Establishment of a Road Research Centre in Mozambique

Review of existing road research and identification of research needs

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Launched in June 2008 and managed by Crown Agents, the five year-long, UK government (DFID) funded project, supports research and knowledge sharing between participating countries to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The programme is currently active in Ethiopia, Kenya, Ghana, Malawi, Mozambique, Tanzania, Zambia, South Africa, Democratic Republic of Congo and South Sudan and is developing relationships with a number of other countries and regional organisations across Africa.

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Report summary

The Mozambican Roads Administration (ANE) has embarked on a project to establish a Road Research Centre (RRC) in Mozambique aiming to provide the basis for improving the long-term capacity to undertake relevant, high quality research relating to the road sector of Mozambique. This project forms part of the Africa Community Access Programme (AFCAP), which is a research programme supported by the Department of International Development (DFID) of the Government of the United Kingdom and managed by Crown Agents Ltd on behalf of DFID. CSIR, in association with LNEC has been commissioned by Crown Agents to provide Technical Assistance for phase 2 A of the project, which aims to address institutional issues relating to the RRC, draft a strategic research plan and develop a 5-year business plan for the RRC. One of the actions included in the work program, the review of previous research studies, served as a starting point for the prioritization of proposed research areas for the RRC. A questionnaire was developed and distributed among RRC stakeholders, aimed at collecting opinions on future research needs. This report presents an overview of previous road research projects developed in Mozambique and addresses future research needs perceived by the main stakeholders of the future RRC.

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List of Abbreviations

AAR	:	Alkali-Aggregate Reaction
AFCAP	:	Africa Community Access Programme
ANE	:	Administração Nacional de Estradas
APT	:	Accelerated Pavement Testing
CSIR	:	Council for Scientific and Industrial Research
DCP	:	Dynamic Cone Penetrometer
DFID	:	Department of International Development

DIMAN	:	Direcção de Manutenção
DPANE	:	Delegações Provinciais da ANE
DIPRO	:	Direcção de Projectos
ESALs	:	Equivalent Single Axle Loads
GIS	:	Geographic Information System
LFWD	:	Light Falling Weight Deflectometer (LFWD) testing
LNEC	:	Laboratório Nacional de Engenharia Civil
LTPP	:	Long-Term Pavement Performance
PI	:	Plastic Index
RRC	:	Road Research Centre
RRIP	:	Regional Roads Investment Programme
SIDA	:	Swedish International Development Agency
SMEs	:	Small and Medium Enterprises

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Abstract/

The Mozambican Roads Administration (ANE) has embarked on a project to establish a Road Research Centre (RRC) in Mozambique aiming to provide the basis for improving the long-term capacity to undertake relevant, high quality research relating to the road sector of Mozambique. This project forms part of the Africa Community Access Programme (AFCAP), which is a research programme supported by the Department of International Development (DFID) of the Government of the United Kingdom and managed by Crown Agents Ltd on behalf of DFID.

CSIR, in association with LNEC has been commissioned by Crown Agents to provide Technical Assistance for phase 2 A of the project, which aims to address institutional issues relating to the RRC, draft a strategic research plan and develop a 5-year business plan for the RRC.

One of the actions included in the work program, the review of previous research studies, served as a starting point for the prioritization of proposed research areas for the RRC. A questionnaire was developed and distributed among RRC stakeholders, aimed at collecting opinions on future research needs.

This report presents an overview of previous road research projects developed in Mozambique and addresses future research needs perceived by the main stakeholders of the future RRC.

1. Introduction

The Mozambican Roads Administration (ANE) has embarked on a project to establish a Road Research Centre (RRC) in Mozambique. This project forms part of the Africa Community Access Programme (AFCAP), which is a research programme supported by the Department of International Development (DFID) of the Government of the United Kingdom and managed by Crown Agents Ltd on behalf of DFID.

