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PROJECT: ROAD MATERIALS AND AGGREGATE INVENTORY DATABASE – PHASE 1

Final Database Report

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Orion Consulting Associates (OCA) in association with Link Asea

RAF2101A

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OCA Link Asea

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AfCAP Final Database Report

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Abstract

This report covers the draft final database report of the project Road Materials and Aggregate Inventory Database Phase 1. The project has three phases: Phase 1 – Scoping study to identify system architecture (current), as covered in this report), Phase 2 – Development and piloting of the database, and Phase 3 – Rollout to partner countries. The project will be implemented in close collaboration with the 12 AfCAP partner countries.

During the Inception stage, a desk review and stakeholder survey was carried out. Only Ethiopia and Zambia have a materials database in place but this is yet to be fully commissioned. Other partner countries have paper-based or Excel spreadsheets materials inventories. The main priority of the stakeholders is to have a materials database with a mapping tool showing borrow pits and quarries, materials properties and potential use.

During Phase 1 Task 2 (fieldwork consultations) the Consultant visited Mozambique, Ghana and Tanzania to better understand current systems for information management related to materials location and testing. Based on the stakeholders' needs, the database model (architecture) was conceptualised, the minimum system requirements defined and an action plan with an indicative budget for Phase 2 and Phase 3 developed.

The Consultant presented and discussed the Draft Database Report and the Recommendations Report at the regional stakeholder workshop held on 5 September 2017 in Maputo, Mozambique. This final report incorporates the recommendations of the regional stakeholder workshop.

Key words

Low Volume Roads, High Volume Roads, Materials, Aggregates, Materials Information Management, Materials Indicators, Materials Database Systems, Sub-Saharan Africa

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Acronyms, Units and Currencies

AASHTO	American Association of State Highway and Transport Officials
ACV	Aggregate Crushing Value
AfCAP	Africa Community Access Partnership
AIV	Aggregate Impact Value
ALD	Average Least Dimension
ANE	National Road Administration (Mozambique)
ASTM	American Society for Testing and Materials
BPIM	Borrow Pit Information Module
BS	British Standards
CBR	California Bearing Ratio
CML	Central Materials Laboratory
CMS	Contracts Management System
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DFR	Department of Feeder Roads (Ghana)
DMS	Data Management Specialist
DRC	Democratic Republic of Congo
DROMAS	District Roads Maintenance System
DUR	Department of Urban Roads
EI	Elongation Index
ERM	Entity Relationship Model
FI	Flakiness Index
FTE	Full Time Equivalent
GBP	Great Britain Pound
GHA	Ghana Highway Authority
GIFMIS	Ghana Integrated Financial Management Information System
GIS	Geographical Information System
GMS	Gravel Management System
GPS	Global Positioning System
GROMAMAS	Gravel Roads Maintenance Management System
HVR	High Volume Roads
iBRMS	integrated Botswana Road Management System
ICMIS	Indonesian Construction Materials Information System
ICT	Information Communication Technology
IT	Information Technology
HIMS	Highway Information Management System
LAA	Los Angeles Abrasion

LAN	Local Area Network
LVR	Low Volume Roads
MCC	Materials Classification Code
MDIS	Materials Database and Inventory System
MESA	Million Equivalent Standard Axles
MI	Materials Inventories
MIM	Materials Information Management
MIMS	Materials Information Management System
MOT	Ministry of Transport
MOU	Memorandum of Understanding
MRD	Ministry of Rural Development
MSC	Materials Source Code
NRA	Namibia Roads Authority
OCA	Orion Consulting Associates
PMU	Project Management Unit
PO-RALG	President's Office – Regional Administration and Local Government
PRMD	Pilot Road Materials Database
RD	Roads Department
RECAP	Research for Community Access Partnership
SABS	South African Bureau of Standards
SADC	Southern African Development Committee
SSS	Sodium Soundness Test
TANROADS	Tanzania National Road Agency
TARURA	Tanzania Rural and Urban Rad Agency
TFV	Ten per cent Fines Value
TMH	Technical Methods for Highways
TL	Team Leader
TOR	Terms of Reference
TRH	Technical Recommendations for Highways
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
URL	Uniform Resource Locator
ZINARA	Zimbabwe National Roads Administration

AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)

Safe and sustainable transport for rural communities

AfCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa. The AfCAP partnership supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The programme follows on from the AfCAP1 programme that ran from 2008 to 2014. AfCAP is brought together with the Asia Community Access Partnership (AsCAP) under the Research for Community Access Partnership (ReCAP), managed by Cardno Emerging Markets (UK) Ltd.

See www.research4cap.org

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Executive Summary

Introduction

This project has three phases: 1) Scoping study to identify a suitable architecture for a materials database, 2) Development of the database; and 3) Rollout to partner countries. This report is the Final Database Report for Phase 1.

The objective of the scoping study is to identify the needs and architecture for a materials database to be implemented by AfCAP partner countries for improved management of road construction materials. Information on materials is recorded at testing laboratories and also in site-specific project reports, but is not readily accessible for reference. The development of a generic database, with details of available road materials, has been identified as a priority by many partner countries. This report sets out the key findings, proposals for a database design and an action plan and indicative budget for implementation (Phases 2 and 3). The study was carried out from April to September 2017 and included: a stakeholder survey, follow up visits to Mozambique, Ghana and Tanzania and an AfCAP regional stakeholder workshop.

Findings and recommendations

Among AfCAP partner countries, only Ethiopia and Zambia report having a road materials database in place. However, these are recent and yet to be fully commissioned. Elsewhere in Africa, middle-income countries like South Africa (Western Cape Province) and Namibia report successful examples of roads materials databases, often in conjunction with road asset management systems.

The main source of information on materials properties, location and potential use in road works, are the materials testing laboratories. This includes two main types: the materials laboratories operated by one or more roads sector institutions and the private laboratories usually associated with the work of consultants and contractors on specific projects. In most countries the **institutional framework** for materials testing and information management lies with the institution responsible for trunk roads. In others (e.g. Ghana, Tanzania), separate institutions manage rural and urban roads, with separate arrangements for materials location and testing, but often rely on the facilities of the institution responsible for trunk roads. A few private and academic/research laboratories have also emerged. While the data from government materials laboratories may be captured directly from test results, the data from other sources may be obtained (albeit perhaps in less detail) from the reports of consultants and contractors and these two sources are proposed as the primary ongoing data sources for the materials database.

The **regulatory framework** for materials extraction varies between countries. In some (e.g. Mozambique), gravel and sand pits are public property, subject to landowner compensation, and are exploited on a permanent basis. In others (e.g. Ghana) compensation is negotiated with the landowner and royalties or license fees paid to the Government. Materials are extracted only for the duration of that project and pits are reinstated after use.

Road sector institutions in many low-income countries struggle to finance their road maintenance needs. Similarly, materials management in terms of location, testing and storing of information for future use is generally under resourced (budget, staffing and equipment). **Resource availability** is therefore one of the key challenges facing the development of the database and its long-term operation.

In terms of stakeholders' needs and ambitions, the priority is to have a road materials database that includes: i) the locations of road materials sources (gravel, sand, aggregate, water etc.), ii) a summary of the material properties, iii) an estimate of the available quantities and iv) their historic and/or potential use in road pavement and surfacing layers.

There is no evidence of any significant use of **industrial by-products** in road construction and maintenance in the AfCAP partner countries. However, provision can be made to add such non-traditional materials as a possible category for future use. Clients, contractors and consultants appear to have good information on supplies of manufactured road material products (lime, cement, bituminous products, asphalt, precast concrete elements, etc.) and there does not seem to be an immediate need to add these sources to the database.

The distinction between **low or high volume roads (LVRs and HVRs)** is not important in the context of materials**,** except to indicate the potential use, including materials that would be rejected based on current HVR specifications that could be used successfully for LVRs, in the different pavement layers.

The literature review revealed that various **materials location indicators** (remote sensing, botanical and landform) could be used for prospecting of unexplored materials sources. This requires specialised expertise, which is not currently available among stakeholders in partner countries. Project engineers, consultants and contractors use prior experience or local consultations to prospect for materials. However, the road materials database does provide an opportunity to link with a **Geographical Information System,** which many countries do operate, to map materials locations and to add data layers that could, in the future, support materials prospecting activities.

Integration with workflows

The designs of the materials databases developed previously are based on data entry **outside normal work processes**. This is common, even with information systems in other sectors, but results in additional work to enter and verify the data. However, if integrated **within the work processes** of the institution, such a system could even reduce workload and verify accuracy as part of the main work process. It is therefore recommended that the road materials database is **closely integrated with existing workflows for materials sampling**, **testing and approval**. A summary of key materials properties as well as location could thereby be extracted automatically from the approved materials test reports. This would also apply to materials **reports submitted by consultants and contractors** for road projects, which incorporate a substantial body of materials test data. Implementation will require the introduction of standard reporting templates for materials information.

It is recommended that the **initial focus** should not be on entering **historic materials testing data**. This is both costly and a source of substantial delay, as documented in several examples. In the countries visited, such data is not systematically archived, nor even available in a consistent format, thus requiring considerable preparation and cleaning of data prior to entry. Instead, the emphasis should be on commencing actual **operation of the integrated workflows**. New test results from existing and new sources of materials, will thereby begin to flow, and a database of accurate, **current data** will be progressively built up, covering materials properties, location and potential use in road works. Historic data, may be input concurrently with day-to-day operations, working backwards from the present, to ensure that materials sources are represented as comprehensively as possible.

Database system

The full benefits of a materials database can only be realised if the information is **accessible** to road sector professionals. This requires a policy decision as well as technology support. It is therefore proposed that the database be developed as a **web-based platform**, with suitable access controls based on the policies of each country. This provides a cost-effective option for both internal and external access. It is also proposed that the database is developed as several modules, each integrated with a selected set of workflows:

- Module 1: Materials Testing (Laboratory Management Tool)
- Module 2: Materials Information and Mapping (Provide convenient access to information)
- Module 3: Contractors and Consultants Reporting
- Module 4: Mobile Phone / Table App (optional – for off-line or on-line use in the field)
- Module 5: Link to existing Road Asset Management System (optional)
- Module 6: GIS Based Materials Prospecting (optional)

Compatibility and integration of the materials database with other systems already implemented is a notable concern in the countries visited. These systems deployed include **GIS, Road Asset Management and Contract Management**. The main interest is to describe the materials sources used in the different pavement layers as part of the **Road Asset Management System**. The key to linkage of these systems lies in adopting a common coding system for **Materials Sources and Materials Classification** across information systems and across all road sector institutions. This will need to be taken into account in the design stage of the road materials database with a future link to the asset management and other systems in view.

The information requirements of the partner countries are sufficiently similar to justify a **generic design**, which may be refined for each country. These variations are not expected to be extensive.

Implementation arrangements

A modular structure is proposed, which will support the adoption of a **pragmatic, staged development process** (based on the Agile Methodology), which is recommended as a means of mitigating risk and improving the prospects of successful implementation. Contracting and resourcing arrangements will also need to be adjusted to support this approach.

Creating high levels of local ownership and nurturing long term partnerships between the beneficiary institution and local technology service providers, is noted as a critical success factor. An **Consultants with international experience** to manage and oversee implementation, combined with **Local IT Service Providers** deployed to develop and implement the system with significant road sector input from the client institution, is therefore recommended.

Engaging just one partner country (with mature institutional arrangements, systems and workflows for materials testing) for pilot implementation in Phase 2 will reduce implementation risks. Roll out to other interested partners will then take place in Phase 3. Country selection for Phase 2 will be based on an agreed set of **selection criteria** such as (among others): a brief proposal outlining the institutional anchorage of the project, and the ability to mobilise staff and IT resources.

It is estimated that the project will take between 2 and 4 years (depending on how many partner countries express interest) starting from early 2018. The time lapse between Phase 2 and 3 (about 18 months) will allow other partners to get ready for implementation.

Three scenarios for implementation are explored: a minimum scenario with the essential modules 1-3 (Scenario 1), an intermediate scenario with 4 modules (Scenario 2) and the full 6 modules (Scenario 3).

The **estimated cost for Phase 2** (development and piloting) for Scenario 1, 2 and 3 is GBP 461,000, GBP 525,000 and GBP 587,000 respectively. This includes a partner contribution of GBP 46,000, GBP 50,000 and GBP 60,000 respectively, some of which will be in kind (such as staff allocation and transport). It should be noted that these estimates are based on approximate average unit rates across countries.

The **estimated cost for Phase 3** (roll out and uptake) is estimated at GBP 193,000 (Scenario 1), GBP 220,000 (Scenario 2) and GBP 244,000 (Scenario 3) per country. This includes partner contributions of GBP 40,000, GBP 44,000 and GBP 50,000 respectively.

1 Introduction

1.1 Africa Community Access Partnership

The Africa Community Access Partnership (AfCAP) is a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID). AfCAP promotes safe and sustainable rural access in Africa through research and knowledge sharing between participating countries and the wider community. The AfCAP partner countries are: Zambia, Ghana, Kenya, Tanzania, South Sudan, Uganda, Sierra Leone, Ethiopia, Mozambique, Democratic Republic of Congo (DRC), Liberia and Malawi.

1.2 Rationale of road materials and aggregate inventory database

Acceptable quality road construction material sources are becoming increasingly scarce in many Sub-Saharan countries. Uncertainty regarding the availability of road materials gives rise to delays in the planning and design of road projects. Although materials information is collected, it is usually contained in project reports and not readily accessible to the community of practitioners.

The development of a generic road materials database linked to a mapping tool, providing detailed inventory of the location, properties, quantity and potential use of road materials, has been identified as a priority by AfCAP partner countries. To prevent duplication of effort, it is intended that this project will scope the general information requirements and architecture of a generic materials database that can be developed by partner countries to suit their own circumstances.

Although the main focus of AfCAP relates to materials sources for Low Volume Roads (LVRs), typically defined as those carrying less than 1 Million Equivalent Standard Axles (MESA) in one direction and less than 300 vehicles per day, in practice, it is difficult to make a distinction between materials information needs for LVRs and High Volume Roads (HVRs). Borrow pits and quarries are not exclusively used by one category of roads. Moreover, institutional responsibilities for road asset management, including materials information management, are assigned according to the administrative and/or functional classification of roads, not by the level of traffic.

1.3 Project scope

1.3.1 Objectives of the project

The ultimate objective of the project is to develop a generic road materials database with a mapping tool showing the location of borrow pits and quarries with typical materials properties and their potential use in road works that can be developed, populated and used by AfCAP partner countries. Capacity building, uptake and embedment forms part of the project, especially relevant in Phase 2 and 3.

1.3.2 Project phases

The project has three phases:

- Phase 1 – Scoping study to identify a suitable architecture for a materials database (current, as covered in this report);

- Phase 2 – Development of the database and partial population for beta-testing;
- Phase 3 – Rollout to partner countries, including training.

Phase 1 of the project has been awarded to Orion Consulting Associates (OCA) in association with Link Asea. The team consists of:

- Jan Bijl, Team Leader (TL), Orion Consulting Associates
- Ravindra Corea, Data Management Specialist (DMS), Link Asea

1.3.3 Objective of Phase 1

The objective of Phase 1 is to identify the needs, architecture and system requirements of a materials and aggregate inventory database that can be implemented at national level for improved management of materials for road works, in particular LVRs. The scoping study will also provide a detailed plan and budget for the development of the database (Phase 2) and actions for training and rollout (Phase 3).

1.3.4 Tasks of Phase 1

Phase 1 of the project (April – September 2017) has four distinct tasks:

- Task 1: Inception and desk review of current database systems;
- Task 2: Problem analysis, conceptualise database model and system requirements through fieldwork consultations in selected countries;
- Task 3: Regional stakeholder workshop to present findings and recommendations;
- Task 4: Finalization of the conceptual database model and recommendations for Phase 2 and 3 including a proposed action plan and indicative budget.

1.3.5 Deliverables Phase 1

The following reports have been submitted as part of Phase 1 of the Road Materials and Aggregate Inventory Database:

- Inception report, J. Bijl and R. Corea, June 2017;
- Draft database report, J. Bijl and R. Corea, July 2017;
- Draft Recommendations Report for Presentation at the Stakeholder Workshop, J. Bijl and R. Corea, August 2017;
- Regional Stakeholder Workshop and Workshop Report, J. Bijl and R. Corea, September 2017;
- Final database report (this report).

All reports can be downloaded from the ReCAP Rural Access Library, which represents an integral part of the Partnership's knowledge dissemination strategy. The library is free to access for anyone interested to find out more about rural access in Africa and Asia: *http://www.research4cap.org*

1.4 Final Database Report

This final report presents the findings and recommendations of the scoping study leading towards the proposed road materials database architecture and system development as well as recommendations for implementation of Phase 2 and 3 of the project as discussed at the Regional Stakeholder Workshop held on 5 September in Maputo 2017, Mozambique. This report includes:

- Chapter 2: Materials database systems, experiences and lessons learned from elsewhere;
- Chapter 3: Road materials information management systems in the partner countries;
- Chapter 4: Database system development;
- Chapter 5: Formulation of Phase 2 and 3 of the Project;
- Chapter 6: Conclusions from Phase 1 and recommendations for Phase 2 and 3.

Annex A presents a list of all documents reviewed and **Annex B** includes a list of persons and stakeholder institutions consulted during the assignment.

2 Road materials database systems, experiences and lessons learned from elsewhere

2.1 Road materials database systems reviewed

During Task 1 (Inception) a review of established materials database systems in Africa and elsewhere was carried out. The purpose of that literature review was to provide an overview of what materials database system initiatives have taken place in low and middle-income countries:

- Indonesia, the Indonesian Construction Materials Information System (ICMIS);
- Cambodia, the Pilot Road Materials Database (PRMD);
- South Africa, Western Cape Province, the Borrow Pit Information Module (BPIM);
- Namibia, the Materials Information Management (MIM);
- Botswana, the Materials Database and Inventory System (MDIS);
- Zimbabwe, the Materials Inventory (MI).

Since submission of the Inception Report, additional information was obtained from Zimbabwe, South Africa and Zambia, which is presented in Section 2.2.1. As part of fieldwork consultations, the Consultant also visited Botswana. A review of their experiences with the development and use of MDIS is also presented in Section 2.2.1. Section 2.3 consolidates the main lessons learned from these systems. More information can be obtained from the Inception Report, see Section 1.3.5.

2.2 Outcome of the review

2.2.1 Updates to the Inception Report

Zimbabwe, Materials Inventories (MI)

As part of the DFID funded Collaborative Research Program on Highway Engineering Materials in the Southern African Development Committee (SADC)[1], the Departments of Roads in Zimbabwe was supported to establish a Materials Inventory. The objective of the project was to have a repository in which data on the location and use of road materials would be centrally accessible. Zimbabwe and Malawi were selected because a significant amount of road materials data was already archived in these countries.

In Zimbabwe, the MI module was part of a larger road asset management system. The MI comprised 9 separate database files including borrow pit location and material properties, road centreline soil testing and road pavement description and testing. It took 4 staff members about 3 years to enter historical data. By the end of the project (1999) the database contained 65,000 records and 2.25 million data items.

Since the inception report, additional information was received from the Zimbabwe National Road Agency (ZINARA) about the current status of the MI. The materials data bank is operational but entirely paper based and used by ZINARA staff. There is no mapping application attached to it. The information contained includes: location description of the deposit, location indicator through a Global Positioning System (GPS), haulage distance, quantity of material deposit, classification of the deposit, using Ministry of Transport (MOT) and American Association of State Highway and Transport Officials (AASHTO) classification, recommended use and the year when the materials deposit was identified. The data is not up to date, mainly due to limited resources for data processing and maintenance. Many records are thought to have been lost due to the paper-based format and implementation of an electronic system would therefore be highly desirable.

The information provided by ZINARA does not provide any reference to the DFID funded Collaborative Research Program. Since the responsible officer indicated that materials data is paper based, it is assumed that the electronic database is no longer operational.

South Africa, Western Cape Province, the Borrow Pit Information Module (BPIM)

In order to make more efficient use of road material sources and legalise their application in gravel road works, the Western Cape Province in South Africa established the Gravel Management System (GMS) in 2007 including a Borrow Pit Information Module (BPIM)[2]. A systems approach was followed to address all processes for the prospecting, sampling, testing and approval of materials in the provision and maintenance of unpaved roads while integration with other management systems was also pursued.

A recently published paper[3] indicated that the original GMS and BPIM had fallen into disuse during a period where staff availability was short and the importance of road materials management went unrecognised. However, recently (2015) efforts to revive the system were begun, now rebranded as the Gravel Roads Maintenance Management System (GROMAMAS), which continues to support the workflows for the maintenance and management of unpaved roads. GROMAMAS was developed in parallel with the development of a Materials Information Management System (MIMS), which is based on the previously used BPIM in order to store information on road materials sources.

Botswana, the Materials Database and Inventory System (MDIS)

A short visit was made to the Materials Research Division (MRD) of the Roads Department (RD) in Botswana.

The MDIS[4] was developed in 2008 through an international consultant, using an Oracle 10g XE database and an interface written in Visual Basic v6. The database was installed on a desktop PC stationed at MRD with a Windows operating system.

The MDIS is deployed with three different user roles:

- System Administrator – can input, edit and review all data in MDIS. One Information Technology (IT) specialist in RD currently holds System Administrator privileges;
- Power User – has similar privileges to the System Administrator, except that data in look-up tables cannot be edited;
- User – cannot edit or input data, can only view data and run reports;
- Guest – can only run reports.

The MDIS includes the road inventory for Botswana allowing materials testing sites to be linked to the existing road network. All areas from which materials samples are taken for testing are referred to as ‘sites’, commonly: borrow pits, stockpiles, roads, quarries, water sources and others.

The primary purpose of MDIS is to record materials test results. No historical data was collected at the start; data collection started from 2008 onwards. The MDIS is only accessible by staff from MRD. Third parties (e.g. RD project engineers, consultants and contractors) only have access to MDIS data by submitting a written request to MRD. The MDIS allows for the investigation of sites, extraction and testing of samples, decisions on their use and communication of their locations and available quantities to third parties although MDIS is not directly linked to a Geographical Information System (GIS) or mapping application.

The MDIS was supposed to be integrated with the Laboratory Management System, the Pavement Management System and the Maintenance Management System but this has not materialised due to technical problems (linking the different technology platforms and formats of the databases) and the lack of in-house expertise to undertake this exercise. The planned development of the integrated Botswana Road Management System (iBRMS) has also not progressed due to lack of resources.

The MDIS is not directly integrated with the workflows for materials testing at MRD. Laboratory technicians process materials test results in excel tables (templates), which are then printed and signed by the authorising officer for submission to the client or customer. The data from the excel tables needs to be re-entered manually into the MDIS. This adds to the workload of already overloaded MRD staff and does not encourage synchronisation of the database. Due to frequent power cuts, a shortage of staff and system security issues, the MDIS is no longer up to date.

MDIS allows road projects to be entered by specifying the site for the work and the materials required (both by type and quantity). A completed project can then be signed off within MDIS by stating where the materials came from and how much remains available. However, MDIS is currently not used as a project management tool and materials usage is not tracked.

The MDIS currently faces a number of operational challenges. Although the initial set up allowed for changes to be made to the source code of the software, this does require a significant level of expertise that is currently not available in-house. Oracle 10g XE software is no longer available and any upgrade to a newer version would need to be purchased, requiring a one off or subscription-based fee. This is a common disadvantage of working with free versions of proprietary software, as opposed to open-source, publicly licensed software: an upgrade is inevitably required once the system is fully operational because it is out dated or has reached its data capacity limit.

MRD would like to improve and integrate the materials database with the central materials laboratory management system. This appears to be a difficult task. Having an external service provider develop the materials database has not allowed for sufficient skills transfer to the beneficiary institution and/or a local service provider. This, among other technical and institutional challenges (transfer or retirement of senior staff who had been leading the development of MDIS and were effective champions), is one of the key reasons why MDIS has not reached its full potential.

Zambia, the Materials Database and Information System (MDIS)

The Zambia Road Development Agency contracted an International Consultant with local representation for the software development of the MDIS. This started in June 2016 and was completed by July 2017. Other consultants are currently in the field to gather materials location data and samples for testing for population of the database.

The system is based on Microsoft technologies with a SQL server database management system and an ASP.net front end, which has full web based capabilities. The database covers aggregates, gravel and sand sources. It has information on the materials properties that are currently specified and used in Zambia with limited flexibility to be extended to other materials or other tests not covered by their current specification.

It is designed for offline data entry therefore not integrated with the materials testing workflows.

This project has demonstrated Zambia's ability to define system specifications and manage an IT project internally.

2.2.2 Comparison of road materials database systems

A comparison of road materials databases in various countries has been summarised in **Table 1** on the basis of level of access, choice of technology, development process, links to asset management systems and their current operational status. As can be seen from the table, none of the countries report that their materials database system is fully operational or fully updated.

System	Year	Access and Choice of Technology			Development Process				Linked to Asset Mngt. System	Current Status
		Level of Access	Platform used	Technology used	Part of laboratory workflows	Historic Data collected	Developed externally or internally	Link to GIS		
Indonesia (ICMS)	1997	Restricted	Desktop	dBase and Fox Pro	No	Yes	Externally	No	No	Status unknown
Cambodia (PRMD)	2008	Restricted	Desktop	Microsoft Access	No	No	Externally	Yes	Yes	Not operational
SA Western Cape (BPIM)	2007	Public	Desktop Web Based	Unknown	Yes	No	Internally	No	Yes	Out of use but now revived.
Namibia (MIM)	2010	Restricted	Desktop Web Based	Re-developed in PostgreSQL	Partially	No	Externally	Yes	Yes	Operational. Not fully updated.
Botswana (MDIS)	2008	Restricted	Desktop	Oracle XE 10g	No	No	Externally	No	No	Partly operational
Zimbabwe, (MI)	1998	Restricted	Desktop	Fox Pro	No	Yes	Externally	Yes	No	Not operational

Table 1: Summary Roads Materials Database Systems

2.3 Important lessons learned

The experiences with developing and operating materials databases in various countries provide important lessons although the specific country context may differ significantly. The lessons learned are briefly highlighted in the following paragraphs.

Level of access:

- Most countries have developed their materials information system primarily for restricted (internal) use. This largely ignores the fact that Consultants and Contractors, in particular for HVRs, are an important user group both for information supply as well as demand.
- Open access and bi-directional flow of information are critical for the successful development and sustained use of the road materials database.

Technology platform:

- The materials database systems reviewed were mostly developed for an office-based, desktop environment. Materials Managers, Project Engineers (Client, Consultants' and Contractors' staff) and Road Researchers are increasingly operating on site, far from their offices.
- The materials database should be developed with convenient access from remote locations including a web-based user interface and additional applications for mobile phone/tablet. This would allow data upload and download on and offline while ensuring ease of administration, maintenance and deployment of updates to software from a single central location. While the coverage of data networks is as yet incomplete in most member countries, there is continued growth of these services, which provides opportunities for remote access to the database.
- The selected technology platform can have significant long-term impacts. Proprietary technologies may seem attractive at the development stage; however, license fees for expansion and upgrade usually result in costs being significantly higher than open-source

alternatives. Where financial resources are limited, this can result in the failure of an otherwise successful implementation. The development and implementation approach and technology platforms should be selected with a view to long-term sustainability of the system, under the constraints of the local environment.

Integration within work processes:

- The review shows that the technological challenge of building and populating an information system such as a materials database, under project-based support arrangements may not be the biggest challenge.
- Embedding the materials database within existing policies, procedures and workflows of the beneficiary institution(s), in particular the materials laboratory management systems, is more difficult, and a fundamental requirement for the long-term success of the database.
- More successful experiences (South Africa and Namibia) can be attributed to the fact that those materials databases form an integrated part of the existing workflows for road materials testing. They do not burden the road sector institution with an additional requirement for data collection and data entry.
- The points of integration need to be identified and embedded in the system design from the outset.

Data capture:

- Most countries have designed their databases for data entry as a separate activity, outside normal workflows and with an initial focus on historic data collection through the same process. This is a common mistake in information systems projects of all types. The preparation, entry and quality checking of both current and historic data can be very time-consuming and costly. It can also frustrate the development process and impose high demands on the limited staff and budget resources.
- The materials database should instead, adopt a forward-looking data collection approach, starting from the date of implementation. Combined with proper integration to ensure that all road sector professionals (client, consultants, contractors and researchers) involved in materials prospecting, sampling and testing, contribute to the information supply chain through their regular work processes, it would ensure that current and relevant data would begin to populate the database from the outset covering existing as well as new materials sources. Past data may then be entered, working backwards from the implementation date, concurrent with ongoing operation of the system.

Building ownership and local capacity development:

- The use of international technical resources to develop and deploy software is often an attractive solution where initial funding is available. It provides access to the required professional expertise and quick results. However, this rarely allows for sufficient local capacity development.
- More attention needs to be paid to knowledge transfer by ensuring substantive roles for the client and possibly local ICT service providers during project implementation. Local ownership as well as a thorough knowledge of the solutions and technologies deployed can be created through their participation in the problem solving and design process.
- Effective capacity development can be achieved though close engagement of the beneficiary institutions through deployment of multidisciplinary project teams, and engagement of local ICT service providers with clearly assigned roles in the software development process.

- The development and roll out of a road materials database needs to be driven by a champion in the partner country, someone in a senior management position to ensure that the project is receiving the required support of the host institution.

Links to other Information Systems:

- The development of road materials database systems is often integrated with other information systems (e.g. road asset management, contract management). This integration can be challenging if such systems are not developed simultaneously, and if a simple and consistent basis of linkage cannot be identified.
- At an early stage of database development, it is important to describe if and how the materials database structure (the Entity Relationship Model or ERM) may be linked with the various other information management systems in use by the beneficiary institution. This can be achieved only if the wider issues are considered during the design of the materials database, even if the software does not initially support some functions. If this is done properly, a consistent logic can be established so that linking these database systems may be done at any stage of the project development cycle.
- In order to link a materials database for example to the road asset management system, it is important to have a unique referencing system for materials sources, which is used consistently across both systems (this is an example of the consistent logic referred to above). If this is recognised and embedded in the procedures of the various related information management systems, subsequent linkage would be relatively simple, even if the systems were built on different technology platforms and were managed by different agencies.

The System Development Process:

- Information Systems projects (not restricted to the particular domain of Materials Databases) often tend to focus on the production of a piece of software as a technological challenge and do not pay adequate attention to the challenges of implementation, such as integration with work flows including change management where needed, user training and support. This often leads to the production of systems that remain under-utilised or even unused.
- Another important consideration in information systems development is the growing recognition that the development approach has a key role to play in the success of the initiative. An approach that sets out to achieve specific outputs that are useful in the regular work of the organisation, within short timescales, is seen to achieve success more consistently than one that strives to cover all requirements in one comprehensive project. By focusing on useable outputs, such an approach also ensures that the issues of implementation are addressed adequately.

