tr>
<tr>
<td>12.</td>
<td>Andrew Otto</td>
<td>TRL</td>
</tr>
<tr>
<td>13.</td>
<td>Leah Musenero</td>
<td>TRL</td>
</tr>
</tbody>
</table>

Attendance list for the wrap-up meeting held on 25th January 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ing. Ernest K. Obeng (Chair of the meeting)</td>
<td>MRH</td>
</tr>
<tr>
<td>2.</td>
<td>Dr. Patrick A. Bekeo</td>
<td>DFR</td>
</tr>
<tr>
<td>3.</td>
<td>Mawusi Joseph</td>
<td>DFR</td>
</tr>
<tr>
<td>4.</td>
<td>Richmond Ankrah</td>
<td>DFR</td>
</tr>
<tr>
<td>5.</td>
<td>Mrs. Olivia Soli</td>
<td>GHA</td>
</tr>
<tr>
<td>6.</td>
<td>Mr. Isaac Tackio-Nyadeh</td>
<td>GHA</td>
</tr>
<tr>
<td>7.</td>
<td>Raymond Oroku Nvamah</td>
<td>GHA</td>
</tr>
<tr>
<td>8.</td>
<td>E. A. Wbadago</td>
<td>MRH</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>Organization</td>
</tr>
<tr>
<td>---</td>
<td>-------------------</td>
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</tr>
<tr>
<td>9.</td>
<td>Edmond Balika</td>
<td>MRH</td>
</tr>
<tr>
<td>10.</td>
<td>Andrew Otto</td>
<td>TRL</td>
</tr>
<tr>
<td>11.</td>
<td>Leah Musenero</td>
<td>TRL</td>
</tr>
</tbody>
</table>
## Cape Coast – Twifo Praso Road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Pot holes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
<th>Surveyor</th>
<th>Date of Reconnaissance</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>N5 23 06.8 W1 26 24.5</td>
<td>N5 23 06.4 W1 26 29.4</td>
<td>Flat</td>
<td>Pseudo fill</td>
<td>Dry at time of inspection (see other notes for more)</td>
<td>Double Surface Dressing</td>
<td>Fair</td>
<td>Medium</td>
<td>27</td>
<td>None</td>
<td>Natural Gravel</td>
<td>7</td>
<td>Sealed shoulders, not easily distinguished from carriageway</td>
<td>Grassed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>N5 22 51.5 W1 24 57.6</td>
<td>N5 22.59.5 W1 25 06.9</td>
<td>Gentle</td>
<td>Cut &amp; Fill</td>
<td>Hard to observe because of the overgrown bush</td>
<td>Double Surface Dressing</td>
<td>Fair</td>
<td>Low</td>
<td>35</td>
<td>Few</td>
<td>Natural Gravel</td>
<td>6.4</td>
<td>RHS has wide unsealed shoulders. LHS has non-existent shoulders (See notes)</td>
<td>Grassed</td>
<td>Leah Musenero</td>
<td>22/01/2019</td>
</tr>
</tbody>
</table>
Other Notes:
- Road marking recently done on this stretch of the road.

**Section 1:**
- High cracking on the outer wheel track of the LHS, very minor cracking on the RHS.
- Rutting was more severe on the LHS, maximum rutting on the RHS was only ~10 mm.
- Wide pothole patch observed.
- The regional maintenance manager intimated that trucks ferry food stuff in the direction towards Cape Coast hence LHS of the road experiences heavier traffic loading than the RHS.
- Although the subsurface drainage was dry at the time of inspection, there were signs of high water table observed from the soil type and the bananas and palm trees growing by the road side.
- If the need arises, this section will be supplemented with a few hundred metres towards the Cape Coast side.

**Section 2:**
- Shoulders on the LHS are heavily silted and grassed, almost non-existent. RHS has wide unsealed shoulders.
- This section was a 2-in-1. Its start had no rutting but midway through the section, rutting and cracking of the outer wheel track were observed on the LHS.
- A longitudinal crack (approximately 120 m) was observed in the centre of the LHS lane. This crack appeared to have resulted from mechanical damage from a moving car with a protruding metal which could have scratched the pavement.
- A culvert and pothole were observed at NS 22 53.8 W1 25 00.5
- Starting NS 22 53.1 W1 24 59.4 about 30 m before the culvert, no cracks were observed. Rutting at this point was minimal.
- Towards the start of the section, there was a large pothole patch which coincided with the starting point of cracking which stretches about 30 m

<table>
<thead>
<tr>
<th>Approx No. of Trucks seen in 1 hour</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrain Description of Road:</td>
<td>Rolling and winding</td>
</tr>
</tbody>
</table>
## Twifo Praso – Dunkwa road

| S/N | Start Chainage/GPS | End Chainage/GPS | Gradient (Steep, Gentle, Flat) | Formation (Cut/Fills/Not Defined) | Sub-Surface Drainage Condition (Dry, High WT, Swamppy) | Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other) | Surface Condition (Good, Fair, Poor, Highly Deteriorated) | Estimate of Crack Intensity (Low, Medium, High) | Estimate of Maximum Rut Depth (mm) | Potholes (None, Few, Numerous) | Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock) | Carriageway Width (m) | Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent) | Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent) |
|-----|--------------------|-----------------|---------------------------------|-----------------------------------|--------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------------------|---------------------------------|---------------------------------|---------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | N5 37 16.1 W1 36 00.7 | N5 37 27.6 W1 36 04.6 | Flat                            | Pseudo fill                       | Dry                                                     | DSD                                                           | Poor                                                       | Low                                                             | 25                              | Few                             | Not seen                                                                         | 7.2             | Sealed                                                                                           | Good, grassed                                                                 |
| 2   | N5 36 46.9 W1 35 01.1 | N5 36 40.9 W1 35 05.6 | Flat                            | Cut & Fill                        | Dry at the time of survey. See 'Other Notes' for more    | DSD                                                           | Fair                                                       | Low - Medium                                                      | 30                              | Few                             | Not seen                                                                         | 7.4             | Sealed                                                                                           | Good, grassed                                                                 |

### Other Notes:

The base material was not clearly visible. According to the regional maintenance manager, the base material is made of natural gravel.

