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

Phase 2 Report

TRL Ltd

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Contents

Tables and Figures

Figure 1 Proposed activity schedule for Phase 3 28
Figure 2 Contractual staff inputs for Phase 3 28

Abstract

Development of Guidelines and Specifications for Low Volume Sealed Roads (LVSR) through Back Analysis is a project being carried out in three phases. It began on 18th April 2017 and is scheduled for completion on 30th April 2019.

Phase 1 of the project involved a review of previously constructed experimental sections and back-analysed LVSR going back four decades, collection of data and information, development of a LVSR database, partial population of the database, and a preliminary information and data gap analysis.

Phase 2 involved further development of the database architecture and structure, a more detailed gap analysis, extensive review of other existing reports and data, training of counterparts from participating countries on the use of the database, and further population of the database. A detailed gap analysis or a meta-analysis (depending on the volume of data) will be carried out on the data to determine any critical information and data gaps. Such additional information, if required, will be collected through limited fieldwork.

Phase 3 may involve field and laboratory work to collect the additional information to cover the data gaps identified from the gap analysis. Other key activities will include dissemination of outputs, preparation for the hosting of the database and preparation of publications.

Key words

Regional Back Analysis, Sub-Saharan Africa, Low Volume Sealed Roads, Performance of Low Volume Roads

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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

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
AfCAP	Africa Community Access Partnership
CBR	California Bearing Ratio
CSIR	The Council for Scientific and Industrial Research (South Africa)
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
esa	Equivalent Standard Axles
HGV	Heavy Goods Vehicle
kN	Kilo Newton
LHS	Left Hand Side
LTPP	Long Term Pavement Performance
LVR	Low Volume Roads
LVSR	Low Volume Sealed Roads
MESA	Million Equivalent Standard Axles
ReCAP	Research for Community Access Partnership
RHS	Right Hand Side
ReCAP PMU	Research for Community Access Partnership Programme Management Unit
SEACAP	South East Asia Community Access Programme
TRL	Transport Research Laboratory
TRRL	Transport and Road Research Laboratory
UKAid	United Kingdom Aid (Department for International Development, UK)
vpd	Vehicles per day

Executive summary

This report covers the period 1st September 2017 to 31st August 2018, under Phase 2 of the project. At the start of this period, a project inception report was produced and approved. Training of members/counterparts from the 12 AfCAP participating countries on data addition, approval, and retrieval from the database was carried out. During the training, improvements to the database were identified and the majority of these improvements have subsequently been incorporated.

Several improvements were made to the web-based database (www.lvroadsdata.com) to make it more user-friendly especially for researchers interested in downloading data. Improvements were also made to the Microsoft Excel-based bulk-upload tool for uploading data into the database. The changes were all geared at making the tool more user-friendly. It is a highly flexible tool that is able to accept different forms of data. A user manual for the database has also been updated and it is included under the ’Help’ section of the database.

Any relevant data, which was obtained by the project team, have been entered into the database. The number of data rows in the database has increased from 1,019,919 at the end of Phase 1 to currently more than 3,183,698 rows. This will increase further following data that will be collected from fieldwork in Phase 3 and when AfCAP partner countries enter more data.

A number of challenges were faced regarding populating the database. A significant number of reports which were sourced either contained no data, or contained data which were not relevant for the LVSR database. A number of reports which were reviewed did not have compete data sets, e.g. some reports had summaries of test results but no site information (e.g. no layer thicknesses, no materials strengths, no climatic information), or they had a set of materials test data without an indication of where the materials were used and how they performed in-service. In addition, in-country counterparts have failed to input their country-specific data. This, despite the fact that training was conducted to capacitate counterparts in all the AfCAP partner countries to use the database and input data from local studies which they identified. Very few of these have made attempts to input the data due to a number of reasons.

Data gaps (and therefore knowledge gaps) have been identified following extensive population of the database. These gaps greatly affect the overall aims of ReCAP. Knowledge on the use of non-conventional surfacings at higher traffic levels (> 0.5 MESA) is still largely unknown. The limiting base material strengths at higher levels of traffic in areas of high rainfall (> 1000 mm) lacks the quantity of data required in order to refine standards. Very little data is also available on research studies on road sections dealing with very weak and moderate subgrade strengths in areas of high rainfall (> 1000 mm). Unfortunately, the current performance monitoring programmes (under a different ReCAP project) in a number of countries cannot bridge this gap immediately since the traffic levels carried by most of these sections is still less than 0.5 MESA. The quickest and most effective way in which to narrow these gaps is by conducting fieldwork in Phase 3 to answer some of the questions that prevail.

We propose to carryout fieldwork in Phase 3 in Ghana, Mozambique, Uganda and Zambia. The final choice of these is dependent on the availability of equipment in these countries and the countries’ willingness to participate in the project. The final choice of countries will be made after the reconnaissance task in Phase 3.

1 Introduction

The “Development of Guidelines and Specifications for Low Volume Roads through Back Analysis” project commenced in April 2016, and is scheduled to be completed in April 2019.

The overall objective of the project is to undertake a review of the performance of LVSRs constructed in the last four decades in order to achieve the following:

1. Provide a database of existing LVSRs that have been investigated related to pavement type and materials, performance and environmental conditions, and consequently:

- Refine existing generic guidelines for seal selection and pavement design based on life-cycle costs.
- Corroborate and refine recent catalogues for pavement design for low volume sealed roads in order to ensure their applicability to a wider range of materials and geographic conditions.

2. To provide a base level for the information on the performance of non-standard designs and materials specifications when compared with conventional designs and specifications for roads carrying higher volumes of traffic (>300 vpd).

The project is divided into three phases.

- Phase 1 involved the identification of data sources, creation of the database structure, collection of historical performance data from previous studies, processing of the data and the creation of a database for LVRs.
- Phase 2 (current phase) involved further development of the database architecture and structure, extensive review of other existing reports and data, capacity-building activities conducted through training of counterparts from the road research centres of the 12 AfCAP partner countries, and further population of the database with studies identified in Phase 1. A detailed gap analysis has been conducted in order to inform the activities to be carried out in Phase 3.
- Phase 3 will involve field and laboratory studies (if gaps exist), dissemination, preparation for hosting the database, and production of a scientific paper.

This report describes the activities carried out during phase 2 of the project between 1st September 2017 and 31st August 2018. It presents the data gaps that exist at the end of Phase 2 and contains proposals for fieldwork needed to bridge the most important gaps. The report is structured as follows:

- Activities carried out in Phase 2
- Studies reviewed and added to the database
- Gap analysis
- Conclusions
- Proposal for Phase 3

Annexes include a list of country-specific studies identified for inclusion into the database and project summaries that were not previously included in the progress reports.

This report is submitted together with a User Manual for the database and a draft Technical Paper that will be submitted to a conference or a journal for publication.

2 Activities carried out under Phase 2

2.1 Training of Data Inputters

Participants from the 12 AfCAP partner countries were trained to be Data Inputters. The overall aim of the training was to build their capacity in inputting and retrieving data from the database so that they will be able to process their own data.

Three training workshops were held between October and November 2017. The main reasons for the workshops were:

- To build capacity to ensure continuity of use after the project ends by members of the African Road and Transport Research Forum; and
- To ensure that existing and future studies from each individual country are correctly captured in the database so that the studies are not 'lost'.

This will ultimately enhance the use of the available information for research and help with refining country manuals and specifications. The training was conducted in three countries to cover the eastern Africa region, southern Africa region, and western Africa region. Participants from Ghana, Liberia, and Sierra Leone were trained in Ghana; participants from Malawi, Mozambique, Tanzania and Zambia were trained in Mozambique; and participants from DR Congo, Ethiopia, Kenya, South Sudan, and Uganda were trained in Uganda.

In all three workshops, participants were trained in the following:

- Criteria for identifying and selecting suitable data studies for inclusion into the database
- The database structure and its main functions
- How to filter and retrieve required data from the database
- How to add different kinds of data into the database including how to create new data types (properties) and measurement types that are user specific
- How to create new data sources, and use the data entry template for bulk data upload
- How to approve uploaded data so as to make it active for viewing by database users
- How to edit and delete erroneous data
- How to write report summaries that aid data analysts
- How to extract data from hard copy documents and prepare them ready for upload, and
- Sorting and organising downloaded data for purposes of analysis.

During the training workshops, participants were given guidance on the kinds of studies that should be added to the database. The participants identified suitable studies (Annex 1) from their respective countries that are suitable for inclusion into the database. The participants were also requested to train their colleagues in their respective organisations in the use of the database.

Details of the training and participants trained are included in the Capacity Building and Training Workshop Report, December 2017.

2.2 Updates to the database tool

2.2.1 User interface

Changes to the user interface were mainly centred on making it easier to use the website, as well as updating some of the terminology used to make the terminology consistent and up to date. By logging onto the website www.lvroadsdata.com one is able to view the new interface.

