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

Desk Study Report

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Abstract

This report covers the activities undertaken in the first period of the project on the Development of Guidelines and Specifications for Low Volume Sealed Roads (LVSRs) through Back Analysis from April to September 2016.

This desk study report includes a review of previously constructed LVSRs going back four decades. The activities included collection of data sources and information, assessment and preliminary analysis of the data sources, identification of a pool of key LVSR experts, and a workshop comprising in-depth discussion of the potential problems and solutions related to the identification and provision of data sources for analysis.

The report provides details of the project, the desk study activities which have been undertaken, and next steps related to the design and development of the database.

Key words

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

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John Rolt	Team Leader	Author
Kenneth Mukura	LVSRs Expert	Author
Tom Buckland	Data Specialist	Author
Andrew Otto	Research Engineer	Technical Reviewer
Mike Mayanja	Research Engineer, Uganda	Team member (data collection)

Regional Partners

Actor Zonde	Head of Research DoR, Zimbabwe	Supplied 11 documents on LVSRs research

Acronyms, Units and Currencies

AADT	Annual Average Daily Traffic
AFCAP	Africa Community Access Partnership
DFID	Department for International Development
DoR	Department of Roads
LVR	Low Volume Roads
LVSR	Low Volume Sealed Roads
MESA	Million Equivalent Standard Axles
MoTID	Ministry of Transport and Infrastructure Development
ReCAP	Research for Community Access Partnership
SFRDP	Secondary and Feeder Roads Development Programme

Contents

Executive Summary

The performance of road pavements depends on many factors; factors that differ from region to region and area to area, based primarily on soils, geology, materials, and climate. As a result, the engineering knowledge is neither comprehensive, in full agreement, nor sufficiently well known throughout Africa. Indeed, there are some apparently contradictory results that undermine confidence but illustrate the difficult nature of road performance analysis and the need for the widest possible data set covering the full range of conditions.

Many good research projects have been carried out over the past years by research organisations. Road investigations and trials have also been carried out by road authorities, universities, individual engineers and others. These projects have been reported in different ways and different places and many are considered to be extremely valuable resources that need to be brought together and made available to all. However, not all such studies have equal merit or are equally accessible.

The purpose of this project is to review these data sets and to 'capture' as much of this knowledge and the data on which it is based as possible. These data are to be made available to engineers, scientists and research workers to study, analyse and improve in the future and to enable comprehensive Regional Guidelines and Specifications to be updated and further developed and updated for low volume roads, making use of all proven innovations.

The review of data sources has identified numerous issues and potential problems with the data sources. The principal issues are:

Data format. Electronic format is straightforward but data from various forms of hard copy sources will be more difficult to extract and add to an electronic database. They will require considerably more effort to such an extent that a ranking and prioritisation methodology needs to be developed.

Data quality. There are very many data sources but only scientifically 'sound' ones will be entered into the database. Initially the reliability of data sources largely depends on the credibility and reputation of the authors but care should be taken to scrutinise the data and a more quantifiable classification scheme will be developed during the pilot phase of this project.

Data content and compatibility. Compatibility between variables has to be obtained if data sources are to be combined and analysed together. Authors use variables that differ substantially but comparisons and combined analysis can only be done if the variables can be related to each other. The problem is compounded by the use of a variety of different test methods and standards.

Good data sources and Pilot Study. 40 examples of good data sources were initially identified. A selection was made for the Pilot stage, initially comprising 15 data sources.

The selection and prioritisation of data sources is essential. It requires a good assessment of several aspects including *scientific quality*, *amount of data*, *range and scope*, and *ease of preparation for entry into the database*. Classification and analyses of these examples are being used to help develop a marking/ranking scheme that takes account of all of these issues. This is complex because each report is different and has different data sets. Also, the ranking scheme should cover unpaved and paved collectively or separately depending on which way is more appropriate. The methodology will evolve during the pilot phase.

1 Background

Road specifications have evolved over many years, largely driven by the requirements of increasingly heavy traffic. The performance and deterioration of high volume roads is primarily determined by the effect of heavy traffic and so the quality of construction and materials are paramount. Due to their substantial construction, most environmental effects, with the possible exception of major floods, have a relatively minor effect. In contrast, low volume roads (LVR) (defined as roads carrying less than 1 million cumulative equivalent standard axles during their design life) do not require material of such premium quality because the traffic is less damaging. However, the deterioration or performance of LVRs depends much more on prevailing environmental conditions. As a result of these differences, the design of LVRs requires a different approach to that of high volume roads.

1.1 Local Materials

The specifications for LVRs do not need to be as stringent as those for high volume roads and this means that local materials with low haul distances and lower costs can often be used instead. The challenge is recognising which materials are appropriate for the projected traffic growth and environmental conditions, and what the revised specifications should be. Engineers are somewhat cautious in making such decisions and will not normally do so unless there is ample proof that the specifications are satisfactory or are incorporated into reliable manuals.

Fortunately, as a result of research undertaken over many years involving trials of different materials and construction methods in a variety of environments, there is a great deal of data available to enable this approach to be used with confidence for many materials and many situations.

1.2 Rediscovering Techniques

There are also various techniques that have been tried and tested in the past that can be used when adequate roadbuilding material is not available. Techniques such as ‘armouring’ and ‘blending’ for example need to be publicised and demonstrated with scientific evidence that already exists.

1.3 Saving Resources

Relatively recent research has shown that despite initial costs being relatively high, whole life costing principles indicate that it is economically effective to provide a surface seal on unpaved roads carrying traffic even as low as 50 vehicles, annual average daily traffic (AADT). The depletion of good roadbuilding material is critical in many regions of Sub-Saharan Africa, so low cost surfacing will be vital in future for preserving the material that is still available.

1.4 Whole Life Costing

As part of the whole life costing exercise, the use of methods that fully quantify the dis-benefits of poor road networks on rural people have helped to demonstrate the importance of sealing roads, not only to preserve good roadbuilding material but in providing all year access.

2 The Project

There is a great deal of information concerning methods for reducing the cost of roads and making them more reliable that has been developed through specific research initiatives such as the DFID funded Research for Community Access Partnership (ReCAP) programme, research carried out by specialist research institutions, investigations of road failures by consultants, and other trials that may not have been reported in the engineering literature. It is the purpose of this project to capture as much of this information as possible, including the initial raw data that was measured and analysed in project reports and to preserve it in a form that engineers and researchers can access, review and use in the future.

Also, by including as much data from different sources as possible, the full range of all the factors that affect pavement performance can be quantified, giving rise to the possibility of combining data sets and carrying out some form of meta-analysis to capture all influences.

There are many factors that influence the performance of road pavements. Performance analysis is actually a rather difficult task and is often done poorly, for example, by simply identifying a component that is 'out of specification' even though this may not be the real cause of the problem, thus the nature of the project becomes apparent.

2.1 Project Phases

The final outputs will be generic guidelines and catalogues on LVSRs and a fully comprehensive database of information for use by research engineers in the future.

Once accomplished, the project will provide evidence-based guidelines which will be applicable in many countries in the region. This will aid the wider uptake of technology not only in ReCAP countries but many others too. This is in line with ReCAP's main objective of uptake and embedment of knowledge and technologies.

The project is in three phases:

Phase 1

- Review of previous studies
- Creation of a suitable database to store the data from previous studies
- Identify gaps in the knowledge base that may result in further research.

The outputs of Phase 1 are:

1. An inception report detailing the progress, challenges and recommendations associated with the delivery of Phase 1. This has been completed, submitted and accepted.
2. Setting up of a pool of experts in LVSRs for the project who will assist in the provision of data and information and provide technical recommendation for the Project Team.
3. A review of data sources is one of the main activities in Phase 1 and selection of those that can be included in the database.
4. A workshop comprising the pool of experts to identify actual and potential problems with the project and to develop solutions.
5. Development of the database itself.

6. An assessment of the scope of the data available and eligible for inclusion in the database and a gap analysis to identify what is missing and what can be rectified in Phase 2.
7. The final report with accepted methodology and plans for Phase 2 of the assignment.

Phase 2

- Field studies in up to 5 countries in Sub-Saharan Africa.

Phase 3

- Preparation of guidelines for LVSR and dissemination.