#### Section 1:
- Few potholes but large in size, these are likely to have resulted from rutting
- Rutting is terminal
- Cracking on the outer wheel track and centre line in a few locations
- N5 37 22.5 W1 36 02.7 appears to have been an experimental section. There is evidence of test pit reinstatement in the inner and outer wheel track of both lanes
- There is evidence of clay subgrade at N5 37 20.2 W1 36 02.0

#### Section 2:
- Start of section has a pothole patch with number '29' written on it
- This section lies in a cut and fill. Cutting on the RHS, fill on the LHS
- Potholes are few but there are several patches. There is shoving around the potholes. Shoving could be due to moisture ingress in pavement when it rains
- Although it was dry at the time of inspection, the regional maintenance manager said that ponding occurs on the road when it rains
- Filling underway at N5 36 45.0 W1 35 02.7 to elevate surface and minimise ponding on the surface

### Approx No. of Trucks seen in 1 hour

13

### Terrain Description of Road:

Rolling
### Daboase – Atieku road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub- Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

**Other Notes:**
- Too bendy, no suitable section found
- This section will not be considered for this study because it is too winding

**Approx No. of Trucks seen in 1 hour:**
- 4 trucks recorded in 15 minutes

**Terrain Description of Road:**
- Winding
## Mpataba Junction – Half Assini road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N5 05 53.9 W2 37 16.7</td>
<td>N5 05 54.0 W2 37 17.0</td>
<td>Flat</td>
<td>Cut and fill</td>
<td>High water table</td>
<td>DSD</td>
<td>Good</td>
<td>Low</td>
<td>0</td>
<td>Few</td>
<td>Laterite</td>
<td>6.9</td>
<td>Non-existent</td>
<td>Excessively overgrown. Almost non-existent</td>
</tr>
</tbody>
</table>

**Other Notes:**
- Minor ravelling
- A few heavily loaded 6-axle trucks were encountered
- Start of section lies in fill, end of section lies in cut
- Only 1 pothole was observed

**Approx No. of Trucks seen in 1 hour:** 8

**Terrain Description of Road:** Rolling with occasional flat sections
<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GP S</th>
<th>End Chainage/GP S</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/No t Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated )</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N6 06 38.0 W0 06 56.6</td>
<td>N6 06 36.4 W0 06 49.7</td>
<td>Flat</td>
<td>Cut and fill</td>
<td>Dry (See notes for more)</td>
<td>DSD</td>
<td>Fair</td>
<td>Medium</td>
<td>20</td>
<td>None</td>
<td>Laterite</td>
<td>6.6</td>
<td>Unsealed gravel</td>
<td>Grassed</td>
</tr>
<tr>
<td>2</td>
<td>N6 07 09.9 W0 08 40.2</td>
<td>N6 07 08.9 W0 08 37.9</td>
<td>Flat</td>
<td>Natural</td>
<td>Dry (See notes for more)</td>
<td>DSD</td>
<td>Highly deteriorated</td>
<td>High</td>
<td>10</td>
<td>Numerous</td>
<td>Laterite</td>
<td>6.7</td>
<td>Unsealed</td>
<td>Grassed</td>
</tr>
</tbody>
</table>

**Other Notes:**

Urban roads cover km 0+000 - 2+500 of the road; the start point of the road considered for this study is at 2+500, coinciding with a blocked culvert.

The GHA staff mentioned that during peak of rainfall, these sections of the road flood.

**Section 1:**
- The end of the section lies in a little fill; start of the section lies under cut.
- Transverse and longitudinal cracking stretches from the outer wheel track to just before the centreline on both lanes.
- Surface condition is fair but with good riding quality. Motorists achieving over 80 km/hr.

**Section 2:**
- Pavement highly deteriorated, traffic diverted to the unsealed shoulders.

**Approx No. of Trucks seen in 1 hour:**

7

**Terrain Description of Road:**

Rolling and winding.
## Koforidua – Suhum road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swamppy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

### Other Notes:

- km 0+000 taken at Ghana Cement (GHACEM) almost opposite the training school for the Ministry of Roads and Highways. There is evidence of crushed rock base at N6 06 38.0 W0 18 14.3 opposite All Nation University Hostel. Thickness of the crushed rock base is approximately 120 mm at 1+450.
- There is a landfill at 2+700. This section will not be considered for this study because of the crushed rock base and its heavy traffic.

### Approx No. of Trucks seen in 1 hour

- 33 trucks in 51 minutes

### Terrain Description of Road:

- Rolling
Annex 6  Mozambique

This section presents the:

- Attendance list for the initial meeting at ANE
- Field notes from the site reconnaissance

Attendance list for the initial meeting held on 28\textsuperscript{th} January 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eng. Irene Simões – Director, Directorate of Maintenance</td>
<td>ANE - DIMAN</td>
</tr>
<tr>
<td>2.</td>
<td>Eng. Rubina Normahomed – Head of Maintenance</td>
<td>ANE - DIMAN</td>
</tr>
<tr>
<td>3.</td>
<td>Eng. Fernando Dabo – Head of Research</td>
<td>ANE - DIMAN</td>
</tr>
</tbody>
</table>

List of those who participated in the site reconnaissance

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eng. Fernando Dabo – Head of Research</td>
<td>ANE - DIMAN</td>
</tr>
</tbody>
</table>
Lindela – Mutamba road

**Site Reconnaissance Form**

**Date of Reconnaissance:** 05/02/2019

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
<th>Sub-surface Drainage Condition (Dry, High WT, Swamopy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0+400</td>
<td>0+600</td>
<td>Flat</td>
<td>Not Defined</td>
<td>Dry</td>
<td>Calcrete DSD/ Slurry Reseal</td>
<td>Fair</td>
<td>High</td>
<td>5 mm</td>
<td>Few</td>
<td>Red Sand CTB</td>
<td>6</td>
<td>Unsealed</td>
<td>Non-Existent</td>
</tr>
<tr>
<td>2</td>
<td>2+300</td>
<td>2+600</td>
<td>Flat</td>
<td>High Fill</td>
<td>Swampy</td>
<td>Calcrete DSD/ Slurry Reseal</td>
<td>Poor (High Deformation)</td>
<td>High</td>
<td>10 mm</td>
<td>Few</td>
<td>Red Sand CTB</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>3</td>
<td>3+400</td>
<td>3+700</td>
<td>Steep</td>
<td>Not Defined</td>
<td>Dry</td>
<td>Calcrete DSD/ Slurry Reseal</td>
<td>Poor (Badly Cracked)</td>
<td>High</td>
<td>5 mm</td>
<td>None</td>
<td>Red Sand CTB</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>8</td>
<td>8+500</td>
<td>8+500</td>
<td>Flat</td>
<td>High Fill</td>
<td>Dry</td>
<td>Calcrete DSD/ Slurry Reseal</td>
<td>Fair</td>
<td>Medium</td>
<td>None</td>
<td>None</td>
<td>Red Sand CTB</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
</tbody>
</table>

**Other Notes:**

- Approx number of Trucks seen in 1 hr
- Terrain Description of Road
### Site Reconnaissance Form

**Boane – Moamba Road**

**Date of Reconnaissance:** 31/01/2019

<table>
<thead>
<tr>
<th>Country</th>
<th>Mosambique</th>
<th>Region</th>
<th>Maputo Province</th>
<th>Road Name</th>
<th>Boane-Moamba Road</th>
<th>Surveyor</th>
<th>Kenneth Mukura</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/N</td>
<td>Start Chainage /GPS Coordinates</td>
<td>End Chainage /GPS Coordinates</td>
<td>Gradient (Steep, Gentle, Flat)</td>
<td>Formation (Cuts/Fills/No t-defined)</td>
<td>Sub-surface Drainage Condition (Dry, High WT, Swampy)</td>
<td>Surface Type (Surface Dressing, Otta Seal, Sand, Combination , AC, Other)</td>
<td>Surface Condition (Good, Fair Poor, Highly Deteriorated)</td>
</tr>
<tr>
<td>1</td>
<td>20+700</td>
<td>20+800</td>
<td>Flat</td>
<td>Fill (0.8-1.5m)</td>
<td>Dry</td>
<td>DSD (20yrs old)</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>21+650</td>
<td>21+950</td>
<td>Flat</td>
<td>Fill (0.8-1.5m)</td>
<td>Dry</td>
<td>DSD (20yrs old)</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>29+700</td>
<td>30+000</td>
<td>Flat</td>
<td>Fill (0.8-1.0m)</td>
<td>Dry</td>
<td>DSD (20yrs old)</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**Other Notes:**