- When a new user registers, it now clearly states the password requirements at the top of the page. Previously these requirements were only shown to the user if the password entered did not meet the requirements – although they were not told what the requirements were. This change makes the process more efficient for new users registering which is crucial as this is the first time many people will interact with the tool.
- When a new user registers, it now also asks them for their organisation and country as this information is now used in the data approval and deletion processes.
- 'Test Results' has been renamed 'Performance Data' in the tool and the data template following feedback on using clearer terminology.
- References to 'Weather' have been replaced with 'Season'.
- Mandatory data is now marked on each page by a red asterisk next to the entry cell. This is as per standard website functionality and makes it clear to the user what data is required and what is optional.
- When creating a new data source as part of the Upload process, the user is now presented with a pop-up message to confirm the successful creation of the data source. This was updated because it was not clear if the data source had been successfully created.
- If a user wishes to raise an issue with the data they have been looking at, there is now a 'Raise Data Query' button on the report page. This opens up an email to send to either the data uploader, or the main administrator for the tool. The data uploader refers to the person from the authorised organisation that uploaded the data to the database whereas the main administrator at the moment is at TRL Ltd. This means that users at any access level can highlight potential data errors in the system.

2.2.2 Data and Database structure

Some of the identified changes meant revisions had to be made to the structure of the database and how data is stored.

- Following the trial of data being entered, one of the differences observed between papers was that some studies collect single readings per section and others collect multiple readings per section. In order to make this distinction clearer, new fields of 'Chainage From' and 'Chainage To' have been added to the database tables for site information and test results. This means that any value recorded against a specific chainage can now be clearly stored against the correct chainage values in the database. If no chainage values have been recorded by the study then these optional fields can be left blank.
- Through the website, data can now only be deleted by someone in the same organisation or country as the original uploader of the data. This is to prevent people from deleting data from studies that they know little about. On the 'Admin' page, for those that have access there is now a new table showing the most recently deleted data. If data has been deleted incorrectly it can now be reinstated through this table as it is never actually permanently deleted from the database.

2.2.3 Data upload process and template

Following the three workshops held between October and November 2017, a number of improvements to the data upload process and data template were identified. These are listed in detail below.

- The 'Upload' process has been simplified into four clear steps on the upload page in the tool to guide the user through the required stages more clearly.
- A new Instructions page has been created in the data template. This clearly outlines all the steps, processes and definitions used in the template. This change was made following feedback that if the data template is passed to other staff members for data population (who may be unfamiliar

with the tool) there were no clear instructions. Additionally, the data template has now got colour coded instructions to clearly show in the template what data are mandatory for entry and which are optional and all column headers now remain frozen at the top of the screen if a user scrolls down the page.

- The data template has drop-down lists for selecting test property and result types. However, it was not always clear if a particular result type already existed in any of the test property groups. To overcome this a new search box functionality was added to the template so that a user can begin to enter the first few characters of the result type they are searching for and the box returns all matching entries, whilst also showing the user which property group the different result types belong to.
- When entering data in the template that is the same for all sections (e.g. rainfall) there is a new option in the Sections drop-down list entitled 'All'. If this is selected, the user only needs to enter the data once and when the template is uploaded, the system will automatically assign the data to every section.
- The columns for 'Year From' and 'Year to' have been updated to drop-down lists to prevent incorrect data being added to those columns. This will help increase the robustness of the data and therefore the reporting. In addition, a 'Month From' and 'Month To' column has been added to allow multiple values to be entered in one year, as per some studies.
- When uploading data templates into the database if there is an error preventing the data from being uploaded there are now enhanced error messages given to the user, which highlight the rows in the data template that are causing the errors. This is because previously there were no row numbers included in the error messages and it was a time-consuming task for a user to search through multiple rows of data to look for a possible error. Therefore, the process is much more efficient than it was.
- The data approval process has been refined so that all data uploaded into the system is now instantly available to all other users to query and report upon. However, until it is approved it will have an 'unapproved' flag against it and the user can choose to exclude unapproved data from their reports if they wish. The reason for making all data instantly viewable was to prevent time-lags in data being available if someone is not available to approve it quickly. In addition, data can now only be approved by someone in the same organisation or country as the original uploader of the data. This is to make sure that the data approval process is completed by the most relevant user with data approval privileges.
- When approving data, there is a new button which allows a user to approve all data, as opposed to approving sections, site information and performance data separately.
- Changes to the manual have been made to reflect clearer guidelines for procedures such as deleting a row of data from the template.

2.2.4 Miscellaneous

- If a data source has a summary link included, the link is now included as part of the data download process so the user can access it when not directly on the Low Volume Roads Database site.
- The earliest year a data source can be set against has been updated to be 1950.
- There is a now a clear warning message that the data template needs Microsoft Excel 2010 or later. In some of the training sessions some errors where encountered by users running an older version of Excel, although this was only for a small number of people and so this restriction is unlikely to cause problems. Those that were affected in the training workshops were happy to update their version of Excel, not least because older version of programs will become unsupported with time.
- Changes to the User Manual have been made to reflect all the changes in the system.

Details of these updates are included in Progress Report 1.

3 Studies reviewed and added to the database under Phase 2

Table 1 shows the studies reviewed and included in the database during Phase 2. During Phase 2, the number of data rows in the database increased from 1,019,919 rows at the end of Phase 1 to currently more than 3,183,698 rows. This will increase further following data that will be collected from fieldwork in Phase 3 and as participating countries enter more data. A major contribution to the data sets was the SEACAP studies.

The participating countries have not yet added to the database the studies that they identified for their respective countries. Three countries: Ethiopia, Mozambique and Tanzania are making tangible efforts. Others have not responded to a questionnaire requesting feedback on challenges to the data-inputting process. The data inputters from the former countries are, however, hindered by the fact that they also have to perform their day to day activities.

Table 1 Studies reviewed for inclusion into the database over the reporting period

No.	Title	Organisation	Author(s)	Remarks
1	The Kenya maintenance study on unpaved roads LR 1111 (1984)	TRRL	T. E. Jones	Added to the database
2	Evaluation of weak aggregates for surface dressing on low-volume roads TRR 1291 (1991)	TRRL	M. E. Woodbridge, P. A. K. Greening, and D. Newill	Added to the database
3	Concrete pavement trials in Zimbabwe TRL RR381 (1993)	TRRL	J. D. Parry, N. C. Hewitt, and T. E. Jones	Added to the database
4	Performance of Sealed Test Sections WP113 (1981)	TRRL	P. W. D. H. Roberts	Added to the database
5	Performance of Unsealed Test Sections WP114 (1981)	TRRL	P. W. D. H. Roberts	Added to the database
6	Performance Review of Design Standards and Technical Specifications for Low Volume Sealed Roads in Malawi (2011)	ReCAP	M. I. Pinard	Added to the database
7	The Hoopstad stabilized Kalahari sand LTPP experiment after 55 years (2017)	ReCAP	F. Netterberg	Added to the database
8	The Kenya road transport cost study: research on road deterioration LR673 (1975)	TRRL	J. W. Hodges, J. Rolt and T. E. Jones	Added to the database
9	Investigations of subgrade conditions under roads in East Africa (1968)	TRRL	M. P. O'Reilly, K. Russam, F. H. P. Williams	Added to the database
10	SEACAP: Rural Road Surfacing Trials (RRST) (2005-2010)	OTB/TRL/INTECH ASSOCIATES	J. R. Cook, J. Rolt, and R. Petts	This provided a large amount of data which was added to the database
11	Performance of slurry seals used in paved road maintenance in Malaysia (1992).	TRL	C. R. Jones, Tan Fah Mee and W. G. Ford	Added to the database
12	The maintenance of paved roads in Malaysia: performance of two full-scale experiments PA3329/98 (1998).	TRL	C. R. Jones, W. G. Ford and Mohd S. Hasim	Added to the database
13	Experimental Use of Cinder Gravels on Roads in Ethiopia PA1184 (1987)	TRRL	D. Newill, R. Robinson, K. Aklilu	Added to the database
14	Vietnam Rural Road Gravel Assessment Programme (RRGAP) (2005)	INTECH/TRL/ITST ASSOCIATES	J. R. Cook, and R. Petts	A study report and a large database, added to the database

15	*Research on the Inter-Relationships between Costs of Highway Construction, Maintenance and Utilization (HDM Data) (1976-1981)*	*Ministry of Transport, Brasil; Geipot, Brasil; and Texas Research and Development Foundation*	*Several Authors (18 reports)*	*Reviewed but not added to the database. Does not contain pavement-related data*
16	*Impact of the Heavy Vehicle Simulator (HVS) programme of the Gauteng Provincial Government 1978 to 1996 (updated to 1998).*	*CSIR*	*E. G. Kleyn, S. V. Kekwick and R. Sutton*	*Reviewed but not added does not contain data*
17	*Promoting the use of marginal materials TRL, PR/INT/205 (2002)*	*TRL*	*J. R. Cook, C. S. Gourley and E. C. Bishop*	*Reviewed, does not contain data but contains references to studies that may be useful*
18	*Ghana highway research programme. Road maintenance study: Measurement of running surface characteristics. TRL WP111 (1981)*	*TRRL*	*P. W. D. H. Roberts*	*The report is not about road or material performance and has no data suitable for the database*
19	*Research on the Inter-Relationships between Costs of Highway Construction, Maintenance and Utilization (HDM Data) (1976-1981)*	*Ministry of Transport, Brasil; Geipot, Brasil; UNDP, World Bank*	*Several Authors (40 reports)*	*Reviewed but not added to the database. Contains very limited pavement-related data*

Summaries of the studies in Table 1 are included in Progress Report 1 and Progress Report 2. For studies whose summaries were not included in the progress reports, the summaries are included in Annex 2 of this report.

4 Gap analysis

4.1 Data and information gaps

Evaluation of the gaps in data and information was carried out in order to determine and prioritise additional data required to refine Guidelines and Specifications for low-volume sealed roads and to provide end users with the necessary information for future analyses.