3 Pool of Experts

A pool of experts was engaged on the project to provide an in-depth understanding and historical knowledge of low volume sealed roads (LVSR). The key experts comprise:

1. Phil Paige Green
2. Mike Pinard
3. Tony Greening
4. Frank Netterberg
5. Gama Sibanda
6. Adekunle Olowosulu

The success of the project hinges on the collaboration of partners. In recognition of this, TRL has selected these key experts for the project based on their knowledge of previous research and access to available data through other organisations where extensive data is likely to be available. In addition, some experts have an extensive personal library and archive which is likely to be an excellent source of data going back many decades. Some of the experts were involved in key studies on LVSRs in the region, Tony Greening (in Southern Africa), Mike Pinard (in Botswana and Malawi etc.), Phil Paige Green (in South Africa) etc.

A meeting of the experts was held at CSIR in South Africa from 26th to 27th of September 2016. The meeting and its outputs are described in detail in Chapter 6 and the meeting is summarised in Annex A.

4 TRL Data Review

4.1 General Introduction

The performance of road pavements depends on many factors and the effect of some of these factors is extremely non-linear. If all factors are to be taken into account in a statistically designed factorial matrix for an experimental study, excluding replicate sections, it has been calculated that several thousand trial sections are required. Of course, all factors do not necessarily have a very strong effect and a smaller experimental matrix can be designed but the point is that fully understanding the behaviour of roads remains a formidable research problem. The largest ever controlled pavement performance experiment – the AASHTO Road Test carried out in the USA in

1960/61 only dealt with one subgrade and one climate. Many other studies of a much more limited scope have been carried out in the last 40 years. The point is that experimental studies of road performance with the objective of improving design and specifications can only deal with part of the problem hence the need for combining as much data as possible into a database that can be used for more comprehensive analysis to develop more robust and more applicable solutions.

Research for the purpose of improving the design and subsequently the performance of rural roads in Africa and SEA has often produced very good results but results that have relatively limited application because they can never be comprehensive enough to cover the required inference space. The consequence of this is that it has been difficult to incorporate the research results in official standards, specifications and manuals and to reap the benefits that ought to be available in terms of reduced costs and better performance. This project is aimed at improving this situation.

There are numerous problems that will need to be solved for the project to be a success. Those described in Chapter 5 are not comprehensive but just a starting point. The experts will be consulted and views canvassed to make sure all the key issues are being tackled.

4.2 Data Review

During the period whilst the pool of experts were being recruited and contracts agreed, TRL began a review of data sources. TRL's own data sources were accessed through the TRL library and Information Centre but the review also included many international studies. The review at this stage consisted of filtering out all the documents that contain data as opposed to the many documents that are very useful in themselves but do not contain data that can be added to a database and analysed further (i.e. manuals, guidelines, specifications and the like). The 257 documents comprising the comprehensive information source list in the *Low Volume Rural Road Surfacing and Pavements – A Guide to Good Practice by J R Cook, R C Petts and J Rolt* and another 80 documents were reviewed. The resulting list, which is not complete at this stage, is shown in Annexes B, C and D. Some of the data sources were reviewed in more detail to identify potential problems and some preliminary solutions proposed. These issues are described in Chapter 5.

The main issues that form an integral part of the review include, but are not limited to, the following:

1. Determination of the full set of parameters which need to be considered in the study.
2. Identification of sources of information which are likely to yield credible information and data which can be used for more detailed analyses for the development of guidelines and specifications for LVRs.
3. Collection and compilation of reports that provide data sets involving previous performance studies of LVRs and classifying the data sources as either 'back-analysis' projects or long term pavement performance studies (LTPPs) because the contents and therefore the data structure are rather different. The data sets should contain details of:
    a. Structural Design. It is one of the most important aspects of the project to determine appropriate pavement structures for LVRs for different levels of traffic loading and environments.
    b. Road building materials including non-conventional materials.

c. The geometrics design and drainage provision have a very strong influence on road performance.

d. Traffic is a primary causative factor in pavement performance. Limits for traffic for low volume roads have been derived, mainly through consensus. The project provides an opportunity for these limits to be derived scientifically and statistically.

e. Environmental factors, primarily rainfall, ground moisture. These data should be available in the study reports but may not always. However information may be obtained from ongoing projects including ReCAP projects in the area concerned.

f. Poor construction is, all too frequently, the main cause of much of the deterioration and premature failures experienced on low volume roads. It is anticipated that many projects will include such data but, if not, it is also possible to obtain such data at a later date through tests such in-situ density tests and DCP measurements and through sampling and laboratory testing. As part of the desk study, reports with these data will be noted for detailed review.

g. Poor maintenance. All roads require maintenance, some more than others. Therefore one of the biggest challenges faced by engineers when analysing road performance data is to determine how much deterioration is a result of the lack of the maintenance that could reasonably be expected. If possible it is desirable to quantify maintenance in some way to capture this effect.

There are also other data sets covered in the report which have been considered as part of the desk study, and the significance of their influence on the performance of LVRs will be ascertained in due course.

At this stage the desk study report is not exhaustive because more information will be considered as more documents and data are assessed and limited analysis is carried out with a view to segregating data and information which is either irrelevant or inaccurate and therefore cannot be used to populate the database. The meeting of key experts provided considerably more data sources, as described in Chapter 6 and Annex E.

The review of additional international data sources was one of the tasks to be undertaken by the key experts at the meeting on 26th-27th of September, and is described in Chapter 6.

5 Summary of Reviews – Preliminary Conclusions

5.1 Types of reports

There are many studies and many reports, both published and unpublished, that are accessible. Their usefulness covers a wide range and it is vital to classify them in such a way that the time of the project team is spent in the most productive manner. A robust classification system is required. As a first proposal, the following classifications illustrate the initial problem of accessing the data in a way that allows it to be entered into a database as easily as possible

Class A1 Data are in digital format. This is the easiest format but even recent data is not necessarily available in digital format.

Class A2 The data are tabulated in printed reports in a word processing format that allows almost instant translation to spreadsheets. A trial with a study that produced about 30 full page tabulations of the various types of data required about one man-day of effort to convert to spreadsheet format.

Class B Data available in non-electronic hard copy format that requires scanning to convert to electronic format. This should be relatively straightforward with modern character recognition programs for example, but is likely to require considerably more time for each document?

Class C Data may be available in digital format but may be too old to be accessed. Technology 'drift' has made old data storage systems obsolete.

Class D1 The data are comprehensive and of high quality but the published documents only record the data in the form of graphs and model equations, the original data being unavailable. Such reports are often very comprehensive in terms of the quantity of data but the data have already been fully analysed as far as the authors are concerned. The data are likely to be extremely valuable but accessing the basic data is a problem that may prove difficult to solve. A good example is the data set emanating from the studies that led to the HDM series of models and published in the mid 1980's from studies completed in 1981.

Class D2 Similar to Class D1 but the reports do not contain sufficient analysis for definitive models to be derived. The graphs within the reports are designed for illustration purposes, not for close numerical analysis. They can contain a great deal of data but it will be difficult to extract.

Most reports contain a mixture of data presentation methods. The easiest to use are those reports that include fully comprehensive data tables, usually as appendices.

5.2 Types of studies

There are a wide range of studies including factorial research studies ranging from monitoring performance from newly built to ultimate failure. The range includes performance studies of existing roads, accelerated loading studies, laboratory investigations, and road failure investigations. The first task is to understand the research study itself in order to ensure that the data are stored properly to prevent future errors.

Many studies are based on specific issues rather than general road performance, for example, comparisons of the performance of different surfacings. The data from such targeted studies may not be so easily amalgamated in a database to provide a wider range of data for a more comprehensive analysis but it is important to do so – missing data may be a problem.

5.3 Quality of Research Studies and Selection for Inclusion in the Database

Data quality is one of the most important characteristics of the data that must be evaluated for each source. Final selection of data to be entered into the database will depend on this evaluation. It is salutary to realise that these days at least 70% of papers submitted for publication to recognised research journals are rejected at review stage because some aspect of 'quality' is inadequate. Quality is judged in many ways for journal publication. In this project the important 'quality'

indicators will be different. Potential problems with data and its analysis are discussed briefly and a ranking scheme is proposed in Chapter 7 that helps to eliminate unreliable and inappropriate data from inclusion. However, comprehensively judging data sets is not the role of the compilers of the database. Such detailed review as may be necessary is the responsibility of the users of the database and forms part of their analysis role. This section is therefore primarily an awareness raising section that may be considered as a summary of the issues considered when reviewing data sets.