Approx number of Trucks seen in 1 hr

Terrain Description of Road
### Site Reconnaissance Form

**Boane – Namaacha Road**

**Date of Reconnaissance:** 31/01/2019

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage</th>
<th>End Chainage</th>
<th>Gradient</th>
<th>Formation</th>
<th>Sub-surface Drainage Condition</th>
<th>Surface Type</th>
<th>Surface Condition</th>
<th>Estimate of Crack Intensity</th>
<th>Estimate of Maximum Rut Depth</th>
<th>Potholes</th>
<th>Base Material</th>
<th>Carriageway width (m)</th>
<th>Shoulders</th>
<th>Side Drain Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1+600</td>
<td>2+100</td>
<td>Flat</td>
<td>Fill</td>
<td>High WT</td>
<td>DSD</td>
<td>Poor</td>
<td>High</td>
<td>20 mm</td>
<td>Numerous</td>
<td>Ryolite (Natural/ Crusher-Run)</td>
<td>7 m</td>
<td>Sealed</td>
<td>Shallow Drains/ Possible Flooding</td>
</tr>
<tr>
<td>2</td>
<td>2+650</td>
<td>2+950</td>
<td>Flat</td>
<td>High Fill</td>
<td>1/2 in dry section and 1/2 Flood Plain</td>
<td>DSD</td>
<td>Fair</td>
<td>Medium</td>
<td>10 mm</td>
<td>Few Patches</td>
<td>Ryolite (Natural/ Crusher-Run)</td>
<td>8 m</td>
<td>Sealed</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>10+900</td>
<td>1+200</td>
<td>Steep (6%-8%)</td>
<td>Fill (LHS)</td>
<td>Dry</td>
<td>DSD</td>
<td>Good</td>
<td>Low</td>
<td>None</td>
<td>None</td>
<td>Ryolite (Natural/ Crusher-Run)</td>
<td>9 m</td>
<td>Sealed</td>
<td>Shallow and Overgrown</td>
</tr>
<tr>
<td></td>
<td>18+100</td>
<td>17+800</td>
<td>Flat</td>
<td>Fill (LHS)</td>
<td>Dry</td>
<td>DSD</td>
<td>Good</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Ryolite (Natural/ Crusher-Run)</td>
<td>10 m</td>
<td>Sealed</td>
<td>Not Necessary</td>
</tr>
</tbody>
</table>

**Other Notes:**

Approx number of Trucks seen in 1 hr

Terrain Description of Road
## Site Reconnaissance Form

**Date of Reconnaissance:** 01/02/2019

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
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<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0+300</td>
<td>0+600</td>
<td>Flat</td>
<td>Fill</td>
<td>High WT</td>
<td>DSD/ Slurry (Reseal)</td>
<td>Fair</td>
<td>Low</td>
<td>5 mm</td>
<td>Few</td>
<td>Red Mixed with Coarse Aggr</td>
<td>6.5 m</td>
<td>Sealed</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>2</td>
<td>4+250</td>
<td>4+550</td>
<td>Flat</td>
<td>Not-Defined/ Level with Ground</td>
<td>High WT</td>
<td>DSD/ Slurry (Reseal)</td>
<td>Fair/ Good</td>
<td>Low/ None</td>
<td>5 mm</td>
<td>Few in 1/2 of Section &amp; None in 1/2 of Section</td>
<td>Red Mixed with Coarse Aggr</td>
<td>6.5 m</td>
<td>Sealed</td>
<td>None/ Deep Canals both Sides</td>
</tr>
<tr>
<td>3</td>
<td>10+100</td>
<td>10+400</td>
<td>Flat</td>
<td>Fill</td>
<td>Dry</td>
<td>DSD/ Slurry (Reseal)</td>
<td>Poor</td>
<td>High</td>
<td>5 mm</td>
<td>Numerous</td>
<td>Red Mixed with Coarse Aggr</td>
<td>6.5 m</td>
<td>Sealed</td>
<td>None/ Deep Canals both Sides</td>
</tr>
</tbody>
</table>

**Other Notes**

- Approx number of Trucks seen in 1 hr
- Terrain Description of Road
## Macaritane – Massingir road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
<th>Sub-surface Drainage Condition (Dry, High WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2+200</td>
<td>2+500</td>
<td>Flat</td>
<td>High Fill (1.5-2 m)</td>
<td>Dry</td>
<td>DSD</td>
<td>Fair</td>
<td>Low</td>
<td>Deformation (OWP)</td>
<td>Few</td>
<td>River Gravel</td>
<td>6</td>
<td>None</td>
<td>Good</td>
</tr>
<tr>
<td>2</td>
<td>9+100</td>
<td>9+400</td>
<td>Flat</td>
<td>High Fill (1.5-2 m)</td>
<td>Dry</td>
<td>DSD</td>
<td>Fair</td>
<td>Low</td>
<td>Deformation (OWP)</td>
<td>None</td>
<td>River Gravel</td>
<td>6</td>
<td>None</td>
<td>Good</td>
</tr>
</tbody>
</table>

**Other Notes:**

Approx number of Trucks seen in 1 hr

Terrain Description of Road
## Site Reconnaissance Form

**Date of Reconnaissance:** 01/02/2019  
**Surveyor:** Kenneth Mukura  

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
<th>Sub-surface Drainage Condition (Dry, High WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11+000</td>
<td>11+300</td>
<td>Flat</td>
<td>Fill</td>
<td>Dry</td>
<td>DSD (20 yrs old)</td>
<td>Fair</td>
<td>High (C/L)</td>
<td>None</td>
<td>Few</td>
<td>CTB (White Sand)</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>2</td>
<td>20+200</td>
<td>20+500</td>
<td>Flat</td>
<td>Fill</td>
<td>Dry</td>
<td>DSD (20 yrs old)</td>
<td>Good</td>
<td>Low</td>
<td>5 mm</td>
<td>Low</td>
<td>Macadam (max 75mm)</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>3</td>
<td>33+900</td>
<td>34+200</td>
<td>Flat</td>
<td>High Fill</td>
<td>Dry</td>
<td>DSD (20 yrs old)</td>
<td>Highly Deteriorated/Poor</td>
<td>Medium</td>
<td>10 mm</td>
<td>Numerous</td>
<td>CTB (White Sand)</td>
<td>6</td>
<td>Unsealed</td>
<td>Not Necessary</td>
</tr>
</tbody>
</table>