The data and information gaps are defined on the basis of the aim of the project (revision of materials requirements for design catalogues, surfacings, and climatic factors), which is to evaluate the performance of LVRs. These are broken down in three sections of the report, 4.2, 4.3 and 4.4. The data, which have been entered into the LVR database, are aimed at providing the evidence of performance of LVRs in different geographical areas and environments, and for different pavements, surfacings and materials. One of the key elements of the study is to evaluate the performance of locally-available materials some of which would be considered as non-conventional or substandard in relation to conventional specification limits.

Data and information were collected from many different sources. The key assumption at the beginning of the project was that more than about 50 reports exist from many sources and projects carried out worldwide. The main task was therefore to collect and collate these data and information into a repository i.e. the LVR Database. Indeed a lot of effort was put into this initiative during both Phase 1 and Phase 2 of the project and a lot of reports and documents have been reviewed and any suitable data have been entered into the database notwithstanding the challenges highlighted in Section 6.

Gaps are referred to in the context of low-volume roads and research studies focussed on the variables being discussed. This does not necessarily mean that road sections have not been built that focus on the variables; it means that research studies on sections with those variables are low (< 9) from the low-volume roads perspective.

Conventionally, low-volume roads are designed to carry traffic loading of up to 1 MESA. However, the traffic loading range of consideration in this gap analysis has been extended to more than 1 MESA in order to enable interpolation when developing or refining standards.

4.2 Traffic loading versus non-conventional surfacing

Conventional bituminous surfacings are considered to be Double Surface Dressing (Double Chip Seal) or Asphalt Concrete. These are proven to work well under various conditions, when designed and constructed well. For the purpose of this study, any other bituminous surfacings are considered to be "non-conventional", especially surfacings that use natural gravels.

Non-conventional surfacings are particularly important in the development of low-volume roads in remote locations where haulage of crushed stone would be very costly. Therefore, more information is required on their performance in order to improve their design and construction. Since low-volume roads are designed to carry up to 1 MESA in their service life (expected to be 15 - 20 years), knowledge on the performance of these surfacings at traffic levels up to and exceeding 1 MESA is important. Moreover, the surfacings are expected to last at least 7 years before requiring a reseal. Table 2 (for surfacing age ≥ 5 years and in areas where rainfall is greater than 1000 mm/yr) shows that currently the database contains very few sections where research has been carried out on non-conventional surfacings, especially at high traffic levels. Many AfCAP partner countries are located in regions that have areas with rainfall greater than 1000 mm/yr, thus making this a very important gap to be filled. The scenario is even worse in areas with average rainfall of 500 – 1000 mm/yr (Table 3) - although geographically these areas are not common and the surfacings that perform well in high rainfall areas would generally be expected to perform well in lower rainfall areas.

Table 2 Number of research sections with non-conventional surfacings in areas receiving rainfall greater than 1000 mm/yr

Surfacing	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
Otta Seal	0	1	0
Combination Seal	0	0	0
Single Surface Dressing	0	3	0
Sand Seal	0	0	1
Sand Asphalt	0	0	0
Cold Mix Asphalt	0	0	0
Road Mix	0	0	0
Age of Surfacing ≥ 5 years, Rainfall > 1000 mm/year			

Table 3 Number of research sections with non-conventional surfacings in areas receiving rainfall 500 - 1000 mm/yr

Surfacing	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
Otta Seal	0	0	0
Combination Seal	0	0	0
Single Surface Dressing	0	0	0
Sand Seal	0	0	0
Sand Asphalt	0	0	0
Cold Mix Asphalt	0	0	0
Road Mix	3	0	0
Age of Surfacing ≥ 5 years, Rainfall 500 - 1000 mm/year			

4.3 Traffic loading versus base material strength

One of the main goals of ReCAP is to promote the use of locally-available materials (such as natural gravels) for the base layers of LVSRs, as using local materials significantly reduces the costs of haulage. However, in order to promote their successful use, it is important that the performance of local materials of varying quality is understood at different levels of traffic and in different environments. Moreover, for pavements built with materials of lower quality, the performance can be significantly affected by individual wheel loads as well as repetitions of the axle loads. Little has been done to study the effect of individual wheel loads on the long-term performance of natural gravel bases. Table 4 and Table 5 show a clear gap in the number of research sections that have included base layers of natural gravels on roads that have carried equal to or more than 1 MESA in areas of annual rainfall greater than 1000 mm/yr. This is a very important gap that must be filled if the objectives of ReCAP are to be realised. It is known, through field experience, that these roads exist on the road network of some countries but forensic research has not been carried out on them. They need to be studied.

Table 4 Number of research sections on various base layer strengths in areas receiving rainfall greater than 1000 mm/yr

Base CBR	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
CBR ≤ 40	1	4	1
40 < CBR < 60	0	8	1
60 < CBR < 80	0	2	0
CBR ≥ 80	0	1	0
Rainfall > 1000 mm/year			

Table 5 Number of research sections on various base layer strengths in areas receiving rainfall 500 - 1000 mm/yr

Base CBR	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
CBR ≤ 40	0	0	2
40 < CBR < 60	14*	0	4
60 < CBR < 80	0	0	1
CBR ≥ 80	1	8	7
Rainfall 500 - 1000 mm/year			

Notes: * All 14 sections are from 1 study. The sections are very short in length, 60 – 120 m.

4.4 Traffic loading vs subgrade strength

The essence of pavement design is to safely and economically transmit traffic-induced stresses to the subgrade layer. Thus, the magnitude of the loading and the strength of the subgrade must form part of any pavement design model. Table 6 (rainfall > 1000 mm/yr) shows a clearly very low number of sections at all traffic levels on all subgrade classes. A similar situation is observed in Table 7 (rainfall 500 – 1000 mm/yr). Therefore, studies need to be carried out on sections in very weak subgrades and on medium strength subgrades. Of course geographically speaking within the AfCAP region, areas of very weak subgrades (CBR < 3) are localised and limited. So perhaps research needs to focus on weak and medium strength subgrade sections. Existing data on the stronger sections can then be used to develop functions that cover the 3 broad subgrade ranges (weak, medium, strong).

Table 6 Number of research sections on various subgrades in areas receiving rainfall greater than 1000 mm/yr

Surfacing	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
Very Weak (CBR<3)	0	0	0
Weak (CBR 3-4)	0	6*	0
Medium (CBR 5-7)	0	1	1
Medium Strong (CBR 8-14)	1	3	0
Strong (CBR 15-29)	0	4	1
Very Strong (CBR>30)	0	2	0
Rainfall > 1000 mm/year			

Notes: * All 6 sections are from 2 studies only.

Table 7 Number of research sections on various subgrades in areas receiving rainfall 500 - 1000 mm/yr

Surfacing	Traffic Loading		
	Medium High (0.3-0.5 Mesa)	High (0.5-1.0 Mesa)	Very high (≥1.0 Mesa)
Very Weak (CBR<3)	0	0	0
Weak (CBR 3-4)	0	0	0
Medium (CBR 5-7)	14[1]	0	0
Medium Strong (CBR 8-14)	0	1	0
Strong (CBR 15-29)	0	4	12[2]
Very Strong (CBR>30)	1	6	3
Rainfall 500 - 1000 mm/year			

Notes: 1. All 14 sections are from 1 study. The sections are very short in length, 60 – 120 m.

2. All 12 sections are from 1 study (different to study 1).

4.5 Key observations/factors for consideration

A gap analysis has been carried out as summarised in Section 4. The analysis shows the different performance parameters required to evaluate the performance of LVSRs and how this relates to the range of parameters and/or combinations of parameters that are currently included in the database. The gap analysis therefore gives a broad picture of how the missing data and information would affect the usefulness of the database and more importantly the adequacy of information for the performance analysis of LVSRs.

We therefore strongly recommend that fieldwork be undertaken to address the gaps in the following eight areas:

1. Insufficient data on non-conventional surfacings. There is very little data and very little information on surfacings particularly the non-conventional bituminous seals. Previous studies, including the Back Analysis Project carried out in Mozambique in 2014, showed that most of the failures occur in the surfacings rather than the underlying pavement layers and subgrade. More data and information are required on the performance of the surfacings particularly non-conventional surfacings. It is a major shortfall that the database is currently not providing adequate data on this. In their paper 'Performance Limits for Bituminous Surfacings on Low Volume Roads', S J Emery, G D Van Zyl, S van Huyssteen and L Sampson conclude that low volume roads constructed using thicker bitumen surfacings with thin pavements and lower quality pavement materials can be more cost effective and perform better than pavements constructed with thin bitumen surfacings with high quality pavement materials and thick pavement layers. It goes further to say that it has become apparent that the choice of surfacing type must be made for each different set of conditions and that one should not assume that any previous good experience with a particular surfacing type will be applicable for different environmental conditions. Currently there is not enough data in the database (see gap analysis on Table 2 and Table 3) on performance of surfacings to provide the necessary evidence of good experiences in different environments.
2. Insufficient data on traffic loading range 0.5 MESA to 1MESA. This is a critical part of the spectrum of traffic loading. Very lightly trafficked roads are unlikely to fail even if they are constructed using low quality pavement materials. Data on traffic loading from the bulk of the studies shows that there is little information on roads having heavier traffic loading i.e. 0.5 MESA to 1 MESA; that is a very serious gap which needs to be resolved. If nothing is done about this then it could defeat the main purpose of the programme. This gap needs to be closed.
3. Insufficient data on impact of high rainfall. Some studies were carried out in high rainfall (> 1000 mm/yr) areas but they lack some of the fundamental data which is necessary to link performance of LVSRs to traffic loading in very wet environments. It is clear that LVSRs can be affected significantly by high moisture regimes and flooding, due to their geometry, and inherently high moisture sensitivity of some of the locally available materials which are usually applied in pavements without modifications. This is a priority gap that needs to be filled and any further development of specifications needs to take this into account.
4. Lack of data on maintenance and its impacts on performance of LVSRs. The impact of maintenance or lack of it, on the performance of LVSRs is largely unknown. Moreover, it is generally understood that poor performance and significant premature failures are often a result of poor or non-existent maintenance. This is largely what causes failures in the surfacings where maintenance backlog leads to unchecked distress and failure. The general perception is that LVSRs last for a long time with a reasonably robust maintenance regime. To this effect, and considering reasons given in (1) above, it is

apparent that maintenance regimes should be designed to suit different types of surfacings and pavements in different conditions and environments. However, without the data to provide the necessary evidence, it is difficult to provide guidance on appropriate maintenance regimes. Some work was carried out during the HDM experiments but this was targeted mainly at HVRs and the original data are not available. The data that are available are in the form of summaries provided without site specific information. This has made it difficult to evaluate the performance in relation to traffic, material properties and the environment. The importance of maintenance data cannot be overemphasised.