5.3.1 Data Range and Quantity

As part of the classification system to value each research study, the key variables in the study and their range needs to be identified. Data sets should include any studies where a basic minimum range and quantity of the key variables have been measured. This is not restricted to research studies. For example, investigations of existing roads for upgrading usually include analysis of performance, hence rehabilitation studies are potentially a source of good information. The minimum acceptable range and composition of each data set needs to be defined.

A recent analysis of a comprehensive research study revealed over 150 measured variables (excluding time series repetitions) for each road link. Many simply confirmed that a specification was met and probably had no bearing on the results of the analysis, but these data are essential for the database.

5.3.2 Variables used

A key problem with amalgamating data from different studies is concerned with the variables (factors) that have been measured and recorded and the measurement system used. Obviously many variables can be converted from one system to another (metric to Imperial, for example) but the problem is considerably more complicated than that. It may be that some similar studies that could benefit enormously from amalgamation will simply not lend themselves to amalgamation for one reason or another. In classifying different studies this problem needs to be addressed in the database design.

5.3.3 Data reduction

Published data should not consist of absolutely raw field data or data that have been more than partially analysed. There is an ideal level that researchers generally recognise but there are potential problems. For example, laboratory data sheets are usually worthless at the level of analysis that is envisaged but can often highlight inadequacies in measurements and therefore can be a pointer to data quality. Again, this is a feature that needs to be included in the classification of research studies and which could easily disqualify a study from consideration for inclusion in the database.

5.3.4 Statistical Problems

The most serious problems with data are concerned with statistical issues. They include sample size, identifying the most important variables, design of the experimental ‘matrix’ to include an adequate range of the variables, adequate control points, duplicate sections, dealing with missing cells in the experimental matrix, and statistical bias amongst others. In practice it is almost impossible to apply ideal statistical design for the kind of engineering studies that are being considered in this project. The researchers’ skills in identifying any serious deficiencies and coping with them is a key measure of the quality of the research. In particular, errors can arise by accident or through inexperience. For

example, statistical bias is part of a potential statistical problem and is fairly common in this area of research. The need for random samples is always emphasised in all statistical text books but the magnitude of its effect is not widely appreciated. Examining the properties of only long-term pavement survivors is a clear case of studying a very biased sample.

5.3.5 Cause and effect – false correlations

This is also a statistical issue. In many cases correlation does not mean causation. An example is the relatively common response to the question 'Why did this road fail early?' The answer may be simply that the specifications for some aspect of the design and construction were not met or, commonly, that the traffic exceeded the design value, but the problem may not be quite so straightforward. There are many examples of roads that did not fail even though one or more of the specifications were not met. Thus analysis of road performance is often complex and this adds considerably to the problem of judging the quality of the research. However this is mainly a problem for the database users provided that the data that is included in the database passes the criteria that form the core of our ranking scheme.

5.3.6 Precision of the measurements

The natural variability of tests such as Atterberg limits, CBRs etc. is sometimes a problem especially in contractual situations. A specification showing the acceptable ranges or, better still, averages/means and percentiles helps to solve this problem. This is also tied into the problem that only a few percent of a road needs to fail for the whole road to be of insufficient standard, thus average values of key variables are generally quite useless unless the average is highly correlated with the lowest percentile – usually a very unlikely situation.

5.3.7 The interactive effect of some material properties

Engineers try to cope with this (e.g. by combining PI with the percentage of fine material, i.e. PP and PM) but properties that do not cause a monotonic change in performance are rarely identified or used in practical performance analysis. A good example is permeability. Permeable may be good, impermeable may also be good, but in between there are likely to be problems.

5.4 Summary

The main point here is that the time spent by the average reviewer of reports for publication is often not sufficient to identify the possible problems with the research. During the first phase of this project it is not intended that detailed problems associated with the data itself and its analysis will be addressed. This is the role of the users of the database. However there is no reason why helpful information concerning how the data were judged as suitable for inclusion in the database should not be included in the user's manual.

6 The Expert Workshop

A meeting of the key experts was held at CSIR in South Africa from 26th to 27th of September 2016. There were some specific requirements for the workshop, for example, the identification and provision of data sources, but much of the workshop comprised brainstorming and the identification of possible problems and solutions. The minutes have been loosely organised and there is also some

natural overlap between topics. Many issues were addressed and principal resolutions and conclusions summarised in the following table.

Items/Issues	Deliberations	Comments
1 Welcome by Chairperson		
	The Chairperson welcomed all participants to the workshop and thanked all for making time to attend and contribute to the project.	
2 Brief by the Chairperson		
	The Chairperson introduced the project and emphasised its importance for ReCAP. i. A great deal of data have been collected and there is a need to capture these data for use now and also for future generations. ii. It is understood by the Client that the project is difficult and a pool of experts is needed. iii. The project provides an opportunity to bring all the experts on low volume roads together. iv. The database which will be produced will be a repository for research data for ARTREF and research work for the upcoming Road Research Centres. v. The Draft Review Report produced by TRL will be finalised based on the outputs of the workshop. vi. John Rolt was requested to make a presentation and highlight all the issues which needed to be discussed.	The participants agreed that the project was complex but it is important to work with what is available.
	CSIR Data. Benoit Verhaeghe confirmed that data from CSIR are available but, when moving to the current building, documents in hard copies were stacked in boxes and not in any particular order so finding any reports would require significant effort.	
3. Presentation by John Rolt	Details	
	The presentation outlined the project and introduced the issues arising from the preliminary review of data sources outlined in Chapter 4 and 5 of the Draft Review Report already forwarded to the expert pool: i. There is a great deal of information about reducing the costs of roads and making them more reliable that has been developed through research studies carried out principally by specialist research institutions, consultants, and academic institutions ii. The project involves the collection of available data on the performance of low volume roads and its inclusion in a database designed for this purpose. This will make it possible for more comprehensive analyses to be carried out enabling the effects of the full range of factors which influence the performance of LVRs to be quantified.	

	iii. The project consists of 3 Phases. The key outputs of Phase 1 include: • Recruitment of a pool of experts to help with the sourcing of data and review of documents. • Creation of a suitable database. • Knowledge gap analysis which may lead to further research under Phase 2. • Partial analysis of data. • Proposed methodology for carrying out Phase 2. The following progress has been achieved: i. The pool of experts has been recruited. ii. A preliminary (sample) list of data sources from TRL has been assembled. iii. A preliminary (sample) list of International data sources has been assembled. iv. Some of the data sources have been reviewed in detail, some potential problems have been identified and some preliminary solutions proposed.
4 Initial Discussions and Actions	
	i. The list of data sources now needs to be completed with sources of data available to the pool of experts. ii. The data sources which should be used for the project should cover key issues, subject areas and topics and should have a geographical balance. iii. 40 examples of data sources were initially identified at the meeting (listed in Annex E). iv. A Pilot Phase is required with a limited number of good data sources (class A – Chapter 5) which will be used to develop the architecture of the database, identify problems and develop solutions. v. A selection of data sources was made for the Pilot stage, initially comprising 15 data sources. Annex E. vi. Summary spreadsheets are being compiled and now a classification scheme needs to be developed. This will evolve from the pilot study. vii. The architecture of existing databases should be reviewed. Examples include: • Bill Paterson's HDM4 Database. (Phil has the Excel version of the database but it is 25 years old) • SEACAP Database (Jasper Cook has a copy). John R is scheduled to meet Dr Cook for this purpose on 30th September
5 Detailed discussions Part 1	Concerned with problems already identified in the draft Review Report and new issues raised at the workshop.
Reviewing, Evaluating, Prioritising and Selecting Data Sources	The selection and prioritisation of data sources is an inherently difficult and time consuming exercise. It requires a good assessment of several aspects including *scientific quality*, *amount of data*, *range and scope*, and *ease of preparation for entry into the database*. It is necessary to develop a marking/ranking scheme that takes account of all the characteristics listed here in order to prioritise the data sources. This is complex because each report is different and has different data sets. Also the ranking scheme should cover unpaved and paved collectively or separately depending on which way is more appropriate. The methodology will evolve during the pilot phase.
Identifying difficulties of 'manipulation' of the data sources.	• The first step is an efficient evaluation system that will quickly identify the level of staff input required for each data source. This will depend on the type and scale of the problems.