3 Road materials information management in AfCAP partner countries

3.1 Countries selected for field work consultations

Task 2 of the Terms of Reference required the Consultant to visit three (3) representative countries to review current institutional and regulatory frameworks, current systems and workflows for road materials testing and information management (including location data of materials sources) and to identify the main challenges, ambitions and needs of the road sector stakeholders. The following 3 countries were initially proposed:

- **Ghana**, western Africa, being a lower middle-income country, with no materials database in place but strong management support systems and resource availability;
- **Ethiopia**, eastern Africa, being a low-income country, having recently established a materials database system with ambitions to link this to a GIS;
- **Mozambique**, southern Africa, being a low-income country with some evidence of electronic storage of materials testing data.

Due to difficulties obtaining visa clearances for Ethiopia in time, it was agreed with AfCAP that Tanzania would be visited instead.

This chapter provides a complementary (qualitative) validation of the stakeholder survey carried out as part of the inception stage (Task 1) on the basis of the checklist for fieldwork consultations **(see Annex C).** The main findings and recommendations of the institutional and regulatory framework (Section 3.2), existing systems and workflows (Section 3.3) and stakeholder challenges, needs and expectation (Section 3.4) are presented. More detailed findings from the country visits are presented in:

- Annex D: Report from Mozambique
- Annex E: Report from Ghana
- Annex F: Report from Tanzania

Kenya also submitted its reply to the stakeholder survey (circulated during the Inception Stage). This has been added to the (updated) summary table presented in **Annex G.**

3.2 Institutional and regulatory framework

The institutional and regulatory framework for materials extraction, testing and information management differs between partner countries but this is not expected to have major implications for the development, piloting and operation of the road materials database.

In most countries, the institutional framework for materials testing and materials information management lies with the institution responsible for trunk roads, typically through the materials and research division, a main central materials laboratory and various sub-national laboratories. In some countries (e.g. Ghana, Tanzania), separate institutions have been established for the management of rural and urban roads. They may have separate arrangements and facilities for road materials testing but generally follow the same materials testing procedures. They are generally less resourced and rely on the facilities of the institution responsible for trunk roads, in particular when it comes to testing of bituminous products.

Another important group is the larger contractors who have permanent or site specific laboratory facilities in the country. They do a significant amount of in-house materials testing and strategies should be developed to capture this data in the road materials database. Other laboratories have emerged, (some private, others linked to academic and research institutions) but they still play a minor role in the materials testing market. However, on an increasing scale consultants and contractors make use of these facilities.

The regulatory framework for materials extraction also varies between countries. In some countries (e.g. Mozambique) gravel and sand pits are considered "open source" public property (once compensation has been paid to the landowner) and exploited on a permanent basis ("open pits") while in others (e.g. Ghana, Uganda) compensation and royalties are paid to the landowner and the responsible Government institutions respectively after which materials are extracted for the duration of the project only (the pits are reinstated after use). This has implications for the management of materials quantities. In countries like Ghana, where materials are privately owned, it would be difficult to control the use of materials (e.g. monitor the remaining quantities available by source), whereas in countries with public ownership of materials sources such opportunities do exist.

Often some form of licensing is required through the institutions responsible for minerals resources and/or environmental management but in practice this is not always adhered to, or at least not for LVR improvement and maintenance projects, due to the limited resources available to implement and enforce laws and regulations. This is quite different for major road development projects, in particular those funded by Development Partners, which are more closely monitored with respect to environmental and social safeguards.

3.3 Current systems and work flows

3.3.1 Road design standards and specifications for HVRs and LVRs

The materials testing procedures in the visited partner countries have a lot in common. They are mostly based on the same international references being a combination of British Standards (BS), American Standards such as AASHTO and American Society for Testing and Materials (ASTM) standards and the South African National Standards (SANS) Series 3001, recently developed under the South African Bureau of Standards (SABS), and superseding the previous Technical Methods for Highways (TMH). Occasionally, these are supplemented by locally-developed or adopted standards particularly in Ghana.

Some AfCAP partner countries have recently developed their own set of LVR design manuals (e.g. Ethiopia, South Sudan, Kenya, Mozambique, Tanzania) with support from AfCAP or other Development Partners. Others are in the process of doing so (e.g. Zambia, Malawi, Uganda, Liberia, Ghana, Sierra Leone). Additional requirements can be captured in the materials database, e.g. for materials strength property, the DCP (Dynamic Cone Penetrometer) test method will have to be added.

The following road design documents and technical specifications are used in each of the partner countries visited:

- Mozambique: Draft Standard Specifications for Road and Bridge Works September 1998[5];
- Ghana: Ministry of Transportation, Standard Specification for Road and Bridge Works, July 2007[6];
- Tanzania: Tanzania Pavement and Materials Design Manual, 1999[7].

It should be noted that differences exist between various test methods used (e.g. AASHTO and the BS methods and equipment), particularly for Compaction, CBR and Atterberg Limits. However, the differences in what materials properties are tested and which method is used can be accommodated in the materials database by allowing a clear distinction to be made between the materials property tested (e.g. strength), the test used (e.g. CBR, DCP-DN), the test method (e.g. BS), the test description (e.g. CBR 4–days soaked), the test value obtained (e.g. % CBR value) and the acceptable ranges differentiating between HVR and LVR and country specific adaptations.

The need for better materials information is applicable to all categories of roads. Most materials are used for both HVRs and LVRs although the test methods and acceptable ranges (specifications) may differ for each category of roads. The materials database should therefore cover all categories of roads and different sources of materials currently in use or with potential to be used (e.g. non-traditional materials) in the future.

3.3.2 Materials testing and information management

The scoping study showed that very few AfCAP partner countries have an operational materials database in place. Ethiopia reports a recently established road materials database, which is yet to be fully commissioned, and Zambia has just completed software development for a new materials database. The opportunity to develop, pilot and roll out a road materials database seems relevant and is welcomed by most partner countries.

The roads materials laboratories visited make use of standard templates for recording materials test results, which are then summarised in excel files and stored on a desktop computer of the laboratory. These templates are printed and then signed before submission to the customer who requested the tests. Examples from Mozambique, Ghana and Tanzania are presented in Annexes D, E and F.

The use of standard templates is an important step towards efficient and seamless data capture for input (or better upload) to the road materials database. This is relatively straightforward for Government controlled processes (e.g. public road materials laboratories), where there is full control over work procedures and templates. For Consultants and Contractors materials reporting this is more challenging but can be made compulsory, i.e. to be specified in the Terms of Reference (TOR) or Conditions of Contract.

The standard templates currently in use can be improved to include additional information required for the roads materials database, such as materials location data, sample description, etc. Because laboratory technicians and managers are already used to these templates, capturing data for the materials database would not be seen as an additional workload since it could be fully integrated in the workflows of the laboratory by replacing the excel templates with a similar looking user interface (see also "lessons learned" in Chapter 2). If the database system is designed such that all testing reports are generated and printed through the database user interface, then data capture will be both automatic and accurate. In this way, the development of the road materials database also provides an opportunity to improve the laboratory management procedure in terms of quality control, data integrity and data protection.

3.3.3 Road asset management

The country visits show that road asset management systems not only differ between, but also within countries (between road sector institutions) and range from tailor made systems in Ghana, e.g. the Road Database at Department of Feeder Roads (DFR) and Tanzania, e.g. the District Roads

Maintenance System (DROMAS) at TARURA (Tanzania Rural and Urban Road Agency), to off-the-shelf customised packages in Mozambique, e.g. the Highway Information Management System (HIMS) at National Road Administration (ANE) and Ghana, e.g. the Road Manager at Department of Urban Roads (DUR).

These asset management systems typically contain data about the road inventory, road condition and road use. HIMS (Mozambique) has provisions to add data on the pavement structure through layer descriptions (wearing course, base, sub base and selected fill). In the tailor-made asset management systems this is not the case but provisions could be made to make modifications to the database structure. However, none of these road asset management systems currently holds data on the "as built" pavement structure.

Linking the road materials database with road asset management systems would require a unique materials source referencing code that can be used by both systems as a point of integration. If this is agreed upon, materials data could be progressively added to the road asset management system if and when "as built" pavement information, including materials sources used, becomes available. Doing this retroactively would, however, be an enormous burden on the limited resources of the road sector institutions and is not the recommended way forward (see lessons learned in Chapter 2).

3.3.4 Information technology

There would be limited benefit if information from the materials database were not easily accessible to professionals in the road sector. In terms of policies on IT and data protection, there does not seem to be a limitation or restriction imposed on the development of the road materials database system and dissemination of road materials source data, in the countries studied.

Consultations indicate that most of the road sector institutions in the partner countries would support open access arrangements albeit perhaps with some level of user control (through registration). It is recommended that acceptance of a policy of open access to data be included as one of the criteria for countries to join the road materials database project during Phase 2 (pilot and testing) and Phase 3 (the roll out and training).

One of the constraints observed in some countries has been the uneven Internet connectivity between the central road sector institutions and their sub-national materials laboratories. This is something that needs to be improved if the road materials database is to be implemented as a fully web-based service. In some countries efforts are already on-going as part of e-government initiatives to improve server capacity and the reliability of the corporate intra network.

Most of the road sector institutions have dedicated units for IT and GIS but the number of staff and skill levels vary considerably. Not having sufficient in-house capacity to manage information systems is an important risk to consider in the materials database development, especially for the pilot stage. It is therefore suggested that the countries' experience with successful development and operation of information systems is considered as one of the most important criteria for the selection of the partner country for piloting the road materials database project during Phase 2.

Regional experience has shown that reliance on international service providers carries certain disadvantages in respect of sustainability (see also "lessons learned" in Chapter 2). The local IT development capacity in the private sector seems to be sufficiently mature in some countries as to be capable of supporting the road sector institutions in their efforts to develop a road materials database, in combination with some international expertise in the design and development stage. Experiences from Ghana (DFR) show the benefits of involving the local private sector in the development of information management systems to ensure the long-term sustainability of the systems through continuous support and mentorship during the operational stages of the database rather than relying only on international service providers who work on a “come and go” basis.

3.3.5 Geographical Information Systems

Some of the road sector institutions (Ghana DFR, Mozambique ANE) already have a fully functional GIS in place, linked to a road asset management system, and managed by a GIS trained staff member(s). Others have GIS software available but limited in-house skills in the use of GIS other than to prepare the occasional maps or to support road survey and design work.

Having a high level understanding of GIS is an advantage but not a critical part of the road materials database development; initially the development focus should be on streamlining the materials data collection procedures and to build up the database. The mapping application will become important once geo-referenced materials source data has been collected.

Climate, soils, geological and topographical maps are becoming increasingly available as shape or raster files (some at a cost) and can be imported as layers into the GIS module and provide valuable background information for the purpose of materials prospecting.

3.4 Stakeholders’ challenges, needs and ambitions

Road sector institutions in most of the AfCAP partner countries struggle to finance their road maintenance needs. It is therefore no surprise that materials testing and information management facilities are generally under resourced in terms of budget, staffing and equipment. The same applies to IT support staff as demonstrated in **Table 2.** Thisis one of the key challenges that will not only affect the development of the database itself but also its long-term sustainability.

Country	Road materials laboratories (public)	Materials staffing (academic, technical and support staff)	IT staff and GIS staff
Mozambique:			
ANE	11	20-30	3 (IT), 2 (GIS)
Ghana:			
Ghana Highway Authority (GHA)	11	86	2 (IT), (GIS)
DFR	11	20-30	3 (IT), (GIS)
DUR	4	10-20	1 (IT)
Tanzania:			
Tanzania National Road Agency (TANROADS)	27	200	3 (IT), 1 (GIS)
Tanzania Rural and Urban Rad Agency (TARURA)	1 (another 8 in preparation)	8	Being recruited

Table 2: Staffing Resources in visited countries

Even middle-income countries like Namibia and Botswana, with much better resource availability, struggle to keep up with the information needs of their materials databases. In the case of Botswana, this may be attributed to the road materials database not being well embedded in the existing workflows for materials testing and therefore imposing an additional workload for data collection. The lessons learned from these efforts will be especially relevant for Phase 2.

In terms of stakeholders’ needs and ambitions the main priority is to have a road materials database system in place that shows the locations of road materials sources (in particular gravel and aggregates), a summary of the material properties, an estimate of the available quantities and historic/potential use in road pavement and surfacing layers. In terms of materials properties, the requirements of the visited countries show sufficient similarity to justify reference to a generic road materials database although some flexibility may be required to meet country specific needs. The key properties for gravel and aggregates are summarised in **Table 3.**

Material properties	Description and importance	Typical laboratory test used
Particle size distribution	Relative proportions of materials particle size important for permeability and level of compaction.	Sieve analysis
Plasticity of the fine fraction of the material	The behaviour of the fine fraction of particles (cohesive or plastic) at different moisture contents.	Atterberg limits, Linear shrinkage
Density and moisture content	Maximum dry density (at OMC) achieved under a specified compaction effort.	Compaction Test
Load bearing capacity	Ability to support/distribute traffic loads under different moisture conditions and compaction efforts.	California Bearing Ratio (CBR), Dynamic Cone Penetrometer (DN)
Volume stability	The volumetric responsive of the material to soaking, moisture susceptibility of the fine fraction of particles.	Swell measurement during 4-day soaked CBR test
Particle strength and durability	The strength of individual particles and their ability to maintain this strength over the anticipated design life of the project under traffic and environmental conditions.	10% FACT, Aggregate Crushing Value, Los Angeles Abrasion, Aggregate Impact Value, Sodium Sulphate Soundness
Particle shape	The shape of the particles and their ability to interlock together.	Elongation Index, Flakiness Index, Average Least Dimension

Table 3: Key Materials Properties[1]

During the regional stakeholder workshop additional materials properties were mentioned as being important such as organic matter content, chemical properties (salinity and acidity), specific gravity and bitumen affinity. However, this may not be equally relevant to all partner countries. It is therefore suggested to distinguish between key materials properties that would be covered in the generic database, and other properties that would include country specific adaptations.

Some countries have specific needs, which can be accommodated in the country specific adaptations. In Ghana for example there are particular concerns because of the high cost of material overhaul rates (beyond 1 km). This would be better controlled if the database included location mapping of roads and materials sources and an ability to calculate haulage distances by road. In Mozambique there is a particular concern of encroachment of public borrow pits by land developers. Better demarcation and registration of borrow pits would protect valuable sources of road materials. In Tanzania, TARURA was only recently established and they require reliable access to materials information that was previously held by the councils.

There is no evidence of any significant use of industrial by-products in road construction and maintenance in the AfCAP partner countries; however a provision can be made to add this as a category of non-traditional materials sources. Clients, contractors and consultants generally are well informed about the suppliers of manufactured road materials products (lime, cement, bituminous products, asphalt producers, concrete pipes, etc.) and there does not seem an immediate need to add these sources to the database also considering the rapidly changing suppliers market. This could be reconsidered during a later stage of the development process, if and when such a need is identified.

In terms of road categories, it does not seem relevant to differentiate between LVRs and HVRs other than to provide an indication of the potential use of road materials in the different pavement layers for HVRs and LVRs and the acceptable ranges of materials specifications. All road materials, including marginal materials, that can potentially be used for maintenance and improvement works on LVRs and HVRs should be added to the materials database.

[1] Adopted from Cook J R and Kackada H, 2009, TRL/HACE, South East Asia Community Access Program, SEACAP No. 19, Task 7, Pilot Materials Database for Cambodia.

3.5 Recommendations

In line with the needs and ambitions of the road sector stakeholders and the resources available, it is proposed that the development of the road materials database is tied in with (on-going) efforts to improve laboratory management procedures including materials testing protocols and workflows for materials sampling, testing, approval and data storage (including the geo-referenced locations of the materials sources that can be shown on an interactive mapping application). Provisions can be made to extract summary data from the laboratory materials testing sheets once approved and signed off by the responsible materials manager. This would also apply to the materials reports submitted by consultant and contractors for the design and supervision of road projects. This requires that client institutions provide standard templates for road materials testing and third parties obliged to adhere to these. A road materials database would thereby embrace the full range of materials tests being carried out in the country.

In terms of materials properties to be covered in the database, the requirements of the visited countries show sufficient similarity to justify the reference to a generic design of a road materials database although some level of flexibility may be required to meet country specific requirements. The key properties in gravels are grading, strength, plasticity and compaction. The key properties for aggregates are grading, strength, shape, resistance to weathering, resistance to polishing and adherence to bitumen. For sand, its grading and level of organic contamination determine its suitability for concrete works, grouting and road surface seals.

The implementation of the materials database should be based on a pragmatic, staged development process**,** initially prioritising the interfaces for the most important user groups: materials technicians carrying out materials testing, materials managers approving the test results and storing the information and project engineers to plan, budget, design and supervise road works. Once this is operational, additional modules (interfaces) can be added for consultants' and contractors' materials reporting, mapping applications and linkages to the road asset management system.

Based on the information obtained from other countries in the region, as well as experiences of information systems development projects in other sectors, the initial focus should not be on collating, preparing and entering historic data, which is mostly paper based in a variety of formats. Instead, the focus should be on establishing integration with workflows so that new data (including materials test results obtained from samples of existing materials sources) begins to get captured automatically as part of the improved laboratory management workflows for materials testing, both at government-managed laboratories as well as those managed by third parties. This will ensure sustained update and growth of the database without the need for additional resources. Once these processes are fully operational the focus may shift to preparation and entry of historic data, working backwards from the present.

4 Database system development

This chapter presents a proposed approach to the development, piloting and roll out of the Road Materials Database, responding to the issues identified and lessons learned. While it necessarily deals with certain technical aspects of information technology and software engineering, the concepts are presented in plain language as far as possible, aimed primarily at a roads practitioner readership.

4.1 Design strategy

The proposed system design is based on the following underlying considerations, derived from the literature review, observations in the countries visited and general experience of information systems projects elsewhere:

a) Simplicity of function and ease of use are important factors in successful implementation. This needs to be balanced with the need to address information requirements in sufficient depth as to make the system useful and attractive to users, which leads to a system design that addresses a limited set of priority areas;

b) The requirement to design a generic system that may be rolled out across AfCAP partner countries (and beyond) must be balanced with the inevitable need to accommodate specific country environments as well as the potential adoption of new technologies, materials and standards over time. This is accommodated by proposing a generic model that addresses the needs of the roads sector overall, while leaving provision for a high degree of adaptation to country requirements through parameter selection rather than extensive database modifications. Some modifications however, especially related to the user interfaces, will be inevitable as the roll out proceeds;

c) The design identifies many distinct modules, which may be developed as self-contained sub-projects, each yielding a useful practical result, so that software development and implementation risks are better managed;

d) It is assumed that levels of Internet and telecommunications access will be uneven between and within countries. Rather than assume that this will improve within a certain timeframe, it is proposed that the system architecture be adapted to the prevailing conditions in sub national offices or laboratories by allowing for a local copy of the sub-national database to be maintained and synchronised at regular intervals with the central (master) database.

e) The proposed design seeks to support existing procedures, workflows and templates so as to reduce the difficulties of implementation and possible resistance to change. The aim is to reduce the workload of users through the implementation of a new system, rather than the opposite, which often occurs if additional data entry requirements are imposed. Changes to workflows may be accommodated where operational efficiencies are identified and supported by the client agency.

f) The desire in many countries to integrate and consolidate the various systems that may already be in operation, can be supported in two ways:

    a. By indicating a specific means of linkage whereby systems such as Road Asset Management or Contract Management that have information requirements related to materials may do so based on the same Materials Source Code (MSC) and Materials Classification Code (MCC);

b. By adopting a strategy for linkage based on specific, identified points of intersection with the workflows, including physical documents if appropriate, rather than depending on linkages at database level or application level. This would allow separate systems to be developed without constraint, subject only to an overall logic (such as the MSC and MCC) which may be integrated at process level. This may be supported by an overarching user interface that draws data from multiple sources for presentation, possibly as a web-based front end.

4.2 System Architecture

The proposed system architecture is illustrated in a simplified schematic form in **Figure 1** below.

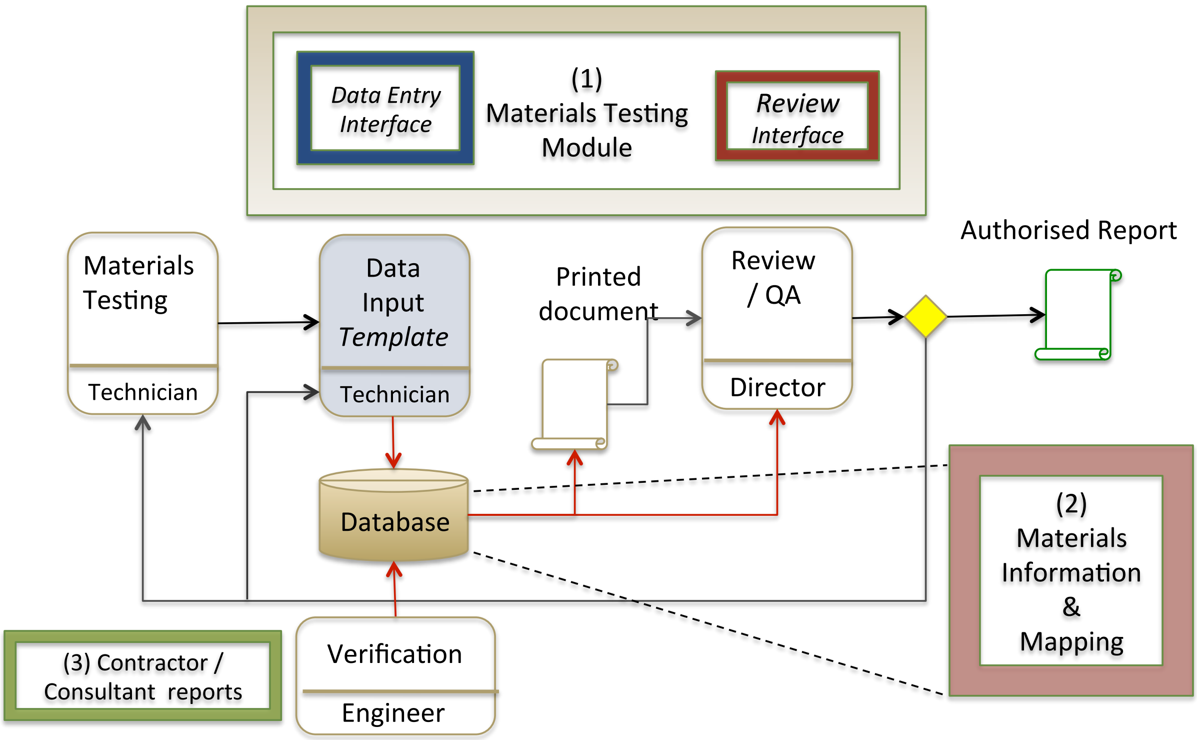


Figure 1: Proposed System Architecture

There will be a central database (the master database) hosted at some central location, either in the nominated lead road sector institution where the project will be anchored, or as a cloud-based service, capable of supporting multiple users from different locations, with multiple security and authorisation levels. A database management platform with the capabilities of MySQL (free open source) or MS-SQLServer (Microsoft proprietary), or similar[2] will be suitable. In some countries such as Mozambique all categories of roads are the responsibility of one government agency. In others such as Ghana, there are separate agencies to manage the different categories, such as highways, feeder roads and urban roads. In the latter case it will be necessary to identify a single entity to lead and host the database on behalf of the sister agencies although there will necessarily be a joint project team to drive system development and its ongoing management.

A web/application server together with suitable server side software will provide the primary access to the database. User interfaces will be mainly browser based, both for users located on the same

[2] Other popular options include: PostgreSQL (open source), Oracle and IBM-DB2 (both proprietary). Certain proprietary products offer free versions (SQL Server Express, Oracle XE, for example). However these are not recommended as they have significant restrictions on data volumes and allowed processor capacity, which inevitably require upgrades and the purchase of licenses early in the implementation process.

Local Area Network (LAN) as well as those accessing the system from remote locations over the Internet. A specialised App (Mobile Phone Application) with a limited set of functions will be developed for remote access, including off-line work, via mobile phone or tablet.

Sub-national offices will access the system via the same web-based application, provided adequate Internet capacity or direct connectivity to the central office, via a corporate intranet, is available. For those offices where connectivity is constrained, the system will be deployed with a local database, which will contain just the sub-national data. There will be provision to synchronise the data on a periodic basis using a background process, or in the worst case, physical transfer of storage media. It is likely that these updates will only be one-way (i.e. from sub-national to the central level) as the data required by the sub-national level will most probably be already in the sub-national database. In Ghana, for example, initiatives are under way to connect the sub-national offices directly to the centre. Such initiatives can be exploited as they become available simply by transferring to the web-based mode of operation.

The primary sources of data entry will be at the Government managed road laboratories, where the majority of the materials testing data is entered, and at sub-national offices, or the central office of the road agency, where materials data from contractor or consultant materials reports will be entered (or uploaded). Depending on the country environment and the decision of the respective government agencies a version of the data entry program and storage capabilities may later be made available to third party laboratories as a means of enhancing the completeness of materials data collected.

A mobile-phone or tablet device App is also proposed for Contractors, Consultants, Project Engineers and other users who will be in the field on a regular basis and will need access to certain materials information. This App will be designed to operate smoothly on locally-stored data when access to the Internet is limited, and to synchronise when connectivity is restored.

4.3 Functional Description

The proposed Materials Information Management System (MIMS) is described in terms of several modules below, representing an initial, high-level functional description of the system. These modules are proposed according to the grouping of features and likely user groups. A summary is provided in **Table 4,** followed by more detailed descriptions of each module in the following subsections.

Module	Users / Location	Functionality
1. Materials Testing	Materials testing laboratories.	User Interface to support sample collection and materials testing process, including data entry screens for Lab Technicians and support for the workflow related to review and approval of results.
2. Materials Information and Mapping	All user groups subject to assigned authority levels.	Presentation of summary and detailed material test data queried by geographic location, road link, material type, test date, sample owner and/or a similar prioritised set of criteria.
3. Capture of Contractor & Consultant Materials Reports	Roads sector sub-national offices and HQ engineers.	User screens to input materials data from templates included in contractor and consultant's materials report; support for query and retrieval of such information.
4. Smart Phone App	Road sector agencies, contractors and consultants in the field.	Downloadable App, providing access to limited set of information and input facilities, intended for use in the field, by roads sector agencies as well as contractors and consultants.

Module	Users / Location	Functionality
5. Linkage with Road Asset Management	Roads sector sub-national offices and HQ, engineers.	Provision to link "as built" information on pavement layers in Asset Management systems with materials sources and classification (based on a unique MSC and MCC).
6. GIS Assisted Materials Prospecting	All user groups subject to assigned authority levels.	Provide topographical, soils, geological and climate map layers on a GIS with overlays of road network, aerial photos and satellite imagery, to assist with prospecting of new materials sources.

Table 4: Summary of Proposed Software Modules

Each module or part of a module may be selected for implementation in each stage of software development as the pilot in Phase 2 progresses. The order of implementation priority is not fixed at this stage, except for Module1, which will be the main data source and therefore needs to be in place before other modules may usefully be implemented, and Module 2, which provides access to the information contained in the materials database. Module 3, which in most countries, will cover a substantial proportion of materials data that is not available in the testing laboratories, should also be regarded as a priority. Modules 4-6 may be regarded as optional and may be selected for implementation based on individual priorities.

1. Materials Testing Module

High level functionality

a) There will be provision for entry of materials test data at laboratories, with input forms designed around current templates as far as possible and supporting current (or desired) workflow. Data will be stored at the level of detail required by the laboratories. The material sources will be identified using a standard referencing system (MSC and MCC) to be agreed between agencies, so that it may serve universally across current and future systems, including especially, road asset management systems and take into consideration the type of materials (sand, natural gravel, aggregates etc.).

b) The laboratory data is typically highly detailed and pertains to each sample taken from a borrow pit or stone quarry. However, this level of detail is not useful for subsequent use by engineers, who require averages and variation ranges of materials properties across the borrow pit. The system will therefore have provision to enter and manage data at the level of detail required by materials management specialists at the laboratory, but it will also provide for computation of the averages and summary information required by Engineers, possibly with some manual intervention. This will be the same level of detail and the same format as the testing data that will be submitted as part of contractor progress reports and payment claims, which will be supported by templates for contractor reporting.

c) There will also be provision to update average values as new samples are tested from the same location. As updated information becomes available from new test results, the system will use that data to recalculate averages and summaries, while maintaining records of the earlier information, to facilitate subsequent research or performance analysis.

d) The system will include provision for management of test samples and results as required by the laboratories, including a basic automated work flow with support for verification and authorisation of data entered, for quality control purposes, on-screen, approval of results, and hard copy output. This will be similar to current procedures where multiple levels of checking and authorisation may take place, based on paper documents and signatures. It is not envisaged that the full workflow will be automated in the initial stages. Accuracy of data will be assured by printing out documents for authorisation at carefully selected points in the workflow, from the MIMS application, so that the information being authorised is guaranteed to be the same as that in the database.

The flow diagrams (**Figures 2 and 3**), illustrate in simplified form, how the materials information system may be integrated within the existing materials testing process, to take advantage of the existing process, while creating no extra data entry work.

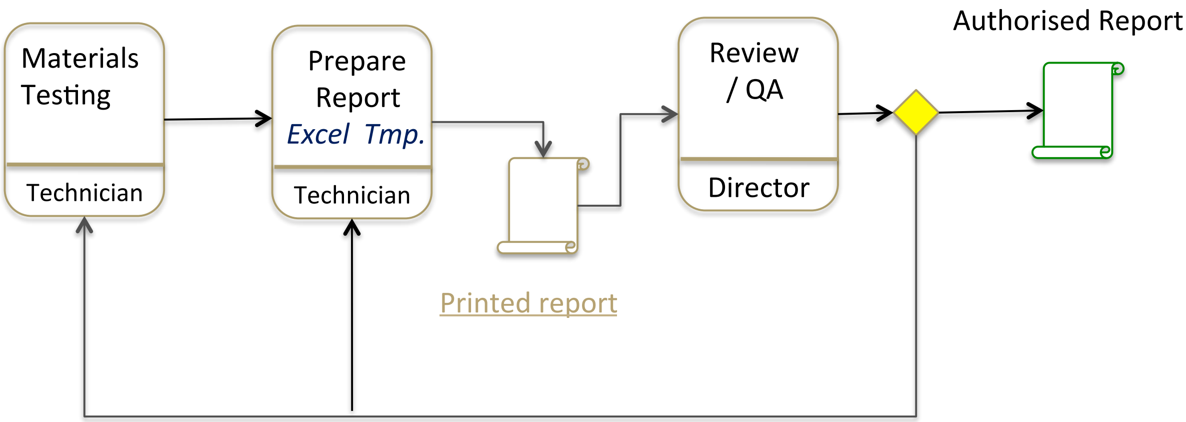


Figure 2: Example of current process at materials testing laboratories (simplified)

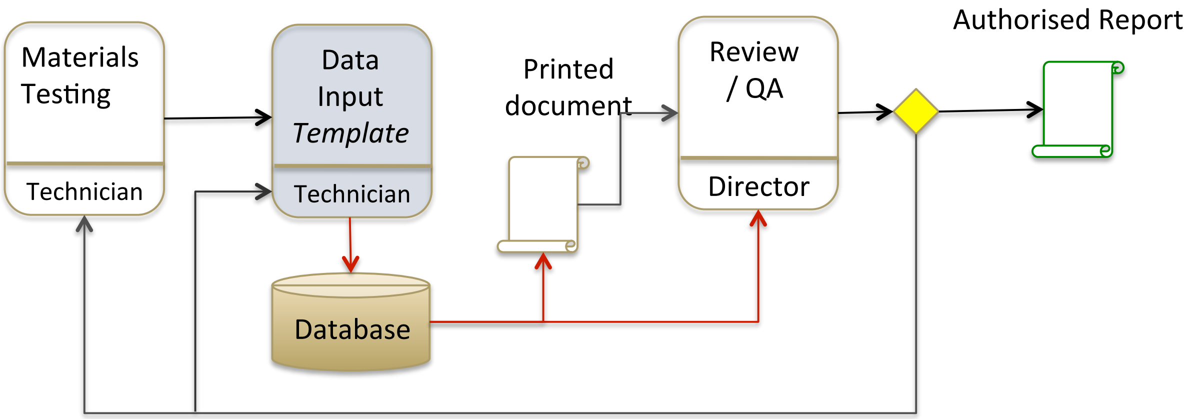


Figure 3: Materials Testing Module Integrated with materials testing process

Main Users

The main users will be technical and management staff of materials testing laboratories located in the capital as well as sub-national locations. Depending on policies of the respective government agencies, technical and management staff of materials testing laboratories operated by contractors may also be provided access to the system on a restricted basis so that relevant test results (if approved and independently verified by the supervising Consultant) could be submitted directly to client agencies, for review and acceptance if appropriate.