5. Insufficient data on unconventional road bases in different environments. This involves the use of locally available materials for road bases, which is aimed at reducing the lifecycle costs of LVSR provision. Some information and data have been entered into the database but there is very little coverage of the higher traffic loading. This means that the locally available base materials, most of which are non-conventional and generally susceptible to high pavement moisture, have not been fully tested for performance under the higher traffic loading spectrum explained in item (2). This is a priority gap that needs to be resolved.

6. Insufficient data on weak subgrades. Weak subgrades are highly prevalent in ReCAP areas of Africa and South-East Asia. Under high volume roads these weak subgrades would be excavated to waste and replaced with imported or selected subgrade. In LVSR provision this would be an additional cost worth avoiding. Therefore an improved understanding of how weak subgrades perform in conditions of high traffic loading and very wet conditions is a critical knowledge gap that needs to be covered. Pavement design specifications depend on it.

7. Insufficient data on durability and age of pavements and surfacings. It is apparent that the data in the database does not cover durability and expected age of surfacings and pavements. This information is critical for design and maintenance and the whole sustainability framework for LVSRs. Without this, any design becomes presumptive and this diminishes the engineering input in LVSR provision. Most of the studies cover standard short periods up to 5 years with most ranging from 1 to 2 years. This is a priority gap that should be closed.

8. Insufficient data on locally-available materials (types and properties). Most of the names of locally available materials (particularly non-conventional materials) are listed in the database in sufficient detail. However, it is the high variability of these locally available materials and their varying response to loading, particularly the heavy wheel loads, that matters most. There are insufficient data on the performance of these materials under high wheel stresses which minimises the confidence in the use of locally available materials because the specifications are not backed by performance evidence on the higher traffic loading spectrum.

4.6 Key Constraints

In deciding how best to provide the data to fill the gaps outlined above, the following constraints need to be taken into account:

1. Long term pavement performance studies (15-20 years) are the most appropriate but getting funding for these is difficult and there are very few studies which have been accomplished at this level. This is unfortunate for innovation.
2. The chance of getting adequate data from previous studies which meet the criteria required for the LVSR database has diminished significantly because experts have retained reports

with summary data, analyses and conclusions but there is a lack of raw or detailed data. Over 40 HDM study reports were reviewed but only a very small part yielded useful data for the LVSR database.

5 Challenges faced in Phase 2

A number of challenges were encountered in acquiring data required to populate the database.

1. Lack of data and information. A significant number of reports which were sourced either had no data or had data which were not relevant for the LVSR database.
2. Incomplete data. A significant number of the reports which were reviewed did not have complete data sets e.g. some reports had summaries of test results but no site information (e.g. no layer thicknesses, no materials strengths, no climatic information), or they had a set of materials test data without an indication of where the materials were used and how they performed in-service.
3. There is a gross misconception by some stakeholders about what “data” and “low volume roads” are. Thus in many instances when they say they have plenty of data, they mean routine materials test results obtained from the day to day running of laboratories. Likewise, they tend to think that a trunk road (often designed to the highest pavement standards) that carries few vehicles per day (could well be designed to carry 10 MESA) also qualify as low-volume roads.
4. In-country counterparts failed to input their country-specific data. Training was conducted to capacitate counterparts in several AfCAP countries to use the database and input data from local studies which they identified. Very few of these have made attempts (as shown in the database log) to input the data due to a number of reasons, the main one being that the counterparts are occupied with other routine activities. The technical paper emphasises the value of data, careful storage of data for future use, coordinated research, and combining different datasets. , This is aimed at encouraging the use of the database.
5. In the case of Mozambique, a database has been developed through a sister AfCAP national project (MOZ2093A Long Term Pavement Performance Monitoring of Trial Sections in Mozambique incorporating Capacity Building of Road Research Centre Personnel). Monitoring data has been added to the local Mozambique database (not accessible outside Mozambique roads administration), but unfortunately the same data has not been added to the regional database. It is likely to be the case for Tanzania that will soon receive its own database, also through AfCAP. This could lead to other AfCAP countries into seeking similar country-specific databases and unwilling to share and contribute to the regional database.

6 Summary

In order to promote sustainability of the AfCAP countries towards conducting research and storing all necessary data, participants from the 12 participating AfCAP countries were trained to be Data Inputters. The overall aim of the training was to build their capacity in inputting and retrieving data from the database so that they may be able to process their own data. Three training workshops were held between October and November 2017. It is now possible for a lot of practitioners and stakeholders to enter and retrieve data from the database. However, data input from the participating countries has not been forthcoming. Questionnaires were circulated to participants from partner countries that were trained on the use of the database. The main constraints to data input were that the respondents found their data sets to be confusing, the demand by other day-to-day tasks that the respondents participate in, and a number of respondents had forgotten what they learnt in the training. The respondents said a refresher over Skype or phone on what they learnt would be sufficient. This refresher was carried out for Mozambique and Tanzania. We propose that ReCAP should ask participating countries to honour their commitments to the programme (by adding data to the database) in the next steering committee meeting.

The LVR database is fully functional. Following feedback during the regional training sessions, many improvements have been made to make the database more user-friendly. The Microsoft Excel-based bulk-upload tool has also been modified, again to make it more user-friendly. The beauty of this tool is that it is flexible to handle various forms of data. A user manual for the database is available for download under the 'Help' section of the web-based database on www.lvroadsdata.com. The user manual is frequently updated based on changes made to the database and feedback from users.

Any relevant data, which was obtained by the project team, have been entered into the database. The number of data rows in the database has increased from 1,019,919 at the end of Phase 1 to currently more than 3,183,698 rows. This will increase further following data that will be collected from fieldwork in Phase 3 and as participating countries enter more data.

The main task for Phase 2 of the project was to populate the LVSR Database with LVR performance data from as many sources as possible. This has been largely accomplished.

Phase 3 of the project will aim to come up results that are immediately applicable (revision of catalogues, materials specifications, and bituminous surfacing design) by recommending revised limits regarding surfacings and base layer materials specifications.

Data gaps (and therefore knowledge gaps) have been identified following extensive population of the database. These gaps impact on the aims of this project and its contribution to the overall aim of ReCAP. Knowledge on the use of non-conventional surfacings at higher traffic levels (> 0.5 MESA) is still largely unknown. The limiting base material strengths at higher levels of traffic in areas of high rainfall (> 1000 mm) lacks a sufficient quantity of data in order to refine standards. Very little data is also available on research studies on road sections dealing with very weak and moderate subgrade strengths in areas of high rainfall (> 1000 mm). Unfortunately, the current performance monitoring programmes (under a different ReCAP project) in a number of countries cannot bridge this gap immediately since the traffic levels carried by most of these sections is still below 0.5 MESA. In conclusion, the most reassuring and quickest way in which to narrow these gaps is by conducting fieldwork in Phase 3 to answer some of the questions that remain.

We propose to carry out fieldwork in Phase 3 in Ghana, Mozambique, Uganda and Zambia. The reasons for proposing these countries are included in section 7.3 of this report. The final choice of these countries is dependent on availability of suitable study sections, availability of equipment in these countries, and the willingness of the countries to participate in the project. In the case that suitable road sections to bridge the gaps are not found in these countries or there is lack of equipment or unwillingness to participate in the project, the search will be expanded to other AfCAP countries. The final choice of countries will be made after the reconnaissance task in Phase 3.

7 Recommendations for Phase 3

7.1 General

Clearly gaps exist in the database in critical areas as seen in the gap analysis section. Efforts have been made to obtain data from several additional sources but they have proved to be unsatisfactory (mostly do not contain performance data or site characteristic data) or the data is not site specific enough to be used in developing or refining standards. Unfortunately, the current performance monitoring programmes (under a different ReCAP project GEN 2132A Capacity Building and Mentorship for the Establishment and Implementation of Monitoring & Evaluation Programmes on Experimental and Long-Term Pavement Performance (LTPP) Sections in Six African Countries and Myanmar) in a number of countries cannot bridge this gap immediately since the traffic levels carried by most of these sections is still below 0.5 MESA. One of the sections in Murang'a, Kenya, is currently receiving a lot of loaded truck traffic from a tunnelling project and could meet this criteria (albeit in an accelerated way). One section in Ethiopia (Gerado) is currently estimated to have carried about 0.3 MESA and in a few years could exceed 0.5 MESA. The data currently being collected from these two sections will be used in Phase 3 of this project. Our recommendation therefore is that we conduct field investigations to narrow these gaps. Certainly many more studies need to be concentrated in these critical areas so that LVSR design moves forward.