	• The pilot study will provide the experience to develop a methodology for this task. • There will be anomalies which may be difficult to resolve unless the authors of the reports are available to explain. This will be a big challenge especially regarding old reports where the authors are no longer accessible. • Ultimately 100 reports are thought to be a realistic target.
Using Data Sources	• Data that is already in digital format should provide the least problems. • Digitising hard data into Excel format is done by scanning (optical character recognition (OCR) software) and can be time consuming because of the need for thorough checking to correct errors. • Old data may only be in obsolete electronic formats and may not be recoverable. • Other data formats are discussed briefly in Chapter 5.
Data Quality	There are very many data sources but only scientifically 'sound' ones will be entered into the database. Initially the reliability of data sources largely depends on the credibility and reputation of the authors but care should be taken to scrutinise the data and a more quantifiable classification scheme will be developed during the pilot phase. Good statistical practices are essential for good science. The complication is that there are many variables and many possible sources of error in analysis. The reviewers will need to be very vigilant.
Data Compatibility and Test Methods	Compatibility between variables has to be obtained if data sources are to be combined and analysed together. A prime example is road deterioration parameters. Authors use variables that differ substantially but comparisons and combined analysis can only be done if the variables can be related to each other. • The problem is compounded by the use of a variety of different test methods and standards. • It is important for the database users to find or develop correlations between test methods so that data from different sources can be correlated or reduced to the same standards, but how can this be done? • It is also important that the significance of the differences in test methods and the magnitude of differences in the test results are known because some will not be significant. • This is an important problem but how can it be resolved? Should the user's manual be used to provide expert help? • The general view was that provided the data sources explain the variables used and how they were measured then it is the responsibility of the users of the database to resolve compatibility issues.
Responsibility for data	The level of responsibility over the quality of the data which will form the database could be an issue in the future when users start accessing the database. How much responsibility could or should TRL and ReCAP have? It was decided that there would be no responsibility on the part of TRL and ReCAP but efforts should be made to check the data so that whatever goes into the database is as accurate as it would be if a journal were to publish it. A disclaimer will be required.
Scope of Data	There is need to make sure that the data sources have enough coverage of parameters therefore an assessment of what is covered in each one is a good idea but somewhat time consuming. A research matrix can be used for this. However, the parameters are very many. An example was shown to the participants on the magnitude of the set of parameters which was over 150 and yet the set was incomplete. Identifying gaps may be difficult.

	General Classification of data sources. a. Report type - general, specific, targeted, laboratory only etc. b. Data range and quantity. c. Reliability –What limits do we set? d. Variables used and conversion (both test method issues and variable definitions) e. Data reduction – how much has been done and can we trust it? How? f. The most serious problems are arguably statistical in nature – omitted variables, bias, and false correlations (cause and effect issues), interactive effects, two valued (not changing monotonically) plus more. g. Age – reports from a period covering 4 decades.	
Users manual	Gathering ideas for the user manual should be .a continuous process	
6 Discussions Part 2		
a. Parameters for LVRs	The parameters for LVRs should be properly defined. This will affect the selection of the reports.	For defining a LVR it was concluded that loading in terms of Equivalent Standard Axles (ESAs) should be the main parameter and traffic volume is not necessarily important.
b. User manual and guide for the database	The preparation of the user manual for the database is one of the key outputs of the project and it is important to review any such manuals which may be available.	It was suggested that Phil Page Green, Dave Jones and Jasper Cook could be consulted on this matter for information and guidance.
c. Nature of the database	The database will be large but that is the nature of many databases. They are designed to handle this. The following suggestions were made about the nature of the database: i. May need to separate LTPP and Back Analysis Projects ii. May need to capture the models and test methods. iii. There may be a need to enter information which qualifies the data e.g. TRL/Kleyn equation for DCP-CBR relationship. iv. There will be a need for data on preconstruction, design and construction where possible.	These requirements were generally accepted. The test data should be accompanied by the test methods unless good correlations are available.
d Accessing information in the database	Easy accessibility of information from the database is a major factor. There were detailed discussions on the various options.	It was concluded that the database should be web-based and multi-layered. Accessing information or data sets would be through queries and key words.
7 The Way Forward		
Providing data sources for TRL	Members of the pool of experts were requested to supply TRL with reports and documents asap.	Some of the reports were transferred to TRL electronically from the pool of experts. Other information and

		reports will be sent electronically by email or in Hard Copies (Mike Pinard will send reports from Botswana by courier) but these will need to be returned.
Rolling out the database	It was suggested that initially TRL should populate the database and then roll it out.	TRL will populate the database. TRL may need to liaise with Client should the estimated time to do this be too constrained.
Inclusion of data from current ReCAP projects	There is a lot of data being collected from many ReCAP projects including the monitoring of trial sections that will need to be captured in the database but much of this will necessarily take place at a future date when it becomes available.	There is need to standardise data collection to ensure synergies in the data format.
Expertise required in populating the database	A question was asked on the level of expertise that is required for populating the database.	Considerable expertise is required for sorting out the data and solving the problems raised in this review and in the workshop. Once this has been done properly (often quite difficult) there is no need for special expertise in converting existing data to digital format and entering it in the database.
Compatibility of the database to others.	It was suggested that there is need to ensure compatibility with other existing databases such as the SEACAP LVR database.	John Rolt is to meet with Jasper Cook on the 30th of September 2016 and one of the key areas of discussion will be the SEACAP database.
Information within countries	There is a lot of information within countries from research and rehabilitation projects including ReCAP research which will need to be accessed.	TRL will need to liaise with Leta particularly on information which can be obtained from AFCAP Countries.
Information from West Africa (Nigeria and Ghana)	West Africa was not represented in the Workshop. However, a key expert, Dr Adekunle Olowosulu from Nigeria has been secured for the pool of experts and he has indicated that he has information and data from West Africa. Also Dr. Osei Bonsu from Ghana should be a good source.	TRL will request these and other sources from West Africa to provide LVR data.
Finalising the Desk Study Report	The Chairperson recognised that a lot of work had been accomplished by TRL but this had not been reflected properly in the Desk Study Report.	TRL was requested to finalise the Desk Study Report, provide more detail in the report and submit by the 5th of October 2016.

The expert team also debated other issues that are recorded here.

Other technical matters	Details	Conclusions/Recommendations

a. Subgrade strength criteria – Fatigue failure theory	There was a question about whether subgrade stress/strain relationships apply to LVRs. Are the stress and strains not mostly below the threshold which is required to effect fatigue failure of the subgrade layers? The background to this issue is that little or no fatigue related subgrade failure has been observed on LVRs	It was concluded that this area needed further investigation but indications are that the subgrade stress/strain relationships are not appropriate in the design of LVRs except such roads which are in special circumstances such as logging or quarry roads.
b. 4^{th} power law	There are schools of thought that believe the exponent in the equation should be less than 4.5 for LVRs - 3 and 2 have been suggested. Some studies on this were sited. It was assumed that the exponent of 4.5 leads to overdesign.	There was no concrete conclusion on this issue. The exponent is an indirect measure of the damaging factor of an axle load in comparison to that of a standard axle of 80kN and is therefore not a fundamental unit of deterioration. Also, a higher exponent leads to low ESA's if the majority of the loading is less than 80kN. This needs to be explored further.
c. Geometric Design standards vs traffic volumes	The background to this was to try and save on construction and maintenance costs by reducing the widths for LVRs. The frequently-used current limit of a maximum AADT of 300 is too low and could be much higher. An example was given of a road in UK with a width of approximately 6m carrying AADT of 14,000 (but a long and perfectly straight road with extremely good sight distances and no large trucks because alternative routes exist). Thus 'functionality' is a key aspect.	It was concluded that road width should be influenced by traffic mix. Where non-motorised traffic or motor cycles are significant, then the road width should be accommodating but, in general 5.5m may suffice.
d. Carbonation of cement-stabilised materials	Carbonation occurs and this is the general agreement. However, there are cases where carbonation occurs and the strength of the layer does not decrease significantly enough to result in failure. The original message was that carbonation was detrimental to road performance. Examples of research carried out by Frank Netterberg were cited.	It was concluded that further deliberations and research were required to determine circumstances where carbonation would have adverse effects.
Closure	Details	Conclusions and recommendations
Closing Remarks of the Chairperson	The Chairperson thanked those present for making time to come and participate in this important workshop and that, as the Chairman and Client he was satisfied with the proceedings and the outcomes of the workshop. There being no further issues to discuss he closed the meeting at 1100hrs on the second day (27^{th} September 2016).	It was agreed by the participants and the Chairperson that workshops of this nature were very important and should be held more often. The Client would consider additional workshops of this nature for this project.