**Other Notes:**

- Approx number of Trucks seen in 1 hr

- Terrain Description of Road
### Site Reconnaissance Form

**Date of Reconnaissance:** 02/02/2019

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
<th>Sub-surface Drainage Condition (Dry, High WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulder Condition (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0+000</td>
<td>0+300</td>
<td>Part Steep/Part Gentle</td>
<td>Fill (RHS)</td>
<td>Dry</td>
<td>Slurry (Fine sand)</td>
<td>1/2 Poor &amp; 1/2 Fair</td>
<td>Medium</td>
<td>None</td>
<td>Numerous</td>
<td>ETB</td>
<td>6</td>
<td>None</td>
<td>Good (LHS)/Not Necessary (RHS)</td>
</tr>
<tr>
<td>2</td>
<td>0+550</td>
<td>0+620</td>
<td>Flat</td>
<td>Not-Defined</td>
<td>Dry</td>
<td>Slurry (Coarse sand)</td>
<td>Good</td>
<td>Low</td>
<td>None</td>
<td>None</td>
<td>ETB</td>
<td>6</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>1+800</td>
<td>2+100</td>
<td>Flat</td>
<td>Not-Defined</td>
<td>Swampy</td>
<td>Blended Wearing Course</td>
<td>Good</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>Blended WC</td>
<td>7</td>
<td>Earth</td>
<td>Poor Drains fill up with water</td>
</tr>
</tbody>
</table>

**Other Notes:**

- Approx number of Trucks seen in 1 hr

- Terrain Description of Road
### Matola – Boane road

**Site Reconnaissance Form**

<table>
<thead>
<tr>
<th>Country</th>
<th>Maputo</th>
<th>Region</th>
<th>Maputo Province</th>
<th>Road Name</th>
<th>Matola-Boane Rd</th>
<th>Surveyor</th>
<th>Kenneth Mukura</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/N</td>
<td>Start Chainage /GPS Coordinates</td>
<td>End Chainage /GPS Coordinates</td>
<td>Gradient (Steep, Gentle, Flat)</td>
<td>Formation (Cuts/Fills/Not-defined)</td>
<td>Sub-surface Drainage Condition (Dry, High WT, Swampy)</td>
<td>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</td>
<td>Surface Condition (Good, Fair Poor, Highly Deteriorated)</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>--------</td>
<td>-----------------</td>
<td>-----------</td>
<td>-----------------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
<td>7+200</td>
<td>7+500</td>
<td>Flat</td>
<td>Not Defined</td>
<td>High WT</td>
<td>DSD</td>
<td>Fair to Poor</td>
</tr>
</tbody>
</table>

*Other Notes:*

*Approx number of Trucks seen in 1 hr*

*Terrain Description of Road*
## Site Reconnaissance Form

**Country**: Mozambique  
**Region**: Inhambane Province  
**Road Name**: Mutamba-Inhambane Rd  
**Surveyor**: Kenneth Mukura  

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage /GPS Coordinates</th>
<th>End Chainage /GPS Coordinates</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cuts/Fills/Not-defined)</th>
<th>Sub-surface Drainage Condition (Dry, High WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand, Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
<th>Other Notes:</th>
<th>Approx. no. of trucks in 1 hr</th>
<th>Terrain Description of Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10+900</td>
<td>11+200</td>
<td>Flat</td>
<td>Fill</td>
<td>Dry</td>
<td>Calcrete DSD + Slurry (Reseal)</td>
<td>Poor</td>
<td>High</td>
<td>5 mm</td>
<td>Very Few</td>
<td>CTB (Fine White Sand)</td>
<td>6</td>
<td>Unsealed</td>
<td>Part Non-Existent &amp; Part Not Necessary in</td>
<td>Other Notes:</td>
<td>Approx. no. of trucks in 1 hr</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17+000</td>
<td>17+300</td>
<td>Flat</td>
<td>Not Defined</td>
<td>Dry</td>
<td>Calcrete DSD + Slurry (Reseal)</td>
<td>Good</td>
<td>Low</td>
<td>5 mm</td>
<td>None</td>
<td>CTB (Fine White Sand)</td>
<td>6</td>
<td>Unsealed</td>
<td>Part Non-Existent &amp; Part Not Necessary in</td>
<td>Other Notes:</td>
<td>Approx. no. of trucks in 1 hr</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19+600</td>
<td>19+900</td>
<td>Gentle</td>
<td>Fill</td>
<td>Dry</td>
<td>Calcrete DSD + Slurry (Reseal)</td>
<td>Poor</td>
<td>High</td>
<td>5 mm</td>
<td>Very Few</td>
<td>CTB (Fine White Sand)</td>
<td>6</td>
<td>Unsealed</td>
<td>Part Non-Existent &amp; Part Not Necessary in</td>
<td>Other Notes:</td>
<td>Approx. no. of trucks in 1 hr</td>
<td></td>
</tr>
</tbody>
</table>

**Terrain Description of Road**
Annex 7  Uganda

The following is presented under this section

Attendance list for the initial meeting at UNRA
Attendance list for the wrap-up meeting at UNRA
Field notes from the site reconnaissance visits

Attendance list for the initial meeting held on 28th January 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Eng. Dr. Mark Henry Rubarenzya</td>
<td>UNRA</td>
</tr>
<tr>
<td>6.</td>
<td>Dr. Rodgers B. Mugume</td>
<td>UNRA</td>
</tr>
<tr>
<td>7.</td>
<td>Isaac Menya</td>
<td>UNRA</td>
</tr>
<tr>
<td>8.</td>
<td>Steven Musumba</td>
<td>UNRA</td>
</tr>
<tr>
<td>9.</td>
<td>Henry Nkwanga</td>
<td>Cardno (AI/CAP)</td>
</tr>
<tr>
<td>10.</td>
<td>Andrew Otto</td>
<td>TRL</td>
</tr>
<tr>
<td>11.</td>
<td>Dominic Leal</td>
<td>TRL</td>
</tr>
</tbody>
</table>

Attendance list for the wrap-up meeting held on 1st February 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Eng. Dr. Mark Henry Rubarenzya</td>
<td>UNRA</td>
</tr>
<tr>
<td>8.</td>
<td>Dr. Rodgers B. Mugume</td>
<td>UNRA</td>
</tr>
<tr>
<td>9.</td>
<td>Diana Mirembe</td>
<td>UNRA</td>
</tr>
<tr>
<td>10.</td>
<td>Steven Musumba</td>
<td>UNRA</td>
</tr>
<tr>
<td>11.</td>
<td>Andrew Otto</td>
<td>TRL</td>
</tr>
<tr>
<td>12.</td>
<td>Dominic Leal</td>
<td>TRL</td>
</tr>
<tr>
<td>S/N</td>
<td>Start Chainage/GPS</td>
<td>End Chainage/GPS</td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>1</td>
<td>N: 00.06001</td>
<td>E: 32.36672</td>
</tr>
<tr>
<td>2</td>
<td>N: 00.59743</td>
<td>E: 32.37069</td>
</tr>
<tr>
<td>3</td>
<td>N: 00.59704</td>
<td>E: 32.37215</td>
</tr>
<tr>
<td>4</td>
<td>N: 00.59711</td>
<td>E: 32.37306</td>
</tr>
<tr>
<td>5</td>
<td>N: 00.59703</td>
<td>E: 32.37528</td>
</tr>
<tr>
<td>6</td>
<td>N: 00.59470</td>
<td>E: 32.38112</td>
</tr>
</tbody>
</table>
Other Notes:

All sections part of LTTP study, 16 sections in total, approximately 8 year old (2010) as part of a programme assessing different construction materials, surface/base type

Section 1
- Trial Section 11 (Double Otta Seal, Stabilised Gravel Base)
- Reinstate test pit (unsealed) @ N: 00.5972 E: 32.36715 (approx 1x1m) and unsealed core holes/DCP in
- Surfacing sheared, starting @ N: 00.59932 E: 32.36774 (for approximately 20-30m) in LHS (Kanyadan bound)
- 5mm (LHS) rutting and series of large potholes at start of section/construction joint with Trial Section 11/12 spanning both lanes (NWSPs, OSWP, and Centre Joint); 5mm rutting at end of site
- Small pothole recorded toward end of site, otherwise generally pothole free site
- Frequent transverse, longitudinal, and L cracking throughout site, in all wheel paths and centre joint (transverse cracking mostly confined to NSWP; 0.2-0.5m long); cracks are fairly fine-medium for the most part
- Minor fatigue throughout site
- Large, coarse granite aggregates used in surfacing
- End of section marked “23km + 650m”
- Drainage generally good, run-off not impeded by grass and can flow down fill fall.
- Site 350m long, 20m fall across site
- Surfacing polished for majority of site

Section 2
- Trial Section 10 (Single Otta Seal with Sand)
- Surfacing is very good condition compared to Section 1, minor longitudinal and transverse cracking throughout site but generally very fine, short in length and less frequent (in all lanes, wheel paths, centre joint, and shoulder), small L cracks (infrequent)
- Concrete edge beam on RHS
- Minor localised edge deterioration on LHS
- Construction joint @ N: 00.59804 E: 32.36973
- Unsealed core holes & DCP in both lanes, both wheel paths @ start of section, and @ N: 00.59779 E: 32.37006
- Drainage the same as Section 1
- End of section marked “23km + 475m”, section 175m long
- No visible rutting

Section 3
- Trial Section 107 (Sign removed, section split into two panels?) - Single Otta Seal but construction joint between and minor difference in surface appearance between section 2-3
- Start of section marked “23km + 300m”
- Severe block cracking at start of site and in localised points throughout section, occurring around carriageway centre, leading to potholes between blocks
- Severe longitudinal cracking throughout section, numerous transverse cracking throughout
- Almost continuous sealed longitudinal cracks throughout section, some potholes have been patched
- Large sealed patches

Section 4
- Trial Section 9 (Double Sand Seal)
- No visible rutting
- Surfacing generally in good condition
- Block cracking visible, but not as severe as previous section, has not developed into wide cracks
- Extensive longitudinal and transverse cracks throughout site
- Long sealed longitudinal cracks throughout section
- End of section marked “22km + 950m”

Section 5
- Trial Section 8 (Single Surface Dressing (14mm) & Sand Seal)
- Trial Pit (unsealed) @ N: 00.59703 E: 32.37528 (approx 1x1m)
- Construction Joint @ N: 00.596675 E: 32.37615
- Trial Pit (unsealed) @ N: 00.59668 E: 32.37639 + core/DCP holes
- Large pothole @ N: 00.59648 E: 32.37702
- Section seems like it ends @ N: 00.59638 E: 32.37737 from construction joint and change in surface aggregate sizes, perhaps coarser sand has been used between the end point and this one
- Frequent block cracking across site, ends 60m before section ends
- Sealed long (5m+) longitudinal cracks and potholes (starting after the first 20m of the section onwards until last 60m of the site)
- Block cracking concentrated in centre of carriageway
- Mostly longitudinal cracking concentrated in wheel paths and centre of carriageway, minor/non-severe (but frequent) transverse cracking concentrated in shoulder and edge of carriageway

Section 6
- Trial Section 6? (inverted seal)
- Surfacing uniform aggregates approx 10mm, granite, generally in excellent condition, no cracking/rutting or visible defects
- Culvert @ N: 00.59418 E: 32.38214
- Reinstated core hole @ N: 00.59381 E: 32.38268 (22km + 054m? faded spray paint)
- Minor localised fattening across site
- Poor drainage, dirt/vegetation build up slightly higher (2-3cm) above road surface, no defined drainage, and overgrown grass

Approx No. of Trucks seen in 1 hour
Approx 25 trucks between 12:09 - 12:51 (mostly small 2 axle rigid trucks loaded with sands)

Terrain Description of Road:
Section 1 gentle slope (20m fall over 350m; 1/18)
Section 2 generally flat (4m fall over 175m; 1/44)
Section 3 generally flat (5m fall over 175m; 1/44)
Section 4 flat/rise (8m rise over 250m, 1/32), gentle bend in the road, starting at 100m into section
Section 5 rise (13m rise over 600m, 1/46)
Section 6 flat (2m rise over 350m, 1/175)

Surrounding area along Matugga road generally flat/gentle rolling, small houses, small farms, and lots of trees/vegetation
All site have clear visibility before and after for traffic to have enough time to slow down safely, but note the site is subject to heavy truck, passenger vehicle, and motorcycle traffic
## Kilembe – Kasese road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GP S</th>
<th>End Chainage/GP S</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/No t Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated )</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimated Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N: 00.18599 E: 30.03230</td>
<td>N: 00.18653 E: 30.03390</td>
<td>Flat</td>
<td>Cut</td>
<td>High</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>None</td>
<td>7mm</td>
<td>Few (Minor)</td>
<td>Stabilised Gravel</td>
<td>5.65m (edge-edge)</td>
<td>Sealed</td>
<td>Poor, Overgrown, Grassed</td>
</tr>
<tr>
<td>2</td>
<td>N: 00.18806 E: 30.03846</td>
<td>N: 00.18807 E: 30.03994</td>
<td>Flat</td>
<td>Cut</td>
<td>Dry</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>None</td>
<td>0mm</td>
<td>None</td>
<td>Stabilised Gravel</td>
<td>5.7m (edge-edge)</td>
<td>Sealed</td>
<td>Non-existent, Gressed</td>
</tr>
</tbody>
</table>

### Other Notes:
- Unnamed road from Kilembe decommissioned copper/cobalt mines to Kasese
- **Section 1**
  - Section generally in very good condition, surface has few defects (only a few localised potholes at the end of the section)
  - High water table expected, wetland reeds growing almost level with the road surface, also locals are growing coca/bananas/cabbages indicating a high water table
  - Minor fatting observed across site
  - Signs of maintenance, patched potholes across site
  - Drainage very poor, shallow drainage channels exist but they are completely overgrown, few culverts along the road allowing water to pass underneath towards the river
  - Good visibility before and after site for safety
  - Very little passing traffic (mostly 4x4, road, sections in extremely bad condition)
- **Section 2**
  - Generally site is in excellent condition, essential no surface defects, all edges and centre joints in very good condition
  - Road subjected to frequent and unpredictable flash flooding
  - End point mile stone KBE 4km/KSE 6km