Implementation Considerations

The Materials Testing Module (Module 1) will be the first to be implemented as it is a primary data source and, in many countries road materials laboratories are mainly operated by government agencies, which would make implementation easier. The laboratories currently use templates for data entry, usually based on Word or Excel, which provide an opportunity for rapid implementation, as users are already accustomed to electronic data entry.

Implementation will focus initially on embedding the system within regular workflows so that new data and updates will progressively and reliably populate the MIMS without imposing any additional workload (e.g. capturing of historic materials testing data is to be avoided initially). Selected sets of historic data, for example, materials data pertaining to currently active contracts, may be input as a subsequent, separate activity, working backwards from the point of implementation if sufficient capacity is available to do so.

A significant proportion of materials testing is done at the sub-national road materials laboratories. Therefore the system design and implementation will need to take account of the connectivity options available at the time.

The provision for Consultants and Contractors to submit test results from their own laboratories may be implemented as a separate module later on and will not have immediate priority.

2. Materials Information and Mapping Module

High level functionality

a) There will be provision for reviewing the details of various types of materials available, by area, road chainage and GPS coordinates, as the basis for making assessments of potential materials sources.

b) Information on material properties will include suggested applications and actual past applications of the material in various projects as an initial guide, based on which further testing may be undertaken for new projects.

c) The location of borrow pits and quarries will be viewable on a map with an overlay of the road network links and possible other sources of relevant information (climate, soils and geological maps). Provision to compute haulage distances for specific materials to be applied to specified road sections will be available.

d) Information on ownership, access rights, and agreements with land owners, estimated quantities and other data required to manage materials sources on an ongoing basis where appropriate, or to consider their suitability for re-use in a new activity will also be included.

e) Support for occasional queries on various information regarding the source, properties, application and performance of materials as may be required for research. This is likely to include potentially complex, one-off queries, which may need to be addressed under technical support arrangements as they arise. A more general query facility may be implemented for user access, possibly as a sub-module.

Main Users

The main users are Materials Managers, Project Engineers located in the Headquarters as well as in sub-national offices, Consultants working from client offices in central and sub-national locations or working from their own project based locations. Provision for all categories of users accessing information from the field will be provided via smart-phone or tablet app, which will be developed as a separate module later on in the MIMS development process. There will be provision to monitor the different types and number of users of the database as an indication of its usefulness. This will require each user to be assigned an account.

Implementation Considerations

Full operation of this module can only happen after the Materials Testing Module has begun successful operation, as there would need to be a reasonable volume of information built up in the database in order to support the expected functionality. Project engineers and materials managers from sub-national offices will need to access the information and therefore available connectivity will need to be taken into account at the point of implementation. The detailed query facilities to support researchers may be implemented as a sub-module, after the main module has been in operation for some time and the database has become sufficiently well populated for such queries to be useful.

3. Contractor and Consultant Reports Module

High level functionality

a) There will be provision for data entry from the materials data provided in progress and materials reports supporting claims for payment. Detailed information on materials is provided in such reports, but at present, the information tends to be scattered and non-uniform making upload to the database difficult other than manual entry. In order to avoid the need for additional work to extract and enter the data, future contracts will need to include prescribed templates for samples collected and materials testing data submitted (including test results which do not comply with specifications for HVRs but might be useful for LVRs). There will also be provision to enter estimates of quantities available (or removed) from a particular source (and possibly quantities remaining), if such data is available.

b) The summarised test data entered here will need to be in a similar format to the summaries derived from detailed data in the Materials Testing Module. Based on the assumption that for some materials sources, no further detailed data will be available, it will be necessary to maintain a consistent set of data at this level of summarisation, within the database. Templates will also need to be designed so that they are consistent with the summarised test data provided via the Materials Testing Module.

c) Entry of materials information will depend on the project engineers and contract managers who review contractor progress and materials reports. Where a contract management system is already in place or planned (as in Ghana - DFR) it will be necessary to take the requirements of that system and its workflow into consideration in order to ensure smooth integration.

d) As a refinement, options for providing restricted access to contractors and consultants to the Materials Testing Module may be explored, so that materials data may be entered directly for approval by the respective road agency engineers (similar to Western Cape Province Gravel Management System in South Africa). If this approach is adopted, it would not only reduce the data entry and processing effort by engineers, but also provide contractor and consultant laboratories with a uniform MIMS providing access to all test results including those deemed unsuitable for a particular application. Where contract management systems are being implemented, it would require a suitable linkage to avoid additional reporting and data entry effort.

Implementation Considerations

As one of the primary sources of data entry, this will be the third module to be implemented. If it is agreed that contractors and consultants will also use the Materials Testing Module as a tool and suitable workflows, some functionality may be implemented even earlier (before the Materials Information and Mapping Module). Integration with any existing Contracts Management System (CMS) will also be important as materials test data is a key part of progress reports that are relevant to the CMS and support payment of contractor's invoices. Provision for data entry from remote locations, possibly including project-based laboratories may therefore need to be taken into account.

The schematic diagram (**Figure 4**) illustrates how modules 1-3 will be integrated with the materials testing process.

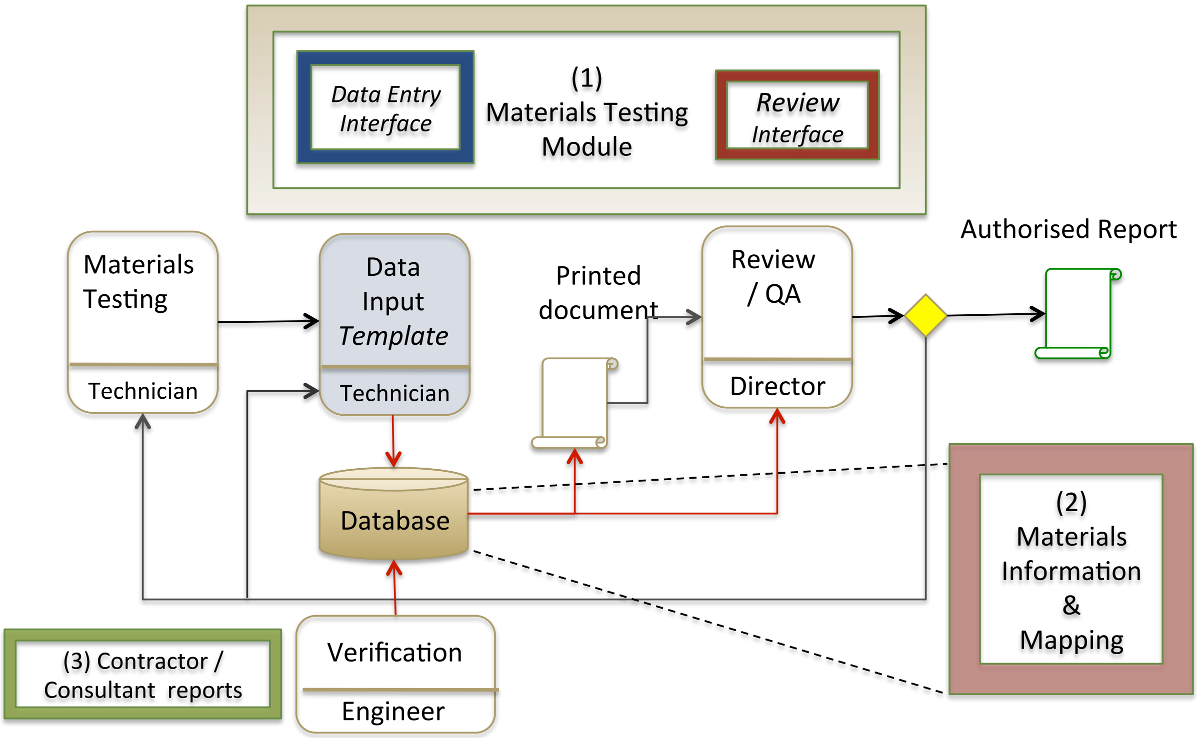


Figure 4: Simplified schematic diagram modules 1-3 integrated with the materials testing.

4. Smart Phone App Module

An App for smart phones or tablet devices will be useful in certain situations especially because some of the projects are based in remote locations with uncertain quality and speed of Internet services. A well-designed App could mitigate the impact of connectivity to some extent while providing the added benefit of mobility to certain users.

High Level Functionality

a) A downloadable App with access to features that may differ according to user credentials identified at login.

b) Provide access to certain identified sets of information that would be of particular value in the field, such as the location and basic materials properties of known borrow pits in specified locations using a mapping tool. This may include using GPS information to identify the current location as well as selecting a location from a list. Contractors, Consultants and Project Engineers would find this especially useful when prospecting for materials around project areas during road design, as part of the bidding process or at site handover stage.

c) Support for input of location data on potential borrow pits being sampled, including GPS reading as well as data entry of chainage and offset to be used alongside standard forms for non-electronic data capture in the field.

d) Support for the use of Munsell soil colour chart and/or similar useful tools for materials identification in the field such as a catalogue of botanical indicators for materials sources.

e) Provision for working off line both for reference and for data entry, when connectivity is poor followed by update when connectivity is available.

f) Design provisions to ensure that data bandwidth requirements are minimised and local data storage requirements are within acceptable bounds for the anticipated type of equipment.

Main Users

The main users are Consultants, Contractors and Project Engineers operating in the field.

Implementation Considerations

As the primary purpose of the App will be to support access to materials information data in the field, where Internet connectivity may be poor, the set of features provided and the associated data storage and bandwidth requirements need to be carefully designed to provide useful but specific functions rather than the full set of features. Where good bandwidth is available, authorised users may access the additional features through the browser interface if necessary. Where connectivity is poor, there will be provision for off-line operation, albeit with some limitations on the features available. The opportunity to access information remotely and also to input certain data remotely creates options for improvements to work flows which should also be considered at implementation time.

5. Module for Linkage with Road Asset Management Systems

High Level Functionality

a) The standard referencing system for Materials Sources and Materials Classification, which needs to be established at the outset, will be the basis of linkage between the materials database and any Road Asset Management Systems used by the respective agencies. The universal identifier will provide a reference to the source and classification of materials actually used and referenced in "as built" drawings and final reports.

b) Details on materials identified in the asset management system will be obtained by linkage with the materials database. The linkage may be established at various levels depending on the decision of the respective agencies. At the simplest level these agencies will have access to the materials database and the ability to make queries based on the identifier. A more sophisticated link could provide a web link / Uniform Resource Locator (URL) directly from the Asset Management System to a purpose designed interface in the materials database, which will provide a specified set of information. This type of linkage does not require that the two systems be directly linked at a software level or database level, nor operate on the same technology platforms.

Main Users

The main users are road asset managers, road researchers and materials managers exploring pavement evaluation and the performance of specific materials, especially marginal materials, in various applications and under different conditions.

Implementation Considerations

While the provision of a linkage between the materials database and asset management systems is relatively simple in a technological sense, implementing a genuinely useful facility will depend on:

a) Ensuring that the concept of a universal identifier for material sources and materials classification is agreed upon and maintained across all agencies and their information systems.
b) Implementation of an asset management system where information on road sections and the materials actually used in those sections is maintained at the required level of detail and accuracy. Again, this would require a proactive client specifying templates for submission of "as-built" drawings with identifiable materials sources and materials classification.

6. Module for GIS Assisted Prospecting

High Level Functionality

a) Provide topographical, soils, geological and climate map layers on a GIS with an overlay of the road network and borrow pit locations that have been previously identified or are in current use, to guide decision-making with regard to likely prospecting sites.

b) Useful information on materials available at each of the borrow pits included in the system will be accessible directly by mouse-over or clicking on the respective symbols. A report listing basic features and locations of selected borrow pits may also be produced for print out and reference.

c) Additional features to be considered for subsequent development may include guidelines and suggestions for investigation based on the geological, soils, climate and botanical features of the areas selected.

d) The module may be implemented with possibly two interfaces: i) with direct access to the GIS layers in order to update information or to obtain more precise or detailed information; ii) a version based on static map images which may be accessed more widely on a browser.

Main Users

Consultants, Contractors, and Engineers engaged in prospecting for materials.

Implementation Considerations

While the provision of information in the various GIS layers will not pose significant technical challenges, the use of this module in practice, will require considerable attention to training and skills development among users. It will be important, therefore, to include a well-crafted program of training as part of the roll out and to develop a set of practical guidelines and procedures.

In order for the module to be useful, the location of current and past borrow pits need to be known. Therefore, this module may only be implemented after the Materials Testing and the Contractor and Consultant Reports Module modules have been in operation for some time.

4.4 Generic design of the MIMS modules

The requirements of the partner countries visited and the discussions during the subsequent workshop indicate that the information needs and work processes are close enough that a generic design with some provision for local refinements is feasible. The requirements of the Materials Information and Mapping (Module 2), are especially suited to a generic design. However, country specific workflows for Laboratory Management (Module 1) and Contractor/ Consultant Materials Reporting (Module 3) will require more attention to local adaptation. The same is applicable to Module 5 (link to Asset Management systems), which is largely country specific, see **Table 5**. These modules will require some refinement to suit individual countries, but the variations as currently identified, are not extensive.

Module Description		Generic Level	Users / Location
1	Materials Testing	Country specific adaptations required. Different laboratory management procedures and workflows (e.g. templates).	Materials Engineers and Technicians. Managed by the Central Materials Laboratory (CML) but accessible by all road materials testing laboratories.
2	Materials Information and Mapping	Generic	All users subject to assigned authority levels. Web based managed by the Roads Authority HQ.
3	Contractor & Consultant Materials Reporting	Country specific adaptations required. Different testing procedures and workflows (e.g.	Project Engineers, Consultants and Contractors. Roads Authority HQ and Sub-national Offices.

Module Description		Generic Level	Users / Location
		templates).	
4	Smart Phone Application for Materials Information and Mapping in the field	Generic. Some country specific adaptations may be required.	Project Engineers, Consultants and Contractors operating in the field. Mobile accessible and linked to Module 2 managed by the Roads Authority HQ.
5	Linkage with Road Asset Management System	Country specific adaptations required. Different road asset management systems in use.	Project Engineers. Other users subject to assigned authority levels. Web based managed by the Roads Authority HQ.
6	GIS Assisted Materials Prospecting	Generic set up with country specific layer information.	Materials and Project Engineers. Other users subject to assigned authority levels. Web based managed by the Roads Authority HQ or CML.

Table 5: Generic design of MIMS modules

4.5 Enterprise data model

The Enterprise Data Model (often represented as an Entity Relationship Model – or ERM) is an important output of the database design process. A well-designed data model, based on detailed analysis of the operating environment and its information needs (both current and anticipated future needs) will be critically important to ensuring that the resulting database is indeed generic and adaptable to the different countries and the changes that may arise in the foreseeable future.

An example of a high level Entity Relationship Model (ERM) based on the limited information obtained in the scoping study, is attached at **Annex H**. The aim is to illustrate how the information in such a model may be broken up into Entities at increasing levels of detail[3] and how this can support future operational changes, such as the adoption of non-traditional materials, test standards or specifications, for example, without changes to the overall structure. In order to be "generic" and adaptable to country specific needs, the data model is designed so that it can support a number of key requirements. For example: the type of material, the properties of interest that will be tested (such as strength or plasticity), the test used (e.g. CBR, DCP), the test method (BS, AASHTO, etc.), the test description (e.g. CBR 4–days soaked), the test value obtained (e.g. CBR or DN) and the acceptable ranges for each type of application such as HVR and LVR, as well as country specific adaptation. The model also provides for future developments such as changes in the way tests are conducted, acceptable ranges and new materials. The aim is to allow for selection of an appropriate combination of parameters in each country (and/or agency) at implementation time so that there is flexibility to change certain aspects without the need for extensive modifications to the underlying database structure, later on. Careful design of the ERM also eliminates duplication and helps the database management system maintain the integrity of data, automatically.

It is emphasised that the ERM here is purely illustrative and does not include some entities required for the detailed software design, in the interests of clarity. Similarly, only a sample set of attributes has been included within each entity, sufficient to illustrate the concept. The model will need further discussion and refinement during the detailed design activity, prior to software development in each country. However, this, together with the functional descriptions proposed in the previous section, sets out the framework of a generic design, which could guide the development and implementation of the MIMS in each AfCAP partner country.

Figure 5 below presents a small part of the ERM, to illustrate how sections of the database are joined to provide views relevant to the different modules, each of which has a slightly different, but related focus. This also illustrates how the database design could be generic, and the main elements of the model are independent of technology platforms. The software modules could, if required, be built on different technologies for some partners, so that countries that have a preference for particular platforms due to ICT policy or skills considerations, have a choice.

[3] A step known as "normalisation"

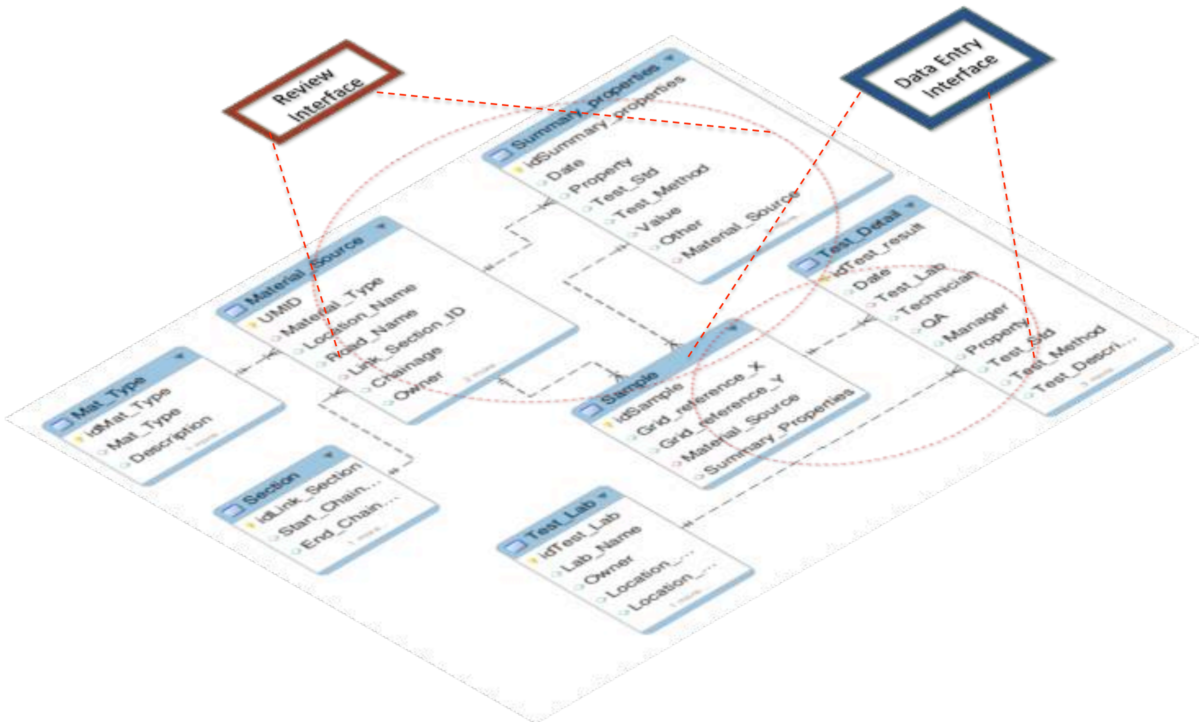


Figure 5: Partial ERM for Material Testing Module (1)

The range of suitable technology platforms capable of delivering the performance and capacity requirements of the MIMS is relatively wide. However, the choice may have a significant impact on long-term sustainability and therefore, should be made with care. The following factors will influence the choice:

1) Whether the country or the client agency has preferred technology platforms and/or service providers identified in its ICT policies;
2) Assessment of the cost of purchase and of continuing maintenance. This is not limited to the initial license fees but also to the cost of ongoing technical support and periodic upgrades to software and underlying hardware (i.e. Total Cost of Ownership);
3) Restrictive procurement procedures in some countries may limit the ability to extend software licenses later on;
4) Availability of skills. For example, the use of open source technologies may appear attractive in terms of cost due to the absence of license fees, but in some environments, may prove unsustainable due to lack of local skills for maintenance.

The desire for compatibility with existing systems need not be a constraint, as modern technology platforms all provide a range of options for interoperability. This is especially true if attention is paid to good design principles, which emphasise de-coupling the logic and process of individual software components, and exchange of data in standard formats through supervised processes[4].

Based on these considerations, **Table 6** presents some of the popular options for consideration.

[4]The strategy for connecting the Ghana contract management system with Ghana Integrated Financial Management Information System (GIFMIS) through approved payment vouchers is a case in point, even though data transfer is manual in this case.

Component	Technology Options	Advantages	Disadvantages
Database Management System	MySQL or PostgreSQL	Free open-source; MySQL is widely used and has as much capacity and multi-user capability as the major commercial offerings; PostgreSQL has many additional features, and is gaining popularity. Skills widely available for MySQL, growing for PostgreSQL	No particular disadvantages.
	SQLServer (Microsoft), Oracle (Oracle Corporation), DB2 (IBM).	Commercial proprietary; Widely used industry leading database management systems with sophisticated administration features. Strong technical support, (somewhat dependent on licensing model). Skills widely available, often with certification.	Total cost of ownership is likely to be higher than open source options
Application server / web server	Apache / Tomcat	Free open source; Majority of websites in the world use these technologies; Known to be robust and reliable; Skills widely available	Slightly more set up effort than commercial options.
	IIS / ASP/ .NET (Microsoft) Websphere (IBM)	Commercial license. Widely used, good features and reliability. Skills widely available. Good tools for system development that promotes productivity. IBM Websphere supports Java technology suite (i.e. non-proprietary).	Cost, due to licenses and the need to maintain underlying hardware and operating systems updated, is likely to be significantly higher than open source options.
User interface software	PHP / Javascript / HTML /Java / JSP	Free open source; Popular and widely used; provides all required features for this application;	Development tools are not as sophisticated as commercial options, resulting in slightly more software development effort and skill requirements.
	Microsoft Visual Studio (C#, ASP .NET)	Commercial Graphical integrated development environment (IDE), popular due to reduced programming effort;	License cost; Restricted to Microsoft suite of technology platforms.

Table 6: Comparison of Popular Technology Options

Based on this comparison, the open-source option has clear advantages and, unless ICT policies or availability of skills dictate otherwise, it is likely to be the more sustainable option for AfCAP partner countries.

4.6 Implementation Strategy

The literature indicates that many attempts to implement MIMS in other countries have not been sustained over time. These initiatives display certain common shortcomings in their approach, some of them well recognised in the software industry. They include:

1) Attempting to specify and build the entire system in one large project, with just one project cycle – usually following the "Waterfall model" which moves progressively through the main stages: Requirements Definition, Design, Software Development, Testing and Implementation in sequence. This allows little room for error and often fails due to inexperience in the requirements definition stage. Users discover inadequacies in the design only when the built system is tested and revisions are often costly and time-consuming. Even if an acceptable system is developed, this approach has the further disadvantage that implementation may require simultaneous adoption by many different user groups at various points in the work flow, which can be hard to manage.

2) The data entry effort imposed by the new system may actually increase the workload of users and therefore becomes unsustainable. This is often due to paying inadequate attention to this aspect at the design stage. It is particularly true if the system is designed for data entry outside of the main workflow, rather than integrating it within the workflow. Notably, systems that have been regarded as successful (e.g. Namibia) also report difficulties in maintaining up-to-date information due to high data entry effort.

3) Attempting to import or enter large volumes of past data prior to commencing live operation (data conversion). This is often impractical, especially if the data is in hard copy, because it is likely to be in a format that was relevant to the processes that existed at the time, but are incompatible with the new system. Data extraction and conversion, especially if done manually, can be tedious, difficult and error prone. If this data is considered valuable, then it can still be added progressively at a later stage once the MIMS is operational.

4) Systems that have been successfully developed and implemented for a while have later fallen into disuse, apparently due to difficulties with ongoing maintenance. This is often a factor when donor-financed projects look after the initial costs, but no strategy for local support is in place. This is sometimes further exacerbated by high ongoing license costs or upgrade costs associated with the software.

The recommended implementation approach seeks to address these issues:

1) It is proposed that an adaption of the "Agile" software development methodology[8] is adopted. This lays emphasis on progressing through small development cycles, technically known as "sprints", that each delivers useful outputs. It also allows for several iterations so that modules already built and in use, may be further developed and refined with the benefit of user experience. The proposed work program identifies several Modules which may be developed individually in sub-projects of between 2-4 months estimated duration. They may also be split into smaller "sprints" if appropriate, at implementation time. Close attention will need to be paid to ensuring that these sub-projects do not expand to encompass a wide range of requirements during implementation.

2) The proposed design is based closely on the processes that road sector agencies operate today and seek to address issues that have already been identified. Data input will occur as part of an existing workflow, based as far as possible on existing templates. Each module seeks to improve the workflow or address an identified issue in that functional area. It is acknowledged that these design recommendations are necessarily based on the countries that have been visited and whose processes and systems have therefore been observed in detail. However, it is thought likely that processes will not differ substantially elsewhere and that differences that exist may still be addressed with these basic design guidelines in mind.

3) It is recommended that implementation should commence without attempting to load past data, so that the workflow itself will capture data from the start date onwards. Over time this will build up into a useful database. If the client agency requires conversion and entry of past data, this may be accommodated, also as formal "sub-projects" under the Agile

methodology, that will focus on working backwards from the start date of implementation rather than forwards from an arbitrary date in the past. By limiting data conversion to what is practicable within a sub-project of one or two months' duration, assessments of what is feasible and useful may be done and further data conversion may be considered accordingly. Importantly, this activity may continue concurrently with development of other modules and need not hold up the development or implementation of those modules in any way.

4) The "ownership" and responsibilities with respect to development and ongoing maintenance is seen to be a critical success factor. It is important that a single lead institution is appointed in each partner country. Joint-working groups representing all stakeholder institutions will be required to enhance the cooperation framework between the road sector stakeholders. There may be a need for two working groups, split according to areas of expertise:

    a. Experts in road construction and maintenance engineers, with an emphasis on materials management, who would represent the users and actively participate in defining detailed system requirements, implementing templates and other changes to procedures, and approving system features through high level testing and review.

    b. Experts in Information System development and management, selected according to their experience in information systems projects, to work with IT consultants and service providers to ensure delivery of user requirements.

   The physical technology resources (servers and other hardware) may also reside with one particular agency, but the responsibility of that agency as a service provider to the other entities involved will need to be clearly and formally established before the project commences in each country.

5) A strong indicator of potential sustainability of an information system is the availability of ongoing technical support and its cost. The use of qualified local service providers to develop as much as possible of the software, with close involvement of the client agency in selection and management of contractors, is therefore recommended as a strategy to ensure continued technical support and client ownership.

All software developed under the project will be open-source, which will give the client the right to use any skilled service provider to maintain the software later on. (Note that open-source in this context does not necessarily mean that the tools and platforms used to develop the software are also open source - countries do have a choice of technologies). The TOR will also need to specify that adequate technical and user documentation needs to be provided for all software.

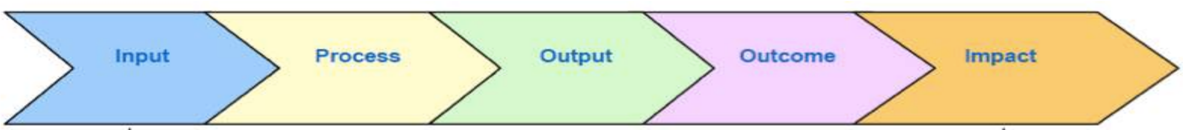
5 Formulation of Phase 2 and 3 of the Project

5.1 Project description

5.1.1 Logical framework

The output of the project is a multi-modular Materials Information Management System (MIMS), which will be developed, populated, tested and used by interested countries that have shown a commitment and readiness to meet the minimum implementation requirements. The MIMS will be developed using a staged development process based on the "Agile" methodology. The proposed implementation arrangements are based on this assumption.

A summary of the logical framework, presenting the cause and effect diagram leading from inputs to impact that the project is expected to achieve, is presented in **Figure 6**.



Input	Process	Output	Outcome	Impact
Phase 2: max. GBP 587,000 per country, being GBP 527,00 0AfCAP support (including 1 FTE international and 4.5 FTE staff years local input) and GBP 60,000 partner country contribution (including max. 3 FTE year staff input). Phase 3: max. GBP 244,000 per country being GBP 194,000 AfCAP support (including 0.2 FTE staff years international and 1.8 FTE local input) and GBP 50,000 partner country contribution (including max. 2 FTE year staff input).	Recruitment of International Consultant and country specific Local Service Providers. Development and piloting of the MIMS in one partner country. Training and capacity building activities. Roll out, adaptation and uptake in other interested AfCAP partner countries.	**Output 1 (Research and Uptake):** Selected AfCAP partner countries have developed and use the MIMS that systematically collects information about the location, availability and properties of suitable road materials as part of their standard work procedures. **Output 2 (Capacity Building):** Representatives of road sector stakeholders in selected AfCAP partner countries have been trained in the development, operation and use of the MIMS. **Output 3 (Knowledge Sharing):** The purpose and benefits of the MIMS have been disseminated to representatives of ReCAP partner countries and the wider community of LVR practitioners and results in further requests for research.	Government road engineers, consultants and contractors will be better able to locate materials that are appropriate to the category of roads to be improved thus reducing wasteful use of scarce resources, reduce the cost of the works and providing better road access.	A more sustainable and cost effective use of road materials leading to improved access to socio and economic services and reduced transport cost.

Figure 6: Logical Framework Concept

Based on the findings of the Scoping Study, a draft Logical Framework has been proposed for Phase 2 and 3 of the development of MIMS as presented in more detail in **Annex I** using the general ReCAP template.