7 Data Source Marking Scheme

A tentative marking scheme has been devised for classifying research documents but it is very preliminary at this stage. No comments were made about this at the workshop.

Property	Definition	Scoring	Weighting	Max Score	%
Age of road (years) at measurement date	>10	10	7	70	20
	6- 10	7			
	3-6	5			
	<3	2			
Type of data	Electronic	10	10	100	29
	Word Tables	9			
	Graphs + models	4			
	Graphs	2			
Quality Assessors judgement	H= High	10	8	80	23
	M = Medium	7			
	L = Low	3			
Quantity Overall Size of Study	H = >15 sections	10	5	50	14
	M = 5-15	7			
	L <5	3			
Statistically Robust (can 10 percentile be defined	Yes	10	5	50	14
	Average only	5			
	No	1			

8 Responsibilities

It is the responsibility of the project team to provide guidance for users of the database, hence a user's manual is required, but how far that responsibility goes is a matter of debate and has been discussed at the workshop (Section 6). So far it has been assumed that the project team will categorize the data based on an assessment of scope, range of data, completeness of data, statistical reliability and so on ranging down to information that may simply rest on value judgements.

Another option is to rely on the judgement of the journals and their reviewers who have approved publication but experience of that approach is not very positive even though, for some well-known journals, about 75% of submitted papers are actually rejected because of poor quality.

Experience indicates that to understand and analyse data collated by others can be difficult and time consuming. End-users of the project database will face this issue and as much help as possible should be provided in the users manual.

It was agreed that neither TRL nor ReCAP could be responsible for guaranteeing the quality of the data and a suitable disclaimer will be provided.

9 Database Architecture

Development of the database is the next task to be tackled now that the data sources to be used in the pilot phase have been identified. Preliminary thoughts have been described in the Inception Report and are repeated here for convenience.

The key to developing a database is accessibility of the data to a range of stakeholders. Without enabling a range of users (both in terms of expertise and geographic locations) to access the data, any use of the data will be severely restricted. Therefore, proper planning and design of the system at this stage will help to identify a sustainable solution going forwards.

There are a number of options for the database platform:

1. Standalone system
    a. Local database: In this case the system and the database would need to be installed on each local machine of every user.
    b. Hosted database: Here the interface would be installed locally on each machine of every user but there would be one central database hosted on a server accessible to all.
2. Web-based: In this option both the system interface and the database would be deployed on a server.

It is proposed that the system will be developed as a web-based tool that allows a user to interact with it through a web-browser. Therefore no specific software will need to be installed locally by users of the system; all they will need is an internet connection and a web-browser. One advantage of the web-based solution is that there is only one version of the database available to every user and so all users will be accessing the same data. A further advantage of the web-based solution is that any updates to the software (e.g. changes to the interface) can be rolled out in one central location, which will then be available to every user simultaneously.

While the database should be available for all to interrogate, there also needs to be restrictions on who can populate the database and who can edit it therefore several levels of authority will be required.

Figure 1 shows the proposed development structure for the complete system. It is proposed that the tool will be developed in Visual Basic .NET. The database platform proposed is SQL Server Express which is a freely available version of SQL Server with no licencing costs associated with it. Both the software and the database will reside on a server.

The database will store all the entered data from previous (and future) studies. In addition, it will be used to hold the export of data for external analysis in other software (e.g. export to .csv format). There will be a two-way flow of data between the middleware (objects and rules) and the database. The business layer will process any calculations within the tool. Any outputs and calculations will be fed to the user interface.

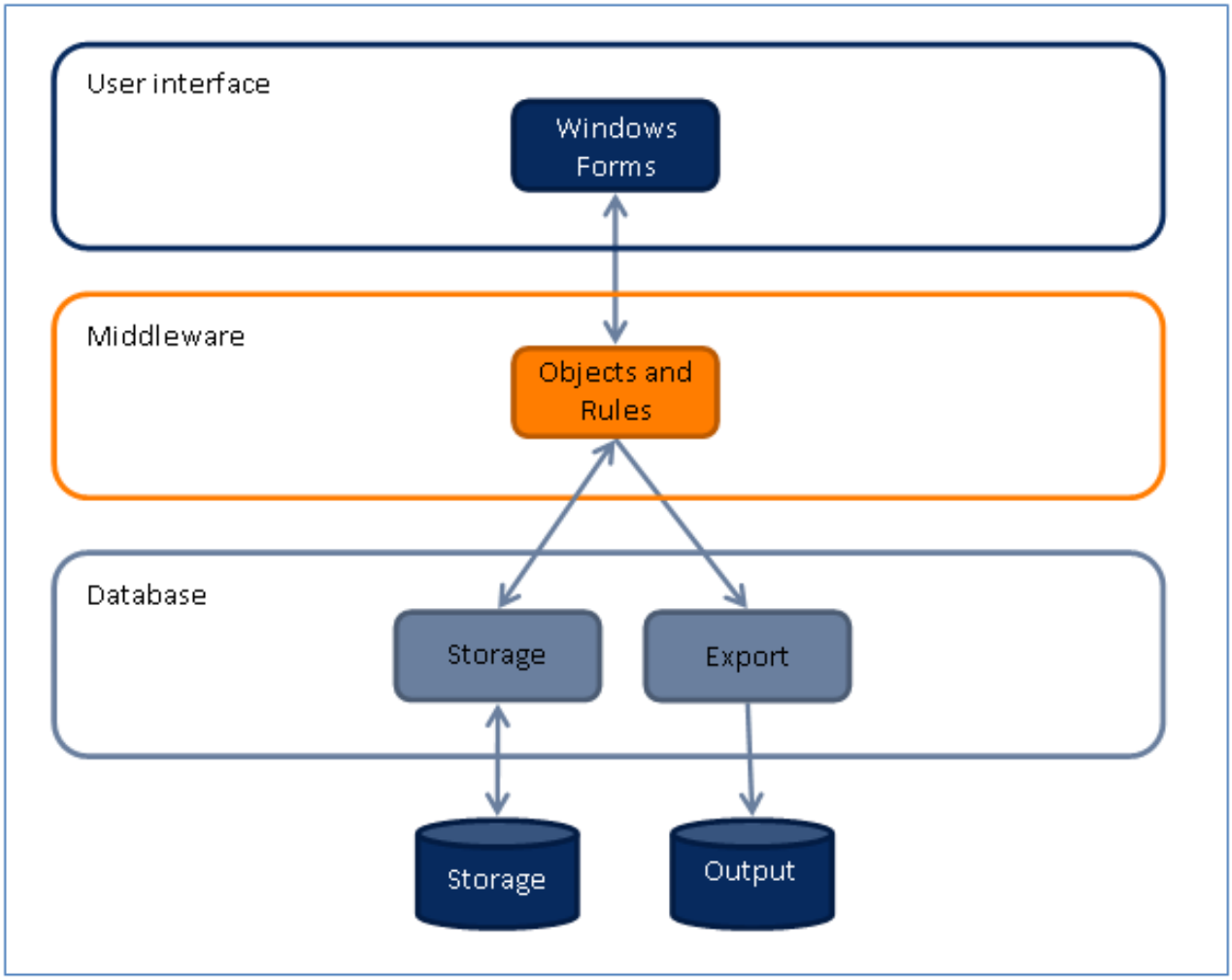

Figure 1. Proposed development structure

10 Concluding Remarks

This report is of the desk study which comprises a major part of Phase 1 of the project, consisting of the following:

1. Establishment of a pool of LVSR experts who will assist in the provision of data and information, and provide technical advice to the Project Team. A workshop comprising the pool of experts to identify actual and potential problems with the project and to develop solutions is described in this report. This was an essential component of the desk study and the workshop outcomes form part of this review.
2. A review of data sources and selection of those that can be included in the database. This review is the subject of this report.
3. An assessment of the scope of the data available and eligibility for inclusion in the database and a gap analysis to identify missing data to be investigated in Phase 2. This is ongoing with the accumulation of data sources and is also discussed herein.

The next steps involve an exploration of existing datasets and the design and development of a database that will be compatible for all data types, and populated with sample data as a pilot study.