The overall objective of the project is to provide the basis for improving the long-term capacity in Mozambique to undertake relevant, high quality research relating to the road sector of Mozambique. CSIR in association with LNEC has been commissioned by Crown Agents to provide Technical Assistance for the Establishment of the RRC.

Phase 1 of this project, namely the *Development of Road Research Strategy* has been successfully completed. The objective of Phase 2 is to proceed with the establishment of the Road Research Centre.

Phase 2 consists of the following two sub-Phases:

i. Phase 2A: To address institutional issues relating to the RRC, draft a strategic research plan and develop a 5-year business plan for the RRC;

ii. Phase 2B: To establish the RRC, including its *capacitation* in terms of human resources, research infrastructure as well as the required supporting systems, and its *operationalization* in terms of human resource development and the activation of research projects, in line with the RRC business plan developed in Phase 2A.

In a previous report "Inception Report for Phase 2A", submitted on 30 November 2013, the general objectives of Phase 2 were outlined, as well as the specific objectives of Phase 2A.

According to the Implementation Plan for Phase 2A, one of the planned activities consists on the collation and technical review of previous and ongoing road/transport research in Mozambique, followed by a preliminary identification of research needs based on the analysis on the research needs questionnaire which has been previously distributed to relevant stakeholders, who have conveyed their responses.

In this report, the above issues are addressed, in its two main chapters: "Review of previous research reports" (Chapter2) and "Identification of research needs" (Chapter 3). Conclusions and recommendations on these subject areas are presented in Chapter 4. Moreover, annexed is a list of references to relevant reports on previous road research carried out in Mozambique.

2. Review of previous research reports

Research into pavement materials and structural design has been carried out in Mozambique for more than 50 years, initially through the LNEC in Lisbon, where considerable work in Mozambique and Angola led to internationally recognised findings and researchers. This research was well documented in conferences over the years (particularly the African Regional Soil Mechanics Conferences) and today forms the basis of specifications used in Brazil for laterites.

After 1975, research ceased in Mozambique and in the early 1990s various post-graduate students from Mozambique carried out research for their theses. This work was not widely published, but various offerings have been presented at local conferences. This work culminated in the use of the MMLS to test various sand/cement pavements in Mozambique, but it is not known where this information is now housed.

This chapter presents a brief review of previous road research reports in Mozambique, focusing on a number of projects mostly performed recently under the financial support of AFCAP. The major reports that were reviewed were made available by ANE and extracted from the AFCAP website and are listed in Appendix 1.

A brief overview of other research reports is also presented, and the main outcomes of the review are summarised in the last section.

2.1 AFCAP project reports

2.1.1 Targeted Interventions on Low Volume Roads in Mozambique

The Mozambican National Roads Administration (ANE) embarked on a Regional Roads Investment Programme (RRIP), supported by the Swedish International Development Agency (SIDA), which provided the funding for construction works, and by the UK's Department for International Development (DFID) through AFCAP, which provided funding for technical assistance for research, application of innovative solutions, development of guidelines, communication, and mainstreaming, mainly related to Low Volume Roads, conducted by TRL

The project "Targeted Interventions on Low Volume Roads in Mozambique" (part of the Rural Road Investment programme (RRIP)) addressed the design and construction of solutions for improvement of low volume roads using locally available materials and techniques. It was developed in 4 phases, involving design and construction works for investigating diverse problems of passability issues associated with LVRs, such as road surfaces, bridges, culverts, floods, etc.

The project included the construction of test sections addressing the use of materials not complying with the current specifications and low cost/appropriate surfacings; subsequently, the performance of these sections was monitored.

One of the main issues raised during the construction of the test sections was the lack of project documentation, approval processes and quality checks. The progress of construction on many projects was very slow, which was attributed to the remoteness of the sites.

Based on data collected and observations made on the constructed sections, some preliminary conclusions were drawn and practical recommendations were made concerning Otta seals, sand asphalt surfacing, marginal base materials such as calcrete/sand mixtures, quartzitic natural gravels, cement stabilised sand bases, and emulsion stabilised sand bases.