The activity itself does not specifically address gender issues but the project will encourage partner institutions to engage female materials engineers, technicians and researchers to be actively involved in the development, population and operation of the materials database. This has been specified in the logical framework milestones and end of project targets, i.e. at least 3 female materials engineers, technicians or researchers are involved in the development and operation of the materials database.

5.1.2 Potential benefits of MIMS

While a full cost-benefit analysis of implementing a MIMS is beyond the scope of this study, it is possible to highlight some of the benefits of the MIMS, which may be taken into account in such an analysis. They include:

- Development of harmonised workflows for materials sampling, testing, reporting and data storage will enhance productivity of the road sector stakeholders, in particular staff working at the road materials laboratories;
- Better information about the location, quantity and properties of existing material sources will result in reduced cost for materials prospecting and haulage;
- Optimization of material use by matching materials properties with the minimum requirements of the pavement layers as determined by the subgrade strength and traffic loading. This would avoid wasteful use of materials that have properties well in excess of those requirements.

Based on a case study of one HVR project in Mozambique the Consultant has estimated the potential benefits of better information about the location, quantity and properties of existing material sources (second bullet point above). The case study showed that 50% of the materials prospected for the HVR project were rejected as not complying with the minimum requirements of the road pavement layers. However, the majority of the rejected material fell within the acceptable specification range for LVR maintenance and improvement projects, either in pavement layers or as wearing course. The materials' reports submitted by consultants and contractors are usually paper based and rarely reach the road authority (or project engineers) responsible for LVR, and as such, this information is often lost.

For the case study in Mozambique, the cost associated with the materials prospecting of the rejected materials was in excess of USD 50,000 and the amount of rejected materials suitable for use in LVR was over 300,000 m^3, representing a market value of USD 2 Million. In a typical AfCAP partner country, there could be up to five (5) such HVR projects in any given year. The benefits would be substantial if this information was stored in a database and accessible to all road sector stakeholders.

It is expected that the potential benefits and related cost savings of the road materials database would give a high return on the initial development cost, which is estimated at approximately GBP 500,000 (see Section 5.4).

5.2 Project management arrangements

5.2.1 Procurement options

The Consultant's experience with database and management information systems indicate that the likelihood of successful development and operation hinges on creating high levels of local ownership and promoting long term partnerships between the beneficiary institution and local service providers to support the development, operation and technical support of such systems.

Based on the skills and experience required, a Consultant with international experience will need to be procured to manage and oversee the design and development of the road materials database. Local IT Service Providers will be engaged to develop software and implement the project together with the beneficiary institution, under the overall supervision of the "International" Consultant.

The adoption of an "Agile software development and implementation methodology" remains a key aspect of the Consultant's recommendations for implementation and an important departure from past practice in many countries. Actually implementing this approach, however, requires considerable flexibility in contracting arrangements, which may run counter to conventional contracting methods where TOR and outputs are well specified at the outset in order to allow tenderers to estimate costs accurately. Under an Agile approach there needs to be flexibility not only with regard to the decision to proceed with each sub-project based on the output of the previous one, but also to make changes to the TOR of those sub-projects and even to create new ones, based on actual implementation experience. In the case of AfCAP, it may even be necessary to revise decisions as to the order of implementation in partner countries depending on the progress of previous sub-projects. Without such flexibility, there is a significant risk that the process reverts, implicitly, to the conventional project approach. This is indeed a noted issue in the literature, especially with respect to public sector procurement.

Options and advice on suitable contracting arrangements for Agile projects, practiced by public sector agencies, including UK and US governments, are available in recent literature [9, 10, 11 and 12]. While some of the approaches discussed may not be feasible in the AfCAP context, an adaptation of a "framework" type contract, for example, could provide the required level of flexibility and is recommended for consideration.

In broad terms, based on familiar procurement methods, two (2) alternatives may be considered:

- **Option 1: Consultant with international experience to select Local Service Providers at tender stage based on clearly defined outputs in the TOR.** AfCAP prepares a very specific and detailed TOR for the road materials database development in a country(s) selected for the pilot development and in consultation with AfCAP partner countries. AfCAP then recruits a Consultant with international experience who, as part of the technical proposal, identifies a local service provider with whom it will work for the development of the database. The project is implemented by the Consultants with international experience through the local service provider and in close collaboration with the pilot partner country(s);
- **Option 2: Consultant with international experience to subcontract Local Service Providers after award of the contract using a negotiated procedure.** AfCAP prepares a more general TOR for the Consultant with international experience with a Provisional Sum for the recruitment of Local Service Providers. The "International" Consultant will refine the country specific TOR for each of the partner countries and select a local service provider jointly with the partner country using a competitive procurement method. The "international" consultant, through the selected local service provider, implements the project. The local service provider will be contracted and paid by the "international" Consultant on a cost plus basis under the Provisional Sum.

The advantages and disadvantages of the two options are compared in **Table 7**:

Option	Advantages	Disadvantages
Option 1	All resources required will be managed by the Consultant with international experience.	Need a fully detailed TOR to allow the Consultant with international experience to provide a realistic cost estimate for the scope of work.

Option	Advantages	Disadvantages
		There is limited flexibility to adapt the assignment to country specific requirements. Limited ownership and buy in from the beneficiary partner country to select the local service providers and other purchases.
Option 2	All resources will be managed by the Consultant with international experience. Flexibility to adapt the assignment to country specific requirements. A fully detailed TOR is not required at contract award. Creates ownership and buy in from the beneficiary partner country in the selection of local service providers and other purchases.	There is a risk of cost variation during the contract implementation if local service providers submit cost estimates that are higher than the provisional sums in the main contract with the Consultant with international experience. Selection of the local service provider may be motivated by priorities that are not in the best interest of the project. The extent will vary from country to country.

Table 7: Options for project delivery

Based on this comparison, Option 2 is recommended as the most appropriate project management arrangement, as it addresses the issues of local capacity and ownership more effectively. The Consultant with international experience remains overall responsible for the development of the database but will work closely with the partner countries to select qualified and experienced local service providers. This will also allow sufficient levels of flexibility to accommodate country specific requirements.

The procurement options will require further discussions between the PMU and the partner countries to determine the most appropriate procurement method.

5.3 Action plan

The action plan is based on the assumption that a staged development process, based on a suitably adapted Agile methodology, is adopted, where small but measurable outcomes are targeted in stages lasting no more than three to four months. Some of them may run concurrently in the different countries in such a way that Phase 2 and 3 may actually overlap, as shown in **Table 8.**

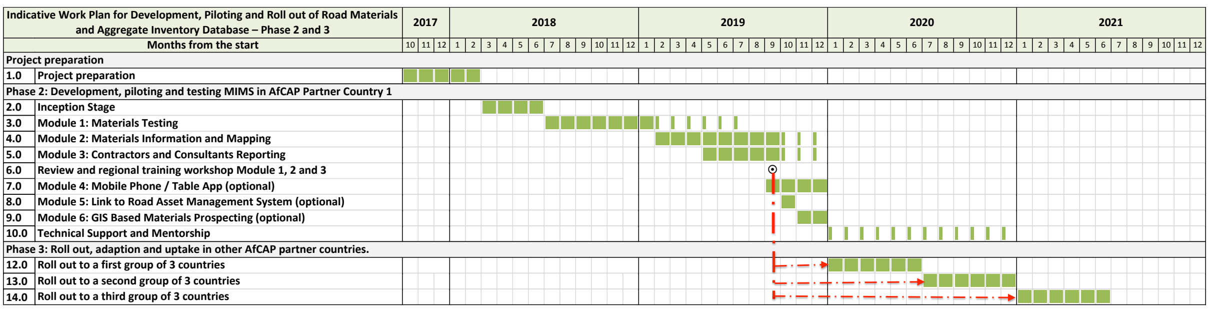


Table 8: Action Plan

This Action Plan assumes a relatively aggressive implementation, to develop and implement all six modules currently identified, over a period of 21 months during Phase 2 and over a period of 12 months during Phase 3. In practice, however, the linkage with Asset Management Systems (Module 5) depends on the Asset Management System being implemented at a sufficient level of maturity.

Modules 4 (Mobile Phone App) and 6 (GIS assisted prospecting) depend on both interest and development of necessary skills across all stakeholders in the road sector. Given these uncertainties and the fact that none of these three modules will significantly reduce the efficacy of the materials database itself, a more conservative plan may also be adopted, where inclusion of these modules would depend on successful development of the first three modules.

After completion of this Scoping Study, AfCAP and the partner countries will probably need about 6 months for project preparation to review proposals of partner countries, select the pilot country for Phase 2, prepare the TOR for the Consultant with international experience, recruitment and mobilization.

It has been assumed that the project will start in the first quarter (Q1) of 2018 following a multi-staged development / implementation approach. The MIMS will be developed and piloted in one (1) partner country that has demonstrated to have the resources to adopt, populate and operate the MIMS as part of Phase 2.

During Phase 3 (roll out and uptake), other interested partner countries will have an opportunity to implement the materials database. The time lapse between Phase 2 and 3, about 18 months, would allow for:

- An in depth review of the development and implementation of Modules 1, 2 and 3 in the pilot country to draw lessons learned for roll out and uptake; and
- Other interested countries to get ready for implementation in particular the institutional arrangements, setting up the project team and have the minimum requirements in place.

During Phase 3 it is proposed that groups of maximum two (2) to three (3) countries join at intervals of about 6 months. The stakeholder workshop in Maputo also revealed interest in exploring three possible scenarios for implementation, especially with respect to the potential impact on budgets. These options are discussed in more detail in the next section. A more detailed Action Plan for Phase 2 is attached in **Annex J.**

5.4 Indicative budget for Phase 2 and 3

The stakeholder workshop in Maputo led to substantive discussion on the action plan and budget for Phase 2 and 3, including suggestions to develop scenarios that may reduce the initial investment.

Selection of MIMS Modules

The indicative budget is therefore presented in terms of three scenarios:

1) Minimal system comprising just the three core modules (1-3);
2) Intermediate system which includes the three core modules and any one of Modules 4-6; and
3) The full six modules.

The minimal scenario with Modules 1-3 is expected to result in a useful database, which, subject to full implementation across sub-national locations, will receive nearly all major materials data sources. However, some countries have noted their interest in the additional modules such as Module (4) –a Phone/Tablet based App. Other countries, that have already implemented Asset Management Systems and Contract Management Systems, are keen to ensure proper integration with those systems (Module 5). The intermediate system in Scenario 2 is designed to respond to such country specific requirements.

Implementation Support for Sub-National Rollout

The budget and action plan also include provision for technical support during the roll out to sub-national locations in each country. Based on the workshop discussions, technical support during the rollout will be provided for the first five locations only. It is expected that adequate local capacity would have been built by then to support roll out to the remaining sub-national locations.

Minor adjustments to the unit cost

In addition to the different scenarios for project implementation (as described above), and based on the feedback obtained during the regional stakeholder workshop, some additional changes have been made compared to the budget presented in the draft database report, reflecting:

- A higher monthly unit cost for the local IT service provider based on prevailing market rates from other partner countries (the initial rate was obtained from Ghana);
- Correction of the monthly unit cost of the International Consultant following the continuous devaluation of the GBP (the required consultant inputs are estimated based on a balance of on-site and remote work in order to reduce overall costs);
- Correction of the monthly unit cost applied to country contributions of staff time;
- The inclusion of one international review / training workshop after implementation of modules 1-3 and a reduction in the number of national workshops.

Indicative budget

An indicative budget (summarised in **Table 9)** has been prepared for the development of the road materials database on the assumption that this will be piloted in one (1) country during Phase 2 and rolled out to other interested AfCAP partner countries during Phase 3. It must be considered indicative only, as there will necessarily be variations across countries during the roll out.

Indicative budget (GBP) per country for three scenarios – Phase 2:

Cost Item	Scenario 1	Scenario 2	Scenario 3
International Consultants	181,000	205,000	238,000
Local IT services	194,000	225,000	239,000
Local and International workshops	40,000	45,000	50,000
Sub-total AfCAP	*415,000*	*475,000*	*527,000*
Country contribution (Equipment, Transport, Logistics, etc.)	30,000	32,000	37,000
Country Contribution – Staff time (valued at GBP 800/month)	16,000	18,000	23,000
Sub-total country	*46,000*	*50,000*	*60,000*
Total Project Cost	**461,000**	**525,000**	**587,000**

Indicative budget (GBP) per country under three scenarios – Phase 3

Cost Item	Scenario 1	Scenario 2	Scenario 3
International Consultants	36,000	41,000	48,000
Local IT services	77,000	90,000	96,000
Local and International workshops	40,000	45,000	50,000
Sub-total AfCAP	*153,000*	*176,000*	*194,000*
Country contribution (Equipment, Transport, Logistics, etc.)	27,000	29,000	32,000
Country Contribution – Staff time (valued at GBP 800/month)	13,000	15,000	18,000
Sub-total country	*40,000*	*44,000*	*50,000*
Total Project Cost	**193,000**	**220,000**	**244,000**

Table 9: Indicative Budgets for Phase 2 and 3 of the Project

Further details about the budget assumptions are presented in **Annex K** (Indicative Inputs for Phase 2) and **Annex L** (more detailed budget breakdown for Phase 2).

Partner Contribution

Partner contributions, including staff commitments, have been estimated based on the assumption of average basis across partner countries. However, there may be considerations that apply to each country that may further reduce or increase the required contribution. These include:

- The number of staff required for each activity. Assumptions are stated in the action plan, but these positions may not be applicable to all countries, depending on the institutional arrangements.
- The number of staff months required during the roll out to sub-national locations assumes an aggressive schedule. This may be relaxed based on country preference, which would reduce the intensity of staff inputs even though the overall staff months required may remain the same and will help agencies that have limited capacity.

Countries are encouraged to further review these issues and to propose amendments or possible alternatives that may apply in their respective environments as they progress to Phase 2 and 3.

5.5 Minimum requirements to implement the MIMS

The development and piloting of the MIMS in the pilot country requires a partner country that is ready to implement and operate management information systems. Whereas AfCAP will support the deployment of international and local expertise for the MIMS development, a dedicated project team representing the beneficiary institutions with experienced staff in the area of road engineering, materials testing and IT, is required to work side-by-side with the International Consultant and Local IT Service Provider.

In addition, minimum hardware infrastructure and software facilities are required to effectively operate the MIMS based on the specific country needs and the ambition to link up decentralised road sector institutions and sub-national road materials laboratories. These goods cannot be funded by AfCAP and are therefore the responsibility of the partner country. The staff and IT requirements for the development, piloting and roll out of the MIMS are described below.

5.5.1 Hardware and software

The minimum hardware and software requirements will depend to a great extent on the volume of data anticipated, the number of concurrent users, and the type and sophistication of network connectivity available. For estimating purposes, it is assumed that there will be:

- Good Internet connectivity in capital cities;
- Around 10-15 users accessing the system through the Internet, a corporate network, or through a local area network (LAN);
- Around 30 sub-national locations, each with up to 5 concurrent users; and
- Approximately 10 sub-national locations will access the system via the Internet while others will require local (partial) databases.

Hardware

With respect to hardware, a server running Windows (e.g. Windows server 2012 or better) or Linux (e.g. Ubuntu 14.04 LTS or similar) Operating systems with 16GB (minimum) to 32GB RAM and Core i5 or better CPU will be sufficient for the first two years of operation. Around 500GB of disk capacity will initially be adequate, although much depends on the particular institutions and data volumes relevant to them. A backup server (which could be of lower capacity than the main server) is highly recommended. Backup disk capacity, ideally well in excess of the main server disk capacity, together with automated backup software is mandatory. A Virtual Machine environment such as VMWare or Virtualbox is also recommended as it would enhance reliability and reduce recovery times. Such an environment would also facilitate the staged development and testing of new modules, even while previous modules are in operation on the same physical server. An uninterruptible power supply (UPS) capable of powering the server and network equipment for at least 15 minutes will also be required in locations where power fluctuations or failures are encountered. Assuming a successful level of operation with widespread use by stakeholders and improving internet facilities, these basic specifications will need to be upgraded, possibly to at least 64GB RAM and multiple CPUs after the first two years.

Where Internet connectivity is such that separate databases are required at sub-national locations or offices of related agencies, a server will be required in every such location. Assuming five concurrent users, a desktop PC with around 16 GB RAM and Core i5 or better CPU may be configured as a server, with suitable backup and power supply arrangements.

Software
In addition to the main operating systems, an enterprise grade database management system capable of secure multi-user operation, such as Microsoft SQLServer, Oracle, DB2, MySQL, or PostgreSQL, is required. A web application server such as Microsoft IIS or Apache/Tomcat will also be required. With all such software, free open source options are available and a combination with suitable capacity and capabilities may be selected, subject to the appropriate technical skills being available locally.

GIS Software, capable of delivering the needs of the roads sector will also be required in order to realise the full vision of a materials information management system. Many AfCAP countries have ArcGIS in place. However, open source options such as QGIS may also be considered, especially where licensing costs are a constraint.

Network facilities
Local Area Networks (LAN) connecting all user machines to the server, via wifi or cable, will be required at the central headquarters and each sub-national location. Ideally, there should be adequate Internet connectivity or corporate network capacity to allow for direct access from all locations, so that there would be one server and system administration staff. However, the proposed system architecture can be adapted to an environment with low Internet connectivity at some locations.

5.5.2 Staffing

The availability of staff with experience of managing the implementation of an information system of similar scope and complexity, in a similar working environment, will be critical to success.

Required experience includes: guiding and facilitating the specification of user requirements; identifying and contracting suitable ICT vendors and service providers; and working with users to achieve a successful implementation and transfer of knowhow that is maintained and sustained over a significant period.

5.5.3 Local ICT services

Technical expertise to build the software and maintain it over time may reside with internal staff or, more likely, with external local service providers. Reliable access to such technical capacity must be regarded as a critical success factor. If external resources are to be contracted, it is also important that there be adequate internal technical capacity to manage such service providers effectively.

Some history of having managed such services, a reasonable supply of local entities with the required capabilities and current or past relationships with such entities will be important indicators of readiness to undertake implementation of the materials database.

5.5.4 Expected partner contribution

It is anticipated that the partner country would need to make available about 2-3 Full Time Equivalent (FTE) staff years for the initial development and piloting of the MIMS (Phase 2) in addition to providing the hardware infrastructure, software facilities, providing venues for national meetings and workshops and local transport. In terms of staffing, this is expected to be an allocation of existing staff rather than new recruits. It is estimated that this is equivalent to a local partner in kind contribution of between GBP 46,000-GBP 60,000 (Phase 2).

For Phase 3 this would be reduced to GBP 40,000 - GBP 50,000 per partner country (including 1.5 – 2 FTE staff years).

5.6 Criteria for country selection

Based on the stakeholder consultations and the diverse institutional frameworks for materials extraction, testing and information management encountered within and between the various partner countries, it is proposed that the country to develop and pilot the road materials database in Phase 2 should be selected using a transparent set of criteria. This was supported at the Stakeholder Workshop, where it was also noted that there may be a case for selecting more than one country for Phase 2, despite the acknowledged risk in terms of implementation complexity. The proposed criteria are:

1. A written request signed and submitted by the head of the road sector institution showing an ambition to take part in the AfCAP road materials database project and commitment to open access to road materials information;
2. A brief proposal outlining:
   - Which institution will take the lead as institutional anchor, in the development of the database;
   - The constitution of the project team clearly showing how the different road sector stakeholders will cooperate on this project;
   - The staff resources available to contribute to the development, operation and maintenance of the database;
   - How the minimum implementation requirements (see Section 5.5) will be met.
3. The maturity of the current institutional arrangements, systems and workflows for materials testing (e.g. laboratory protocols, work flows) and information management in the country;
4. The country's experience with successful development/operation of information systems.

Based on the proposals submitted by the partner countries, the AfCAP PMU, in consultation with the AfCAP Steering Committee, will select a country for developing and piloting the MIMS during Phase 2, with an anticipated start of early 2018. The first two criteria are also applicable to countries that wish to participate in Phase 3 for the roll out of the MIMS. The proposed evaluation framework for country selection is presented in more detail in **Annex M.**

5.7 Risk assessment

Based on the findings of the Scoping Study, a summary of the risk assessment framework for Phases 2 and 3 is presented in **Table 10.** These risks are formulated only for the development stage of the road materials database.

Potential Risk	Risk Grading[5]		Description of risk probability and impact	Proposed risk mitigation
	Probability	Impact		
Risk 1: Selected partner countries may struggle to allocate local contributions (in particular staff and IT resources) required for the development or roll out of the materials database.	Medium to High	High	This is a medium to high probability risk and common if multiple (often unplanned) projects are implemented which rely on limited staff resources in the host institution, in particular in the area of IT. The risk impact is high as this will delay project implementation and reduce transfer of technology between host institution, International Consultant and Local Service Providers.	The selection criteria of the partner country should include the availability of staff resources. This can be further mitigated through an MOU[6], which spells out the scope of the database and the responsibilities of the parties. The MOU is signed between AfCAP and the partner country and closely monitored by the International Consultant.
Risk 2: Selected partner countries may struggle to create a workable platform of cooperation between the road sector institutions and external stakeholders required for the development of the materials database.	Medium	Medium to High	This is a medium probability risk and may affect those partner countries where multiple road sector institutions are responsible for different parts of the road network. The risk impact is medium to high. If some of the road sector institutions do not participate fully, this will affect the coverage of the materials database and the extent of the data collection.	The selection criteria of the partner country should include a strategy to create a workable platform of cooperation between the many different roads sector institutions. This can be further mitigated through an MOU, which spells out the scope of the database and the responsibilities of the parties. The MOU is signed between AfCAP and the partner country and closely monitored by the International Consultant.
Risk3: Procurement and contracting method may result in the Agile methodology not being implemented in practice.	Medium	High	This is a medium probability risk, which may arise due to the applicable contracting procedures not taking account of the needs of a project based on an Agile methodology. The impact could be high, as it will eliminate the benefits of an Agile methodology, which especially in the context of a rollout across partner countries, are substantial.	The procurement and contracting process needs to take account of the particular needs of an Agile methodology from the outset. A framework arrangement may be considered as one option that would provide much of the flexibility required, without the contract management complexity of some of the other approaches available.
Risk 4: Selected partner countries may have different requirements, undermining the need for a generic materials database.	Low to Medium	Low	This is a low to medium probability risk. The scoping study concluded that the country requirements are reasonable similar. The risk impact is low since minor country specific adaptations can be accommodated in the database system design.	Building in some level of flexibility in the database design can accommodate country specific requirements, e.g. modules with differing functionality within the same technical architecture.
Risk 5: Selected partner countries may resist changing existing procedures and work flows essential for the development of the materials database.	Low	Low to Medium	This is a low probability risk. There may be some resistance to changes in existing processes and workflows but this is unlikely since the majority would not require any changes in regulations and policies. The risk impact is low to medium. It will not affect the database development itself but could affect data collection.	Attempt to demonstrate benefits from examples elsewhere; ensure that proposals are staged, to proceed in relatively small, easily assimilated steps.

Table 10: Risk Assessment Matrix

[5] **Probability** = the likelihood of this risk occurring despite the management and mitigation activities being in place. **Impact:** = the effect on the ability of the programme to achieve its objectives without major revision or review.

[6] A number of partner countries already have overarching MOUs in place with AfCAP, with subsidiary agreements for specific projects to ensure commitment of resources by partner institutions during project implementation.

6 Conclusions from Phase 1 and Recommendations for Phases 2 and 3

While the findings and recommendations of Phase 1 are dealt with in detail in the preceding sections, this section revisits only the key points, in order to emphasise those areas that are likely to have the greatest impact on Phase 2, the development and piloting of the Materials Information Management System (MIMS) and Phase 3 (the roll out).

6.1 Summary of findings

There are several examples of materials databases in Africa, as well as elsewhere, but only a few appear to have been sustained long term. Among the reasons cited are: lack of resources, loss of key personnel (and, therefore, reduced ownership of the system), limitations of the selected technology platform and lack of technical support. Closer investigation also reveals certain common characteristics in their designs and implementation that may have exacerbated these problems. They include:

- System designs that depend on separate data entry, outside the normal work flows, which require additional resources for data entry and challenges in the data verification process;
- Consequently, the lack of a specific approach to establishing a process that ensures efficient ongoing data collection and verification;
- A focus on preparing and entering historic materials testing data, often from paper records which may be in a variety of formats and not easily located;
- An initial choice of technology platforms with insufficient consideration of long term expansion needs and costs; and
- An implementation approach that attempts to specify and build a database as a single project ("the Waterfall model"), which often fails due to inexperience in the requirements definition stage. Inadequacies are only uncovered when the system is populated and tested.

It is noted that these issues are not uncommon in information systems development projects in other sectors as well as other regions.

Based on the scoping study, it is concluded that the needs of roads sector institutions with respect to materials information (properties, location, potential use) are sufficiently similar across the region as to justify the concept of a generic model which may be adapted to each partner country's specific needs.

Institutional ownership, which is noted as an issue in some of the past initiatives reported, will also require close attention in this context, as many AfCAP partner countries have more than one road sector institution; each assigned a responsibility for a different category of roads.

6.2 Key recommendations

The key issues noted with regard to information systems development are addressed through a series of recommendations in four key areas, as set out below:

1) System Design:

a. The population of the database should not depend on a separate data entry activity (which creates additional work) but rather on carefully identified points of integration with existing or proposed workflows.

b. The system should be designed to be accessible to the full range of personnel who require materials information, including those at remote work sites.

2) Implementation:

a. The establishment of an integrated workflow should be the first priority of implementation. This will ensure that a sustainable flow of data is secured from the outset. The entry of past data, which will require preparation and separate data-entry, may be addressed as a separate activity if considered essential.
b. It is recommended that implementation be based on the "Agile Methodology", which is current best practice in Software Engineering. This will result in a project consisting of several small stages, each targeting a useful result.

3) Ownership and capacity:

a. Strong ownership by the implementing agency is of fundamental importance. Therefore a formal statement of commitment to the project is proposed as a primary selection criterion for Phase 2.
b. Equally important in building local ownership, is the full participation of stakeholders throughout implementation. The proposed project formulation is therefore based on substantial inputs from sector agencies at every stage of system development.
c. In order to build the capacity of local technology providers who will provide subsequent technical support, a suitable provider will be identified and engaged from the outset.

4) Technology platforms:

a. There are several technology platforms, both open source and proprietary, capable of delivering the requirements of the materials database. The main considerations that will direct the choice, in the AfCAP context, are:
    i. The actual costs of long-term operation, based on an assessment of requirements in respect of: capacities, features, and licensing.
    ii. The availability of local technical support and any preferences dictated by the host institution or national ICT policies.
b. The technologies on which other existing systems in these institutions may be built, need not be a strong consideration, as most modern platforms are able to inter-operate, through common industry standards.

6.3 Workflows and Integration

There are two main sources of materials information, which, in turn dictate the workflows that will be integrated with the MIMS:

1) Materials testing carried out at central and sub-national laboratories of the main road sector institutions, which will be a primary source of information regarding material properties, location and potential use.
2) The reports submitted by consultants and contractors as part of their obligations under road design, construction and supervision contracts.

Integration with laboratory testing processes will be based on current reporting templates, adapted appropriately to ensure materials testing data captures information about the materials source of the samples, its environment and to support the (quality) management procedures of the laboratory.

The consultant and contractor reports (e.g. feasibility and preliminary design reports, detailed design reports, progress reports) currently include materials information, but are not in a specified format. Implementation will therefore require policies to adopt specific reporting formats and compliance measures.

Successful development and integration of the MIMS will also require full support by senior management of the road sector institutions in the AfCAP partner countries including their commitment to allocate local resources to system development and to ensure that the required policies, training and awareness are in place for proper usage of the database.

6.4 Key Risks

A number of risks have been identified. Assuming that the main institutional issues of ownership and resource allocation are overcome, the main technical risks are that the concepts underlying the key recommendations are gradually eroded due to issues that arise during implementation, for example:

- The implicit transition to a conventional (based on the Waterfall rather than the Agile methodology) development approach where project specifications are set out in advance and the concept of small, flexible sub-projects is diluted, due to procurement constraints;
- The temptation, often driven by technology providers, to design systems based on anticipated growth in Internet services in the regions. It will be important, therefore, to review progress on a periodic basis and ensure adherence to a single coherent approach.

6.5 Next steps

The action plan presented in Chapter 5, provides for a period of about five months for project preparation, which will be required before implementation of Phase 2 can commence. The key activities in this stage include:

- Partner countries to confirm their decision to proceed with implementation (or otherwise) based on their assessment of priorities and benefits against the estimated cost.
- Partner countries and AfCAP to reach an agreement on the scope and approach to implementation based on the recommendations of this report, as well as other considerations that may be identified.
- Selecting a partner country (or countries) for participating in Phase 2 based on their interest, readiness and other criteria.
- Procuring a qualified and experienced international consultant for project implementation.