Annex A: Pool of Experts Workshop

Venue: CSIR, Pretoria, South Africa
Date: 26th and 27th September 2016

1 Participants:

	Name	Organisation	Role	Contact
1	Les Sampson	ReCAP/PMU	Chairperson	Les.Sampson@cardno.uk.com
2	Nkululeko Leta	ReCAP	PMU	nkululeko.leta@cardno.uk.com
3	Mike Pinard	InfraAfrica	Expert	mipinard@global.bw
4	Phil Page Green	Private Consultant	Expert	paigegreenconsult@gmail.com
5	Tony Greening	Private Consultant	Expert	tonyk.greening@sky.com
6	Gamalihle Sibanda	Private Consultant	Expert	gamasibanda@gmail.com
7	Frank Netterberg	Private Consultant	Expert	fnetterberg@absamail.co.za
9	Benoit Verhaeghe	CSIR	Host	bverhaeg@csir.co.za
10	John Rolt	TRL	Team Leader	jrolt@trl.co.uk
11	Kenneth Mukura	TRL	LVRs Expert	kmukura@trl.co.uk

2 Apologies:

1. Andrew Otto – Senior Research
2. Adekunle Olowosulu – Private Consultant – Pool of Experts (West Africa)
3. Tom Buckland – TRL- Data Specialist (Database)
4. Michael Mayanja – TRL – Data Specialist/Researcher (Database)

3 Agenda:

1 Personal Introductions

2 Introduction to RECAP

3 Introduction to the project and workshop

4 Classification of research reports and data sources to identify the best material for inclusion in the database. How to evaluate:

- (i) Data range
- (ii) Data quality
- (iii) Data reliability
- (iv) Statistical validity

5 Responsibility for data 'quality'.

6 Format for providing the database specialist with data.

7 Role of the pool of experts

8 Next steps

9 Closure

The details of the workshop are presented in Chapter 6.

Annex B: Sample of TRL Data Sources

Project	Project/Subject area	Date	Publications	Authors	Report	Notes
No					**Available**	
1	Performance of calcrete gravel and paved roads in Botswana	1980-90	The development of specifications for the use of calcretes on lightly trafficked roads in Botswana	Lionjanga, Toole and Greening, Transport Research Record 1106 Vol 1 1984	TRL Library	
			The use of calcretes in paved roads in Botswana.	Lionjanga Toole and Greening. Soil Mechanics and foundation Engineering Conference for Africa, Lagos 1987	TRL Library	
			Laterites in Road Pavements	J H Charman. Construction Industry Research and Information Association (CIRIA/ TRRL) 1988	Yes	Contains useful data
			Evaluation of weak aggregates for surface dressing low-volume roads	Woodbridge Newill and Greening Tranportation Research Record 1291 Vol 2. 1991	Yes	
			Calcrete in road bases in the Kalahari region of southern Africa	Greening and Rolt PR/ORC/081/96, Transport Research laboratory	Yes	Lab and performance data
2	Sweroad Secondary and Feeder Roads project in Zimbabwe	1990 – 96	The design and early performance of the paved roads in the Secondary and Feeder Roads programme Zimbabwe	O'Connell Gourley and Greening PR/ORC/552/95. Transport Research Laboratory	TRL Library	
			Material properties and design of gravel roads in the secondary and feeder roads programme Zimbabwe	Gourley and Greening PR/ORC/552/95. Transport Research Laboratory. 1995	TRL Library	
3	Collaborative research programme on highway engineering materials in the SADC region	1994 – 2000	Use of sub-standard lateritic gravels as road base materials in southern Africa	Gourley and Greening. International Symposium on Thin Pavements. Surface Treatments and Unbound roads. University of New Brunswick, Canada. 1997	TRL Library	
			Establishment of information systems for managing road construction material resources in southern Africa	Gourley and Greening TRL Project Report PR/OSC/170/99 Transport Research Laboratory. 1999.	TRL Library	
			Performance of chemically stabilised road bases.	Greening and Gourley. TRL Project Report	Yes	Data in

			Results and recommendations from studies in Southern Africa. Environmental damage from extraction of road building materials. Results and recommendations from studies in southern Africa.	PR/OSC/168/99. Transport Research laboratory. 1999 TRL Project Report PR/OSC//169/99. Transport Research Laboratory. 1999	 Yes	appendices
	Research project on natural and stabilised materials used in road bases in southern Africa	1980-90	Performance of low-volume sealed roads. Results and recommendations from studies in southern Africa. Environmentally Optimised design.	Greening and Gourley TRL Project Report PR/OSC/167/99 Transport Research Laboratory 1999. Gourley, Hine and Greening PR/INT/183/00 Transport Research Laboratory 2000	Yes	Data in appendices
4	Research on the increased application of labour-based technology through appropriate standards roads Ethiopia Ghana Lesotho Mozambique Uganda Zimbabwe	1998-2006	Performance of labour-based gravel roads in Lesotho Minimising the cost of basic rural access Increasing the skills of labour-based contractors through the transfer of appropriate surfacing technology. New approaches to the provision of all-weather access at relatively low levels of traffic.	Morosiuk, Mukura and Elsworth Unpublished TRL Project Report 2006 Gourley, Done, Elsworth and Greening PR/INT/184/00. Transport Research laboratory. 2000 Gourley, Tournee and Greening. First Road Transportation Technology Transfer for Africa. Arusha, May 2001. Greening. 11th Regional seminar for labour-based practitioners Mombasa Kenya October 2005.	Yes TRL Library TRL Library TRL Library	Materials and monitoring data
5	Appropriate surfacing for low-volume roads	2001-3	Manual for the construction of labour-based surfacing on low-volume roads	Project Reference R7470. 2003	TRL Library	Data
6	Development of the SADC Guideline for low - volume sealed roads	1999 – 2006	SADC Guideline: Low-volume sealed roads New approaches to the provision of low-volume roads in the SADC region of Africa. New approaches to the provision of all-weather access at relatively low levels of traffic	Various authors and contributors Southern Africa Development Community. Revised version July 2006. Greening, Pinard, Gourley and Overby. Seminar on sustainable access and local resource solutions, Siem Reap Cambodia Nov 2005 Greening.	Yes TRL Library TRL Library	Summary data

Annex C: Sample of International Data Sources 1

The details are not all completed as the document goes to press. There is also some overlap with Annex D.

No.	Report Reference	Authors	Year of publication	Age at study date	Data type	Quality	Size of study	Statistically Robust	Title and Other	Country
1	Proc. Int. Conf. on Eng. in Tropical Terrains, Malaysia	Allan D.P., Chant C. & Thomson R.R.	1989						The use of calcareous and volcanic ash soils in road construction in Papua New Guinea.	
2	Special Publication 47	Charman J H	1988						Laterites in Road Pavements	All
3	SEACAP 3 Pavement Options and Technical Specifications	Cook J R et al.	?						Low Volume Rural Road Standards and Specifications Part II	
4	SEACAP 27 Final Report	Cook J R and J Rolt	2009						The Rural Road Surfacing Research Database	Vietnam
5	SEACAP 3 Application of LVRR Standards and Specifications	Cook J R et al.	2008						Low Volume Rural Road Standards and Specifications Part III	Lao
6	TRL Project Report PR/INT/205/2001	Cook J R, E C Bishop, C S Gourley, N E Elsworth	2001						Promoting the use of marginal materials	All
7	SEACAP 19 Final Project Report	Cook J R, J Rolt et al.	2009						Rural Road Standards and Specifications	Cambodia
8	SEACAP 4 Final Report	Cook J. R. & Petts R.C.	2005						Rural road gravel assessment programme. SEACAP 4, Module 4, Final Report. DfID Report for MoT,	Vietnam