### Approx No. of Trucks seen in 1 hour
- 1 (small rigid 2 axle good truck)
## Terrain Description of Road:
- Section 1: 190m long, flat 4m fall (1/50)
- Section 2: 160m long, flat 1m fall (1/160)
- Road in valley basin, surrounded by mountains (LHS has banana plantations, RHS small houses, forestry and bare mountain sides where the copper mines are located).
- Road adjacent to River Nyamwamba - mountain run off causes river to overflow and has washed away large sections of this road. Last major flood in 2015. Run-off from mine side mountain has to cross the road in order to reach the river which sits 40-60ft below the road level
- Kilembe copper/cobalt mines (carrying ore down to Kasese railway) closed in 1982, with little activity since
## Kikorongo – Mpondwe road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GP</th>
<th>End Chainage/GP</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/No t Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N: 00.00940 E: 29.90858</td>
<td>N: 00.00959 E: 29.91220</td>
<td>Flat</td>
<td>Shallow Fill</td>
<td>Dry</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>None</td>
<td>3mm</td>
<td>Few</td>
<td>None (Stabilised Gravel)</td>
<td>6.1m (edge-edge)</td>
<td>8.5m (shoulder-shoulder)</td>
<td>Sealed Non-existent, grassed</td>
</tr>
<tr>
<td>2</td>
<td>N: 00.01128 E: 29.95461</td>
<td>N: 00.01128 E: 29.95225</td>
<td>Flat</td>
<td>Shallow Fill</td>
<td>Dry</td>
<td>Double Surface Dressing</td>
<td>Fair</td>
<td>Low</td>
<td>30mm</td>
<td>Few (all patched)</td>
<td>None (Stabilised Gravel)</td>
<td>6.1m (edge-edge)</td>
<td>7.8m (shoulder-shoulder)</td>
<td>Sealed Non-existent, grassed</td>
</tr>
<tr>
<td>3</td>
<td>N: 00.00674 E: 29.98347</td>
<td>N: 00.00576 E: 29.98506</td>
<td>Flat</td>
<td>Shallow Fill</td>
<td>Dry</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>Low</td>
<td>0mm</td>
<td>None</td>
<td>None (Stabilised Gravel)</td>
<td>6.15m (edge-edge)</td>
<td>8.85m (shoulder-shoulder)</td>
<td>Sealed Non-existent, grassed</td>
</tr>
</tbody>
</table>
Other Notes:

**Section 1**
- Surfacing generally in good condition
- Major ravelling across entire site, some loss of surface material
- Very little visible rutting
- Construction approximately 15-20 years old
- Majority of traffic heading towards Kinyamaseke
- Shoulder and edge deterioration (infrequent)
- Infrequent patched potholes across site (slurry seal still in good condition)
- Very small potholes occurring immediately after a few patched potholes
- Drainage, although not defined, run-off has clear unimpeded path away from road surface
- Section starts at culvert and ends at mile stone MPD 27/KRG 11
- Small 1m burrow pit next to site between road and cotton fields showing very weak clay soil

**Section 2**
- Section in fair/good condition
- Major ravelling across entire site, some loss of surface material
- Poor centre joint condition
- All potholes have been patched, with slurry seals in good condition
- Deepest rut occurring next to area affected by potholes
- Most potholes occurring in centre line between lanes
- Longitudinal cracking in LHS NSWP toward the end of the section
- Fill high from surrounding low lying areas

**Section 3**
- Excellent condition section
- No ravelling, unlike previous sections
- Small potholes have been patched and slurry seal in good condition
- Small (30cm long) transverse cracks in shoulder
- Centre joint in good condition

**Approx No. of Trucks seen in 1 hour**
19 trucks (mostly large 6-9 axle overloaded, heading towards nearest town) from 11:44am-12:39pm
<table>
<thead>
<tr>
<th>Terrain Description of Road:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1: 400m long, 5m rise (1/80), essentially flat</td>
</tr>
<tr>
<td>Section 2: 270m long, 1m fall (1/270) flat</td>
</tr>
<tr>
<td>Section 3: 230m long section</td>
</tr>
<tr>
<td>LHS flat/gentle uphill cotton plantations (weak/loose clay soils) &amp; reeds - RHS flat/gentle uphill Queen Elizabeth National Park (mostly tall grasses, shrubs and trees)</td>
</tr>
<tr>
<td>Burrow Pit between sections 2-3, with loaded traffic heading towards Kikorongo (LHS is covered in white dust)</td>
</tr>
<tr>
<td>Good visibility before and after all sites, enough stopping distance for traffic</td>
</tr>
</tbody>
</table>
## Ntungamo – Katunguru – Rukungiri road

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WTF, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S: 00.87840 E: 30.24745</td>
<td>S: 00.87816 E: 30.24473</td>
<td>Gentle Rise</td>
<td>Fill-Cut</td>
<td>Swampy</td>
<td>Double Surface Dressing</td>
<td>Fair-Poor</td>
<td>Low</td>
<td>0mm</td>
<td>None</td>
<td>Crushed Stone</td>
<td>6.6m (edge-edge)</td>
<td>Sealed</td>
<td>Good (grass cut)</td>
</tr>
<tr>
<td>2</td>
<td>S: 00.86267 E: 30.21757</td>
<td>S: 00.86146 E: 30.21620</td>
<td>Flat-Gentle Rise</td>
<td>Shallow Cut</td>
<td>Swampy</td>
<td>Double Surface Dressing</td>
<td>Fair</td>
<td>Low</td>
<td>0mm</td>
<td>None</td>
<td>Crushed Stone</td>
<td>6.3m (edge-edge)</td>
<td>Sealed</td>
<td>Good (grass and soil level 2-3cm above surface)</td>
</tr>
</tbody>
</table>

### Other Notes:
- Section 1
  - Large 9mm granite aggregates used in surfacing, some loss of surface material
  - Slurry seals used to longitudinal cracks
  - Minor ravelling across site
  - Surface dressing looks relatively young
  - Verge grass recently cut
  - Wide sealed shoulder 8-10mm stone used
  - Section starts at construction joint, end s at 2km + 400m marking

- Section 2
  - Minor ravelling & fatting across site, fairly consistent
  - Isolated sections of mechanical damage, wide
  - Drain lined on RHS, dirt drain on LHS
  - RHS 2-3cm higher than LHS, RHS has been surfaced more recently?
  - LHS Aggregates used in surfacing are not uniform in size, RHS seems to have a single surface dressing on top of the double surface dressing, DSD only uses uniform aggregates 8-10mm in size
  - Stabilised base was replaced with crushed stone between late 1990/early 2000s

Granite aggregates used in surfacing
<table>
<thead>
<tr>
<th>Approx No. of Trucks seen in 1 hour</th>
<th>5 trucks (between 13:32 - 13:52)</th>
</tr>
</thead>
</table>
| Terrain Description of Road:       | Section 1: 300m long, 11m rise (1/27)  
                                        Section 2: 200m long, 5m rise (1/40)  
                                        Hillside sites, swampy and hilly surroundings |
<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GP S</th>
<th>End Chainage/GP S</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/No t Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated )</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S: 00.49810 E: 30.10916</td>
<td>S: 00.49646 E: 30.10969</td>
<td>Flat</td>
<td>Cut</td>
<td>Swampy</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>None</td>
<td>20mm</td>
<td>None</td>
<td>Stabilised Laterite</td>
<td>6.4m (edge-edge)</td>
<td>Unsealed earth/grass</td>
<td>Overgrown</td>
</tr>
</tbody>
</table>