Further research was recommend on topics such as using different aggregate sizes and different materials for the base course, Emulsion Treated Bases (ETB), hot sand asphalt, etc.

The need for assessment of contractors' capabilities through prequalification and for support of small scale contractors to acquire surfacing equipment and quality control kits in order to be able to control the quality of work they will be producing.

The techniques that were specified in the designs are implementable and should therefore be disseminated to the practitioners so that subsequent projects can benefit. It is important to develop method statements related to this work for the benefit of all practitioners concerned. More work, however, is needed to further develop these technologies.

The reports refer to the preparation of "Guideline on Specifications and Work Norms for Low Volume Roads in Mozambique" and a future manual, the new version of the "Normas de Execução", but these documents were not available to the team.

2.1.1.1 Summary

A number of documents relating to this part of the RRIP project were provided by ANE. These included various inception, progress, monitoring and final reports. Of the 25 documents provided for this project, there were a significant number of duplicates, with various final reports (which themselves duplicated their contents). At least one of the reports was a draft that included "un-accepted" track changes. The reports themselves include useful test results, data and monitoring information which must be utilised to its full extent as discussed below.

It is very difficult to make head or tail of the progress and content of this project, primarily as a result of various phases being undertaken. It would probably be easier if a consecutive numbering system for the important final reports be used with second level numbers for progress and interim reports being implemented. It would also be useful if the final reports contained a complete summary of all previous pertinent information and are self-standing or have clear references to earlier reports. Many of these do not actually have report numbers that are

useful to someone going through the documents. It is suggested that AFCAP documents be numbered by the producer as well as by AFCAP (eg, AFCAP/MOZ/002 for the final report of project 2 and AFCAP/MOZ/002.1 for the first interim report) in order to minimise the need to peruse unnecessary and repetitive documentation and that they be controlled by AFCAP so that only final reviewed and accepted documents are lodged with the "client" and on the AFCAP website.

However, the valuable information and test results in the interim and progress reports must be accessible. A significant deficiency noted in the reports was the lack of any reference to test methods used and sample preparation/pre-treatment, factors that can influence the comparison of such test results and derived specifications significantly.

In essence, the contents of many of the reports reviewed are considered to not really be in a format that makes them easy to implement.

2.1.2 Back Analysis project

The objective of this project was to complement the Road Rural Investment Programme (RRIP) (part of Phase 4) through a retrospective evaluation of performance of LVRs built 10 years ago or earlier, since the "age parameter" was missing from the RRIP. It included a review of the standards used for design and construction, assessment of road condition and laboratory tests.

The selected sections included some fairly recent projects as well as some old (> 30 years) pavements that had been rehabilitated. In total, 8 roads were analysed, one of them comprising 4 different pavement sections (experimental road). The selected pavement sections represent several combinations of surface and base materials, as indicated in the table below.

Table 1 –Materials represented in the selected pavement sections of the back analysis project

Surface	Base
Double surface dressing Otta seal Ottal seal using lateritic aggregate Sand seal Unsealed (one section)	Crushed aggregate Natural gravel (Laterite) Cement treated base Emulsion treated base

Some of the main conclusions from this analysis are listed below:

- Some of the sections showed a good long term performance, even with relatively high traffic volumes, considering that they are LVRs;
- The fact that some of the structures are built over existing older roads provides an improved strength of the road foundation through previous traffic compaction;
- Specifications for Low Volume Roads can be relaxed, in order to allow for the wider use of locally available materials.

The project also demonstrated the need to develop and implement a quality assurance system to ensure that materials (including bitumen) are as specified and construction is performed according to best practice as well as the need to control overload operations through enforcement.