									Vietnam.	
9	SEACAP 27 Technical Report 2	Cook J.R.	2009						The rural road surfacing research (RRSR) database: A summary of structure and content. Report to DfID to MoT, Vietnam.	Vietnam
10	SEACAP Technical Paper	Cook J.R., Rolt J., Dzung B.T. & Tuan P.G.	2008						A case study of the premature failure of a trial road in Dak Lak province Vietnam. .	Vietnam
11	Proceedings of Annual Transportation Convention, Pretoria, RSA	Emery S J, Van Zyl G D, Van Huyssteen S & Sampson L R	1991						Peformance limits for bituminous surfacings on low volume roads.	RSA
12	REAAA ???	Faustino R.P., Caeg N., De Guzman A.C., O'Connell M.J., & Rolt J.	2006						Performance of stabilised sub-base trials in the Philippines.	Philippines
13	TRL Project ReportPR/OSC/167/99	Gourley C S and P A K Greening	1999		√			10	Performance of low-volume sealed roads. Results and recommendations from studies in southern Africa.	Zimbabwe, Malawi, and Botswana
14	Nat Symp. On Thin Pavements, Surface Treatments and Unbound Materials, Canada	Gourley C.S. & Greening P.A.K.	1997						Use of "sub-standard" laterite gravels as roadbase materials in southern Africa. .	Southern Africa
15	PR/ORC/552/95	Gourley, C S and P A K Greening	1995						Material properties and design of gravel roads in the secondary	Zimbabwe

									and feeder roads programme Zimbabwe	
16	TRL Project Report PR/OSC/168/99	Gourley, C S and P A K Greening	1999		√			10	Performance of chemically stabilised road bases. Results and recommendations from studies in Southern Africa.	Zimbabwe, Malawi, Botswana
17	PR/ORC/552/95	Gourley, C. and Greening, P.A.K.	1995						Material properties and design of gravel roads in the secondary and feeder roads programme Zimbabwe	Zimbabwe
18	4th In Conf on Low Volume R TR 1106 TRBoads	Grace H and D G Toll	1987						Recent investigations into the use of ploastic laterites as bases for bituminous surfaced low volume roads	
19	Int Symp. On Thin pavements, Surfacing and Unbound Roads. Canada	Greening P.A.K. & Rolt J	1997						The use of marginal materials for road bases in the Kalahari region of southern Africa.	Southern Africa
20	TRL PPR686	Greening, P.A.. and Rolt, J.	1995 and 2015		√	10	10	10	Calcrete in road bases in the Kalahari region of southern Africa	Botswana
21	Design Report. AFCAP Project Report KEN/89	Hongve J	2012						Research project for establishment of appropriate design standards for low volume sealed roads in Kenya:	Kenya

22	SEACAP 1 Final Report	Intech-TRL	2006						SEACAP 1 Final Report (3 vols). DfID Report for MoT, Vietnam.	Vietnam
23	SEACAP 8. Cambodia low cost surfacing. Phase 2. Final Report	Intech-TRL	2006			10	10	10	SEACAP 8. Cambodia low cost surfacing. Phase 2. Final Report for DFID	Cambodia
24	?	Janoo, Cortez et all. Full working papers available	2007		10	10	10	10	Pavement subgrade performance study: Final Report. US Army, Washington DC.	
25	REAAA Conf. Malaysia.	Jones C.R., Tan Fah Mee & Hasnar R. I.	1990						Early performance of slurry seals used for paved road maintenance in Malaysia.	Malaysia
26	TRL LR 1111	Jones T.E.	1984			10	10	10	The Kenya maintenance study on unpaved roads research on deterioration.	
27	TRL Report PA1181_1987 and Proc 4th Conf on Low Volume Roads. TRB	Lionjanga, A. Toole T, and Newill D.	1987						The development of specifications for the use of calcretes on lightly trafficked roads in Botswana	Botswana
28	TRL Report PA1185_1987	Lionjanga, A. Toole, T. Greening, P.A.K.	1987						The use of calcretes in paved roads in Botswana.	Botswana
29		Morosiuk G and T Toole	1997						Review of research on the deterioration of unpaved roads	All

30	MTRD Construction Report Wamwangi - Karatu Rd D379	MTRD	2014						Pavement monitoring Report	Kenya
31	MTRD Report 1229 Wamwangi - Karatu Rd D379	MTRD	2014						Pavement monitoring Report 1229	Kenya
32	AFCAP/MOZ/001/GCPR1612	Mukura K, Rolt J, Dangare F, Otto A.	*2015*						Back Analysis of Previously Constructed Low Volume Rural Roads in Mozambique	Mozambique
33	CSIR Report 286	Netterberg F	1971						Calcrete in Road Construction	Southern Africa
34	WP/OU/107/1981	Newell, D. Toole, T. Stewart, M.	1981						Use of calcretes for road construction. Construction of a full-scale experiment	Botswana
35	9th Reg Conf for Africa SMFE Nigeria	Newill D., Robinson R. & Kassaye Akilu	1987						Experimental use of cinder gravels on roads in Ethiopia.	Ethiopia
36	TRL WP/OU/107/1981	Newill, D. Toole, T. Stewart, M.	1981						Use of calcretes for road construction in Botswana: Construction of a full-scale experiment	Botswana
37	TRL Research Report 381	Parry J D, Hewitt N C, & Jones T E.	1993						Concrete pavement trials in Zimbabawe.	Zimbabwe
38	HDM Series IBRD	Patterson W D O	1987		4	10	10	10	Road Deterioration and maintenance Effects	All
39	SEACAP 8 Final Report	Petts R et al			?	10	10	10	Low cost surfacings	Cambodia
40	AFCAP Project Report MAL/016.	Pinard M I	2012						Performance review of design standards and technical specifications	Malawi

									for low volume sealed roads in Malawi.	
41	ARRB ??	Robinson P, T Oppy, G Giumarra	1999						Pavement materials in road building - guidelines for making better use of local materials	
42	SEACAP 19 Paper No. 2.1	Rolt J	2007		4	10	7	10	Behaviour of engineered naturally-surfaced roads	Cambodia
43	SEACAP 19 Paper No. 2.2	Rolt J and J R Cook	2008		4	10	10	10	Behaviour of engineered naturally-surfaced roads	Cambodia
44	SEACAP 27 Technical Paper 1	Rolt J and J R Cook	2009						Visual Condition Assessment of RRSR Trial Road Options	Vietnam
45	Transportation Research Record 1117	Rolt J. R., Williams S.G., Jones C.R. and Smith H.R.	1987		10	10	7	10	The performance of a full-scale pavement design in Jamaica.	Jamaica
46	AFCAP Progress Report.	Roughton Int.	2011						Demonstration sites along Bago-Talawanda road, Tanzania.	Tanzania
47	TRL WP/OU/211/1986	Toole, T.	1986						The use of calcretes in paved roads in Botswana.	Botswana
48	Design Report. Design Report. AFCAP/MOZ/001/C	TRL	2012						Targeted interventions on low volume rural roads in Mozambique. .	Mozambique
49	Pavement Investigation Research 6th ADB Project Final Report	TRL	2006		?	10	10	10	53 individual research reports on 6 main research projects (1) Longer life bituminous surfacings (2) Rehabilitation of PCC	Philippines

									pavements (3) Use of marginal materials (4) Stabilised Materials for heavy traffic (5) Recycled materials	
50	SEACAP Technical Paper	TRL-OTB	2008			10	3	10	Case study of Dak Lak RRST pavement and surface determination; Ea Soup road..	Vietnam
51	SEACAP Technical Paper	TRL-OTB	2008			10	3	10	Case study of Dak Lak RRST pavement and surface determination; Buon Ho road.	Vietnam
52	SEACAP ? Final Report	TRL-OTB	2009						Rural Road Surfacing Trials Phase III; Trials preparation (Module 1) final report. .	Vietnam
53	SEACAP 31 Final Report	TRL-OTB	2009		?	10	10	10	Trialling the new standards specifications and extending the Lao LVRR surfacing and paving knowledge base . .	Lao
54	UNB International Symposium on Thin Pavements, Surface Treatments, and Unbound Roads. University of Brunswick.	Villibor D.F, Bernucci L. B., Serra P. R. & Nogami J S.,	1997						Low-cost pavements in Brazil using lateritic clay bases and thin surface courses.	Brazil
55	The HDM Model	Watanatada T, C Harral, W D O Paterson, M Dhareshwar, A Bandari, and K	1987		4	10	10	10	HDM Main Report	

		Tsunokawa								
56	TRL Research paper WP/OU/276	Woodbridge M.E. & Newill D.	1992						Use of marginal materials for roadbase construction in Belize, Central America.	Belize
57	TRL Report PA1254_1991 and Transport Research Record 1291	Woodbridge, M.E. Greening, P.A.K. Newill, D.	1991						Evaluation of weak aggregates for surface dressing low-volume roads	Botswana
58	?								The design and early performance of the paved roads in the Secondary and Feeder Roads programme Zimbabwe	Zimbabwe
59	?								Use of sub-standard lateritic gravels as road base materials in southern Africa	Southern Africa
60	?								Environmental damage from extraction of road building materials. Results and recommendations from studies in southern Africa.	
61	?								Environmentally Optimised design.	
62	?								Performance of labour-based gravel roads in Lesotho	

63	?								New approaches to the provision of all-weather access at relatively low levels of traffic.	
64	?								SADC Guideline: Low-volume sealed roads	
65									New approaches to the provision of low-volume roads in the SADC region of Africa	

Annex D: Sample of International Data Sources 2

The details are not complete.