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Annex B: List of persons and institutions contacted

Institution	Name
AfCAP Project Management Unit (PMU)	
Cardno Emerging Markets	Jasper Cook, Team Leader Les Sampson, ReCAP Infrastructure Research Manager Nkululeko Leta, Regional Technical Manager, East and Southern Africa Pauline Agyekum, Regional Technical Manager, Western Africa
Mozambique	
ANE HQ Directorate of Maintenance	Irene Langa, Director of Maintenance
ANE HQ Directorate of Projects, Monitoring Department	Hilario Tayob, Materials Specialist, Head of the Road Research Team Raquel Langa, Materials Specialist
ANE HQ Directorate of Maintenance, Maintenance Management Department	Rubina Normahomed, Head of Maintenance Department Member of the Road Research Team Fernando Dabo, Staff Member of Maintenance Department Member of the Road Research Team
ANE HQ Directorate of Planning, Department of Road Network Management	Manuel Tungane, GIS Specialist Calado Ouana, HIMS Specialist
ANE HQ, Directorate of Projects, Department of Contract Management	Antonio Devesse, Contract Specialist Andre Chachine, Contract Specialist
ANE Provincial Delegation Maputo	Cardoso, Provincial Delegate Osorio, Head of Maintenance Armindo de Acensão, Head of ANE Maputo Provincial Laboratory
CPG Provincial Road Maintenance Consultant	Rui Serra
LEM Mozambique Engineering Laboratory	Henrique Filimone, Director LEM Carlos Cumbane Antonio Pedro dos Santos Arone Jantos Aurelio Cuinia
Federation of Mozambican Contractors (FME)	Elisa Mangueleze (Executive Secretary FME) Silvio Mathabimu (Contractor JJR) Alferino Sargenio (Contractor CETA) Mario Paulo Monteiro (Contractor Mondego) Dalmildo S. Consalves (Contractor CETA) Frank Pagolho (Contractor CSM) Eugenio Migongo (Contractor CSM)
Ghana	
MRH, Directorate of Procurement	John Asiedu, Director Procurement and AfCAP Country Coordinator
MRH, Research Statistics and Information Management	Edmond Balika Abdul Wahab Ibrahim
GHA, Central Materials Laboratory	Nana Kwesi Agyepong, Director of Materials Olivia Naa-Afi Soli, Principal Materials Engineer
GHA, Management Information Systems	Maame Baawa Osei-Akuamoah, Director MIS
GHA, Road Maintenance Division	Kingsley Osae-Boateng, Road Maintenance Program Manager
GHA, Safety and Environment Division	Belinda Asante Ashan, Environmental Officer
GHA, Eastern Region	Emmanuel Laryea Odai, Regional Maintenance Manager
DFR HQ, Planning Division	Kwasi Osafo Ampedu, Deputy Director Planning Frank Amoah, DFR Road Engineer

Institution	Name
DFR HQ, Maintenance Division	David Brobey, Deputy Director Maintenance
DFR HQ, Development Division	Patrick Amoah Bekoe, Deputy Director Development
DFR, Eastern Region	Sem Osei Nketeiaa, Regional Manager Alphonso Atitey Quaye, Deputy Regional Manager Isaac Mensah, Contracts Manager Benedict Nannor, Assistant Quantity Surveyor
DFR, Eastern Region, Regional Laboratory	Asiedu Mintah, Laboratory Technician Christopher Essel, Laboratory Technician
DFR, GIS/IT	Ankrah Richmond, Head of the GIS/IT Section
DUR, Planning and Development Division	James Amoo Gottfried, Deputy Director of Planning and Development I. B. Armah, Assistant Director Maintenance and Operations Department Richard Komieteye, Materials Engineer Greater Accra Region Baah Tetteh, Project Engineer Greater Accra Region
Association of Road Contractors in Ghana (ASROC)	Kwaku A. Nuamah, Executive Secretary William Apraku Bondzie, National Treasurer Amoako Anaafi, Member
University of Ghana, Department of Computer Science	Jamal-Deen Abdulai, Lecturer and IT Consultant
Tanzania	
PO-RALG/DID	Elina Kayanda, Director DID Gilbert Mwoga, Deputy Director DID Fikiri Magafu, staff member DID
TARURA	Victor H. Seff, Chief Executive Officer Vincent Lwanda, Laboratory Engineer, Head of LoGiTReC Laboratory Ahsante S. Kamba, Assistant Laboratory Engineer Joshua Tenge, DROMAS Coordinator
Tanroads Regional Office Dodoma	Leonard Chimago, Regional Manager Cyprian Hossea Lubida, Head of Planning (and also Head Regional Materials Laboratory)
Dodoma Municipal Council, Works Department	Sasocha M. Matenya– Architect Mohamed A. Muanda – Road Engineer Ludigija M. Ludigija – Quantity Surveyor
Tanroads HQ	Mussa Mataka, Head of Materials and Research Department
Other AfCAP Partner Countries	
Ethiopia, Ethiopia Roads Authority	Alemayehu Endale, Director of Research and Development
Uganda, Uganda National Roads Authority	Mark Rubarenzya, Head - Research and Development Musinguzi Begumisa, Materials Engineer Rosemary Kisembo, Head of ICT Joshua Waserekere, IT Consultant
Botswana	
The Ministry of Works and Transport, Roads Department	David Bogagu, Head of Research and Materials Division Kgosietsile Solomon, Principal Engineer, Research and Materials Division Sollie Gabanakgosi, Principal Engineer, Research and Materials Division
Other key informants	
Zimbabwe, National Road Administration	Eric Gumbie, Chief Director of Roads Irene Doka Michaels, Materials Engineer

Annex C: Checklist for fieldwork consultations

Activity	Objectives / issues
Briefing Head of National Roads Authority	Introduction and project brief: • Presentation of the Consultants, OCA, Link Asea • Project brief • Main challenges with road materials sourcing, testing and information management? • Ambitions of the host institution? • Previous and ongoing initiatives?
Meeting Head Materials and Research	Become familiar with the institutional framework, regulatory framework, current systems for materials testing and information management, stakeholders needs and ambitions: **Institutional framework and resource availability:** • Review organizational set up, roles and responsibilities of materials and research department • Institutional framework for materials testing and information management (HVR vs. LVR, public vs. private, etc.) • What role do they play on HVR? Design, contract supervision, pavement evaluation? • What role do they play on LVR? Design, contract supervision, pavement evaluation? • Review resource availability in terms of number of laboratories (public/private), staffing and budget. • Discuss ongoing research activities. **Regulatory framework:** • Who regulates and licenses materials extraction? Who owns pits and quarries? Are there land ownership issues? • Is there any control mechanism on the volume of materials extracted? • Do contractor pay for materials sources from public borrow pits? • Who regulates, accredits and licenses the establishment of private materials laboratories? • Is there a register of materials laboratories? • Is there an inventory of pits and quarries? If so, what information is contained? • Is there a quality control or quality assurance system in place for private and public laboratories? **Current materials information management systems:** • What pavement design standards and specifications are used for LVR and HVR? • Does road design make use of historical materials testing data? • What kind of materials testing is done for pavement layers, gravel wearing course and surfacing? • Understand how materials information is currently collected, processed, managed and stored? • Discuss current materials information systems, workflows and the main challenges. Map the process as precisely as possible – e.g. how does information originate, when does it get accepted as being “OK”, by whom, where does it go for storage, how is it accessed, by whom? • Let them explain the relationships (or structure) of information. Are borrow pits referenced by their position, the material grade, or some other parameter? What information is stored about the borrow pits and or the materials? • Ask for example templates and inventory list of borrow pits and quarries.

Activity	Objectives / issues
	• If consultants/ contractors do their own materials testing, how is this data captured in the materials information system? • What is the approach to identify new sources of materials? What material indicators are used? • Have they ever used materials reports and testing results from consultants and contractors – working on major roads - to update their materials source inventory? • Are there any industrial by-products used in road projects? • Is there duplication because there is no free access or no sharing of available information? **Stakeholders' needs and ambitions:** • Discuss previous or on-going initiatives to improve materials testing and information management. • What are the main challenges of materials sourcing and testing? • What are the main ambitions? • Why do they want to have a road materials database? • If there was road materials database, what information should be covered? • How is AfCAP research data captured and stored in terms of materials testing, "as built" and pavement performance?
Visit Materials Laboratory	Become familiar with existing system and procedures for laboratory management, materials testing procedures and data storage. Review resource availability for materials information management at the laboratories: • Who are the main clients of the laboratory? Do they pay? List of standard unit prices? • What testing is carried out in the laboratories? • Explain the procedures and protocols for materials testing, who collect samples, who does the preparation and testing of samples, who records and approves the testing result? What is the process for accepting test results as being accurate and useable, what items of information are required and how is it stored, who authorises it, when? • What are the procedures in place for quality control and quality assurance? Is equipment being regularly calibrated? Who does it? How is it done? • After completing materials testing, how are results disseminated to the client or user? • How are the materials testing results stored? • Whatever the current system, how is it managed and what problems do they see with the way it is managed? E.g. if it is Excel, who is in charge of it, how is accuracy of the information guaranteed on an on-going basis, how is it added to?
Meeting Local Roads Authority	Discuss specific requirements for LVRs: their materials information needs, challenges and ambitions: **Institutional framework and resource availability:** • Review organizational set up, roles and responsibilities for materials testing and information management for LVRs? • Discuss responsibilities for design and supervision of LVR road works (between in-house and consultants?) • Review resource availability in terms of number of laboratories (public/private), staffing and budget. • Discuss ongoing research activities. **Regulatory framework:** • Who regulates and licenses materials extraction? Who owns pits and quarries? Are there land ownership issues? • Is there any control mechanism on the volume of materials extracted? • Do contractor pay for materials sources from public borrow pits?

Activity	Objectives / issues
	• Is there an inventory of pits and quarries? If so, what information is contained? **Current materials information management systems:** • What pavement design standards and specifications are used for LVR? • Does road design make use of historical materials testing data? • What kind of materials testing is done for pavement layers, gravel wearing course and surfacing? • Understand how materials information is currently collected, processed, managed and stored? • Discuss current materials information systems, workflows and the main challenges. Map the process as precisely as possible – e.g. how does information originate, when does it get accepted as being "OK", by whom, where does it go for storage, how is it accessed, by whom? • Let them explain the relationships (or structure) of information. Are borrow pits referenced by their position, the material grade, or some other parameter? What information is stored about the borrow pits and or the materials? • Ask for example templates and inventory list of borrow pits and quarries. • If consultants/contractors do their own materials testing, how is this data captured in the materials information system? • What is the approach to identify new sources of materials? What material indicators are used? • Have they ever used materials reports and testing results from consultants and contractors – working on major roads - to update their materials source inventory? • Are there any industrial by-products used in LVR road projects? • Is there duplication because there is no free access or no sharing of available information? **Road asset management system for LVRs:** • Is there a road asset management system? • What is it used for? • What information is stored, what are the processes surrounding its update and access? • What technology platform is it built on? • Is it proprietary or open source? • Does the Roads Authority have the capability to maintain it or is that outsourced? • Does it contain information about pavement layers, materials and their sources? **Stakeholders' needs and ambitions:** • Discuss previous or on-going initiatives to improve materials testing and information management. • What are the main challenges of materials sourcing and testing? • What are the main ambitions? • Why do they want to have a road materials database? • If there was road materials database, what information should be covered? • How is AfCAP research data captured and stored in terms of materials testing, "as built" and pavement performance?
Meeting Consultants	Discuss Consultants road materials information needs: • What is the involvement of consultants in the road sector? • Are they responsible for road materials sourcing and testing for road projects? • What is the approach followed to source and test road materials for road projects? • Which laboratories do they use for materials testing facilities? Who takes the

Activity	Objectives / issues
	samples and transport to the laboratories? Do they pay for the materials testing? How do they get the results of the materials testing? Who signs off on those forms? • What materials testing is typically done for pavement layers, gravel wearing course and surfacing? • Explain the procedures for materials testing? Do they pay? • Have they ever approached the road authority for information about the location, availability and properties of existing materials sources? • What is the approach to identify new sources of materials? What material indicators are used? • What are the main challenges of materials sourcing and testing? • If there was road materials database, what information should be covered?
Meeting Contractors	Discuss Contractors road materials information needs: • When bidding, what information is contained in the tender documents concerning road materials? • What is the approach followed to source and test road materials for road projects? • Which laboratories do they use for materials testing facilities? Who takes the samples and transport to the laboratories? Do they pay for the materials testing? How do they get the results of the materials testing? Who signs off on those forms? • What materials testing is typically done for pavement layers, gravel wearing course and surfacing? • Have they ever approached the road authority for information about the location, availability and properties of existing materials sources? • What is the approach to identify new sources of materials? What material indicators are used? • What are the main challenges of materials sourcing and testing? • If there was road materials database, what information should be covered?
Meeting select group of project engineers(s) from National or Local Roads Authority	Discuss specific materials information needs, challenges and ambitions for design and supervision of HVRs: **Current materials information management systems:** • What pavement design standards and specifications are used for HVR? • Does road design make use of historical materials testing data? • What kind of materials testing is done for pavement layers, gravel wearing course and surfacing? • Understand how materials information is currently collected, processed, managed and stored? • Discuss current materials information systems, workflows and the main challenges. Map the process as precisely as possible – e.g. how does information originate, when does it get accepted as being "OK", by whom, where does it go for storage, how is it accessed, by whom? • What information is contained in the tender documents concerning road materials? • If consultants/contractors do materials testing how is this data captured by the roads authority? • What is the approach to identify new sources of materials? What material indicators are used? • Are there any industrial by-products used in HVR road projects? • Is there duplication because there is no free access or no sharing of available information? **Stakeholders' needs and ambitions:** • What are the main challenges of materials sourcing and testing? • What are the main ambitions?

Activity	Objectives / issues
	• Why do they want to have a road materials database? • If there was road materials database, what information should be covered? • How is AfCAP research data captured and stored in terms of materials testing, "as built" and pavement performance?
Meeting Road Asset Management System	Obtain information about the road asset management system of the roads authority: • Is there a road asset management system? • What is it used for? • What information is stored, what are the processes surrounding its update and access? • What technology platform is it built on? • Is it proprietary or open source? • Does the Roads Authority have the capability to maintain it or is that outsourced? • Does it contain information about pavement layers, materials and their sources? • If there was road materials database, what information should be covered? • How could this database be linked to the road asset management system?
Meeting IT section	Review existing IT policy, resources, challenges and ambitions. The actual hardware tends to be the least problem today. Available skills and familiarity, and policies in place are more important: • Is there a government or department-wide IT policy / strategy, which may dictate the types of technologies used, how they are managed, etc. If so, please describe in as much detail as possible. • What is the usual approach to development of information and database systems? In house, custom developed by external party, purchased off the shelf and integrated? • What are the main policies in terms of sharing road sector information with the public and industry professionals? • What are the IT facilities in place: network server, systems, Internet, software? • What internal staff capacity is available? What technical skill areas? Programmers? • Are there successful systems for data collection and storage (on other areas) currently in place? • How do they operate? • How is the quality and reliability of Internet connectivity, including mobile services?
Meeting GIS section	Review existing GIS resources, challenges and ambitions: • GIS resources? Staffing, software packages? • What are the skills levels? • What is GIS used for? • How does GIS interact with other information management systems? • How could GIS be used for materials source locations and prospecting of new sources?
Debriefing Head Materials and Research and Head of Roads Authority	Project debriefing and discuss main findings of the visit: • Would the host be interested to develop a road materials database? • Would the host accept public access and information sharing? • Ability to mobilise staff resources: engineers, materials, IT and GIS specialists? • Ability to mobilise financial resources?

Annex D: Report 1 Mozambique visit

Visit Mozambique: 5 – 7 June 2017 (3 days):

2/5/2017	Activity	Objective	Person
Morning	Briefing meeting with the AfCAP Country Coordinator (ANE Director of Maintenance) and a select group of staff	Propose program of the Mozambique country visit and discuss other AfCAP country activities.	Jan
5/6/2017	**Activity**	**Objective**	**Person**
Morning	Meeting Materials and Research section.	Review the survey questionnaire. Discuss institutional framework, current systems, other on-going initiatives, challenges and ambitions.	Jan
Afternoon	Visit ANE's Provincial Materials Laboratory Maputo Province.	Become familiar with existing system and procedures for laboratory management, materials testing procedures and data storage. Review resource availability for materials information management.	Jan
6/6/2017	**Activity**	**Objective**	**Person**
Morning	Meeting Provincial Delegation of ANE. Visit Mozambique Engineering Laboratory (LEM).	Discuss specific requirements for regional and district roads: their materials information needs, challenges and ambitions. Become familiar with their systems and procedures for laboratory management, materials testing and data storage. Obtain their views on materials information management.	Jan
Afternoon	Meeting Provincial Maintenance Consultant, Maputo Province. Meeting representatives of Mozambican Federation of Road Contractors.	Discuss Consultants road materials information needs. Discuss Contractors road materials information needs.	Jan
7/6/2017	**Activity**	**Objective**	**Person**
Morning	Meeting ANE Project Department - Contract Management Unit. Meeting IT section of ANE. Meeting HIMS section of ANE Meeting GIS section of ANE.	Discuss specific materials information needs, challenges and ambitions for design and supervision of primary and secondary roads. Review existing IT policy, resources, challenges and ambitions. Become familiar with the road asset management system and explore possible links with materials information management. Review existing GIS resources, challenges and ambitions.	Jan
Afternoon	Meeting Materials and Research section. Meeting Director of Maintenance ANE and Road Research Team.	Discuss main findings of the visit. Project debriefing.	Jan

Institutional framework

The National Road Administration (ANE) falls under the Ministry of Public Works and Housing. The responsibility for materials testing and information management at ANE falls under the Directorate of Projects, Department of Monitoring, who have two (2) staff members, both Geologists, responsible for road materials. Their main task is to respond to materials testing and quality control issues arising out of major road projects. They interact with the Departments of Studies and Projects to respond to materials issues as part of project design and to the Department of Contract Administration as part of contract supervision. They also interact with the Directorate of Maintenance, mainly for LVR research projects (such as those supported by AfCAP).

The AfCAP funded LVR research projects include monitoring of trial sections and improving the laboratory proficiency in Mozambique. These activities are coordinated by the Research Team established under the Directorate of Maintenance; a stepping-stone towards the establishment of a fully-fledged Road Research Centre or Unit.

The ANE Central Materials Laboratory (CML) is not operational but efforts are underway to rehabilitate it with new testing equipment purchased under WB funding. In addition to CML, there are 10 Provincial Materials Laboratories (of which 8 are operational), which fall under the responsibility of the ANE Provincial Delegations. The current institutional responsibility for materials testing and information management is somewhat scattered with responsibilities spread between the Directorate of Maintenance (Research), Directorate of Projects (Materials Monitoring) and the ANE Provincial Delegations (Materials Testing). There are related challenges with coordination of materials information management.

Regulatory framework

Material testing facilities, both public and private, in Mozambique are supervised by the Engineering Laboratory of Mozambique (LEM), which also falls under the Ministry of Public Works and Housing. Under its supervisory role, LEM carries out regular visits to the public and private materials laboratories for inspection, quality control and calibration of equipment. A MOU was signed between ANE and LEM in which LEM would take full responsibility for overseeing and managing the ANE laboratories. However due to various institutional constraints (e.g. staff transfer, budget allocation) this has never fully materialised (except for LEM's supervision role). The ANE provincial laboratories, now report directly to the ANE Provincial Delegations.

Materials extraction in Mozambique is licenced by the Ministry of Mineral Resources (MMR) for the purpose of a particular project. For major road projects, ANE request a project-based permission (license), on behalf of the contractor. After compensation is paid to the landowners or land occupants, the borrow pit or quarry is used (free of charge in case of public works) for the purpose of the project and needs to be reinstalled after project completion. In some cases, contractors opt to apply for a commercial license to continue extracting materials after project closure (for which the Government charges a levy).

For minor projects (road maintenance) on national and regional roads, contractors make use of about 800 existing borrow pits. The ownership status of these borrow pits is not very clear (there is no cadastral registration), but they are used for public works and in practice managed by ANE and the local authorities. As a result of economic development, especially around towns, there is increasing encroachment on areas where materials are being extracted for road projects. This led ANE to start geo-referencing and mapping borrow pits in populated provinces of Maputo and Nampula. The idea is to register all borrow pits in the country in the name of the Road Fund (RF). Contrary to ANE, RF has full autonomy and can register land in its name.

Current systems and workflows

Road design standards and specifications

Mozambique uses the Southern African Transport and Telecommunications Commission (SATCC) pavement design manual and technical specifications, which has since been restructured into the Southern African Development Commission (SADC).

The Code of Practice for the Design of Road Pavements September 1998 (Reprinted July 2001)[5] presents the pavement catalogue deemed appropriate to the SADC region on the basis of the Transport Research Laboratory's Overseas Road Note 31 (RN31) and the South African pavement design guide TRH4. The pavement catalogue presents various alternative pavement structures using granular, bituminous and cemented base and sub base for different traffic classes (T1 – T8) ranging from 0.3 million ESA up to 30 Million ESA and for two different climate regions (wet and dry). The key design parameters for Granular Base are a soaked CBR > 80%, Granular Sub base a Soaked CBR > 30% and Selected layer a Soaked CBR > 15%. The key design parameters for a Cemented Base are a 7-day UCS of 1.5 - 5MPa (depending on traffic class) and for a Cemented Sub Base a 7-day UCS of 0.75 - 3MPa (depending on traffic class). The fines should preferably be non-plastic with PI < 6 and Linear Shrinkage < 3. **Table 11** provides a brief summary of the materials design parameters:

Layer	Material	Nominal strength
Base	Granular	Soaked CBR>80% @ 98% mod. AASHTO density
	Cemented	7 day UCS*1.5 - 3.0 MPa @ 100% mod. AASHTO density (or 1.0 - 1.5 MPa @ 97% if modified test is followed)
	Bituminous	See specification
Subbase	Granular	Soaked CBR>30% @ 95% mod. AASHTO density
	Cemented	7 day UCS*0.75 - 1.5 MPA @ 100% mod. AASHTO density (or 0.5 - 0.75 MPa @ 97% if modified test is followed)
Capping/ selected	Granular	Soaked CBR>15% @ 93% mod. AASHTO density
* 7 day unconfined compressive strength		

Table 11: SATCC nominal strength classification of materials in the design catalogue[5]

The SATCC Series 3000 describes the technical specifications for mass earthworks, pavement layers of natural gravel, crushed stone or stabilised, as follows:

Natural gravel:

- Selected fill: minimum soaked CBR of 15 % and maximum PI of 3 x grading modulus + 10;
- Sub base: the minimum grading modulus >1.5, PI <10%, soaked CBR of the natural material shall be >30% (not less than 95% Modified AASHTO);
- Base: the minimum grading modulus > =2.0, PI <6%, soaked CBR >80% at 98% Mod AASHTO density, the quality/durability measures with the Durability Mill Index (DMI) <125, the percentage passing 0.425 mm sieve after any DMI treatment shall be <35 and the Flakiness index <30%.

Crushed aggregate:

- The aggregate crushing strength (10% FACT), determined in accordance with TMH 1 Method B2, shall be > 110 kN. The wet dry ratio >75%;
- Atterberg limits: Liquid limit < 25, PI < 6 % and Linear Shrinkage < 3%;
- Flakiness Index < 35%;
- Grading requirements see **Table 12:**

Sieve size (mm)	Percentage passing (by mass)	
	Nominal maximum size 37.5 mm	Nominal maximum size 26.5 mm
37.5	100	100
26.5	84 - 94	100
19.0	71 - 84	85 - 95
13.2	59 - 75	71 - 84
4.75	36 - 53	42 - 60
2.00	23 - 40	27 - 45
0.425	11 - 24	13 - 27
0.075	4 - 12	5 - 12

Table 12: Grading requirements for crushed aggregate

- The quality of the natural base course material measures as Durability Mill Index (DMI) shall be < 125;

- The minimum dry density to which the material shall be compacted shall be 102% of modified AASHTO density.

The SATCC Series 4200 describes the technical specifications for aggregates for asphalt pavements and surfacing, as follows:

- Resistance to crushing: 10% FACT used in asphalt base and surfacing, when determined in accordance with TMH1 Method B2, shall not be less than 180. The wet/dry ratio shall be more than 75%;
- Shape of the aggregate. For Asphalt Base the flakiness index when determined in accordance with TMH1 Method B3 shall not exceed 35% for the minus 26.5 mm sieve plus 19.0 mm sieve and minus 19.0 mm plus 13.2 mm sieve fractions respectively. For Surfacing Asphalt the flakiness index shall not exceed 25 for nominal size 19 and 13.2 mm aggregate and not exceed 30 for nominal size 9.5 and 6.7 mm;
- The Polished Stone Value (PSV) of aggregate used in continuously graded asphalt surfacing, when determined in accordance with SABS Method 848 or equivalent, shall not be less than 50;
- Adhesion of the aggregate and binder. The Reidel and Weber test (TMH1 Method B11) on the aggregate must > 1.0. Pre-coating of the aggregate will be required if values of <1.0 are recorded;
- Absorption. When tested in accordance with TMH1 Methods B14 and B15, the water absorption of the coarse aggregate shall not exceed 1% by mass, and that of the fine aggregate shall not exceed 1.5% by mass;
- Grading limits are set for combined aggregate and mix proportions for asphalt surfacing and bases.

The SATCC Series 4300 describes the technical specifications for bituminous surface seals, as follows:

- Hardness. When tested in accordance with TMH1 Method B2 the 10% FACT value (dry) shall be at least 210 kN and the wet to dry ratio shall be at least 75%;
- The polished stone value (PSV) when tested in accordance with SABS Method 848 or equivalent shall be at least 50;
- Shape. The maximum flakiness index, when tested in accordance with TMH1 Method B3, shall not exceed 25 for nominal size 19 and 13.2 mm aggregate and not exceed 30 for nominal size 9.5 and 6.7 mm;

The SATTCC specifications were prepared for HVRs and may lead to overdesign of LVR (< 1 Million ESALs). AfCAP is currently supporting ANE with the development of a LVR design manual, which would take better account of the various locally available natural gravels that have shown to perform well in road pavements but may not meet the requirements of the SATCC specifications, in particular PI. Following the development of the LVR Design Manual (now in its final stages), some additional aspects may need to be considered to capture the full range of material properties suitable for LVRs, among others:

- Inclusion of the DCP DN value for soil strength;
- Inclusion of the CBR values at OMC and 75% of OMC in addition to the soaked CBR values;
- Classification of the soil for use as wearing course according to TRH-20 (Grading Coefficient and Shrinkage Product).

It also needs to be mentioned that Mozambique is planning to review its road design standards and specifications for HVRs. This may also have ramifications for the materials testing data to be collected and stored in the road materials database.

Materials Testing and Information Management

There is a clear distinction between materials testing and information management for major works on HVRs and for maintenance works on HVRs and LVRs. The former are predominantly designed and supervised by consultancy firms and implemented by international contractors who have their own laboratory facilities. Testing is mostly done on site and only in the absence of testing equipment outsourced to LEM or one of the four private materials laboratories in Mozambique. A summary of test results for materials prospecting to identify sources close to the works and workmanship testing is contained in project specific reports. These reports are archived at ANE HQ as paper based copies without electronic data storage. In addition a wealth of materials testing data is kept in the consultants' and contractors' own archives and never reaches ANE, many of these materials test results relate to areas prospected for use in pavement layers but because the results may not have been satisfactory for HVR projects they are disregarded. Nonetheless, these materials can still be very useful for LVR projects.

The maintenance works are managed by the ANE Provincial Delegations and supervised by local consultants and implemented by local contractors. Road materials required for these projects (primarily for re-gravelling) are sourced from the existing open borrow pits and commercial quarries. These sources of materials have been used for many years and their properties all well known to provincial road engineers. Materials prospecting and testing is rarely done during project preparation stage. During project implementation (mainly for re-gravelling), the properties of the materials are tested (Grading, Atterberg Limits, Compaction/OMC and CBR) and the level of compaction verified in-situ. An overview of materials testing results is kept in the provincial laboratories as paper-based and electronic files by project reference and a summary for each borrow pit. The soils are also classified according to the AAHSTO classification, and their appropriateness for use in pavement layers (CBR, PI) and wearing courses (TRH-20). There is a central archive (Excel) at ANE HQ showing the location of the borrow pits (by road chainage) with the area of the pit (m^2), the quantity of the soils (m^3) and the potential use in road construction and maintenance projects (base, sub base or selected fill). However, this central archive is not updated.

The establishment of laboratory protocols for materials testing was done in the late nineties under a technical assistance project to the (then) Department of Roads and Bridges under the Ministry of Works and Housing. Each province has a laboratory-testing manual with standard forms for materials testing and a borrow pit inventory showing the test results. The inventory (see **Figure 7**) is an excel file showing borrow pit locations referenced by road number, chainage and coordinates) with a summary of testing results (Atterberg Limits, Grading, Compaction/OMC, CBR and AAHSTO Classification).

MAPA RESUMO DE RESULTADOS DOS TESTES

LABORATÓRIO DPAMPT MAPUTO

MAPA RESUMO DOS DADOS DAS CÂMARAS DE EMPRÉSTIMO

CONSULTANT : Delegação Provincial de Maputo
PROJECT : R 403 CATEMBE/BELA VISTA

LAYER TESTED : CÂMARAS DE EMPRÉSTIMO
DONY BY : ARMINDO

DATA: 10/10/13
BOLETIM Nº 1

PERFIL KM	Coordenadas Geográficas	NÚMERO DA CÂMARA	Atteberg Limits		Grading (% Passing)					G.M.	Compaction test		C.B.R. (2,5mm)			Classificação AASHTO
			L.L.(%)	P.I.(%)	19.0	4.75	2,36	0.425	0.075	(%)	MDD(g/cm3)	O.M.C.(%)	93%	95%	98%	
2+500LD	S 26°00'21,7" E 032°33'04,7"	1	NP	NP	89,0	82,5	81,2	76,6	11,0	1,32	1,940	10,7	20,0	20,7	29,0	A-2-4
17+300LD	S 26°06'15,6" E 032°37'55,4"	2	32,60	15,81	100.0	84,8	77,8	70,2	48,4	1,04	2.083	9,5	2,9	2,9	3,2	A-6
22+200LD	S 26°08'36,6" E 032°38'33,2"	3	30,60	11,70	100.0	99,5	99,1	94,6	47,9	0,58	1,928	12,8	1,7	2,2	3,4	A-6
33+600LD	S 26°14'16,7" E 032°28'43,2"	4	26,20	10,50	100,0	96,0	94,6	88,4	39,8	0,77	2,003	9,0	7,2	8,6	13,0	A-6
38+600LD	S 26°16'45,5" E 032°38'42,7"	5	37,80	12,10	100,0	91,4	83,8	65,4	48,0	1,14	1,765	19,4	3,8	4,9	5,5	A-6
40+700LD	S 26°17'38,0" E 032°38'33,9"	6	NP	NP	100,0	100,0	100,0	93,3	24,1	0,83	1,930	15,2	12,0	16,0	22,0	A-2-4

Figure 7: Summary Map of Borrow Pits in Maputo Province

The head of materials laboratories are trying to keep these inventories updated but with limited facilities and without data protection, data goes missing. Materials testing data information sharing between ANE HQ and the provincial laboratories no longer take place. To obtain recent data of road materials availability and properties once has to visit the ANE Provincial Laboratories.

After material testing is done, the results are entered into standard Excel sheets, printed and signed by the Technician who did the test and the Head of Laboratory. The materials testing results are sent to the ANE Provincial Delegate and forwarded to the Provincial Consultant through an official letter.

There is no evidence of industrial by-products being used as materials in the road sector.

Road Asset Management

The ANE Planning Directorate has a road asset management system in place, the Highway Information Management System (HIMS), which covers the classified road network of the entire country. HIMS is organised by road number and road link and includes road inventory (road width, surface type and pavement construction, structures and road furniture), road condition data (visual condition, roughness and deflection) and traffic. Data on the pavement layers and subgrade are only provided for the paved network and show the thickness of the layer, the type of materials (granular, cement stabilised or bituminous stabilised), the subgrade class, the year of construction and the maintenance interventions. HIMS also has an interface with HDM-4 for strategy, program and project based analysis in support of preparing annual investment and maintenance plans.

The HIMS is currently only accessible to a restricted group of ANE engineers who are registered and have a password. Provincial Delegations have no direct access other than to request information from the ANE HQ, the Planning Directorate. The only public access to HIMS is an online application called RIS, which only show inventory and condition data of the classified road network.

ANE expressed an ambition to provide details of the materials used (source and properties) in the pavement layer field of HIMS but this would require manually collection of materials data from the project completion reports and “as built” drawings. Efforts are underway to establish an electronic documentation centre at ANE HQ, to store reports and documents electronically and centrally.

The HIMS was developed as a customised application by an International Consultancy firm who provides technical support and maintenance services. One technician of ANE has been trained to act as the system administrator and make changes to HIMS such as to import and delete data however changing the structure (source code) of the database would have to be done though the Consultant.

GIS

ANE has a dedicated GIS unit inside the Directorate of Planning, Department of Road Network Management. Studies and Projects, which is staffed by 2 experienced GIS staff both with academic degrees. Their main task is to support the ANE road network management functions with GIS and mapping applications. ANE has access to ArcView GIS, QGIS and MapInfo software applications. The HIMS also has a build in GIS application for mapping purposes. The GIS unit has started to geo-reference and to map borrow pits in Maputo and Nampula provinces. The ambition is to do this nationwide.