Two similar reports were provided by ANE (with different numbers (RPN 2585 and CPR 1612)) and a copy of the Inception Report (CPR 1410) is on the AFCAP website. It is suggested that one of the final reports replaces the inception report on the AFCAP website.

2.1.3 Calcrete Mapping, Classification System and Road Use Specifications

Following the research and investigations carried out in the Southern African region in the past forty years, new, more appropriate, performance-related specifications have been developed. These specifications permit the use of calcrete in all layers of a road pavement, as fill, as a wearing course and as surfacing aggregate. The degree of cementation is the main factor which determines the suitability of calcrete for specific use in road construction.

This Project aimed at the following objectives:

- To provide guidance to ANE and the Inhambane provincial authorities on the location of calcrete deposits in the province;
- To develop a classification system for calcretes as road building materials;
- To prepare technical specifications for the use of calcrete in road construction.

The project concentrated on using remote sensing techniques to locate calcrete and came up with a number of recommendations in this regard. This together with botanical indicators and the use of a calcrete probe achieved reasonable success in locating calcrete deposits. However, the project failed to recommend specifications for the use of calcretes in Mozambique, bearing in mind the significant climatic differences between Mozambique and Botswana and Namibia where calcretes are used extensively with relaxed specifications.

Recent experience on projects implemented by ANE in Inhambane has shown that calcrete can be used both as base material when blended with local sand and in graded aggregate seals with a soft bituminous binder. The admixture of sand to calcrete improves the material properties by reducing plasticity and improving stability and improving workability to achieve the required density. Nodular calcrete has also been blended with red sands to provide an effective, armoured wearing course.

It can be expected that there will be more effective and efficient utilisation of calcrete in road construction in Inhambane Province after the various deposits are evaluated and their engineering properties determined. This will be facilitated by the development of a GIS database for calcretes which is one of the key outputs of the project. One area of investigation not discussed is the form of the calcrete deposits - the project team has noted that the calcrete often occurs as large boulders scattered in the red sands making its winning and processing expensive and difficult.

2.1.4 Other AFCAP projects

There are other AFCAP projects not directly related to road engineering, such as:

“Using road works to enhance community water supplies in Mozambique” – The objectives were to identify and design pilot projects whereby road works can be used to enhance community water supplies on a larger scale in Mozambique.

“Follow Up Assessment of The Feeder Roads Project, Zambézia Province”. It was designed to assess the outcomes and consequences of the Feeder Roads Project on communities and people living in the vicinity of rehabilitated roads, ten years after the Project’s final socio-economic impact study. In this case some socio-economic studies and market research were performed.

2.1.5 General comments

The majority of the reports reviewed contained no references. These are essential in such research reports where different test methods and monitoring and analysis techniques are used and comparisons with other work are

made. The use of modified specifications is very difficult if the test methods used in their development are not fully complied with.

The actual content of the reports and the test and research methodologies reported comply with conventional research methods and the actual research principles are considered to follow international norms.

It should be pointed out that the current and previous research projects funded by AFCAP are in line with a number of the projects rated as high priority in the questionnaire that is discussed in Section 3 of this report. Aspects such as the use of local materials for structural and surfacing layers, the development of a materials data base and issues relating to material location and usage have all been addressed to some extent by the past and existing projects. Other aspects such as traffic characterisation and material improvement have been included in these projects to varying extents, mostly as secondary investigations but providing useful information that needs to be built on.

2.2 Other non-AFCAP research reports

2.2.1 Training contractors for targeted Interventions on Low Volume Roads in Mozambique

This report relates to the "targeted interventions" (spot improvements) mentioned in 2.1.1. The pilot projects were managed by ANE Directorate of Maintenance (DIMAN) in Maputo and administered by provincial delegations of ANE (DPANE) together with provincial consultants in the various provinces. A contractor training programme was initially financed by AFCAP and later financed by the Swedish International Development Agency (SIDA) and executed by Scott Wilson.