**Other Notes:**
- Good side drains, lined in both directions, however the grass/dirt build-up on the verge is so overgrown there is no way for the run-off to reach it
- @ 50km +200m the surfacing has been removed (approx. 2x1m) and the sub-base is exposed - possible trial pit - visible scraping marks from plant
- 19mm granite aggregate used in surfacing
- Approximately 20+ years old
- Fatting across entire site in both directions
- Edge deterioration cross entire site

**Approx No. of Trucks seen in 1 hour:** 10 trucks (heavy traffic, many clearly overloaded trucks passing through)

**Terrain Description of Road:** Section 1: 100m long, 1m rise (1/100)
### Ishaka – Kasese road (2)

<table>
<thead>
<tr>
<th>Country</th>
<th>Uganda</th>
<th>Region</th>
<th>Ruburizi</th>
<th>Road Name</th>
<th>Ishaka – Kasese road</th>
<th>Surveyor(s)</th>
<th>Dominic Leal</th>
<th>Date of Reconnaissance</th>
<th>29/01/2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5/N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Start Chainage/GPS</strong></td>
<td><strong>End Chainage/GPS</strong></td>
<td><strong>Gradient</strong> (Steep, Gentle, Flat)</td>
<td><strong>Formation</strong> (Cut/Fills/Not Defined)</td>
<td><strong>Sub-Surface Drainage Condition</strong> (Dry, High, WT, Swampy)</td>
<td><strong>Surface Type</strong> (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</td>
<td><strong>Surface Condition</strong> (Good, Fair, Poor, Highly Deteriorated)</td>
<td><strong>Estimate of Crack Intensity</strong> (Low, Medium, High)</td>
<td><strong>Estimate of Maximum Rut Depth (mm)</strong></td>
<td><strong>Potholes</strong> (None, Few, Numerous)</td>
</tr>
<tr>
<td>1</td>
<td>S: 00.32915 E: 30.10513</td>
<td>S: 00.32681 E: 30.10613</td>
<td>Gentle Rise</td>
<td>Cut</td>
<td>Damp</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>Low</td>
<td>10mm</td>
</tr>
</tbody>
</table>

**Other Notes:**
- Section 1
  - Block cracking, cracked through to sub-base
  - Patches of mechanical damage, exposing base
  - Crudely patched potholes (filled with dirt)
  - Minor fatting across site
  - Minor longitudinal and transverse cracking across site
  - 2 trial pits, base exposed on 1, 1 sealed
  - Patching (sings of routine maintenance), some patches have failed leading to local cracking and pothole formation
  - Approx 20+ years old construction
  - Granite aggregate used in DSD
  - Very poor drainage

**Approx No. of Trucks seen in 1 hour:**
3 trucks + 1 coach (but many cars 20+ over 20 minute period)

**Terrain Description of Road:**
Section 1: 280m, 10m rise (1/28)
- Mountainous surroundings, very hilly, site 500m (LHS) from large lake (Lake Africa apparently), site uphill from lake, large hill on RHS covered in forest
Annex 8  Zambia

This section presents the:

- Attendance lists for the initial meeting with RDA and NRFA
- Field notes from the site reconnaissance visits in Zambia

Attendance list for the initial meeting held on 15\textsuperscript{th} January 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Christopher Kapasa (Chair of the meeting)</td>
<td>RDA</td>
</tr>
<tr>
<td>2.</td>
<td>Presley Chilonda</td>
<td>RDA</td>
</tr>
<tr>
<td>3.</td>
<td>E. M. Kakoma</td>
<td>RDA</td>
</tr>
<tr>
<td>4.</td>
<td>Yobe Mwalula</td>
<td>RDA</td>
</tr>
<tr>
<td>5.</td>
<td>Phillimon Goma</td>
<td>RDA</td>
</tr>
<tr>
<td>6.</td>
<td>Sundie Silwimba</td>
<td>RDA</td>
</tr>
<tr>
<td>7.</td>
<td>Wamunyima Hendrix</td>
<td>RDA</td>
</tr>
<tr>
<td>8.</td>
<td>J. K. Mukwatu</td>
<td>RDA</td>
</tr>
<tr>
<td>9.</td>
<td>Mwaunza Nachula</td>
<td>NRFA</td>
</tr>
<tr>
<td>10.</td>
<td>Alinani Msisya</td>
<td>NRFA</td>
</tr>
<tr>
<td>11.</td>
<td>Winfridah P. Ludaka</td>
<td>NRFA</td>
</tr>
<tr>
<td>12.</td>
<td>Maxson Shilukukwa</td>
<td>NRFA</td>
</tr>
<tr>
<td>13.</td>
<td>Andrew Otto</td>
<td>TRL</td>
</tr>
<tr>
<td>14.</td>
<td>Dominic Leal</td>
<td>TRL</td>
</tr>
<tr>
<td>15.</td>
<td>Leah Musenero</td>
<td>TRL</td>
</tr>
</tbody>
</table>
### Samfya – Musaila road (off D451)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampl)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S: 11.34410 E: 029.54633</td>
<td>S: 11.34460 E: 029.54294</td>
<td>Flat</td>
<td>Shallow fill</td>
<td>Dry/Damp</td>
<td>Double Surface Dressing (DSD)</td>
<td>Fair - Good</td>
<td>High</td>
<td>3</td>
<td>Few</td>
<td>Mainly laterite</td>
<td>6.2</td>
<td>Unsealed gravel</td>
<td>Good/Partially Overgrown</td>
</tr>
<tr>
<td>2</td>
<td>S: 11.35062 E: 029.50772</td>
<td>S: 11.35022 E: 029.50548</td>
<td>Flat</td>
<td>Fill</td>
<td>Dry, good drainage</td>
<td>DSD</td>
<td>Good</td>
<td>Very low</td>
<td>0mm</td>
<td>Few</td>
<td>Mainly laterite</td>
<td>6.2</td>
<td>Gravel shoulder with grass verge</td>
<td>Good</td>
</tr>
</tbody>
</table>
The material exposed on the 0.5m wide unsealed shoulders appears to be chemically stabilised. The RDA engineer hinted that it could have about 3% cement

Base appears to be cement-stabilised. RDA engineer mentioned it was stabilised with 3% cement

Lots of tall grass, trees and vegetation at the verge side

**Section 1:**
- Start of section has a large pothole filled with rainwater at approximately km 5+280
- End of section has water tank tower at approximately km 5+600
- There is a telephone pole towards the beginning of the section at S: 11.34410 E: 029.54679
- There is a cross junction at S: 11.34420 E: 029.54563. In choosing the location of traffic count stations, consideration of this junction should be made in order to minimise getting misleading results.
- Major cracking/crazing across site, longitudinal cracking, potholes approx. 10 cm deep. Minor ravelling/debonding surface observed.
- The potholes are localised within the stretch. 3 large pot holes near the start of the section. There is a thermometer-shaped defect on surface damage that ends in a pothole (about 10 cm wide) exposing the base layer. It appears to have emerged from mechanical damage of the pavement from exposed car rears.