Information Technology

ANE has a dedicated IT unit under the Directorate of Finance and Administration, which is staffed by three academic IT specialists. Their main role is to make sure that ANE’s communication and information technology systems are up and running and protected against outside treats.

ANE has no IT policy and strategy in place to outline how the institution deals with information sharing and data protection. However, there is an overarching GOM policy in place, which ANE as a semi-autonomous institution, is abides by. Currently, ANE has various information and data management systems in place such as HIMS (road asset management system which is programmed in SQL Server 2008 and runs on Windows Server 2008 R2 platform), Primavera (a financial and human resource management system) and an Electronic Document Information System (EDIS). These systems, email and Internet access run on a Local Area Network (LAN) running on Windows server 2012 that is being managed from a well designed and managed Data Centre (DC). The DC has 10 servers Dell PowerEdge M610 installed of which one is currently standing idle. There are no problems with server capacity. Access to Email and Internet is running on Linux and provided by two different service providers, one government and one private. Both offer a connection speed of 2 MB per second which at peak times is used by up to 150 staff members at ANE. Connection speed is therefore on the slow side and with frequent downtime. The ANE Provincial Delegations are not linked to the local area network of ANE HQ (which is one of the reason why they don't have direct access to HIMS). They have their own isolated local area network; hence none of the ANE staff in the provinces has direct access to the management information systems at HQ.

Stakeholders' needs and ambitions

Client view

Meetings with ANE HQ Directorates of Maintenance, Planning and Studies & Projects the ANE Provincial Delegation of Maputo, made clear that ANE has ambitions to develop a materials database. Some efforts are underway to map borrow pits. The establishment of a materials database system would require a centralised system for materials data storage. It also requires a change of workflows moving towards standard templates for materials sample collection, materials testing and materials reporting. Currently, the workflows are predominantly paper-based.

Based on the meetings with staff responsible for the planning, design, supervision and maintenance of the classified roads and the current road standards and specifications, the following key materials parameters have been identified:

- Materials type and description, location specific information (including maps) and environment;
- Materials properties and quantities;
- Materials classification (AASHTO is used in Mozambique);
- Materials potential use in road pavement layers;
- Materials historical use with reference to more detailed materials reports.

In terms of materials properties Particle Size Distribution, Atterberg Limits, Strength (Soaked CBR) and Compaction/OMC were identified as key properties for soils. For aggregate this would be Particle Size Distribution/Product Size, Strength (ACV, 10%FACT), Shape (Flakiness, Elongation and ALD), Porosity (Absorption test), Resistance to Weathering (Sodium Sulphate Soundness), Resistance to Polishing (PSV) and Bitumen Adhesion.

Consultant view

The Consultant met with the Provincial Maintenance Consultant (CPG) who is based in Maputo and works with the ANE Province Delegation to supervise the road maintenance works. The main challenge of road materials sourcing and testing in Maputo is to find good road building materials especially in the coastal areas, which is covered in single sized non-plastic sands. It is becoming very difficult to find aggregates and gravels. With various degrees of success, the Consultant has tried to experiment with mechanical stabilization of sandy and clayey soils but these experiences are not well documented.

Reference was also made to the Maputo – Ponto d'Ouro road upgrading project where reportedly the Chinese contractor has managed to find suitable materials for selected fills and sub base layers in areas where previously it was thought that no such materials were available. It is this kind of information that should be captured in a materials database so that it would be easier to locate suitable materials for LVR works.

Another challenge is that almost half of the existing borrow pits are depleted or being encroached by economic activities. Without proper registration of borrow pit areas it will become increasingly difficult to find good materials in Maputo province and as a result road construction and maintenance cost will further escalate.

The Consultant reaffirmed that current proceedings for materials testing rely mostly rely on the ANE Provincial Materials Laboratory. Established procedures are that the Consultant submits a request for materials testing to the ANE Provincial Delegation who will then instruct the laboratory to take the samples and complete the tests. The results are submitted to the ANE Provincial Delegation who forwards an official letter to the Provincial Maintenance Consultant. All testing carried out for GOM financed works is done free of charge. Some of the larger contractors operating in Maputo province have their own (well-equipped) laboratory facilities. These are increasingly being used; they are much better equipped than the ANE Provincial Laboratories.

The Consultant reiterated that the development of a materials inventory and database would be a welcome initiative and facilitate the design and supervision of road maintenance works.

Consultants' and Contractors' view

In a meeting with the Mozambican Federation of Contractors (FME) the main challenges of road materials sourcing and testing were discussed as well as opportunities to better map road materials. The representatives (CETA, JJR, Mondego and CSM) are mostly working on medium sized LVR contracts let by ANE Provincial Delegations or the Municipalities.

The tender documents for LVR road works usually don't contain specific information about road materials sources and this can make it difficult to price for the works. The tender documents refer to the specifications of materials required, an estimated average transport distance and an overhaul rate. Although the overhaul rate provides some protection for the contractor, transporting materials over longer distances always carry an additional risk for the contractor.

During the site visits, as part of the tender process and contract award procedures, the client indicates the available borrow pits for information purpose only. The Contractor needs to confirm the properties and quantities of material available and is also free to prospect for additional sources. In practice it often happens that existing borrow pits no longer have materials meeting the minimum specifications and quantities required or landownership has changed and material is no longer freely available (paying for gravel becomes increasingly common in the more populated provinces of Mozambique where rates paid vary between 45 -100 Meticais, USD 0.7-1.5, per m^3).

Some contractors have their own laboratory facilities (CETA, JJR) and are well equipped to go out and prospect for road materials. Other contractors rely on third party facilities (ANE provincial laboratories, LEM, private laboratories). To find additional road materials closer to the works, contractors look in the vicinity of existing sources and consult with local people. None of the contractor uses maps, landform or botanical indicators.

The contractors think that it would be beneficial to have prior information about the location of borrow pits and their materials' properties although this does not replace the need for materials testing. ANE raised concerns that providing such information as part of tender documents could raise future claims if information provided is either out dated or incorrect. Like in most other public database systems this can be resolved through a disclaimer stating that information is provided "for information purpose only" similar to what consultants do in the materials report of a detailed design project.

Contractors often manage to identify additional borrow pits (not previously mapped by the client) and carry out various mix designs for mechanical stabilization of different materials in order to meet the specification of the pavement layer. Such trials are well documented in the Contractor's project files but rarely get recorded in reports submitted to the client.

On a conclusive remark, participants underlined the importance of having a road materials database showing borrow pit locations and their properties but only adds value if it is accessible on a public platform.

Conclusions and recommendations

ANE and the Mozambican road sector in general (Contractors, Consultants, LEM) subscribe to the objective of having better and more reliable access to road materials information. There is an obvious demand for road materials information in the road sector, in particular for LVR because at that level resources are rarely available to go out for extensive materials prospecting and testing. Contractors require similar information to be able to realistically price for the works. For HVRs there are similar benefits, in particular for maintenance works.

A materials database would need to include the location, properties and quantities of materials sources (gravel, sand and aggregates). In addition there should be a mapping tool to show the location of materials sources in a selected area. The need to include prospecting tools for new sources of materials was less apparent but could still be considered.

The current institutional framework for materials testing and information management in Mozambique is dispersed and lacks ownership at central level. The development of a road materials database requires a concerted effort to collect, store and process data, and also dedicated staff and financial resources. This challenge could be overcome if the Road Research Centre is given a clear mandate for road materials information management with adequate staff resources in place.

The management and oversight of the ANE laboratories shows various weaknesses but efforts are ongoing to improve the laboratory proficiency (testing protocols) under another AfCAP project. The development of a materials database should be part and parcel of a wider effort to improve the road materials laboratory management including established protocols, work flows, quality control and information management.

Annex E: Report 2 Ghana visit

Visit Ghana: 27 - 30 June and 4 – 7 July 2017 (8 days)

27/6/2017	**Activity**	**Objective**	**Person**
Morning	Briefing meeting AfCAP Country Coordinator of the Ministry of Roads and Highways (MRH) and AfCAP Regional Technical Manager. Meeting Director of Materials (DOM) Ghana Highway Authority (GHA).	Discuss the program. Presentation of the team and project briefing. Project briefing. Review survey questionnaire. Discuss institutional framework, current systems, challenges and ambitions.	Jan, Ravi
Afternoon	Visit Central Materials Laboratory GHA, Director of Materials. Meeting Department of Feeder Roads (DFR), Director of Planning and a select group of staff.	Become familiar with existing system and procedures for laboratory management, materials testing and data storage. Discuss the specific requirements for feeder roads engineers doing in-house road design: their materials information needs, challenges and ambitions.	Jan, Ravi
28/6/2017	**Activity**	**Objective**	**Person**
Morning	Follow up meeting Department of Feeder Roads (DFR), Head GIS/IT section under the Director of Planning. Meeting Head of Research Statistics and Information Management (RSIM) Directorate of the Ministry of Roads and Highways (MRH)	Become familiar with the road asset management system and explore possible links with materials information management. Review existing IT policy, resources, challenges and ambitions. Discuss the ongoing initiative to build a web based and publically accessible GIS repository of transport infrastructure in Ghana.	Jan, Ravi
Afternoon	Meeting DANIDA Technical Adviser of the Ghana Local Government Service Meeting Road Engineer Department of Urban Roads (DUR)	Discuss the specific requirements for non-classified and district roads engineers doing in-house road design: their materials information needs, challenges and ambitions. Discuss the specific requirements for urban road engineers doing in-house road design: their materials information needs, challenges and ambitions.	Jan, Ravi
29/6/2017	**Activity**	**Objective**	**Person**
Morning	Meeting DFR Regional Manager, Eastern region and a select group of staff. Visit Regional Materials Laboratory of DFR in Koforidua.	Discuss the specific requirements for feeder roads engineers doing in-house road design: their materials information needs, challenges and ambitions. Become familiar with existing system and procedures for laboratory management, materials testing and data storage.	Jan, Ravi
Afternoon	Meeting GHA Director of Maintenance, Eastern region.	Review training activities in LVR research and materials testing and materials	Jan, Ravi

27/6/2017	Activity	Objective	Person
	Visit GHA Regional Materials Laboratory, Eastern region.	information management. Become familiar with existing system and procedures for laboratory management, materials testing and data storage.	
30/6/2017	**Activity**	**Objective**	**Person**
Morning	Meeting select group of Contractors working for DFR and GHA. Meeting Environmental Section of GHA	Discuss stakeholders' needs and expectations – contractor's view. Discuss regulatory framework for materials extraction and environmental management. Review procedures for locating, measuring and compensating land area.	Jan, Ravi
Afternoon	Meeting Management Information Section of GHA Meeting Head of Bridge Management System (BMS)	Discuss management information systems in use at GHA. Review current status of BMS.	Jan, Ravi
4/7/2017	**Activity**	**Objective**	**Person**
Morning	Meeting Department of Urban Roads, Director of Maintenance Meeting University of Ghana, Head of Department of Computer Science	Discuss the specific requirements for urban roads engineers doing in-house road design: their materials information needs, challenges and ambitions. Discuss current local capacity in IT and software development in Ghana. Obtain local rates for various categories of IT staff for budgeting purposes.	Jan, Ravi
Afternoon	Reporting work		Jan, Ravi
5/7/2017	**Activity**	**Objective**	**Person**
Morning	Meeting Department of Urban Roads, Assistant Director of Maintenance and Operations and Materials Engineer from Greater Accra Region continued from previous meeting.	Discuss the specific requirements for urban roads engineers doing in-house road design: their materials information needs, challenges and ambitions.	Jan, Ravi
Afternoon	Meeting Pavement Management System (PMS)	Become familiar with the road asset management system and explore possible links with materials information management.	Jan, Ravi
6/7/2017	**Activity**	**Objective**	**Person**
Morning	Meeting select group of Consultants.	Discuss stakeholders' needs and expectations – consultant's view.	Jan, Ravi
Afternoon	Debriefing meeting AfCAP Country Coordinator, AfCAP Regional Technical Manager and a select group of staff.	Debriefing meeting. Present and discuss main findings of the visit.	Jan, Ravi

Country report Ghana 26 – 30 June and 4 – 7 July 2017

Institutional framework

The road sector in Ghana is managed by different institutions, Ghana Highway Authority (GHA responsible for the 14,000 km of trunk roads), Department of Feeder Roads (DFR responsible for the 42,000 km of feeder roads), Department of Urban Roads (DUR responsible for 15,000 km of urban roads), which operate under the

Ministry of Roads and Highways (MRH). With the setting up of the Local Government Service (LGS), some of DFR operations in the Districts and Regions are transferred to the District Assemblies and the Regional Coordinating Councils. DFR's implementation functions will be limited to those roads and programmes that are of strategic national importance. DUR is creating decentralised Road Units in the urban areas (Metropolitan/Municipal/District Assemblies) for the provision and management of the urban roads. With the setting up of the LGS, DUR is to be a division under the Ministry of Roads and Highways while DUR Units in the municipalities are to be fully integrated into the District Assemblies.

The responsibility for materials testing and information management of GHA lies with the Director of Materials who oversees a Central Materials Laboratory (CML) and 10 Regional Materials Laboratories (RMLs). The Director of Maintenance reports to the Deputy Chief Executive of the Development Division. GHA laboratories employ 86 staff of which 34 have an academic degree, 42 technicians and 10 support staff. CML has five different sections of materials testing (geotechnical, soils and aggregates, pavements, bituminous products and research) each headed by a Manager. Besides doing materials testing and providing quality control of GHA highway development and maintenance projects, CML also provides technical oversight of the other public laboratories in Ghana, in particular those managed by DFR. At DFR, the responsibility for materials testing and information management is delegated to the DFR Regional Managers who each run a Regional Materials Laboratory. The regional laboratories employ on average 2 – 3 staff members mostly technicians. The DFR laboratories have basic testing facilities for gravel and aggregates. For more advanced testing on concrete and bitumen, these laboratories rely on the GHA facilities. AT DUR the responsibility for materials testing and information management is delegated to the DUR Regional Managers. There are currently 4 laboratories in operation in the larger Municipalities of Accra, Kumasi, Tamele and Takoradi. The DUR laboratories have basic testing facilities for gravel, aggregates and concrete. For more advanced testing on bitumen and asphalt, they rely on the GHA CML facility.

In addition to the laboratories falling under the road sector institutions, there are three (3) public materials laboratories, among those the one operated by the Building and Road Research Institute (BRRI), the Department of Civil Engineering of Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi. There are also six (6) private materials laboratories.

Other AfCAP funded LVR research projects in Ghana include:

- Development of a Low Volume Roads Design Manuals and Update of the Standard Specifications and detailed drawings for the three AfCAP member countries in West Africa (tender being evaluated);
- Use of appropriate high-tech solutions for road network and condition analysis, with a focus on satellite imagery (in progress);
- Alternative Surfacing for Steep Hill Sections in Ghana - Phase I (in progress);
- Investigation into the suitability of roller compacted concrete as pavement material in Ghana (completed);
- Training and Application of DCP-DN Pavement Design Method in Ghana (completed).

Although a substantial amount of data is being collected for these projects, there is no central database in place other than to store reports on the AFCAP website. These projects are coordinated by MRH through the Director of Procurement who is the national AfCAP Country Coordinator. The use of industrial by products in Ghana in the road sector is limited to the use of lime, crumbed rubber and recycled plastic in asphalt.

The current institutional responsibility for road materials testing, information management and research is clear and organised by road sub sector (GHA, DFR and DUR) with GHA being the main anchor point due to their resource availability (in terms of equipment, staff, expertise level and budget allocations.

Regulatory framework

The Minerals Commission (MC) is responsible for the regulation and management of the utilization of the mineral resources including those required for road works. Before applying for the mineral prospecting licence, the applicant must identify the area and the minerals to be used. The Environmental Protection Agency (EPA) is the responsible for environmental protection and management. Road works are subject to the Environmental Protection Agency Act, 1994, which in practice implies conducting environmental impact assessments and the preparation of Environmental Management Plans for the planning and execution of major road development projects, including compliance in respect of existing projects. For the purpose of road maintenance works, the sector has prepared a Strategic Environmental Impact Assessment, which resulted in a number of standard procedures that contractors must comply with to ensure that the works, including road materials extraction, are implemented with minimal environmental impact. EPA has limited capacity to monitor road maintenance works and their role is therefore limited to major road development works. For this level of projects, materials extraction would require an EPA permit. For road maintenance works, the contractor is required to compensate the landowner for loss of income and property (standard rates apply), for the extraction of materials (negotiated between contractor and landowner) and the reinstatement of the borrow pit after the project has been completed (a separate item is included in the Bill of Quantities to compensate the contractor for this). As such there are no permanent borrow pits in Ghana other than stone quarries and sand pits that are commercially operated by the private sector.

The Ghana Standards Authority (GSA) is the National Standards Body. The development of technical standards is grouped under relevant technical sectors including TC 11 for building and construction works, which mainly covers the use of materials and construction processes for (reinforced) concrete and masonry works. The National Petroleum Authority (NPA) of Ghana regulates, oversees and monitors the petroleum downstream industry in Ghana including petroleum-derived products such as bitumen. Both GSA and NPA certify suppliers of cement and bitumen.

Current systems and workflows

Road design standards and specifications

Road design in Ghana is guided by the Standard Specifications for Road and Bridge Works, July 2007[6]. It is applicable for trunk, urban and feeder roads although a separate road design manual will be prepared for LVR with support from AfCAP. These specifications are a combination of Ghana Standard (GS), British Standard (BS), American Society for Testing and Materials (ASTM) and AASHTO. Soils are further classified following the standard AAHSTO classification.

The materials types for gravel materials are specified as per their CBR value (G80, G60, G40 and G30) for particular use in any of the road pavement layers (selected fill, sub base and base layers). Material class and typical use are G80 (min CBR of 80%) for the base course (HVR), a G60 or G40 for the base course (LVR) and a G30 for the sub base layer.

The minimum requirements for natural gravel materials in pavement layers is as follows, see **Table 13:**

Material properties	Material Class			
	G80	G60	G40	G30
CBR (%)	80	60	40	30
CBR Swell (%)	0.25	0.5	0.5	1.0
Grading				
% Passing Sieve Size (mm)				
75	100	100		
37.5	80 - 100	80 - 100		
20	60 - 85	75 - 100		
10	45 - 70	45 - 90		
5.0	30 - 55	30 - 75		
2.0	20 - 45	20 - 50		
0.425	8 - 26	8 - 33		
0.075	5 – 15	5 – 22		
Grading Modulus (min)	2.15	1.95	1.5	1.25
Maximum size (mm)	53.0	63.0	75.0	2/3rd layer thickness
Atterberg Limits				
Liquid Limit (%) (max.)	25	30	30	35
Plasticity Index (%) (max.)	10	12	14	16
Linear Shrinkage (%) (max.)	5	6	7	8

Material properties	Material Class			
Plasticity Modulus (PM)(max.)	200	250	250	250
Other properties 10%Fines (kN) (min) Ratio dry/soaked 10%Fines (min)	 80 0.6	 50 0.6	-	-
Notes: Grading Modulus (GM) = 300 – (percentage passing 2.0 + 0.425 + 0.075 mm sieves) x 100 **Plasticity Modulus (PM)** = Plasticity Index x percentage passing 0.425 mm sieve				

Table 13: Requirements for natural gravel materials in pavement layers

The key parameters for natural gravels are:

- Maximum dry density and optimum moisture content;
- CBR and swell;
- Particle size distribution, grading modulus and plasticity modulus;
- Atterberg limits and PI;

The technical specifications for lime and cement stabilised layers are slightly different in terms of their thresholds but they can be determined from the same parameters as for the non-stabilised layers. It should also be noted that the requirements for Ghana are not significantly different than those for Mozambique.

The materials types for graded crushed stone in road pavement layers and specified as stone classes A, B, C and D. The aggregate shall be produced entirely by the crushing of rock. Such aggregate shall be free from clay, organic or other deleterious matter, derived from hard, sound, durable and un-weathered parent rock. The minimum requirements for crushed aggregate materials in pavement layers is as follows, see **Table 14:**

	Base				Sub base			
Stone Class	A	B	C	D	A	B	C	D
CBR at 98% MDD and 4 days soak				80				
CBR at 95% MDD and 4 days soak								40
PI (max.)				6				
LAA (%) (max.)	30	40	45	50	40	45	50	
Water absorption (%) (max.)	1.5	2.0	2.0		2.0	2.5	2.5	
Flakiness Index (%) (max.)	25	30	30		35	35	35	
10% Fines (kN) (min.)	110 (dry)	110 (dry)	110 (dry)	100 (dry)	50 (wet)	50 (wet)	50 (wet)	50 (wet)
Wet/Dry % (min.)	75	75	75	75	60	60	60	

Table 14: Requirements for crushed aggregate materials in pavement layers

As can be seen from the **Table 14,** the key parameters for crushed aggregates are:

- CBR;
- LAA;
- Water absorption;
- Particle size distribution;
- Flakiness Index
- 10% Fines (wet/dry)

The technical specifications for aggregates used in concrete and road surfacing (asphalt and bituminous seals) are slightly different in terms of their thresholds but they can essentially be determined from the same parameters as for the road pavement layers (above) with the addition of the Average Least Dimension (ALD) Test, Stripping Test (ASTM D 4867) and the Sodium Sulphate Soundness Test for aggregates to be used in surface seals.

Materials Testing and Information Management

Materials tests for major road development projects are done as part of the project feasibility and detailed design studies and result in the materials report. During project execution, tests are carried out by the Contractor and (when necessary) independently verified by the Supervising Consultant. For maintenance projects, it is not common practice to carry out materials testing prior to tendering of the works. The bidding documents will indicate the amount of materials required for the pavement design with a free haul of 1 km and an overhaul rate for distances beyond 1 km. The amount required for overhaul is estimated based on local knowledge and experience from previous projects in the same area but it is left to the contractor to carry out prospecting of the borrow pits after the contract has been awarded.

Since there are no permanent borrow pits in Ghana (all open pits are to be re-instated after the project), there has never been much incentive to establish a road materials information system other than a list of permanent and commercially operated stone quarries and sand pits. The only evidence of materials information management is a MSc. Thesis from 2008[13], which evaluated materials properties of natural gravel samples from 454 borrow pits distributed throughout the country for their suitability as road base and sub base material. The results indicated that only 26% of the pits meet the requirement of sub base material (CBR>30%) and less than 2% for base material (CBR>80%) for HVR. Although the requirements for base and sub base material will be reviewed for LVRs (as part of the AfCAP supported preparation of a LVR manual for Ghana), it is clear that the availability of natural gravels is becoming increasingly scarce (in particular in the Western Region of the country). With road materials becoming increasingly scarcer and harder to find, the road sector institutions are now beginning to see a benefit in establishing a road materials database for optimum use of locally available materials and to better manage the cost of materials overhaul.

The procedures for materials testing are well established. For GHA, the customer (mostly contractors and consultants) submits a request to CML, or one of the RMLs, which triggers a quotation to be prepared. After payment by the customer, the appointed laboratory technician will undertake the tests using standard forms that are filled by hand. The summary of the test results are then entered into excel spread sheets and printed out for signature by the technician (who conducted the test), verified by the head of the section (the Manager) and signed by the Director of Materials (CML), or the Regional Director in case of the RMLs, after which the results are send back to the customer. Examples of excel forms from Ghana are presented in **Figure 8** (Soils and Aggregates).

GHANA HIGHWAY AUTHORITY
CENTRAL MATERIALS LABORATORY
SUMMARY SHEET FOR SOILS TEST

CUSTOMER: REF:GHA / CML / TF 13 /.............

PROJECT:

TECHNICIAN: DATE

SAMPLE IDENTIFICATION	GRADING TEST PERCENTAGE BY WEIGHT PASSING B.S SIEVE													NMC	ATTERBERG TEST			COMPACTION TEST		CBR TEST 96 Hrs SOAKED			
Soil samples Labelled	75 mm	53 mm	37,5 mm	26,5 mm	19 mm	9,5 mm	4,75 mm	2 mm	1 mm	425 µm	300 µm	150 µm	75 µm	%	LL %	PL %	PI %	MDD kg/m³	OMC %	100%	98%	95%	93%
RCC P1 A1	100	100	100	97	92	80	67	55	52	43	39	25	21	5,8	26	18	8	2220	7,6	100	76	60	53
RCC SS P1 A	100	100	100	100	86	77	63	50	46	40	36	29	26	6,1	26	18	8	2130	8	49	37	30	20
RCC SS P1 B	100	100	100	100	100	99	98	96	91	71	60	37	28	4,1	22	15	7	2120	7,2	52	40	35	22
RCC P2 A1	100	100	93	91	84	70	58	49	46	39	35	30	29	5,4	21	14	8	2150	7,4	43	34	20	18
RCC P2 C1	100	100	100	100	100	99	99	98	97	91	86	67	58	9,6	28	12	15	2115	7,9	25	17	14	10
RCC P2 B2	100	100	100	100	93	91	88	85	84	76	69	44	34	4,7	29	16	13	2210	6,6	20	18	15	10
RCC P1 B1	100	100	100	100	98	85	72	61	57	48	44	31	25	8,4	22	15	7	2185	6,7	58	35	20	18
RCCP3B	100	100	100	100	94	91	76	47	36	25	22	17	15	5,2	28	18	10	2160	6,5	51	30	24	15

NOTE: THE TEST RESULTS DO NOT CONSTITUTE APPROVAL BY GHA

PRINCIPAL T.O.
FOR:TECHNICIAN ENGINEER
(SOILS AND AGGREGATES)

SOILS & AGGREGATES MANAGER

DIRECTOR OF MATERIALS

GHANA HIGHWAY AUTHORITY
CENTRAL MATERIALS LABORATORY
AGGREGATES TEST SUMMARY SHEET

CUSTOMER

PROJECT

TECHNICIAN

DATE:

CHIPPINGS SOURCE

SAMPLE IDENTIFICATION	PERCENTAGE OF WEIGHT PASSING SIEVE														LOS ANGELES ABRASION %	AGGREGATE IMPACT VALUE %	FLAKINESS INDEX %	ELONGATION INDEX %	APPARENT DENSITY Kg/m	BULK DENSITY Kgm³	ABSORPTION %
	53,0 mm	37,5 mm	28 mm	20 mm	14 mm	10 mm	6,3 mm	4,75 mm	2,36 mm	1,18 mm	600 µm	300 µm	150 µm	75 µm							
20MM CHIPPING	100	100	85	43	2	1	0	0	0	0	0	0	0	0	28	15	**12**	15	2681	2643	0,34
14MM CHIPPING	100	100	100	100	52	2	0	0	0	0	0	0	0	0			**29**	25	2684	2679	0,45
10MM CHIPPING	100	100	100	100	100	99	62	46	34	29	24	15	10	5			**23**	14	2665	2601	0,80

PRINCIPAL T.O
FOR CHIEF TECHNICIAN ENGINEER
SOILS & AGGREGATES

AG. SOILS AND AGGREGATES MANAGER

DIRECTOR OF MATERIALS

Figure 8: Standard templates for materials testing on soils and aggregates

The paper-based copies of the materials testing are archived. The electronic copies of the summary of the test results are stored onto a desktop computer, one weaknesses being the lack of protocols for back up copies and data protection. The procedures for DFR are more or less similar to GHA with the exception that customers are not paying for materials testing. The materials test results are attached to the payment certificates, to facilitate payment of the contractor's invoices. One of the weakness in materials information management in Ghana is the lack of a clear referencing system for the location of the borrow pits and the specific locations of samples taking from within the borrow pit grid. This can only be determined based on sketches included in the "taking-off sheets" of the payment certificates to allow calculation of the overhaul distance. On a conclusive basis, it can be observed that most of the materials test data carried out by GHA, DFR and DUR is already being collected and electronically stored as part of existing workflows of the road contract management procedures.

Materials testing reports that are being prepared and submitted by project design and supervision consultants are sent to GHA, DFR and DUR for approval but this information is not electronically stored. Hard and soft copies of these materials reports are kept in the offices of the road agencies as part of the project filing system and not easily accessible.

Road Asset Management

GHA has a Pavement Management System (PMS) in place but this is mostly a standalone function to prepare annual reports for road inventory and condition surveys and it not integrated with the planning and programming of road maintenance works. A Bridge Management System (BMS), developed in 2001, is no longer operational.

DFR is using the locally developed Road Database (RD) asset management system for the planning, programming and budgeting road maintenance and improvement works. The budgeting function works though a standalone Excel wizard, which was developed under the Maintenance Planning and Budgeting System (MPBS). The RD was completed in 2005 with support from DFID. Three (3) local consultants were deployed for road inventory and condition surveys. The DFR GIS/IT section, under the Deputy Executive Director of Planning, now successfully manages the RD using in-house staff with occasional support from local IT service providers. The Road Database contains road inventory and condition data at 1 km intervals, which is updated on an annual basis and linked to a GIS system for mapping purposes. The DFR Regional Managers' Offices have no direct access to the database other than through a GIS reader. Updates (e.g. road length and condition) are sent manually through email transfers of attribute files. Road condition is updated annually through visual condition assessments and (speed correlated) roughness measurements.

In addition to the RD, DFR has also developed (in-house) a Contract Management System (CMS), which allows monitoring of road improvement and maintenance projects from tender preparation, to evaluation, to contract management and project closure. All payment certificates, materials reports and taking off sheets are generated through the CMS. The system, which can now also be accessed from a mobile phone application, is currently rolled out to the regions with accompanying training activities. CMS is to be linked with the Ghana Integrated Financial Management Information System (GIFMIS) to improve Financial Management and Controls and introduce Programme Based Budgeting among others.

The MRH has also initiated a project to develop a consolidated GIS database of road transport infrastructure in Ghana, which would be available to the public as a web based application. Not much progress has been made on this initiative.

GIS and IT

The staff IT and GIS resources are strongest at DFR who have managed to develop and operate their road asset management system and GIS with limited external support.

Stakeholders' needs and ambitions

Client view

Meetings with MRH, GHA, DFR and DUR clearly indicate that there is a scope to develop a road materials inventory and database in Ghana. The main purpose is to have the ability to source to road materials for pavement layers and pinpoint locations of borrow pits to manage the calculation of overhaul rates and to contain cost overrun. No previous efforts have been undertaken to establish a road materials database, which can be explained by the fact that borrow pits in Ghana are reinstated after their use.

Road materials testing data is collected by three (3) different road authorities/road departments (GHA, DFR and DUR) and the establishment of a road materials database would therefore require strong oversight and coordination by MRH. Based on the consultative meetings with staff responsible for the planning, design, supervision and maintenance of the classified roads in Ghana and the current road standards and specifications in use, key materials parameters can be easily identified (mentioned above).

This information provided should cover both HVRs and LVRs. Following the development of the Ghana Low Volume Roads Design Manual (in preparation), some additional aspects may need to be considered to capture the full range of materials suitable for LVRs similar to what was mentioned in the Mozambique country report **(Annex D).**

Contractors' view

In a meeting with the Association of Ghana Road Contractors (ASROC) the main challenges of road materials sourcing and testing were discussed as well as opportunities for road materials mapping.