2.2.2 Developments towards a mechanistic design method in Mozambique

This report presents a research study for the development of guidelines for a mechanistic-empirical design method for cement-stabilized bases in Mozambique, with the aids of Accelerated Pavement Testing (APT). Following a small scale laboratory testing exercise, 6 full-scale pavement sections were comprehensively trafficked and tested using a full-scale machine in Mozambique.

One of the outcomes of this project was the analysis of failure mechanisms on cement treated pavements. Another outcome described in the report is the development of software for mechanistic-empirical analysis: "ANE-PD".

2.2.3 Other documents

It is known by the project team of various trials and experiments carried out some years ago through South African consultants and post-graduate students. Attempts will be made to obtain information regarding these projects and any research reports or published papers.

ANE's website presents summaries of other research studies, concerning hot sand asphalt, the use of clay bricks, cobble stones and concrete for surfacing or stone matrix asphalt and various presentations and newsletters. No other project reports were available to the team. It is important that the original research reports on which some of the papers are based (only brief summaries of the important material test data and monitoring records are included in the papers) be located and added to the knowledge base or report repository.

3. Identification of research needs

3.1 Questionnaire on identification of research needs

A questionnaire was prepared to identify potential research needs for Mozambique (see Appendix 2). This questionnaire was used as an input for the project prioritisation process, which ultimately will result in the development of a Strategic Research Plan which will be integrated into the Business Plan of the RRC.

The research needs were sourced from ANE/DIPRO, ANE/DIMAN, the Final Report of Phase 1 and the AFCAP website, complemented by potential research needs identified by the AFCAP Project Team based on prior experience.

The potential research needs listed in the questionnaire have been grouped under the following six headings:

- A: Infrastructure engineering;
- B: Infrastructure delivery;
- C: Environmental impact of roads and the preservation of natural resources;
- D: Planning and operations;
- E: Policy, economics and decision support, and
- F: Resources which support the above.

A total of 146 potential research topics were listed under the above headings in the questionnaire, but space was provided to include additional research topics.

The respondents were asked to rate the importance of each topic, as follows:

- 'A' for topics that are considered to be of High Priority: topics that are of critical importance and that should be undertaken as soon as possible
- 'B' for topics that are considered to be of Medium Priority: topics that are still important but it is not essential that they be undertaken immediately
- 'C' for topics that are considered to be of Low Priority: they are of less immediate importance and could be placed 'on hold' for now
- Blank (i.e. do not rate) if there is no interest in the topic.

The questionnaire was distributed among different groups of stakeholders representing the Administration (ANE), as well as private entities, such as consultants, contractors and professional associations. In total, 21 replies were collected. (see Appendix B). The respondents are identified in the table below.

Table 2 - Respondents to the questionnaire

Nome	Organização	Cargo na organização
Adérito Guilamba	ANE	Director de Projectos
Agapito Manuel da Cruz	DPANES	Chefe do Deptº Técnico
Agostinho Diogo Raiva	Autoridade Rodoviária (Administração Nacional de Estradas – Delegação Provincial de Sofala)	Técnico no Departamento de Planificação
Alberto Jetimane	ANE – Inhambane	Chefe do Departamento Técnico
Américo Dimande	LABORATÓRIO DE ENGENHARIA DE MOÇAMBIQUE	Investigador Auxiliar
Andre Tomas Vilanculo	ANE-Delegação Sofala	Tecnico
Carlos Quadros	TÉCNICA-Engenheiros Consultores, Lda	Director
Daniel Albino Machaie	ANE-Delegação de Tete	Delegado Provincial
DANIEL ANTÓNIO PATEL DOS SANTOS	DELEGAÇÃO DA ANE - ZAMBÉZIA	DELEGADO PROVINCIAL
FERNANDO M. D. DABO	ADMINISTRAÇÃO NACIONAL DE ESTRADAS – DELEGAÇÃO PROVINCIAL DE NIASSA	DELEGADO PROVINCIAL
Irene Langa Simoes	Administracao Nacional de Estradas	Delegada da ANE - Sofala
James Nyirongo	Scott Wilson Mozambique Limitada	Fiscal Sénior
Jeremias Mazoio	ANE – Delegação de Maputo	
Jorge Joaquim Mecuve Govanhica	Autoridade Rodoviária (Administração Nacional de Estradas - Delegação Provincial de Sofala)	Chefe de Departamento de Planificação
Luís Fernandes	ADMINISTRAÇÃO NACIONAL DE ESTRADAS	Chefe do Departamento da Manutenção
Mateus Seva Espirito Santo Pinastevo	ANE-Sofala	Tecnico
Nelson Arantes V. Martins	Ordem dos Engenheiros de Moçambique	Membro
Ramiro Joaquim Rudais	ANE	Tecnico
	CETA - Construção e Serviços, S.A.	Administrador