7.2 Way forward

The most feasible way to close some of these data gaps is to carry out a back analysis of previously constructed LVSRs to evaluate their performance in different areas and under different conditions, and where different locally available materials were used. To achieve this, the followed aspects need to be considered:

1. The data gaps need to be prioritised in terms of their importance in defining their influence on the performance of LVSRs.
2. That these gaps are interlinked i.e. if test sections are carefully selected some useful data or performance evidence can be collected that bridges several gaps in one go. This will involve targeting sites which provide wider data bands which will help to expand the specification limits.
3. Specialised tests should be considered which provide a better assessment of the properties and quality of the materials, especially bituminous surfacings, which will better quantify their durability and resilience.

7.3 Proposed scope of fieldwork

An indicative budget for Phase 3 was proposed at the beginning of Phase 2 of the project and this was premised on the assumption that there was plenty of data all over the ReCAP regions and beyond and that it was possible to fully populate the LVSR database without carrying out much of field work. However, this is not the case now and site work is absolutely necessary otherwise the benefits of this project will be greatly diminished.

There are two options of narrowing the gaps through the field investigations:

1. Working within the confines of the provisional budget estimated at the beginning of Phase 2. This is not recommended because of the limited scope that focuses on between six and twelve sections in three or four countries. The willingness of the countries and the availability of equipment in these countries will determine the final choices.

2. Work to a more realistic budget which is based on a realistic scope of field investigations based on the actual gaps identified during Phase 2 with the aim of narrowing some critical data and knowledge gaps which will influence future development of standards and specifications for LVSRs within the allowable project timeframe. This is the recommended option, with a wider scope that targets about 10 to 16 sections in the same three or four countries.

Option 1 focuses on between six and twelve sections in three or four countries. Option 2 has a wider scope in that it targets about 10 to 16 sections in the same three or four countries. Having more study sections (Option 2) gives greater reliability and confidence to the data that would be collected. An addendum to the project would be required if Option 2 is to be adopted. The Proposed Addendum is presented outside this report. The strategy is to cover three geographical regions in Africa in order to make the results more widely applicable. The proposed target countries are Ghana, Mozambique, Uganda, and Zambia. Uganda could be substituted with Tanzania, and Zambia could be substituted with Malawi. The primary reasons for selecting these countries are summarised below.

Ghana is proposed due to:

- An MSc. 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 to fill the gaps discussed in Section 4.
- Rainfall of 1250 – 2000 mm/yr in a large part of the country.

Mozambique is proposed due to:

- A large network constructed with marginal quality materials.
- Highly varied climate.

Uganda is proposed due to:

- A large variety of non-conventional surfacings were constructed to the east and north of the country between 2011 and 2014.
- High quantity of rainfall with many areas receiving more than 1250 mm/yr
- Large areas of swampy subgrades. The likelihood of finding weak subgrades is therefore high.

Zambia is proposed due to:

- Average rainfall conditions (750 -1500 mm/yr) 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.

The selection of sections will be based on the matrix in Table 8 keeping in mind that 1 section, if carefully selected, can cover several gaps.

Table 8 Proposed field study investigations to cover key data and knowledge gaps (based on available budget)

No.	Investigation Matrix	Selection Criteria	Key Activities
1	Surfacings vs Traffic and Environment and Age	5 priority surfacings, Age>5 years Rainfall<1000mm, Rainfall>1500mm, (0.7<MESA<1.5)	Selection of surfacing types Traffic Counts Axle load surveys Rainfall data from Met. Dept.
2	Bases vs Traffic loading and Environment	5 Priority non-conventional bases, (Age>15years) Rainfall<1000mm, Rainfall>1500mm (0.7<MESA<1.5) CBR<40, 40<CBR<60, 60<CBR<80	Selection of surfacing types Traffic Counts Axle load surveys Rainfall data from Met. Dept.
3	Weak Subgrades vs Traffic loading, Climate and Age	4 Priority weak subgrades, (Age>15years) Rainfall<1000mm, Rainfall>1500mm (0.7<MESA<1.5)	Selection of areas with weak subgrades Materials testing Traffic Counts Axle load surveys Rainfall data from Met. Dept.
4	Maintenance vs Climate, Traffic Loading, Age and Type of Surfacing	2 sections without maintenance and 2 sections with good maintenance Age>15 years Rainfall < 1000 mm, Rainfall > 1500 mm 0.7<MESA<1.5	Selection of roads where maintenance has been carried out e.g. Reseal. Materials testing, Traffic Counts, Axle load surveys, Rainfall data from Met. Dept.

7.4 Proposed Methodology for Phase 3

This section covers the methodology that TRL proposes to employ in delivering Phase 3 of the project. The individual tasks are described in the following sections.

Task 1: Pre-visit desk study

Prior to the reconnaissance visits, the team will conduct a desk study to obtain as much information about the proposed study countries as possible. The desk study will be geared at obtaining climatic maps (rainfall and temperature), a study of soils maps to estimate the areas that possess the kind of subgrades targeted for the investigation, the road network to 'superimpose' over the climatic maps and soils maps (so as to identify possible candidate roads). Communication with the countries about the intended reconnaissance study and visits will also commence at this stage. Any other information obtained from the countries that will be useful to the purpose will also be studied. If any of the proposed study countries does not express willingness to participate in the study or lacks critical equipment for field study, then an alternative country will be contacted for possible involvement in the study.

In addition, draft terms of reference will be prepared for the country components of the project stipulating the responsibilities of the participating authorities so that there is clear understanding of the objectives and mandates of the parties involved. These will be shared with potential countries during the reconnaissance visits. The draft terms of reference will be under the umbrella of the memoranda of understanding that ReCAP has with the partner countries.

Task 2: Visiting selected countries and selecting candidate roads and test sites

For costing purposes it is assumed that four countries will be visited. Several potential candidate countries were contacted during Phase 1 of the project, all of whom showed great interest to be partners and willingness to collaborate on the project. These countries included Mozambique, Uganda, Ghana, Kenya, Zimbabwe, Zambia and Tanzania.

During the site visits the project team will coordinate with the local staff in order to gather local knowledge and also obtain assistance in the selection of candidate LVRs for the field investigations, based on the Phase 2 gap analysis exercise.

Particular attention will be given to the main data and knowledge gaps that have been selected for study based on outputs described in section 4 above. Both good and poorly performing sections shall be included in the study. During the initial site visits vital information about the candidate roads shall be obtained so that the sites selected for the study are those with the greatest potential for providing good data that can be analysed with confidence. This will also include tentative section demarcations, information on the prevailing conditions, and insights into the perceived performance from the local road authorities. In addition, photographs of the different roads and sections shall be taken for comparison with other potential candidate sections.

Task 3: Analysis of the candidate roads and sections, prioritisation and final selection of candidate countries, roads and test sections

After the initial field visits, a desk study will be carried out to select the roads most likely to yield good data bearing in mind that this process will highlight both candidate roads and, therefore, candidate countries. This will be carried out based primarily on the scientific requirements of the studies themselves but other factors shall also be considered including the geographical coverage, capacity of the candidate countries to facilitate and participate in the investigations (and contribute in cash or kind), the availability of reasonable field survey equipment and laboratory capacities to do the testing, and other criteria to be decided.

Task 4: Signing of memoranda of understanding

After finalising the selection, the draft terms of reference prepared in Task 1 will be finalised and circulated for signing. This will commit various local parties to the collaborative research.

Task 5: Mobilisation

The field surveys will be conducted in collaboration with the local road authorities and RRCs where they exist. The local laboratories will play a leading role in both the field work and any laboratory testing. The research may involve the following categories of activities:

1. Mobilisation of personnel and equipment – It is important to mobilise appropriate equipment for the field surveys but it is also important to bear in mind that the primary task is to fill the identified gaps and much of this is likely to be surface condition measurements that require very little equipment. Secondment of personnel from the RRCs and road authorities, particularly the laboratories, will be required to carry out the field work together with the project team.
2. Transport – There will be the need for transport to take personnel to and from sites and also to transport any samples that need to be sent to the laboratories.
3. Testing of pavement materials shall be carried out in both government and private laboratories.

Task 6: Field and laboratory investigations

The field investigations will include some or all of the following key tests/measurements:

1. Condition surveys. These include the observation and measurement of surface defects such as cracking, potholes and patching, geotechnical movements, general deformation, rutting, edge break, etc.

2. In-situ strength surveys, material sampling and destructive tests (trial pits). These tests and surveys include deflection tests (lightweight deflectometer (LWD) or falling weight deflectometer (FWD), DCP measurements, trial pits (for layer thickness measurements and sampling.

Transportation of samples to laboratories – It is anticipated that most of the tests will be carried out in-country. However, it is also anticipated that there will be some specialised tests which may need to be carried out outside the country, most likely in the UK. Such tests may possibly include Brookfield viscosity and gas chromatography tests on surfacings.