No	Report Ref.	Authors	Yr. of publication	Age of road at study date	Data type	Data quality	Data size of study	Data stat. robustness	Title and other	Country
1		Ulf Brudefors, O Andersson, C Eriksson, P A K Greening, C Gourley, Gamalilhe Sibanda et al.	Nov. 1995 (19 years)		Hard copy	10	10	10	Secondary and Feeder Roads Development Programme (SFRDP) – Final Report Contains raw data and analyses	Zimbabwe
2		Gamalilhe Sibanda, CP Seager, M.P. Grant, T. Toole, M O'Connel, C. Munetsi et al.	Feb. 1995 (19 years)		Hard copy	10	7	7	SFRDP – Low Volume Surfaced Roads Contains measured data and specification used at the time, field densities, CBRs, PIs, as built data for surfacings, costs of construction, evaluation of pavement strength and performance, CBRs vs time, climate, drainage, triaxial vs CBR for natural materials, comparison of road base selection for different road classes in Africa, comparison of surfacing material selection for different road classes in Africa, aggregate parameters, texture depth, Ls vs CBR, 10% FACT vs ACV, ACV vs Los Angeles Abrasion Value, Otta	Zimbabwe

									seals	
3		Ulf Brudefors, J Hine, J Njunga, A. Matthews	May 1995 (19 years)		Hard copy	7	3	7	SFRDP – Feasibility, Geometry Standards, Quality Control and Testing of Low Volume Roads Contains Geometric standards, social and economic data	Zimbabwe
4		SweRoad Ulf Brudefors	June 1997		Hard copy	7	3	7	SFRDP – Long Term Monitoring of Sealed and Unsealed Roads Contains data on traffic, road condition, roughness, maintenance history, rainfall, gravel wearing courses, drainage	Zimbabwe
5		Min. Transport/ SweRoad/ TRL	March 1996 to March 1998		Hard copy	7	3	7	SFRDP – Long Term Monitoring of Sealed and Unsealed Roads Contains data on traffic, age of road and surfacing, type of surfacing, reseals, climate, shoulder type, unpaved sections, rainfall, in-situ CBRs	Zimbabwe
6		TRL/SweRoad			Hard copy	10	10	10	SFRDP – Material Properties and Design of Gravel Road Test Sections Contains description of test sections, design specifications, geometrics, corrugations, potholes, drainage, camber, loose material, roughness, gravel loss, climate drainage, etc.	Zimbabwe
7		SweRoad/ TRL	Nov. 1992		Hard copy	7	3	7	SFRDP – Progress report Number 16 Contains road economics including construction and maintenance data for test sections	Zimbabwe
8		SweRoad/TRL	Feb. 1995		Hard copy	10	7	7	SFRDP – Low Volume Surfaced Roads	Zimbabwe

			(19 years)						Contains Triaxial tests and specifications for road bases, deflection tests, etc.	
9	CPR1620	K Mukura, J Rolt. A Otto,	June 2013		Electronic	10	10	10	Back Analysis of Previously Constructed Low Volume Roads Contains data on test sections, material properties deflection (LWD), trial pits, DCPs, visual condition survey, roughness, climate, drainage, etc.	Mozambique
10	NDF/HW/S001	COWI/ Dansk Beton Teknik	Aug. 2005		Electronic	10	10	10	Consultancy Services for Feasibility Study, Detailed Engineering Design and Construction Supervision of Matugga - Semuto - Kapeeka Road Using Innovative Technologies Contains design data and information	Uganda
11		J Rolt / K Mukura	Dec 2002		Electronic	10	10	10	National Highways Programme – Trinidad and Tobago Contains data on economic appraisals, traffic, climate, drainage, geotechnical failures, condition surveys, DCPs, trial pits, Deflections (FWD), materials, designs, etc.	Trinidad and Tobago
12		J Rolt / K Mukura	Dec 2003		Electronic	10	10	10	National Highways Programme – Trinidad and Tobago Contains data on economic appraisals, traffic, climate, drainage, geotechnical failures, condition surveys, DCPs, trial pits, Deflections (FWD), materials, designs, etc.	Trinidad and Tobago

Annex E: Data Sources Provided by the Expert Pool

The blue shaded data sources have been selected for the pilot study.

No.	Country	Project/Report	Authors	Data Format	Materials	Climate	Traffic	Drainage	Geometry	No. of sections
1	Botswana	LTPP/ Back Analysis	CPP, InfraAfrica, Haas Consult	Digital spread sheet	8	3	3	Q	-	23
2	Botswana, Malawi, Zimbabwe	Natural gravel road bases - R6020	C Gourley, P A K Greening (TRL)	Digital spread sheet	5	3	y	y	y	55
3	SA and Namibia	LVR study – paved and unpaved	P Page Green (CSIR)	Digital spread sheet	9	3	y	Q	Y	54
4	Botswana	Jwaneng LTPP Exp. sections - calcrete/sand	TRL Report - P A K Greening, J Rolt (calcrete) and CSIR report F Netterberg (sand) Ref: DPVT/C	Hard copy	3	1	2	1	-	12/12
5	Zimbabwe	SFRDP	DSR, SweRoad Report, Nov 1995	Hard copy and digital	3	2	y	Q	y	15
6	Botswana	NATA LTPP Experiments	Botswana Road Depart, CSIR, FN, Ref DPVT/C-124.1	PDF	2	1	2	y	y	8
7	Botswana	Panda/ Kazungula – weathered basalt/stabilisation	Botswana Road Deprt. (Mike Pinard)	Hard copy	1	1	2	y	y	2
8	Zimbabwe, Uganda, Lesotho,	Eng. Stds and LCC for LV unpaved roads	TRL (K Mukura, P A K Greening, G Morosiuk)	Digital spread sheets						

	Ghana, Ethiopia, Mozambique									
9	Brazil & Kenya	HDM 3&4	W Paterson	Digital spread sheets						
10	SA	Moisture deflection measurement	P Page Green, C Gourley							
11	Kenya	Ken 042 LVR	MTRD/NPRA (C Overby)							
12	Botswana	Serowe/Orapa Sands,	F Netterberg							
13	RSA	Grootfontein -Rundu Back Analysis (stabilised calcrete and carbonation)	F Netterberg							
14	RSA	Backstrom stabilisation: anti-carbonation LTPP Exp.	F Netterberg							
15	Zambia	Stabilisation in Zambia	C Gourley, P A K Greening							
16	Jamaica	Jamaica Trials (Marly limestone +	J Rolt							
17	Mozambique	Back Analysis	TRL (J Rolt, K Mukura, A Otto)	Digital						
18	Malawi	Back Analysis	M Pinard							
19	Botswana	Sehitwa - Tsau: curing experiment	F Netterberg							
20	Hoopstadt	Stabilisation with bitumen and cement	F Netterberg							

21	Namibia	Basalt experience	F Netterberg							
22	Namibia	Karibaba experiments - Sabilasation lateriate	F Netterberg							
23	Namibia	Luderitz - gypsum, seawater calcrete	F Netterberg							
24	Namibia	Hallenberg - salt, gypsum, cacrete	F Netterberg							
25	Namibia	Blesiesrei calcrete untreted and treated	F Netterberg							
26	Trinidad and Tobago	National highways programme	TRL (J Rolt, K Mukura)	Digital						
27	Vietnam, Cambodia, Laos	SEACAP data	TRL/OTB/Intech Assoc. (J Cook, J Rolt, R Petts)	Digital						
28	Namibia	Calcrete, Seawater	F Netterberg							
29	SA	Cape flats roads	F Netterberg							
30	SA	PE calcrete roads	F Netterberg							
31	SA	Morgason weathered dolerite	P Page Green							
32	SA	HVS LVR	?							
33	SA	Emery moisture thesis	Emery							
34	Kenya	Lyon Association study - laterite	?							

35	Regional Southern Africa	AFCAP laterites/sands	M Pinard, Page Green							
36	SA	Cape study	P Page Green							
37	Botswana	Tshaneni/Mosama Swacon	?							
38	SA	Southern Perimeter Roads	F Netterberg							
39	SA	Vasputs Experiments	F Netterberg							
40	SA	Appropriate Standards	Mycube (GvZ)							
41	Uganda	NDF/HW/ S001	COWI/ Dansk Beton Teknik							