The table below lists the topics considered and presents the number of replies on each level of priority for each topic.

A. ROAD INFRASTRUCTURE ENGINEERING

A.1 Traffic & Operational Environment

A.1.1 Traffic Loading & Contact Stresses

		A	B	C	Blank
A.1.1.1	Improved understanding of the effects of traffic loading on pavement performance: * Characterisation of distribution of axle load grouping and/or vehicle classes on the primary, secondary and tertiary road networks; * Updating of equivalent single axle loads (ESALs) per heavy vehicle factors for Mozambique	19	2		
A.1.1.2	Development of guidelines for the collection of traffic data	9	8	3	1
A.1.1.3	Guidelines for estimating attracted and generated traffic resulting from new road construction and road upgrades	11	7		3
A.1.1.4	Other (specify): *1)Estudo do comportamento dos utentes e sua sensibilidade sobre a necessidade e importância do controle das cargas transportadas nas estradas; 2)Avaliação dos desequilíbrios resultantes da ocupação desregrada do território que induz á um comportamento diferenciado do tráfego e por conseguinte diferentes ações do tráfego*		2		

A.1.2 Impact of Climate

		A	B	C	Blank
A.1.2.1	Quantification of the influence of temperature and moisture variation on pavement performance, and development of design methodologies to mitigate their impact	12	4	4	1
A.1.2.2	Impact of climate change (e.g. increased intensity of storms, effects of sea level rise on coastal roads) on the integrity and safety of road infrastructure and the development of adaptation strategies	11	5	4	1
A.1.2.3	Other (specify):				

A.2 Geometric Design

		A	B	C	Blank
A.2.1	Geometric design guidelines for rural and urban roads, reflecting best international practice, adopted for the Mozambican environment	9	9	2	1
A.2.2	Geometric design guidelines for unsurfaced roads and upgraded unsurfaced roads to sealed standards so as not to compromise driver safety	5	15	1	
A.2.3	Relationship between design speed, operating speed and road alignment for surfaced and unsurfaced roads	8	11	1	3
A.2.4	Other (specify):				

A.3 Bound & Unbound Pavement Materials

A.3.1 Mix Components & Characterisation thereof

		A	B	C	Blank
A.3.1.1	Test methods and criteria for the assessment of aggregate durability	14	7		
A.3.1.2	Identification of suitable and cost-effective binders and soil stabilizers, for use as cement and/or bitumen replacements	18	2	1	
A.3.1.3	Other (specify):				

A.3.2 Thin Bituminous Surfacings

		A	B	C	Blank
A.3.2.1	Capturing of long-term performance data on roads with thin bituminous surfacings	11	7		3
A.3.2.2	Appropriate standards for surfacings on low-volume roads taking cognisance of operating conditions, base types and drainage design	16	4		1
A.3.2.3	Performance of thin bituminous surfacings using marginal aggregates	11	8		2
A.3.2.4	Study into the causes and mechanisms of premature failure of thin wearing courses	11	8	1	1
A.3.2.5	Other (specify):				