The laboratory investigations are expected to include but not be limited to the following:

1. Tests on bases, subbases and subgrades – grading, Atterberg limits, CBR, laboratory DN where possible, proctor tests.
2. Tests on surfacings – binder content, binder ageing, viscosity, softening point, and other specialised tests on binders. Tests on aggregate strength and other material properties such as grading and shape.
3. Test on stabilisation – cement, lime and bitumen content (for emulsion treated based).

Task 7: Analysis

All field and laboratory tests results will be compiled and recorded in spreadsheets which conform to the database requirements. Inputting data shall form an aspect of capacity building and it is anticipated that the participating staff will carry out a significant amount of the work. Analysis of the data shall be carried out primarily by the TRL team but in such a way that capacity building of colleagues from the RRCs is part and parcel of the process.

Task 8: Updating the Database

Relevant data collected from the field and laboratory investigations will be entered into the database.

Task 9: Training/Capacity

Whilst the local teams will already have various skills, this research project will require skills and knowledge that covers a relatively wide range. These will be acquired through carrying out field and laboratory investigations together. Another key contributor to the capacity building exercise is the joint analysis and interpretation of results between the TRL Team and the RRC counterparts. Finally the dissemination workshop will repeat some of the analysis and interpretation of results for the benefit of those who would not have been privileged to be part of the project directly.

Task 10: Preparation of the Final Report

The report will cover details on the research methodology, results and outputs of Phase 3. The report will also provide guidance on how the results/recommendations can be used and any precautions which should be considered in using the data. In addition, it will recommendations on downstream issues which should be considered by the client and the beneficiaries.

Task 11: Dissemination

The outputs of the project shall be disseminated to the stakeholders with the following objectives:

1. To develop awareness of the outputs and their importance to the provision of LVSRs.
2. To transfer ownership of the outputs to the intended beneficiaries of the research.
3. To provide the technical basis for the outputs of the study.
4. To obtain feedback from the stakeholders on any additional improvements.

Dissemination of the project outputs shall be through:

1. Presentation in forums such as the T2 and other international conferences (costs not included in our proposal).
2. The project dissemination workshop.
3. Publication of a scientific paper on the findings.

Task 12: Preparation of scientific paper

A scientific paper will be prepared for publication in a journal. The primary objective will be to publicise the field investigation findings as well as use of existing data in the database. The paper will be published in a journal that has recognised reviewer quality. The objective is to reach a wider audience, develop international awareness and confidence in LVSR technology.

7.5 Proposed Milestones for Phase 3

Table 9 shows the proposed milestones for Phase 3. The description of what the milestones will contain is as follows:

- Inception Report – This report will cover the activities described in Tasks 1 to 4 in section 7.4. This will include findings from the pre-visit desk study, a summary of the correspondence with the various countries, the findings of the reconnaissance visit, and prioritisation and final selection of candidate countries, roads and test sections, and a description of the field and laboratory tests proposed for each section
- The Fieldwork Report – This report will cover the activities described in Task 5 and part of Task 6 in section 7.4. This will include a description of the mobilisation made by the project team for the fieldwork, a description of the field measurements made, and a partial analysis of the results of the measurements. The analysis at this stage is partial since a complete analysis needs to take into account the laboratory test results which would still be underway at the time when the report will be produced
- The Final Report and Scientific Paper - This report will provide a summary of the activities described in the Inception Report and in the Fieldwork Report.
  More importantly, it will cover in detail the activities described in part of Task 6 up to Task 12 in section 7.4. This will include a description of the laboratory test results, an analysis that combines fieldwork and laboratory data collected in Phase 3 with data already contained in the database. The analysis will be aimed at addressing two main objectives of the project a) review design tools and catalogues and make recommendations for any modifications to the catalogues and material specifications based on the analysis of the project data b) review existing guidelines for the selection of surfacing seals and make recommendations on revisions to existing guidelines that would incorporate the full range of key performance factors observed under the study. SEACAP data obtained and included in the database and more yet to be obtained will also be included in the analysis. The report will also describe activities related to updating the database, capacity building, and the project dissemination workshop. A scientific paper will also be produced and included as part of the Final Report.

Table 9 Proposed milestones for Phase 3

No.	Milestones	Schedule
1	Inception Report	12th February 2019
2	Fieldwork Report	15th April 2019
3	Final Report and Scientific Paper	17th June 2019

7.6 Inputs for Phase 3

The proposed activity schedule for Phase 3 is shown in Figure 1 and could be revised during the project inception stage depending on the findings during the reconnaissance task. The staff inputs for Phase 3 are contained in the existing contract and are included here in Figure 2.

Figure 1 Proposed activity schedule for Phase 3

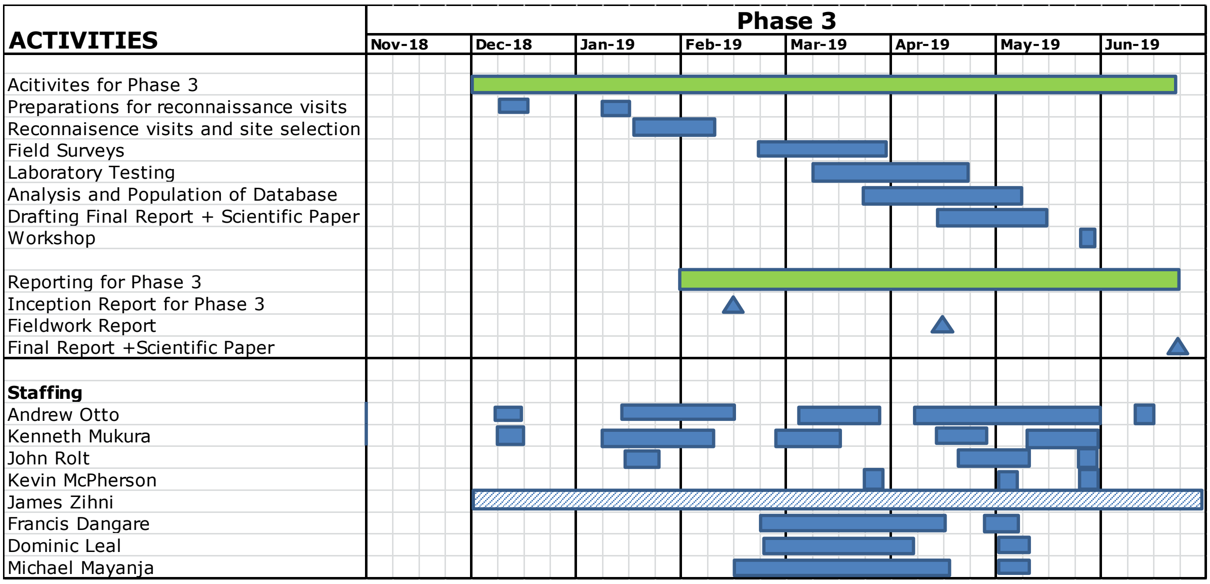


Figure 2 Contractual staff inputs for Phase 3

Staff	Post	Staff Inputs for Phase 3 (DAYS) Field work and Dissemination								
		Total Staff Inputs for Ph3	Reconnaisance visits	Field Work	Lab testing	Analysis	Managing and Populating database	Scientific Paper	Dissemination	Reporting (incl Final Report
Greg Morosiuk	**Project Manager**	**6**	2	1	1					2
Andrew Otto	**Team Leader**	**48**	8	10	5	5	5	5	5	5
Kenneth Mukura	**LVRs Expert**	**34**	0	10	5	5	0	4	5	5
John Rolt	**Senior Researcher**	**15**	0	0	2	3	0	4	2	4
Thomas Buckland	**Data Management Specialist**	**5**	0	0	0		3	0	0	2
James Zihni	**Data Management**	**27**	0	0	0		18	0	5	4
Francis Dangare	**Field Engineer**	**32**	10	20	2	0	0	0	0	0
Deepu Prabhakaran	**Field Engineer**	**20**	5	15	0	0	0	0	0	0
Michael Mayanja	**Field Engineer**	**46**	5	20	15	0	0	0	0	6

Annex 1 Country specific studies identified during the training workshops

The studies identified are listed below.

Workshop in Ghana

Ghana:

1) Japan International Cooperation Agency (JICA) study - developing of low volume roads using labour based surfacing technology (cold mix asphalt, single surface dressing)
2) Alternative surfacing on steep slopes

Liberia:

1) United States Agency for International Development (USAID) surfacings experiment – data yet to be obtained
2) Rehabilitation data

Sierra Leone:

1) African Development Bank Project
2) Mange-Mambolo road

Workshop in Mozambique

Tanzania:

1) AfCAP 2: Long term pavement performance study
2) AfCAP 1: study Bagamoyo (Chalinze), Siha
3) Otta seal (2004)? Morogoro

Zambia:

1) Chinsali – expected to start 1 year from now

Malawi:

1) Back analysis low volume roads – M Pinard
2) Completion report on 5/6 lvsr sections – ASWAP

Mozambique:

1) Civil Design Solutions/ANE AfCAP 2 LTPP monitoring project
2) AFCAP 1 LTPP monitoring of trial sections by TRL
3) Laterite studies 1970s?
4) Hot sand asphalt monitoring – N1 Chissibuca

Workshop in Uganda

Uganda:

1) Pilot project for demonstration of innovative technologies on Matugga – Semutto – Kapeka RD - 42km- 10 trial sections (different seals – Otta Seal, Sand seal, paving blocks, Inverted SD, bitumen emulsion base, cement-stabilised bases): completed 2010. Baseline report is available with UNRA. COWI consultants could have other reports
2) Trial sections being monitored by Mount Elgon Labour-based Training Centre – UNRA staff to check for reports
3) Upcoming – sections using different stabilisers (soilworks products) Busaba Rd 3 km
4) Upcoming - Lweza – Kigo, Kalule – Bamunanika, Misindye in Mukono, Kyankwanzi area: all four being designed
5) Upcoming – Probase products at Nansana

Ethiopia:

1) Otta Seal Trials (AFCAP 1) (Gerado and Tullubullo)
2) Laterite trials Assosa region
3) LTPP Regional trials

Kenya:

1) LTPP Study under AfCAP
2) McKenzie Kandara – Labour-based trials
3) Agence française de développement (AFD) and European Development Fund (EDF)
4) KEN042 by Charles Overby 1980s
5) Single layer pavements studies
6) Upcoming – rolled out 500 projects of total 4000 km

South Sudan:

1) Several Seals (Otta Seal, Chip Seals) Trial Sections 3 km different wearing courses – current monitoring; Heavy trucks with wet sand – AfCAP Trials
2) Geocells trials at Aweil
3) World Bank 2016 gravel road trials (security)

D R Congo:

AfCAP DCP Trials at Kalimi (not yet constructed)

1) Gravel roads loss data on 3300 km (Akula – Zongo, Central Africa, Bunduki-Bumba Isalla Gemena, Mobanza – Mobayi, Kisangani – Beni, Komanda – Bunia – Goli, Kasomeno – Kambu, Bukavu – Goma: next may not be completed yet – Bujumai-Bukavu, Niania – Isiro, Miti – Wombo- Walikali)
2) Lwambo – Manono
3) Kolwezi – Solwezi
4) Kolwezi – Dilolo

Annex 2 Project summaries of added studies

Performance of Slurry Seals Used in Paved Road Maintenance in Malaysia by C. Jones, T. Mee, and W. Ford (Transport Research Laboratory) (1992)

This study was carried out to examine the performance of three types and combinations of slurry seals used on 22km of road (split into 22 sections) in Malaysia. Monitoring was carried out from March 1998 to January 1991, this was an LTTP study. This study investigated slurry performance relative to cracking, skid resistance, deflections, traffic loading and slurry material composition on a number of different pavement constructions. The report does not provide details regarding the specific dimensions or properties of each section. The study firstly assesses types of slurries (individually and in combination) in sealing cracks of various intensities. Secondly the study assesses the slurries ability to improve skid resistance characteristics of the surface.

The three types of seal include:

- Type 1 – Fine mix (10-16% bitumen) for maximum penetration in fine cracks
- Type 2 – Standard mix (7.5-13.5% bitumen) for general purpose applications
- Type 3 – Coarse mix (6.5-12% bitumen) for crown corrections

Prior to installing the slurry seals the existing condition of each section was established, in terms of crack intensity, skid resistance (using the Pendulum Tester at 20 points per section at 6 monthly intervals), deflection surveys (using a Road Rater at 50 points per section at 12 month intervals), and traffic volume surveys. These tests were carried out throughout the study, alongside measurements of surface texture (using the Sand Patch method at 20 points per section at 6 monthly intervals). The study also examined slurry properties such as thickness (using a mechanical depth gauge) and curing time before reopening the road to traffic.

The study found that general purpose (Type 2) slurries were ineffective at sealing cracks. Type 3 slurries, and combinations, were no more effective than Type 2 slurry at high traffic levels. The decrease in skid resistance (of granite aggregates) was related to flow of commercial vehicles. This indicates that the material would be suitable for surfaces with traffic levels up to 1500 ADVC. End of study (at 36 months) measurements showed that texture depths of Type 2 slurries were related to commercial traffic flows.

Table 1 Types of Slurry Seal

Sieve size (mm)	Per cent passing		
	Type 1	Type 2	Type 3
9.50	100	100	100
4.75	100	90-100	70-90
2.40	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.600	40-60	30-50	19-34
0.300	25-42	18-30	12-25
0.150	15-30	10-21	7-18
0.075	10-20	5-20	5-15
Bitumen content*	10-16	7.5 - 13.5	6.5 - 12

Table 2 Mix Design - Type 2 Slurry

Test	Specification	Site No		
		1-6	7-12	13-22
Cement (%)	-	0.5	0.5	0.5
Emulsion (%)	-	15.0	15.0	15.0
Water (%)	-	15.5	14.0	15.0
Consistency (%)	20-30	25-30	25	20-25
Wet Track Abrasion (gm/sq ft)	<75	23.6	24.0	25.0
Sand Equiv. Test (%)	>45	68	75	74

Table 3 Mix Design - Site No 16-22

Test	Specification	Type 1	Type 3
Cement (%)	-	0.5	1.5
Emulsion (%)	-	17	13
Water (%)	-	17	13
Consistency (%)	20-30	30	20-30
Wet Track Abrasion (gm/sq ft)	<75	53	21
Sand Equiv. Test (%)	>45	67	67

The intensity of the cracking in each block was recorded using the following scale.

0 - No cracks
1 - Single crack
2 - More than one crack - not connected
3 - More than one crack - interconnected
4 - Crocodile cracking

Table 5 Bitumen Content

Type of Slurry	Design (%)	Bitumen Content (%)	
		Mean	Range
1	10.2	8.9	7.9 - 10.2
2	9.0	9.4	6.9 - 13.6
3	7.8	6.9	5.7 - 8.5

Table 6 Thickness and Curing Time

Type of Slurry	Thickness (mm)		Curing Time (Hrs)	
	Mean	Range	Mean	Range
1	3.4	3.0-4.3	3.2	2.5-3.9
2	5.4	4.3-6.6	3.7	3.4-6.4
3	6.1	5.0-8.0	4.3	3.4-6.4

The Maintenance of Paved Roads in Malaysia: Performance of Two Full-Scale Experiments by C. Jones, W. Ford (TRL), and M. Hasim (Government of Malaysia Public Works Department) (1998)

This study examined the performance of crack relieving interlayers and surface dressings to mitigate the impact of cracking on two full scale experimental roads in Malaysia. The construction and early performance trials are reported elsewhere; this study describes the measurements taken in January/February 1997 – this study was an LTTP.

The first part of the study was carried out on Route 5, between Melaka and Muar. This was constructed in June/July 1993 and had a single 7.3m wide carriageway. There were 8 sections (each 210m long) which used crack relieving interlayers were overlayed with 50mm of ACWC20 wearing course (excluding 2 control sections). These interlayers included:

- Geogrid Reinforcement
- Needle-punch Fabric
- Cut and Patch (40mm layer)
- Surface Dressing (14mm stone)
- Surface Dressing (10mm stone)
- Control (50mm overlay)
- Control (90mm overlay)
- Pervious Macadam (40 mm layer)

The study made measurements of crack intensity and extent along each section (each section was split into 21 10m blocks). It also modelled the whole life costs of five stress relieving interlayers (including the two controls) over a period of 20 years. This found that Cut and Patch was the most cost effective measure.

The second part of the study took place on Route 10, using a 4km experimental trial section. This report does not provide details of pavement dimensions, traffic levels, and is very brief in its descriptions of the site overall. It compared two types of seals performance (Double Surface Dressing and Racked-in Surface Dressing) as compared to a 50mm ACWC20 overlay. This trial examined reflection cracking, texture depth (in the nearside wheel path, using a TRL Mini Texture Meter) and skid resistance (using a portable Pendulum Tester) and traffic loading.

The study compares both trials and results gained from Route 5 and 10 and concludes a number of findings. Firstly, the rate of reflection crack progression is similar in both types of surfacing when interconnected cracks were not treated before construction. Secondly, increasing the thickness of overlay or applying 10mm surface dressing interlayer were the most cost effective solutions. And finally, the surface dressings used on Route 10 had maintained a satisfactory level of texture depth after 30 months.

Vietnam Rural Road Gravel Assessment Programme by J.R. Cook and R. C. Petts.

Intech Associates, TRL and ITST (2005).

The study was carried out in over 40 provinces of Vietnam (2001 – 2005) on 766 road sections. The study focussed on measuring gravel loss of different materials, in different terrain and climates of Vietnam. Most of the roads carried more than 50 vehicles per day, but traffic flow on specific sections has not been included. Rainfall ranged from 580 mm/yr to 4500 mm/yr.

Gradient ranged 0% to over 6%.

Materials studied included laterite gravel, hill gravel, graded crushed stone, non-graded crushes stone, alluvial gravel, clay and gravel mix, hand-packed stone, gravel mixed with stone/rock, and other undefined gravels.

Supplementary information is held in a Microsoft Access Database – a link to this database is provided. Subgrade strengths of the different sites were measured using the DCP equipment and stored in the database.

The codes to the headers in this database are defined in tables below:

FieldA1:C30	Description
ID	DB sequence number
Rd-prov	Province
Rd-name	Road
Pr-chain	Chainage of profile along road
Rd-refno	Unique road ref no.
Pr-cway	Carriageway width (m)
Pr-grad	Road gradient
Pr-curv	Horizontal curvature
Pr-sect	X-section shape
Pr-thck	Measured gravel thickness 1
Pr-thick2	Measured gravel thickness 2
Pr-Mat	Not used
Pr-grav1	Primary gravel type

Pr-grav2	Secondary gravel type
Pr-eros	Surface erosion
Pr-visap	Visual appearance
Pr-sfrun	Surface run-off
Pr-loos	Loose material
Pr-osiz	Oversize material
Pr-rut	Rutting
Pr-corrg	Corrugations
Pr-pthol	Potholes
Pr-swidl	Shoulder width left (m)
Pr-swidr	Shoulder width right (m)
Pr-smatl	Shoulder material Left
Pr-smatr	Shoulder material Right
Pr-sconl	Shoulder condition Left
Pr-sconr	Shoulder condition right
Pr-sdl	Side drain left
Pr-sdr	Siode drain right
Pr-dconl	Drain condition left
Pr-dconr	Drain condition right
T-dcp-1	DCP test ref no.
T-dcp-2	DCP test ref no.
T-samp-1	Sample no.