The meeting made clear that tender documents for road improvement and maintenance works (other than major development projects which involve a Consultant for road design) do not contain specific information about the location of road materials sources and this can make it very difficult for contractors to price for the works. The tender documents mention the quantity of material required, a free haul of 1 km and an estimated overhaul rate based on the client's perception of the likely haulage distance. It is left entirely to the contractor to assess the availability of road materials and to negotiate with the landowners concerning compensation for loss of property and payment of royalties for materials extraction. This creates a high level of uncertainty (risk) for the contractor particularly in view of the royalties to be paid to the landowners (which are not regulated in any way).

Contractors do not have their own laboratory facilities and rely entirely on third party facilities (GHA, DFR laboratories etc.) to prospect and test materials. It is not common to employ road materials engineers other than on a part-time arrangement / temporary contract for the purpose of a specific road project. To find additional road materials closer to the works, contractors use their previous local knowledge and consult with people. Contractors do not make use of materials indicators such as landform and botanical indicators.

The contractors support the imitative to develop a road materials database and further suggested that this be publically accessible on a web based platform and a mobile phone application since most of these projects are located in remote areas of the country with limited or no access to Internet.

Conclusions and recommendations

The institutional framework of the Ghana road sector is clear and well defined. Its stakeholders subscribe to the objective of having better and more reliable access to road materials information. There is an obvious demand for better road materials information management in the road sector. The planning and design of road improvement and maintenance projects, in particular for LVR, carries a level of uncertainty with respect to the location of suitable road materials. This information has been collected over time (as part of materials testing for on-going road projects) but is not centrally stored and not easily accessible other than project based reports, both paper and electronic based.

A materials database would need to include the location, properties and quantities of available materials sources (mainly gravel, sand and aggregates). In addition a referencing system should be developed for different types of materials sources with a mapping tool. The database and mapping tool should be accessible to all road sector stakeholders.

The GHA laboratories are well equipped and staffed, whereas the DFR and DUR laboratories operate under equipment and staffing constraints. However, all road sector institutions operate under the same Ministry (MRH) and there is a natural tendency to cooperate and share limited resources, i.e. DFR and DUR make frequent use of the GHA materials laboratories.

Current systems and workflows for materials testing and information management are well established and collecting road materials source data would not require a major change in operating procedures other than some improvement to the templates, the way data is stored and the back up facilities.

Although the use of road materials in Ghana is regulated by various Acts of Parliament entitling the Government to have free access to such materials for the general public interest (with due respect to compensation procedures), in practice this is a complicated process due to lack of information about the customary rights of landownership and the trend to charge royalties on the extraction of road building materials. This time consuming and volatile procedure has to be repeated for every single project since no borrow pits are considered permanent.

In Ghana road materials sources are not clearly referenced by their location. There was no such incentive because borrow pits are only temporarily used for the duration of a project (they have to be reinstated after use) with the exception of commercially operated sand pits and stone quarries.

The overall conclusion is that road sector stakeholders in Ghana seem convinced of the need for the development of a road materials database but that some form of cooperation framework between the three major various road sector institutions would have to be set up to effectively achieve this.

Annex F: Report 3 Tanzania visit

Visit Tanzania: 13 and 14 July 2017 (2 days)

Day 1	Activity	Objective	Person
Morning	Meeting head of the PO-RALG/DID Meeting Chief Executive TARURA Meeting Head of Laboratory, LoGITReC (Road Transport Research Centre). Visit TARURA Materials Laboratory LoGITReC.	Project briefing. Project briefing. Progress update establishment of Tanzania Rural and Urban Road Agency (TARURA) Review survey questionnaire. Discuss institutional framework, current systems, challenges and ambitions. Obtain RTCC's views on materials information management. Become familiar with existing system and procedures for laboratory management, materials testing and data storage.	Jan
Afternoon	Meeting TARURA DROMAS coordinator Meeting TANROADS Regional Manager Dodoma Meeting select group of project engineers from the Municipal Council of Dodoma.	Become familiar with the road asset management system and explore possible links with materials information management. Discuss the specific requirements for feeder roads engineers doing in-house road design: their materials information needs, challenges and ambitions. Discuss the specific requirements for urban road engineers doing in-house road design: their materials information needs, challenges and ambitions.	Jan
Day 2	**Activity**	**Objective**	
Morning	Visit Dodoma Regional Materials Laboratory of TANROADS and meet Laboratory Manager. Meeting Chief Executive TARURA and head of TARURA LoGITReC. Debriefing head of PORALG/DID.	Become familiar with their systems and procedures for laboratory management, materials testing and data storage for local roads. Present and discuss main findings of the visit. Present and discuss main findings of the visit.	Jan
Afternoon	Travel to Dar Meeting Head of Research and Materials TANROADS and visit CML TANROADS. Meeting Dr.Magafu, previously Head of LoGITReC (Road Transport Research Centre).	 Obtain views of TANROADS on materials information management. Become familiar with their systems and procedures for laboratory management, materials testing and data storage for national roads. Obtain views on materials information management.	Jan

Country report Tanzania 13 – 17 July 2017

Institutional framework

The institutional framework for road asset management in Tanzania has undergone recent changes. The national roads (about 34,000 km) remain to be managed by the Tanzania National Road Agency (TANROADS) under the Ministry of Works, Transport and Communications (MOWTC). Local government roads (rural and urban roads, about 52,000 km of classified roads and another 60,000 km or so of unclassified roads) where previously managed by the 184 District and Municipal Councils under the oversight of the President's Office for Regional Administration and Local Government (PO-RALG), Department of Infrastructure Development (DID).

The management of rural and urban roads has now been handed to the newly created Tanzania Rural and Urban Road Agency (TARURA) set up under PO-RALG. All executive tasks for the management, planning, maintenance and development of rural and urban roads are now the responsibility of TARURA who will have delegations at the Regional Level (Regional Coordinators) and the District Councils (Council Managers) who each have a team of technical staff to manage the road networks under their jurisdiction (see **Figure 9** Organogram). TARURA is expected to recruit a total of about 3,000 people (engineers, technicians and support staff).

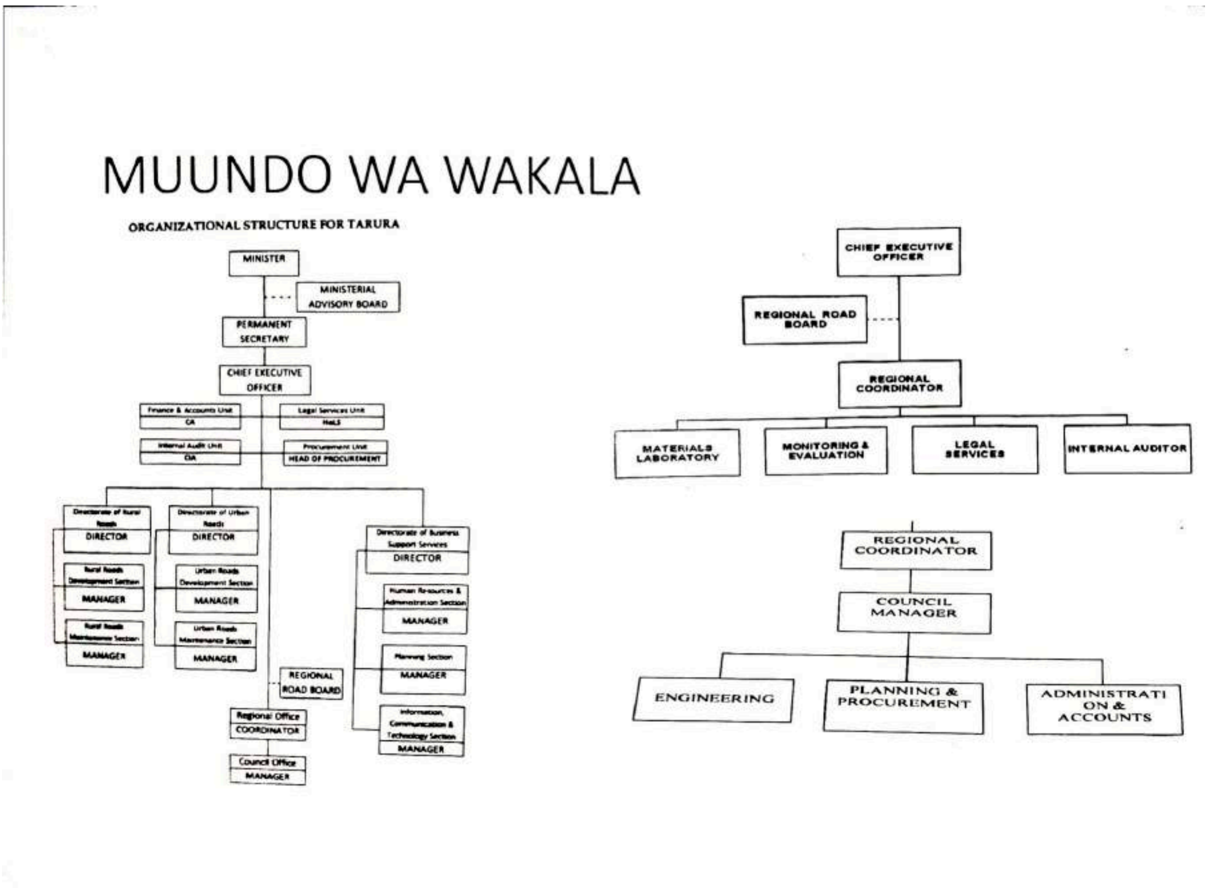


Figure 9: Organogram TARURA

The responsibility for materials testing and information management within TANROADS lies with the Director of Planning, through the Manager of Research and Materials who also oversees the Central Materials Laboratory (CML) and 26 Regional Materials Laboratories (RMLs). TANROADS CML and RMLs employ 28 staff of which 8 have an academic degree, 8 technicians, 6 laboratory assistance technicians and 8 support staff. Besides doing materials testing and providing quality control of highway development and maintenance projects, they also review and approve materials reports submitted by Consultants and Contractors and supervise the 26 RMLs.

Since TARURA has only recently been established, it has limited testing facilities and relies entirely on the facilities of the AfCAP supported Local Government Infrastructure and Transport Research Centre (LoGITReC), located in Dodoma. The objective of LoGITReCis to undertake relevant research related to local government roads and transport. LoGITReC has now been transferred from PO-RALG/DID to TARURA. LoGITReC has two materials engineers, one trained at CSIR, and five technicians, trained at CML, employed. It was supposed to have an additional 4 Researchers and 1 Information Specialist (to run the knowledge centre) but this is currently under review now that LoGITReC has been transferred to TARURA. LoGITReC also has a few mobile gravel test kits to support quality control of on-going road maintenance works upcountry.

At the moment the District Councils and Municipalities have no materials testing facilities other than to rely on the TANROADS RMLs. TARURA's has received funding from the World Bank supported Transport Strategic City Program (TSCP), which would allow for a further eight (8) Municipal Materials Laboratories to be set up in major cities of Tanzania. The plots have been purchased but it may take a few years before these laboratories are up and running.

In addition to the laboratories falling under the road sector institutions, there are four (4) major public laboratories with Universities (DSM University, DSM Institute of Technology, Arusha Technical College and Mbeya Technical College). There is also one licensed (1) private materials laboratory.

Other AfCAP funded LVR research projects in Tanzania include:

- Development of a Low Volume Roads Design Manuals (completed);
- Long Term Pavement Performance (LTPP) Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania (Project reference: TAN2098A);
- Capacity Building and Skills Development of LoGITReC laboratory personnel (Project reference: TAN2095A).

The current institutional responsibility for road materials testing, information management and research is clear and organised by road sub sector (TANROADS and TARURA) with TANROADS having the lead due to resource availability (in terms of equipment, number of laboratories, staff, expertise and budgets).

Regulatory framework

Road materials extraction for road construction and maintenance requires a mining license to be issued by the Ministry of Energy. In addition, the legal and institutional framework for environmental management in the country is provided for in the Environmental Management Act (2004). The Division of Environment under Vice President's Office is responsible for the overall environmental policy and regulation, formulation, coordination and monitoring of environment policy implementation in the country, including the environmental impact assessment and preparation of environmental management plans for roadwork.

For major roads development projects (TANROADS), borrow pits are acquired by the Contractor through compensation payment to the landowners and then handed to TANROADS after the project for future maintenance works. This is why TANROADS has permanent borrow pits in use throughout the country, which are indisputable pubic property. There is no central register of materials sources, but it is estimated by TANROADS that there are on average 3 to 4 stone quarries and up to 20 borrow pits per region, making a total of 150 commercial quarries and 500 borrow pits currently in use by TANROADS nationwide.

Like in many other low-income countries there is limited capacity to enforce mining and environmental regulations for the lower tier of roads other than obliging the contractors to negotiate compensation with the landowners and pay levies. Current market rates for gravel are in order of Tsh 20,000 (for sub base) to Tsh 28,000 per m^3 (for base), from which the contractor would have to pay compensation to the community or landowner and a levy to the Councils and the Ministry of Energy.

The Tanzania Bureau of Standards (TBS), who is also responsible for calibration and certification of testing equipment, certifies all materials laboratories in Tanzania. In addition, the Road Materials Laboratories require to be professionally registered by the Engineers Registration Board (ERB). As a minimum requirement anERB registered engineer should head a Materials Laboratory.

Current systems and workflows

Road design standards and specifications

Road design in Tanzania is guided by the Pavement and Materials Design Manual[14]. It is applicable for trunk, urban and feeder roads although a separate manual for the provision of LVR (roads up to 1 Million ESAS) has recently been prepared with support from AfCAP and now officially adopted. The design standards and specifications in Tanzania are mostly based on British Standard (BS) and American Society for Testing and Materials (ASTM). On few occasions it also refers to South African Standards (TMH). Like Ghana and Mozambique, soils are classified following the AAHSTO classification.

Granular materials are classified according to their use in road pavement layers: CRR (crushed fresh rock), CRS (Crushed Stones and oversize), DR for Dump Rock, G25, G45, G60 and G80 for natural gravels with the numbers referring to their minimum CBR value for pavement layers, G3, G7 and G15 for mass earthworks and selected fills, CM for modified cemented materials (UCS > 0.5 Mpa) and C1-C4 for Stabilised materials with UCS of > 1 MPa to > 4 MPa).

Coral rock is a major source of pavement material along the East Coast while volcanic tuff and pozzolan are common in the northern and western rift valley regions. Pedogenic materials, such as laterite and calcrete, are also common throughout Tanzania. The minimum requirements for granular materials in pavement layers is as follows, see **Table 15:**

Material properties	Material Class			
	G80	G60	G45	G25
CBR (%) at 4 days soaking @ 98% MDD BS Heavy CBR Swell (%)	>80 < 0.5	>60 < 1.0	> 45 <0.5	> 25 <1.0
Grading% Passing Sieve Size (mm)				
63	100			
37.5	80 - 100			
20	60 - 95			
5.0	30 - 65			
2.0	20 - 50			
0.075	5 – 15			
Grading Modulus (min)	> 2.0	> 2.0	> 1.5	
Maximum size (mm)	< 2/3 x layer thickness	< 2/3 x layer thickness	< 2/3 x layer thickness	> 1.2 < 2/3 x layer thickness
Atterberg Limits				
Liquid Limit (%) (max.)	30	35	40	45
Plasticity Index (%) (max.)	8	10	14	16
Linear Shrinkage (%) (max.)	4	5	7	8
Other properties				
10%Fines (kN) (min)	>80	>50	-	-
Ratio dry/soaked 10%Fines (min)	> 60%	> 60%		

Table 15: Minimum requirements for granular materials in pavement layers

The key parameters for natural gravels are similar to Mozambique and Ghana:

- Maximum dry density and optimum moisture content;
- CBR and swell;
- Particle size distribution, grading modulus and plasticity modulus;
- Atterberg limits and PI;

Like in Mozambique, the performance of natural gravels for the wearing course is evaluated through the South African Standard TRH-20 (based on Shrinkage Product and Grading Coefficient) with an additional requirement of having a minimum compaction of 95% of MDD (BS Heavy) and a CBR > 25%.

The materials types used for graded crushed stone in road pavement layers are classified as CRR and CRS. The aggregate shall be produced entirely by the crushing of fresh rock (CRR) or blasting and screening of rock (CRS). The minimum requirements for crushed aggregates are as follows, see **Table 16:**

Stone Class	CRR	CRS
Field density	>88% of aggregate density	>100% of MDD BS Heavy
Particle size distribution	Specified envelope for coarse and fine type, max. size of 50 mm and not more than 12% passing the 0.075 sieve	
Liquid Limit (%) (max.)	30	35
Linear Shrinkage (%) (max.)	3	4
10% Fines (kN) (min.)	>110 (dry)	>110 (dry)
Wet/Dry % (min.)	>75%	>75%

Table 16: Minimum requirements for crushed aggregates

As can be seen from Table 16, the key parameters for crushed aggregates are:

- Liquid Limit
- Linear Shrinkage
- Field density
- Particle size distribution
- TFV

The technical specifications for aggregates used in concrete and road surfacing (asphalt and bituminous seals) are slightly different in terms of their thresholds but they can essentially be determined from the same parameters as for the road pavement layers (above) with the addition of the Flakiness Index (FI), the Average Least Dimension (ALD) Test, Water Absorption Test and the Polishing Stone Value (PSV).

Materials Testing and Information Management

The materials testing methods are clearly spelled out in the CML Laboratory Testing Manual (2000)[15] and Field Testing Manual (2003)[12]. These are excellent reference manuals and were developed with support from the Norwegian Road Agency.

Materials tests for major road development projects are done as part of the project feasibility and detailed design studies and result in materials reports. During project execution, tests are carried out by the Contractor and verified by the Supervising Consultant before submission to the Client. Some contractors use CML for their materials testing needs but most of their own facilities. For maintenance projects, similar to what was seen in Ghana and Mozambique, it is not common practice to carry out materials tests prior to tendering of the works. During the site handover, contractors are shown where existing (mostly TANROADS) borrow pits and quarries are located. According to CML staff, all regions have mapped their borrow pits with GPS coordinates however during the visit to Dodoma region no evidence was found of any register of materials sources.

The procedures for materials testing are well established. For TANROADS, the customers (in-house project engineers, contractors and consultants) submit a request to CML or one of the RMLs. The appointed laboratory technician will undertake the tests using standard forms that are filled by hand. The summary of the test results are then entered into excel spread sheets and printed out for signature by the Lab Technician (who conducted the test), verified by the Head of the Laboratory and signed by the Materials Manager (LoGITReC), or the Regional Manager (in case of the RMLs), after which the results are send back to the customer. These procedures are quite similar to Ghana.

The paper-based copies of the materials testing are archived. The electronic copies of the summary of the test results are stored onto a desktop computer. On a conclusive basis, it is clear that materials test data carried out by TARURA and TANROADS is already collected electronically as part of existing workflows but not being uploaded to a central materials database. Materials testing reports prepared and submitted by project design and supervision consultants sent to TANROADS are only available as hard and soft copies and kept at HQ as part of the project filing system. This data is not used for any other purpose than project management.

With support from CSIR, laboratory management software has recently been installed at TARURA's LoGITReC. The program is known as Laboratory Work List, which monitors daily work schedules and stores all relevant information related to materials testing. The program contains two interfaces; jobs and samples. The job screen allows entry of job related information and the sample screen contains information about the test results of on the samples.

Road Asset Management

The annual budgeting for road maintenance at TANROADS uses the Routine Maintenance Management System (RMMS). This system evolved from Road Mentor that was developed in about 2003 through DFID funding [16]. The RMMS has GIS capability, which has been used extensively for road mapping. The RMMS has contributed positively to the planning and project control, especially in the Regional Managers' offices (RMOs) where the Contract Management module is used to generate quarterly and annual reports. However, RMMS has limitations as a network-level strategic planning tool. The RMMS is a stand-alone system, where distress data collected by RMOs can only physically brought to the HQ in flash disk, and loaded in RMMS-HQ. The bulk of data collection (road condition, traffic counts and classification of vehicle types) is based on visual assessment. The mechanized data collection is carried out on paved roads and limited to road roughness (IRI), rut-depth and structural capacity using Falling Weight Deflectometer (FWD). RMMS contains no information about the pavement structure and the type and the source of road materials used. This information can only be obtained from "as-built" drawings.

TARURA uses the inherited District Roads Management System (DROMAS) which was recently upgraded under the DFID funded IRAT project with a frontend interface in Visual Studio software and the database in PostgreSQL software. DROMAS includes modules on Admin, Road Network, Annual Road Maintenance Planning, Contract Management, Cost System (currently not working) and a Mapping application (with an external browser linking to QGIS software). DROMAS was developed and upgraded by an International Consultant who, before handover of the project, needs to train TARURA staff in accessing the source codes to make modifications if necessary. DROMAS has now been rolled out to all the 184 councils who can access the software using an Internet connection. Access is restricted to local government engineers who require a user name and password. Nominated engineers in the councils have authority to make changes to the road network module. The Road Network module has a sub module for pavement structures, which includes a pavement layer description and a general reference to the materials used (granular, stabilised, etc.) but not to the materials source or the class of materials. However, once TARURA has access to the source codes these changes can be accommodated if required.

GIS and IT

Being a new institution, the GIS and IT facilities at TARURA are limited for the time being. There are currently no GIS and IT specialists but it is expected that under the Division of Business Support Services, the Section for Information, Communication and Technology IT and GIS specialists will be recruited. The same applies for IT infrastructure and facilities. The IT and GIS facilities of TANROADS are summarised in **Table 17:**

SN	Item Description	Count
1	Number of IT Personnel (HQ + 25 Regional Managers' Offices)	3
2	Desktops (workstations), PCs and Laptops (*220 at HQ; 300 in Regional Managers Offices)*	520
3	Number of Servers	6
4	Desktop software application types	10
5	Database software platforms: *(MS Access, MS SQL, Oracle, HDM-4, GIS ArcView)*	3

Table 17: IT Facilities of TANROADS[16]

The acquisition of ITC hardware and software has historically happened in an *ad-hoc* manner without clear synergy and long-term strategy or guiding principle. As a result, current challenges related to integrating existing systems and hardware. Some other important findings obtained from the Strategic Business Process Mapping to Develop a Quality Management System for TANROADS[16] include:

- Absence of an ICT policy and strategy, a business continuity plan and disaster recovery site;
- TANROADS had an acute shortage of IT professionals to support its LAN/WAN;
- Low customer support from the LAN (intra-net) service provider;
- Internet connectivity was extremely slow.

Stakeholders' needs and ambitions

Meetings with TARURA, TANROADS and District Councils indicate that there is a scope to develop a road materials inventory and database in Tanzania.

The main purpose is to have the ability to source different types of suitable road materials (which are increasingly becoming depleted) for pavement layers and surfacing and to identify locations where such materials can be found.

No previous efforts have been undertaken to establish a road materials database but TANROADS recently approached the Namibia Roads Authority for more information about their Materials Information Management system. This, and PO-RALG approaching AfCAP to assist with the development a road materials database, are clear indicators that the road sector institutions in Tanzania are serious about establishing a national materials database.

Conclusions and recommendations

The institutional framework for LVRs has improved considerably with the recent establishment of TARURA. This provides an opportunity to have better control over rural road asset management with uniform procedures for the planning, budgeting, design and implementation of road maintenance and improvement works. One of the main concerns is that TARURA is a new institution that may still need some years before it is fully operational. Currently it only has one operational laboratory whilst eight (8) are in the process of being established in the largest Municipalities in Tanzania. The institutional framework for HVRs is well established and tested through TANROADS where materials testing and information management is done through the 26 RMLs with oversight by CML.

With road materials becoming increasingly scarcer and harder to find, both TANROADS and TARURA are seeing the need for developing a road materials database for optimum use of locally available materials and to reduce the need for overhaul. There is an obvious demand for better road materials information management in the road sector. The planning and design of road improvement and maintenance projects, in particular for LVR, carries a level of uncertainty with respect to the location of suitable materials. This information has been collected over time (as part of materials testing for on-going road projects) but is not centrally stored and not easily accessible other than project-based reports.

Similar to Mozambique and Ghana, the materials database would need to include the location, properties and quantities of available materials sources. The database and mapping tool should be accessible to all road sector stakeholders covering LVRs and HVRs. Current systems and workflows for materials testing and information management are established but may need improvement, in particular with respect to collecting and registration of samples, the way materials testing data is stored and the back up facilities.

Unlike Ghana and Mozambique, the road sector responsibility in Tanzania is shared between two different Ministries (PO-RALG for LVRs and MOWTC for HVRs), who compete for the same road materials sources. For the purpose of developing a national road materials database ownership will be a critical issue.

Annex G: Updated Stakeholder Survey Feedback

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
PART A								
A2. Institution responsible for road materials info management National Roads	Ethiopian Roads Authority	Ghana Highway Authority (GHA)	Ministry of Transport and Infrastructure, Materials Testing and Research Division (MTI/MTRD)	National Road Administration (ANE)	Ministry of Roads and Bridges, Materials and Research Department	TANROADS, Central Materials Laboratory	Uganda National Roads Authority (UNRA)	Sierra Leone Roads Authority (SLRA)
Rural roads	-	GHA / Department of Feeder Roads	MTI/MTRD	ANE	Ministry of Roads and Bridges, Materials and Research Department	PO-RALG - DID	District and local government authorities	SLRA / Feeder Roads Department
Urban roads	-	GHA / Dept. of Urban Roads	MTI/MTRD	Municipalities	Ministry of Roads and Bridges, Materials and Research Department	PO-RALG - DID	City Council Authorities	Sierra Leone Roads Authority (SLRA)
A3. Staff numbers (total)	14	86	No information provided	6	14	10	26-36	24
A4. IT expertise available?	Yes	Yes	No	Yes	No	Yes	Yes	Yes
IT staff, how many and type	1	1 Director 6 Programmers 4 Technicians.	-	-	-	It is a department within PO-RALG and they are responsible for all IT requirements in the ministry.	5 - ICT Officers (Database Administration, Security, Applications Development, Systems Administration, Hardware and Networks)	6 1 Manager 2 Computer Programmers 3 Deputies Programmers
Are they available to support materials information management?	Yes	Yes	No	Yes	No	Yes	Yes	Yes
A5. Experience in GIS? What software package do you use?	Yes Arc GIS	Yes GTRANS – Ghana transportation systems	No	Yes Arc Map 10.03.1 Global Mapper Google Earth QGIS	No	No	Yes Arc GIS	Yes ArcView 10
For what purpose is GIS being used?	Planning	Extensive use at survey and design	-	Collecting, analysing road data to produce	-	-	Survey and development of	Mapping major roads.