**Section 2:**
- There was a telephone pole at start of the section, the end of the section was near a sign post for Makasa Catholic Church
- The fill is minimal, almost same level as the adjacent ground.
- Minor cracking emanating from edge of the carriageway to the nearest wheel track. There were infrequent major longitudinal cracks towards the start of the section (approx 40cm long)
- Possibly reinstated trial pit at the start of the section where major defects end

<table>
<thead>
<tr>
<th>Approx No. of Trucks seen in 1 hour</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrain Description of Road:</td>
<td>Flat and level, straight road</td>
</tr>
</tbody>
</table>
### M3 (Mansa – Chembe and Mansa – Bahati road)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GP S</th>
<th>End Chainage/GP S</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/No t Defined)</th>
<th>Sub-Surface Drainage Condition (Dry, High, WT, Swampy)</th>
<th>Surface Type (Surface Dressing, Otta Seal, Sand Combination, AC, Other)</th>
<th>Surface Condition (Good, Fair, Poor, Highly Deteriorated)</th>
<th>Estimate of Crack Intensity (Low, Medium, High)</th>
<th>Estimate of Maximum Rut Depth (mm)</th>
<th>Potholes (None, Few, Numerous)</th>
<th>Base Material (Lateritic, Quartizitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S: 11.41218 E: 028.81662</td>
<td>S: 11.41642 E: 028.81499</td>
<td>Flat</td>
<td>Shallow fill</td>
<td>Dry/Damp</td>
<td>Double Surface Dressing (DSD)</td>
<td>Good</td>
<td>Low (none)</td>
<td>8</td>
<td>Few</td>
<td>Laterite</td>
<td>6.32</td>
<td>Unsealed gravel</td>
<td>Good/Partially Overgrown</td>
</tr>
<tr>
<td>3</td>
<td>S: 11.06846 E: 028.85814</td>
<td>S: 11.00671 E: 028.85814</td>
<td>Gentle</td>
<td>Trough</td>
<td>Dry/Damp</td>
<td>DSD</td>
<td>Highly deteriorated</td>
<td>Not measured</td>
<td>90</td>
<td>Numerous</td>
<td>Laterite</td>
<td>6.3</td>
<td>Unsealed earth</td>
<td>Non-existent</td>
</tr>
</tbody>
</table>
### Other Notes:

- **Section 1**: This is a potentially good site for investigating the impact of maintenance on performance of LVSRs
  - The fill is minimal, almost same level as the adjacent ground.
  - The aggregates in the surfacing are coarse in nature. It appears that the DSD was inverted
  - Edge drop (that is continuously deteriorating) observed on either side of the road,
  - Lots of tall grass, trees and vegetation at the verge side
  - RHS has poor drainage in parts coinciding with overgrown grass and vegetation at the carriageway edge, and silty loam verge. LHS has good drainage for the most part, clayey sand verge
  - Large surface aggregates, surfacing estimated 4-6 years old, road markings in good condition
  - 1 large pothole approx 0.6x0.6m 7-8cm deep was observed towards the end of the section; at the start of the section, there was pothole patching in good condition

- **Section 2**:
  - Start of Section has Oasis Restaurant Food and Beverages; end of section has a marker post with "MWE 81, MAN 27"
  - The fill is minimal, almost same level as the adjacent ground.
  - Locals stated that the road is the main route between DRC and Mansa, Zambia and has "far too many trucks all year round, especially during harvest season from April-May"
  - Major L-shaped crack, minor fating towards the end of the section
  - Potholes are few, infrequent but severe. There was a large pothole approximately 1 m long and 0.5 m wide

- **Section 3**:
  - Section is highly deteriorated. Vehicles use the "Hard Shoulder" instead of the road. Shoulder is severely rutted, water cannot make it to the verge
  - Cracking not estimated because the road was heavily deteriorated, interlinking potholes
  - Very large potholes, a few reinstated which are in good condition. However, many in their proximity are in very bad condition

### Approx. No. of Trucks seen in 1 hour

- **13**

### Terrain Description of Road:

- Mansa - Chembe stretch: Generally flat
- Mansa - Bahati stretch: Rolling
### Mukuku Bridge – Samfya road (D235)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Start Chainage/GPS</th>
<th>End Chainage/GPS</th>
<th>Gradient (Steep, Gentle, Flat)</th>
<th>Formation (Cut/Fills/Not Defined)</th>
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<th>Base Material (Lateritic, Quartzitic, Rhyolitic, Granitic, Weathered Rock, Crushed Rock)</th>
<th>Carriageway Width (m)</th>
<th>Shoulders (Sealed, Gravel, Earth, Grassed, Non-existent)</th>
<th>Side Drain Condition (Good, Silted, Scoured, Overgrown, Non-existent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S: 12.04817 E: 029.65314</td>
<td>S: 12.04678 E: 029.65077</td>
<td>Flat</td>
<td>Fill, wide embankment</td>
<td>High water table</td>
<td>Double Surface Dressing</td>
<td>Good</td>
<td>None</td>
<td>4</td>
<td>None</td>
<td>Laterite</td>
<td>6.3</td>
<td>Grassed</td>
<td>Overgrown</td>
</tr>
<tr>
<td>2</td>
<td>S: 12.05037 E: 029.65704</td>
<td>S: 12.04817 E: 029.65314</td>
<td>Flat</td>
<td>Fill</td>
<td>High water table</td>
<td>Double Surface Dressing</td>
<td>Fair</td>
<td>Low</td>
<td>4</td>
<td>Localised, deep</td>
<td>Laterite</td>
<td>6.3</td>
<td>Grassed</td>
<td>Overgrown</td>
</tr>
<tr>
<td>3</td>
<td>S: 12.05212 E: 029.66021</td>
<td>S: 12.0537 E: 029.65704</td>
<td>Gentle, climbing</td>
<td>Fill</td>
<td>High water table</td>
<td>Double Surface Dressing</td>
<td>Poor</td>
<td>Medium</td>
<td>not measured</td>
<td>Numerous</td>
<td>Laterite</td>
<td>6.3</td>
<td>Grassed</td>
<td>Overgrown</td>
</tr>
</tbody>
</table>

**Other Notes:**

Base appears to be cement-stabilised. High water table <1m below road surface, pooled water approx 20 m from roadside, surrounding area has tall grass and very swampy/marshy. Road has had periodic maintenance.

**Section 1:**
- Marker post SME 102 (S: 12.04767, E: 029.65222) located about 100 m from start of the section
- Frequent fatting in centre around construction joint, joint in good condition, some reinstated potholes

**Section 2:**
- Transverse cracks towards the edge, crazing around the centreline

**Section 3:**
- Observing from the shoulders, transverse cracks can be seen on the base. However, these cracks have not been reflected in equal measure on the surface. Crazing and heaving around the centreline. Water is ponded on both sides of the road.
- Many open untreated potholes 7-8cm deep and very wide <1m; there is also a widening likely to be from mechanical damage, with water inside.

**Approx No. of Trucks per hour:**

7

**Terrain Description of Road:**

Flat