T-samp-2	Sample no.
Pr-Align	Cross-section type
Pr-wtab-c	Water table current
Pr-wtab-m	Water table maximum
Pr-flood	Road flood history
Id-Svydate	Survey date
Id- Svyteam	Survey team
Id-indate	Date input date
Id-update	Update
Id-verify	QA
Id-inby	Input by
Id-mem1	Memo (Vietnamese)

Field	Description
Rd-prop	Province
Rd-dist	District
Rd-comm	Commune
Rd-name	Road Name
Rd-refno	Unique reference number
Rd-contno	
Rd GPS Ref1	GPS Ref Start
Rd-co-ord1	Co-ord Start Latitude Deg, min, decimal min,
Rd-co-ord2	Co-ord Start Long. Deg, min, decimal min,
Rd-GPS Ref2	GPS Ref Finish

Rd-co-ord3	Co-ord finish Lat, Deg, min, decimal min,
Rd-co-ord4	Co-ord Finish long. Deg, min, decimal min,
Rd-type	MoT Designation RoadType
Rd-D-Thick	Gravel design thickness (mm)
Rd-terr	Terrain type
Rd-month	Months since construction
Rd-date	Date of survey
Rd-condit	General road condition
Rd-traff	Traffic
M-Cway	Carriageway width (m)
M-Shold	Shoulder condition
M-Ditch	Side drain
Id-indate	Data in-date
Id-update	Update
Id-inby	Operator
Id-verify	QA
Id-mem1	Vietnamese Memo

Database of Pavement Condition Monitoring of the Rural Road Surfaces Research. by J.R. Cook. OTB, and J. Rolt. TRL (2011).

The study was carried out in Vietnam, Cambodia, Laos.

The Rural Road Surface Trials (RRST) consisted of two main phases of trial construction between 2004 and 2006. 107 representative sections of between 80 m to 200 m length were selected for on-going performance and whole-life-cost monitoring. Key aspects of the two phases are as follows:

The RRST-I programme concentrated on four roads in the Mekong Delta and the Central Coastal area. Short lengths (100-200 m) of different pavement options were constructed on each trial road. Each trial road had, in addition, short lengths (100m) of control sections of unsealed road or penetration macadam sealed road.

The RRST-II programme was undertaken in a wider set of physical environments in the Northern Highlands, Central Highlands and the Red River Delta as an extension of the RRST-I programme. It involved much longer lengths of trial and control section, from 500 m to more than 2 km. The SEACAP 1 project included initial as-built condition surveys and some initial condition monitoring up to March 2007. The SEACAP 27 project was an extension of SEACAP 1 and was concerned primarily with the continued collection and analysis of pavement performance information from the RRST I and RRST II trial road sections. The sections were monitored up to August 2010.

The surfacings studied included Double Bituminous Surface Treatment (DBST), Penetration Macadam (Pen Mac), Hot Mix Thin Asphalt (HMTA), and Concrete.

The trial sections carried traffic up to 745 vehicles per day and up to 610 equivalent standard axles per day. Rainfall data for each specific site is not included and the user has to obtain this from other sources.

The monitoring focused on visual condition assessment only. The codes for the data in the database are shown below.

Codes for bituminous surfacings

Carriageway

Type	0	No cracks
	1	Crocodile
	2	Longitudinal
	3	Transverse
	4	Block
	5	Parabolic
Intensity	0	No cracks
	1	Single
	2	>1 not connected
	3	>1 connected
	4	Interconnected (crocodile)
	5	Interconnected (loose)
Position	0	No cracks
	1	Edge
	2	Wheel track
	3	Centre line
	4	All carriageway
Width	0	No cracks
	1	<1mm
	2	1-3mm
	3	>3mm
	4	Spalling/crumbling

Extent		Crocodile cracks	Other cracks
	0	No cracks	No cracks
	1	0-10%	<1m
	2	10-50%	1-5m
	3	>50%	>5m
Ruts		Maximum (mm)	

Additional

M	Maintenance required
R	Repair required

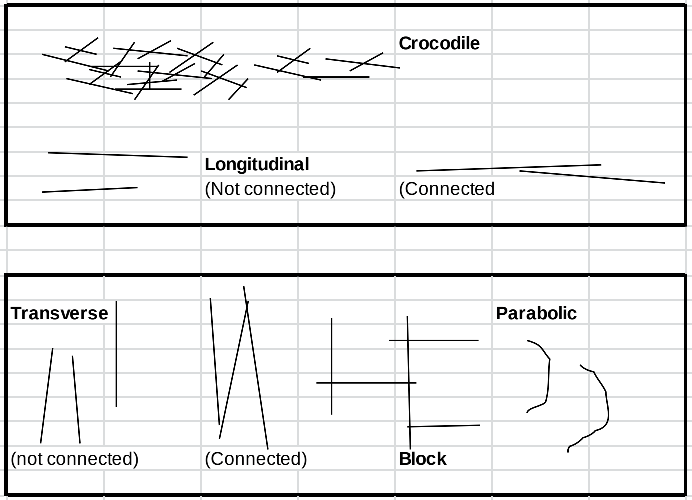
Carriageway

Potholes	0	None
	1	1
	2	2-3
	3	>3
Seal Loss Extent	0	None
	1	0-5%
	2	5-10%
	3	10-25%
	4	25-50
	5	>50%
Edge Failures >150mm	0	None
	1	0-10%
	2	10-50%
	3	>50%

Shoulder

Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure
Run-off	0	Unimpeded
	1	Impeded by crossfall
	2	Impeded by debris/vegetation

Carriageway Cracking



Drainage

Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Version F.1

Codes for concrete pavements

RRST Pavement Condition Monitoring
Concrete Pavement Condition Assessment
Condition Codes (Version LPDR.1)

SEACAP 1

Block Seals

Condition	0	Satisfactory
	1	Minor cracks (width <3mm)
	2	Severe cracking (width <3mm)
	3	Depressed joint seal
	4	Loss of seal

Cracks

Type	0	No cracks
	1	Crocodile
	2	Longitudinal
	3	Transverse
	4	Block
	5	Parabolic
Intensity	0	No cracks
	1	Single
	2	>1 not connected
	3	>1 connected
	4	Interconnected (crocodile)
	5	Interconnected (loose)
Position	0	No cracks
	1	Edge
	2	Wheel track
	3	Centreline
	4	All carriageway
Width	0	No cracks
	1	<1mm
	2	1-3mm
	3	>3mm
	4	Spalling/crumbling

Extent		crocodile cracks	Other cracks
	0	No cracks	No cracks
	1	0-10%	<1m
	2	10-50%	1-5m
	3	>50%	>5m

Additional

M	Maintenance required
R	Repair required

General Carriageway

Surface	0	Good
	1	Crazed cracking
	2	Surface stripping- aggregate exposed
Potholes	0	None
	1	1
	2	2-3
	3	>3
Edge	0	No deterioration Clean-sharp
	1	Minor degradation
	2	Cracking
	3	Block spalling

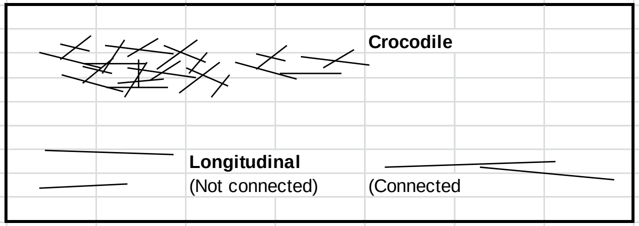
Shoulder

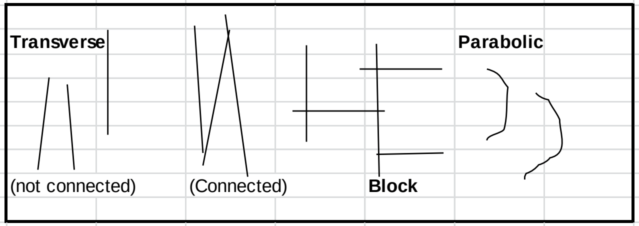
Cracks	0	No cracks
	1	Isolated individual
	2	Several individual
	3	Space interconnected (> 250mm)
	4	Close interconnected <250mm
	5	Severe crocodile/crumbling
Erosion	0	None
	1	Slight (material loss 5-20mm, area <10%)
	2	Moderate (material loss 5-20mm, area10-50%)
	3	Severe (material loss > 20mm, area>10%)
	4	Total (material loss > 20mm, area>50%)
	5	Shoulder failure
Run-off	0	Unimpeded
	1	Impeded by crossfall
	2	Impeded by debris/vegetation

Drainage

Condition	0	No side drain
	1	Good shape and level -clean
	2	Adequate shape and level - minor silting only
	3	Defects /silting evident but can function
	4	Significant defects/silting - drainage impaired
	5	Serious scouring/defects - no longer effective

Carriageway Cracking





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