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
		division.		Maps			location maps, road network database.	
Data management software packages in use?	dTIMS	Pavement maintenance management software.	-	HIMS	-	-	dTIMS, BMS, TIS	PMMP
For what purpose?	Asset Management	Prioritising roads for maintenance.	-	Road Management	-	-	Data storage, Network data analysis for strategic planning	Managing road data
A7. Number of materials laboratories managed by the institution	1 National	1 National 10 Sub national	7 National 16 Sub national	11 National	1 National	1 National 7 Sub national.	1 National 1 Referral laboratory No other substantial laboratories but the institution monitors various project based laboratories.	1 National 3 Sub national
A8. Other public materials laboratories	4	3	4	1	2	60	4	1
Private laboratories	10	6	5	4	10	15	7	1
A9. Road research activities?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What areas?	Materials and Transport	Use of polymerised soil and asphalt stabilisers.	Research on Alternative Soil Stabilizers Road Marking Paints/Road Furniture Use of other appropriate/marginal road construction materials Cold applied bituminous materials	Proficiency of laboratories Monitoring of existing experimental sections Climate adaptation: Risk management and resilience optimisation	Pavement trial section Geocels technology Stabilisation of black cotton soil.	Back Analysis of trial sections First mile improvement and rural road safety improvement.	-	Road Asset Management research project - AfCAP
PART B								
B1. Do you have an operational road materials database?	Yes	No	No	Yes	No	No	No	No
B2. Is it regularly	-	-	-	No	-	-	-	-

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
updated?								
How often?	It is new.	-	-	-	-	-	-	-
What is the process for updates	New data obtained from design reports, material properties at the Road Research Centre, etc.	-	-	-	-	-	-	-
B3. What data is contained in the database?	Engineering characteristics of the material (grading, Atterberg limits, strength etc.), location, quantity estimate and pictures of the material and location	-	-	Borrow pits and quarries location and materials description.	We have data from Road Assessment, road design, trial sections, and regular testing of road building materials.	-	-	-
B4. Is the database electronic or paper based?	Electronic	-	-	Both electronic and paper	Both electronic and paper	-	-	-
What database software does it use?	Access	-	-	Excel	Excel	-	-	-
What operating systems and server infrastructure?	*[Windows]*	-	-	Windows	Windows	-	-	-
Web enabled?	Yes	-	-	No	Yes	No	-	-
Custom developed or off-the-shelf?	Custom	-	-	Custom	Custom / Off-the-shelf	-	-	-
If custom – was it developed internally?	Yes	-	-	Yes	Yes	-	-	-
How is it supported?	Internal resources	-	-	-	-	-	-	-
-Database maintenance contract to a service provider?	Yes	-	-	No	No	-	-	-
Linked to a GIS in any way?	No	-	-	No	No	-	-	-
If "YES", what GIS	-	-	-	-	-	-	-	-

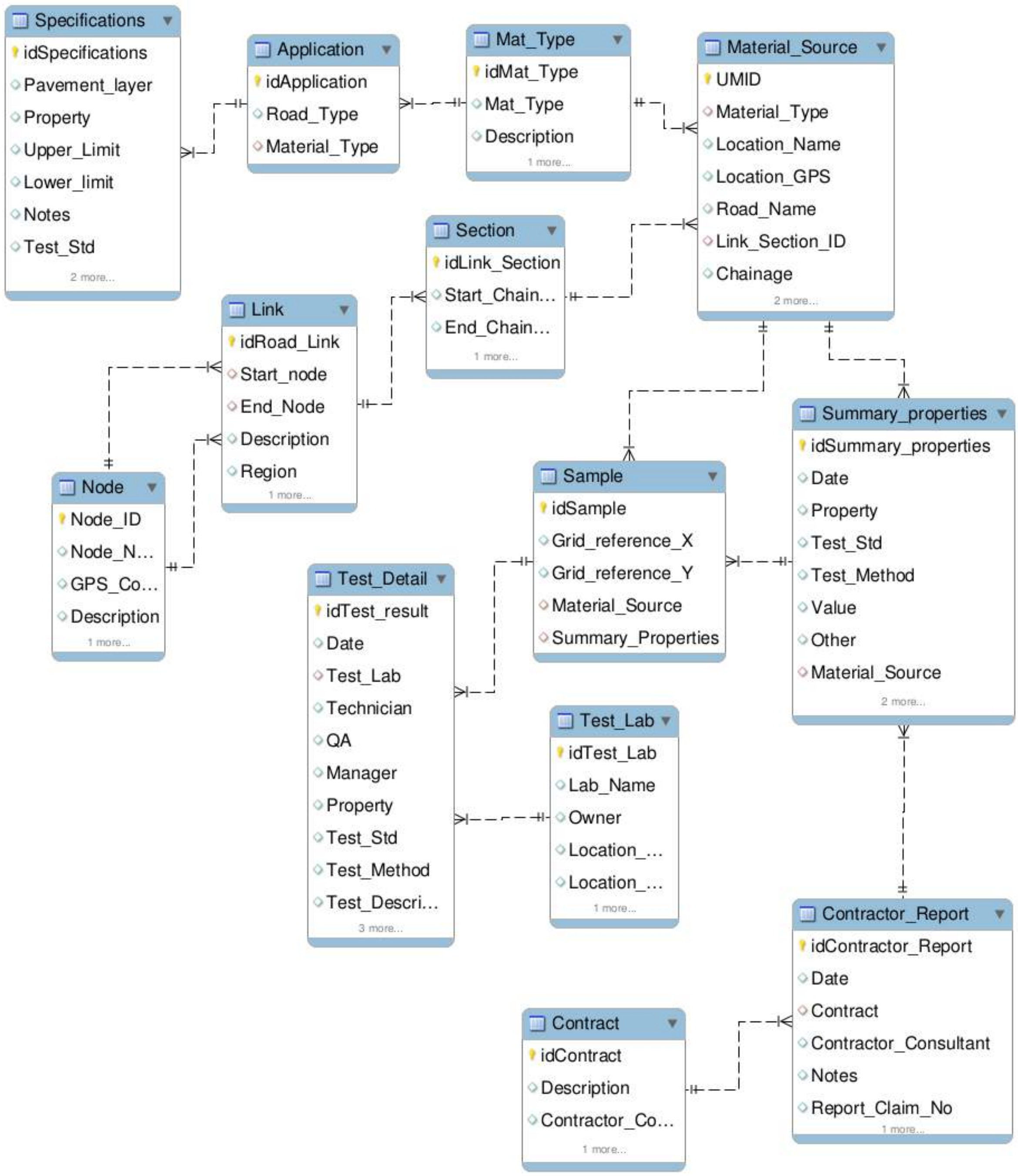
Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
standards or software?								
Who has access to the database?	Researchers and road designers	-	-	-	Road sector partners	-	-	-
B5. Who are the main users of the database?	Researchers, designers and design project management teams	-	Road Authorities/Agencies Consultants/Design Engineers County Governments Road Contractors	ANE, Consultants and Contractors	Government Institutions, Academic Institutions, Development Partners, and Contractors.	-	-	-
B6. Which of the following modules are covered in your database?								
Materials properties of existing quarries and borrow pits	Yes	No	Yes	Yes	Yes	No	No	No
Road subgrade materials testing	Yes	No	Yes	No	Yes	No	No	No
Geotechnical investigations	Yes	No	Yes	No	No	No	No	No
Materials and workmanship testing data for road construction and maintenance contracts.	No	No	Yes	No	Yes	No	No	No
Road pavement performance data.	No	No	Yes	No	No	No	No	No
Mapping tools for the locations of quarries, pits and road sections.	No	No	No	No	No	No	No	No
Tools for identifying unexplored sources of road materials.	No	No	No	No	No	No	No	No
Others	None	None	None	None	None	None	None	None
B7. Are external users paying for information from the database?	No	No	No	No	No	No	No	No

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
B8. Is the materials database linked to a road asset management system?	No	No	No	No	No	No	No	No
PART C								
C1. What are the main challenges with your road materials information management?	It is new and the challenges are not yet fully identified.	Require support in the use of software to manage road construction materials etc.	1. Lack of secure and organized Data base 2. Lack of Experienced Information Management experts 3. Inadequate use Technology for data/information gathering	An update of data for quarries and BP in whole country and availability and properties and pavement structure.	Data collection, Information base yet to be created and management of the database (including availability of IT specialist).	1. No clear info on the quality and quantity of available materials. 2. Material management system not established. 3. Location of materials not known clearly.	Not applicable	We don't have a materials database.
Any particular stakeholders' demands that cannot be satisfied by the current database system?	It is new. Expect feedback as usage increases.	Private consultants and contractors.	-	Yes	Geotechnical investigations are difficult to do because of lack of facilities	No database system but existing practise leads to higher overhaul cost and longer period of time to locate proper construction materials.	Not applicable	Not applicable
Specific functions that have been prioritised for improvement?	Attaching it to GIS so that locations and other information are shown on the map	Not applicable	Development of IT/Data Base Systems	Construction materials location using GIS	Provision of testing facilities: foundations, bituminous materials and building materials	We would like to have a material database and we have requested AfCAP to assist.	Not applicable	Not applicable
C2. Are there past or on-going projects to improve the database?	Yes	-	Yes	No	No	No	-	No
If yes, please describe the projects and briefly state the outcome.	Currently internal IT experts are trying to attach the database to a GIS	-	1. National wide Mapping of Road Construction Materials ongoing 2. Baseline survey of Performance of Road Pavements	-	-	-	Not applicable	Not applicable

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
If no, briefly explain why this has not been possible.			-	Budget constraints	Lack of qualified personnel and budget for data collection.	We are waiting for AfCAP to approve our concept note.	Not applicable	Not applicable
C3. What information is taken from the materials database (please specify for each stakeholder)?								
Government road engineers	Expect material characteristics data, location and quantity estimates to be of high interest from the preliminary discussions.	-	Materials Sources and Quality/ Quantity Materials Properties	Materials location, quality and quantities.	-	-	-	Not applicable
Other government agencies (e.g. transport, environment, natural resource management, mining, etc.)	Not known (no request so far as the data base is new).	-	-	Idem	-	-	-	Not applicable
Consultants	As above	-	Materials Sources and Quality/ Quantity Materials Properties	Idem	-	-	-	Not applicable
Contractors	As above	-	Materials Sources and Quality/ Quantity Materials Properties	Idem	-	-	-	Not applicable
Academic or research institutions	As above	-	Materials Sources and Quality/ Quantity Materials Properties	Idem	-	-	-	Not applicable
Others	-	-	-	-	-	-	-	Not applicable
C4. What functions should the database cover (in order of priority, starting with number 1 for the highest priority)?								
Materials properties of existing quarries and borrow pits	Material type Quantity Location	3	1	1	3	2	2	2
Road alignment (subgrade) materials testing	Subgrade strength (CBR)	6	5	6	7	4	4	3
Geotechnical investigations	-	2	6	2	6	3	3	4

Survey questions	Ethiopia	Ghana	Kenya	Mozambique	Sudan	Tanzania	Uganda	Sierra Leone
Materials and workmanship testing data for road construction and maintenance contracts	-	4	2	3	2	3	6	1
Road pavement performance data	-	1	3	7	5	5	5	5
Location mapping of quarries, borrow pits, etc.	-	7	4	4	4	1	1	6
Screening tools for initial assessment of unexplored sources of road materials	-	5	7	5	1	6	7	7
Other (Specify)	-	-	-	-	-	7 – Quantity of material in a specific borrow pit; 8 – Distance from specific borrow pit to various nearby village centres.	-	8. Training geotechnical engineers to manage the database 9. Training of the MIS staff to input and manage the data electronically 10. Training of technicians to identify and test available materials
C5 Are there any particular training needs identified for road materials inventory and information management?	Materials database management (data entry, retrieval)	-	HDM 4 and GIS Training Data Management Training	Use of advanced technology in materials investigation.	Data collection, testing facilities and techniques (asphalt and geotechnical investigations), management and use of data.	The use of topographic map, satellite image and Google earth to locate materials. How to translate the imagery to locate the material.	None so far identified but can be advised on the best available training on the market.	-

Annex H: High-level Entity Relationship Model (Illustrative)

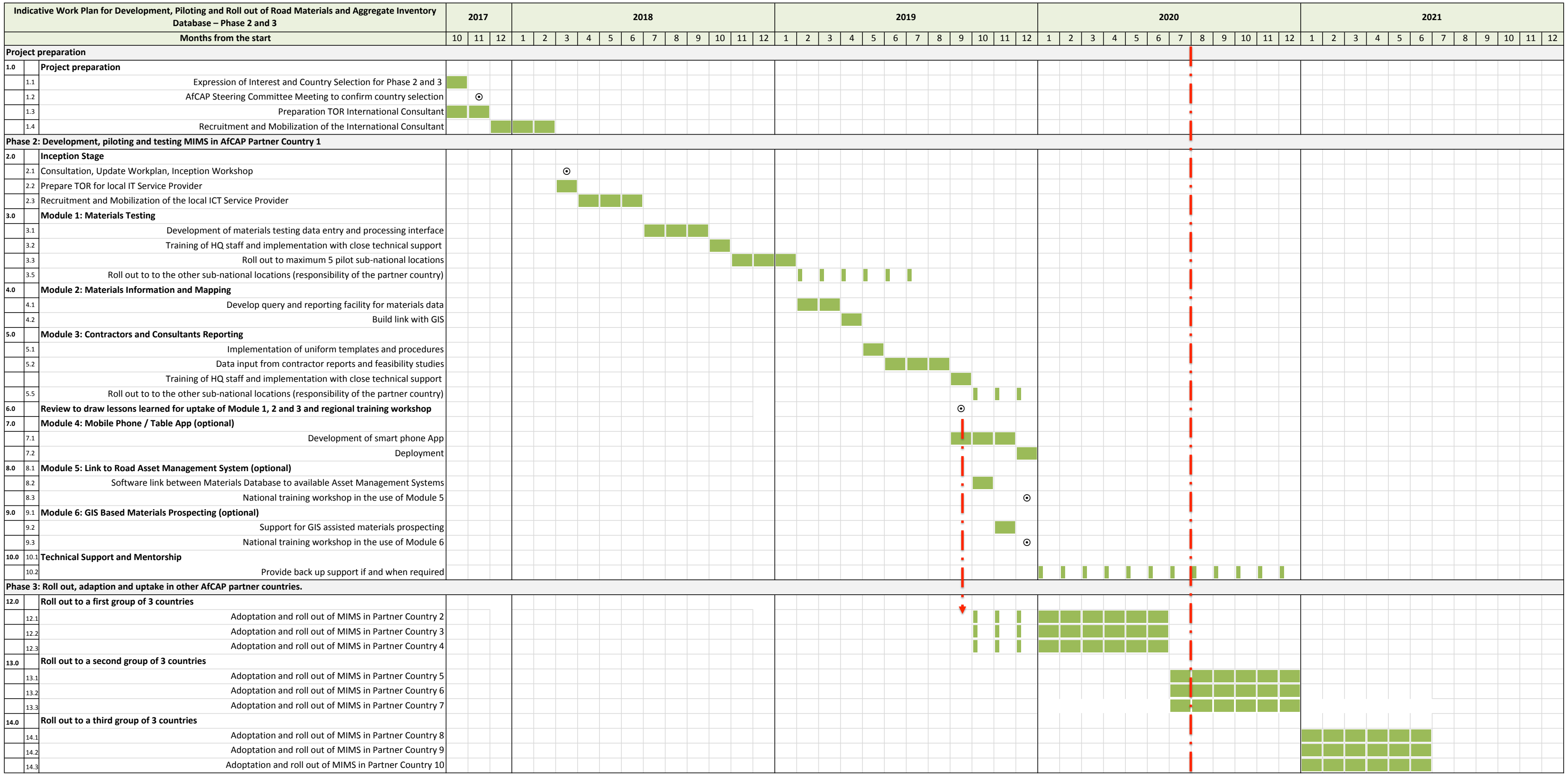


Annex I: Draft logical framework

Intervention Logic	Indicator	Source of Verification	Baseline 1 April 2017	Milestone 1 31 July 2017	Milestone 2 31 July 2018	Milestone 3 31 July 2019	End of Project Target (Cumulative by 31 July 2020)	Assumptions
OUTCOME: Sustained increase in evidence base for more cost effective and reliable low volume rural road and transport services, promoted and influencing policy and practice in Africa and Asia	1. SUSTAINABILITY: Partner Government and other financiers co-funding research with ReCAP. Contributions in kind (K) and Core Contributions (C)	Annual budget and work plan of the Ministry or Road Agency responsible for materials information management.	None	None	At least 1 partner country has adopted the MIMS and allocated resources for its development, population and use.	At least 1 partner country has adopted the MIMS and allocated resources for its development, population and use.	At least 3 partner countries have adopted the MIMS and allocated resources for its development, population and use.	Activity only completed by 31 July 2020.
	2. Concrete examples of change (applied or formally adopted), influenced by ReCAP research that will be applied to #km of road in focus countries.	Annual progress reports of the Ministry or Road Agency's responsible for materials information management.	None	None	More than 20 registered users of the MIMS in at least 1 partner country.	More than 50 registered users of the MIMS in at least 1 partner country.	More than 100 registered users of the MIMS (in at least 3 partner countries).	Activity only completed by 31 July 2020.
	3. Number of citations in academic articles of ReCAP peer reviewed articles and/or working papers, conference papers etc.	Scientific journals and conference proceedings.	None	None	At least 1 citation of about the development, population and use of the MIMS.	At least 2 citations of about the development, population and use of the MIMS.	At least 3 citations of about the development, population and use of the MIMS.	Activity only completed by 31 July 2020.
OUTPUT 1: RESEARCH and UPTAKE: Generation, validation and updating of evidence for effective policies and practices to achieve safe, all-season, climate-resilient, equitable and affordable LVRR and transport services in African and Asian countries.	1.1 LVRR: Number of peer reviewed papers generated from ReCAP supported or related LVRR research projects made available in open access format.	Scientific journals and conference proceedings.	None	None	At least 1 peer-reviewed paper related to MIMS published.	At least 2 peer-reviewed papers related to MIMS published.	At least 3 peer reviewed papers related to MIMS published.	Activity only completed by 31 July 2020.
	1.3 Engineering Research: National policies, manuals, guidelines and/or research outputs that have been fully incorporated into Government/Ministerial requirements, specifications and recommended good practice as a result of ReCAP engineering research (including climate change adaptation and AfCAP and SEACAP adaptations).	Website portal and progress report of the Ministry or Road Agency's responsible for materials information management. Tender documents and materials reports of road	None	None	The MIMS is accessible through a web-based portal hosted by the lead institution. Information about the MIMS forms part of standard bidding and contract documents in at least 1 partner country.	The MIMS is accessible through a web-based portal hosted by the lead institution. Information about the MIMS forms part of standard bidding and contract documents in at least 1 partner country.	The MIMS is accessible through a web-based portal hosted by the lead institution in at least 3 partner countries. Information about the MIMS forms part of standard bidding and contract documents in at least 3 partner countries.	Activity only completed by 31 July 2020.

Intervention Logic	Indicator	Source of Verification	Baseline 1 April 2017	Milestone 1 31 July 2017	Milestone 2 31 July 2018	Milestone 3 31 July 2019	End of Project Target (Cumulative by 31 July 2020)	Assumptions
		maintenance and construction works.						
	1.6. LVRR and TS information generated for dissemination, and disseminated, that is not peer reviewed. Total to include research papers, final research reports, workshop reports, manuals and guidelines.	Scientific journals and conference proceedings.	None	None	At least 1 non-peer reviewed paper related to MIMS prepared for national or regional conference.	At least 1 non-peer reviewed paper related to MIMS prepared for national or regional conference.	At least 3 non-peer reviewed papers related to MIMS prepared for national or regional conference.	Activity only completed by 31 July 2020.
OUTPUT 2: CAPACITY BUILDING: The building of sustainable capacity to carry out research on low volume rural roads, and rural transport services in African and Asian countries.	2.1. African / Asian experts or institutions taking lead roles in ReCAP Research Projects.	Project progress reports.	None	None	At least 1 national expert takes the lead in the development, population and use of the MIMS in at least 1 partner country.	At least 1 national expert takes the lead in the development, population and use of the MIMS in at least 1 partner country.	At least 3 national experts takes the lead in the development, population and use of the MIMS in at least 3 partner countries.	Activity only completed by 31 July 2020.
	2.3. Research projects with female researcher inputs at senior technical level.	Project progress reports.	None	None	At least 1 national female materials engineer/technician/ researcher is involved in the development, population and use of MIMS.	At least 1 national female materials engineer/technician/ researcher is involved in the development, population and use of MIMS.	At least 3 national female materials engineers/technicians/ researchers are involved in the development, population and use of MIMS.	Activity only completed by 31 July 2020.
OUTPUT 3: KNOWLEDGE: Generated evidence base of LVRR and transport services knowledge is widely disseminated and easily accessible by policy makers and practitioners (incl. education and training institutions).	3.2. ReCAP generated knowledge presented and discussed at high level international development debates and conferences	Project progress reports. Scientific journals and conference proceedings.	None	None	At least 1 presentation about the MIMS on a high-level international conference.	At least 1 presentation about the MIMS on a high-level international conference.	At least 2 presentations about the MIMS on a high-level international conference.	Activity only completed by 31 July 2020.
	3.3.ReCAP generated knowledge disseminated through significant workshops and dedicated training, virtually or physically, that are rated by participants as effective.	Project progress reports.	None	At least 1 workshop attended by a total 30 participants.	At least 3 workshops attended by a total of 90 participants and 1 training course attended by a total of 30 participants.	At least 3 workshops attended by a total of 90 participants and 3 training courses attended by a total of 90 participants.	At least 5 workshops attended by a total of 150 participants and 3 training courses attended by a total of 90 participants.	Activity only completed by 31 July 2020.

Annex J: Indicative Project Work Plan



Annex K: Indicative Inputs for Phase 2

		Task	Expected Outputs	Duration (mths)	International Consultant					Local IT Service Provider		Client Staff (Person Days)	Basis of estimate
					International IT (Person Days)	Basis of estimate	International Civil (Person Days)	Basis of estimate	Total Interntaional (Person Days)	Local Contractor (FTE)	Local Contractor (Person mths)		
2.0	**Inception Stage**												
	2.1	Consultation, Update Workplan, Inception Workshop	Detailed Plans for 1st Year subprojects agreed with client;	0,25	5	On-site full time	0		5			24	6 client staff eng + IT, 4d
	2.2	Prepare TOR for local IT Service Provider	TOR for the local IT Service Provider	0,25	5	On-site full time	0		5			4	4 client staff eng + IT, 1d
	2.3	Recruitment and Mobilization of the local IT Service Provider	Tendering, evaluation, contracting	2,5	5	Joint evaluation with client (off-site)	0		5			12	6 client staff eng + IT, 2d
		Subtotal		**3,00**	**15**		**0**		**15**	**-**	**-**	**40**	
3.0	**Module 1: Materials Testing Module**												
	3.1	Development of materials testing data entry and processing interface	User Interface to support materials testing process, including data entry screens for Lab Technicians. Provision for review on-screen and approval, including hard copy output, as well as basic automated work flow on the system. Summarisation and storage of test data at appropriate level (in addition to detailed lab data), possibly with manual intervention.	3	26	10d requirements and design, First sprint, guide Local prov & client first mth (on-site), plus 8dx2 subseq mths	4	For review of requirements and further review of developed user interfaces	30	3,0	9,0	45	6 engineering, 3 IT staff, approx 5 days overall
	3.2	Training of CML staff and implementation with close technical support	Training Central Materials Lab staff and implementation there, with close technical support.	1	6	1 day per week plus 2 overall (on-site for initial training & review of software)	2	Review of training	8	2,0	2,0	10	Possibly 5 staff over 2 days
	3.3	Roll out to 5 pilot regions at the sub-national level	Core group of materials staff trained, including sub-national, and IT staff from road agencies to roll out implementation to sub-national locations. Technical support to five locations, especially those requiring local database due to Internet limitations.	3	16	Review of plans, idenified people and impln outputs -2 days per week for 2 locations, then 1 day/wk (remote)	2	Review of implementation	18	2,0	3,0	27	6 engineering, 3 IT staff, 3 days
	3.5	*Roll out to other locations (Client responsibility)*	*Progressive roll out to the sub-national locations, using enhanced teams from each of those departments. Note: this assumes significant support from client agencies.*	6									
		Subtotal			**48**		**8**		**56**	**7,00**	**14,00**	**82,00**	
4.0	**Module 2: Materials Information and Mapping Module**												
	4.1	Query and reporting facility for materials data	Presentation of summary and detailed test data on screen and on a limited set of hard copy formats, queried by location, road link, material type, test date, sample owner and/or a similar prioritised set of criteria.	2	18	10 days requirements and design (on-site, end of this & start of next task), 2 days per week 2nd mth	5	For review of requirements and further review of developed user interfaces	23	3,0	6,0	27	6 engineering, 3 IT staff, approx 3 days overall
	4.2	Link with GIS	Provision to link material source locations as a layer in ArcGIS, with further provision to provide summary information as above, on mouse-over in GIS Screen. To be accomplished via suitable linkage of database tables or view. Offered to agencies that have GIS in place	1	8	5 days design and tech guidance (on-site), 1 day per week thereafter	2	For review of requirements and further review of developed user interfaces	10	2,0	2,0	12	3 IT/GIS staff, 1 day per week
	4.3	National training workshop in the use of Module 2	Training representatives from national & sub-national level in the use of Module 2.	0,25	2	Review of training content & process	1	Review of training content	3	1,0	0,3	40	20 staff in total, 2d training
		Subtotal		**3**	**28**		**8**		**33**	**6**	**8**	**79**	
5.0	**Module 3: Contractor and Consultant Reporting Module**												
	5.1	Implementation of uniform templates and procedures	Templates for materials data in contractor / consultant outputs implemented through contract provisions. Materials Source code and Materials Classification code implemented on all new tests and contracts;	1	6	1 day per week plus 2d (Remote)	4	Review of templates and follow up	10	-	-	90	Contract Managers, engineers, materials managers from all regions for training and implementation - 40 x 2d, preparation of templates - 5 x 2d
	5.2	Data input from contractor reports and feasibility studies	User screens to input materials data from templates; provision to store materials test data at appropriate summary level in materials database, to match lab data summaries. Provision for authorised users to query and produce output regarding materials data by contract, road link, project area and/or other limited criteria.	3	26	10d requirements (on-site) and design, first mth, plus 2d per week, subseq mths	5	For review of requirements and further review of developed user interfaces	31	3,0	9,0		
	5.3	Roll out to 5 pilot regions at the sub-national level	Implementation, training and technical support for 5 locations; Training of core implementation team in preparation for roll out to the sub-national level.	3	14	2 days per week , first 2, then 1 day per week	1	Review of implementation	15	2,0	3,0	27	6 engineering, 3 IT staff, 3 days
	5.5	*Roll out to other locations (Client responsibility)*	*Progressive roll out to the sub-national locations, using enhanced teams from each of those departments. Note: this assumes significant support from client agencies.*	3									
		Subtotal		**6**	**46**	**38%**	**10**	**8%**	**56**	**5**	**12**	**117**	
6.0	**Review to draw lessons learned for uptake of Module 1, 2 and 3**												
	6.1	International workshop to review the implementation and development of Module 1, 2 and 3 to draw lessons learned for Phase 3 (roll out)	Representatives from HQ and the sub-national levelregions, including contractors and consultants; Representatives from other countries (Est 50 persons)	0,25	5	5d for workshop preparation and facilitation	5	5d requirements for workshop preparation and facilitation	10	4,0	0,3	20	6 engineering, 3 IT staff, 2d to guide design and test.
		Subtotal		**9**	**51**	**28%**	**15**	**8%**	**66**	**9**	**12**	**137**	
7.0	**Module 4: Smart Phone App Module**												
	7.1	Development of smart phone App	Provide a facility that would allow an external program, using a URL or a simple API, to view a selected set of information related to a specific Materials Source code and Materials Classification code on screen (as a pop-up) and to generate a report of that summary or more detailed information regarding that material and its source. Technical support to assist programmers of Asset Management system use this capability, including documentation	3	15	7d requirements and design, first mth, plus 1d per week subseq mths	4	For review of requirements and further review of developed user interfaces	19	2,0	6,0	20	6 engineering, 3 IT staff, 2d to guide design and test.
	7.2	Deployment	Training of selected users and other trainers; guided deployment among a selected set of users.	1	5	1 d per week plus 1d	2	Review of training and implementation	7	1,0	1,0	45	6 engineering, 3 IT staff, 5 days
		Subtotal		**4**	**20**	**25%**	**6**	**8%**	**26**	**3**	**7**	**65**	
8.0	**Module 5: Linkage with Asset Management Module**												
	8.1	Software link between Materials Database to available Asset Management Systems	Provide a facility that would allow an external program, using a URL or a simple API, to view a selected set of information related to a specific UMID on screen (as a pop-up) and to generate a report of that summary or more detailed information regarding that material and its source; Technical support to assist programmers of Asset Management system use this capability, including documentation	1	5	2d design and 3d oversight (remote)	2	For review of requirements and further review of developed user interfaces	7	2,0	2,0		
	8.2	Training of users – HQ and selected Asset Management Staff from other locations (National workshop)	Training of IT staff and users of Asset Management Systems on use of linkage features (Local facilitation)	0,25	5	5 days per week	1	Review of training	6	1	0,5	40	20 staff in total, 2d training
		Subtotal		**0**	**5**	**100%**	**2**	**40%**	**7**	**2**	**2**	**86**	
9.0	**Module 6: GIS Assisted Prospecting Module**												
	9.1	Support for GIS assisted materials prospecting	GIS layers of relevant information, in particular the countries' road network, soil, geological, climate and topographical maps to be provided, together with a GIS layer showing known material sources, that would facilitate prospecting.	1	5	2d design and 3d oversight	10	Technical guidance and establishing processes for GIS based prospecting	15	1,0	1,0	6	6 x IT/GIS staff, 1d
	9.2	National training workshop in the use of Module 6	Training of selected users on the techniques of GIS based prospecting. *NOTE: This will require the input of other experts unrelated to the local or international IT consultants.*	0,25	5	5 days per week	10	Training and oversight	15	-	-	40	20 staff in total, 2d training
		Subtotal		**1**	**10**	**40%**	**20**	**80%**	**30**	**1**	**1**	**46**	
10.0	**Technical support and mentorship**												
	10.1	Provide back up support if and when required	Continued support to all implemented modules, mainly on a remote basis, starting from mth 3.	16						0,2	3,2		
		Subtotal		**16**						**0**	**3**		
		Total		**47,4**	**202,5**		**64,5**		**265,5**	**31,2**	**53,8**	**570,5**	

Annex L: Indicative Project Budget for Phase 2

Indictaive budget for Phase 2	Scenario 1			Scenario 2			Scenario 3			Reference Scenario (Maputo Workshop)		
	Months / Units	Rate (GBP)	Total (GBP)	Months / Units	Rate (GBP)	Total (GBP)	Months / Units	Rate (GBP)	Total (GBP)	Months / Units	Rate (GBP)	Total (GBP)
International Management Consultant												
Information Systems Specialist												
Roads Engineer	10	13.244	132.109	11	13.244	149.326	13	13.244	175.814	15	12.000	180.000,00
Procurement contracts and Admin												
Travel and other expenses	8	6.175	49.400	9	6.175	55.575	10	6.175	61.750			45.000,00
Subtotal			**181.509**			**204.901**			**237.564**			**225.000,00**
Local IT Service Provider												
Senior Engineer / Team leader												
Developer - database												
Developer web application	44	4.042	176.130	51	4.042	204.424	54	4.042	217.561	56	3.000	168.000,00
Developer Server Side												
Developer - Smart Phone												
Travel budget (10% of fees)			17.613			20.442			21.756			17.000,00
Subtotal			**193.743**			**224.867**			**239.317**			**185.000,00**
Training and Workshops												
Local workshops	2	5.000	**10.000**	3	5.000	**15.000**	4	5.000	**20.000**	8	5.000	**40.000,00**
International workshop	1	30.000	**30.000**	1	30.000	**30.000**	1	30.000	**30.000**			
Subtotal			**251.356**			**290.309**			**311.073**			**242.000,00**
Partner Country Contribution			**291.356**			**335.309**			**361.073**			
Local staff contribution - in kind	20	800	**15.860**	23	800	**18.460**	29	800	**22.820**	48	1.000	**48.000,00**
IT equipment and facilities			**14.000**			**14.000**			**14.000**			**40.000,00**
Local transport (equal to fees)			**15.860**			**18.460**			**22.820**			**12.000,00**
Subtotal			**45.720**			**50.920**			**59.640**			**100.000,00**
Total			**460.972**			**525.688**			**586.521**			**550.000,00**

Annex M: Evaluation Framework for Country Selection

1. Initial Sreening (using pass/fail criteria)		**Max. Points**	**Description**	**DRC**	**Ethiopia**	**Ghana**	**Kenya**	**Liberia**	**Malawi**	**Mozambique**	**Sierra Leone**	**South Sudan**	**Tanzania**	**Uganda**	**Zambia**
1. Initial Sreening (using pass/fail criteria)	1. A written request to AfCAP signed by the head of the proposed lead road sector institution.	Yes/No	A 'Yes' is required in order to be considered for Phase 2 and 3												
	2. Declaration of undertaking showing a commitment to meet the project's counterpart contribution and support open access to road materials information.	Yes/No	A 'Yes' is required in order to be considered for Phase 2 and 3.												
	3. Brief proposal outlining how the road materials database project would be implemented using the template provided.	Yes/No	A 'Yes' is required in order to be considered for Phase 2 and 3.												
2. Scoring matrix of the proposal against key selection criteria (minimum 50 points for project readiness for Phase 2 and 3, highest ranked country with > 50 points is selected for Phase 2)	4. Level of commitment demonstrated during Phase 1 of the project (the country returned the stakeholder survey).	5	Countries who completed and returned the stakeholder survey (5 points). Those who did not (0 points).												
	5. The experience of the lead institution with successful development/operation of similar information systems (based on max. 3 project reference sheets).	15	Each successful project implemented (5 points). Successful is defined as operational and in use by the institution.												
	6. The maturity of the existing regulatory framework for road materials testing (independent oversight, quality assurance procedures and the use of standard protocols).	10	Laboratories are inspected and equipment is calibrated at minimum required intervals by an independent authority (5 points).												
			Materials testing manual and protocols are in place and used (5 points).												
	7. The effectiveness of the proposed institutional cooperation framework (constitution of the project team and proposed mechanism for project coordination with road sector instititions, academic & research institutions and the private sector).	15	Institutional cooperation framework (5 points).												
			Expertise and experience of the road materials database project team (10 points).												
	8. The availability ICT facilities and current use of Information Systems within regular operations and/or a proposal on how any gaps will be addressed.	30	IT policy, strategy and data protection mechanism in place (5 points).												
			Hardware facilities in the lead institution (5 points).												
			Hardware facilities in sub-national offices (5 points).												
			Network facilities: LAN in Lead Institution (4 points).												
			Network facilities: LAN in sub-national offices (4 points).												
			Network facilities: Corporate network links to sub-national offices or adequate Internet at those locations (2 points).												
			Significant use of information systems in operations (5 points).												
	9. The availability of in-house staff with experience of managing the development, maintenance and operation of information system of comparable scope and complexity.	25	Staff with experience of managing external contractors or internal teams for development of Information Systems projects (8 points).												
			Staff with experience of developing functional requirements and specifications for Information Systems projects (8 points).												
			System administrator, Database administrator (5 points).												
			Progammer, developer and/or dedicated user technical support staff (4 points).												
	Total assessment score	**100**													