A.3.3 Hot, Warm and Cold-Mix Asphalt

		A	B	C	Blank
A.3.3.1	Development of hot, warm and/or cold-mix asphalt design guidelines (including binder specifications) for Mozambique	19		1	1
A.3.3.2	Development of specifications and quality control/assurance standards for hot, warm and/or cold-mix asphalt	17	2	1	1
A.3.3.3	Other (specify): AVALIAÇÃO DO USO DE MISTURAS BETUMINOSAS DE AREIA (HOT SAND ASPHALT) COMO REVESTIMENTO – existe uma experiência efectuada no tempo colonial e algumas secções efectuadas agora em 2009 (N1, Pambara/Rio Save e N10, Quelimane/Namacurra).	1			

A.3.4 Cement Concrete

		A	B	C	Blank
A.3.4.1	Performance-based concrete mix design system integrated with structural design and field quality control for pavements and/or structures	7	11	1	2
A.3.4.2	Study into the use of: * low-cost reinforcement, * self-compacting concrete, * self-curing concrete, * one-pass paving, * (ultra) high-strength concrete (and others) to make concrete pavements and/or structures more economical to construct, to speed up the construction process to reducing traffic delays, and to provide safeguards to ensure that the pavement and/or structure will meet the design objectives without resulting in premature distress	8	8	3	2
A.3.4.3	Other (specify):				

A.3.5 Recycled Materials

		A	B	C	Blank
A.3.5.1	Development of codes of practice for cold in-place recycling with bitumen-emulsion, foamed-bitumen and/or cement	10	8	2	1
A.3.5.2	Development of standard specifications for cold in-place recycling with bitumen-emulsion, foamed-bitumen and/or cement	12	5	3	1
A.3.5.3	Other (specify):				

A.3.6 Lime & Cement Stabilised Materials		A	B	C	Blank
A.3.6.1	Development of best-practice guidelines on the beneficiation of sandy materials through the addition of cement stabilisers, and identification/specification of most appropriate cement types to suite local conditions	15	3	2	1
A.3.6.2	Evaluation of the effects of high quality cements on the behaviour and long-term performance of cement-treated/stabilized materials	13	4	3	1
A.3.6.3	Production of guidelines for the selection of the most appropriate modifier to treat high Plasticity Index (PI) materials	14	5	2	
A.3.6.4	Assess the effects of pre-cracking cement stabilised layers on pavement performance and life-expectancy	12	4	3	2
A.3.6.5	Other (specify):				

A.3.7 Unbound Materials		A	B	C	Blank
A.3.7.1	Recommendations on modification/treatment options for marginal aggregate in order to render them suitable for road construction	16	3		2
A.3.7.2	Assessment of the ability of the Dynamic Cone Penetrometer (DCP) method, and its correlation to triaxial testing, to predict shear responses in unbound granular layers	11	8	1	1
A.3.7.3	Guidelines for characterisation of lateritic soils for use in road construction, taking into account the effect of water and drying processes on their behavior	13	5	1	2
A.3.7.4	Behavioural analysis of mixtures of soil and coal ash	6	9	6	
A.3.7.5	Development of procedures for assessing the permeability of sandy soils	4	8	6	3
A.3.7.6	Other (specify): *Uso de misturas de 2 ou 3 solos em camadas de pavimento com estabilização mecânica*	1			

A.3.8 Gravel Wearing Courses (Unsurfaced Roads)		A	B	C	Blank
A.3.8.1	Improved deterioration models for gravel roads	10	5	3	3
A.3.8.2	Review of specifications for gravel wearing courses	11	6	3	1
A.3.8.3	Development of design models for the use of granular materials of varying quality in pavements	13	5	1	2
A.3.8.4	Development of appropriate tests and criteria for assessing the durability of bituminous and pozzolanic treatments	9	6	4	2
A.3.8.5	Development of appropriate tests and criteria for the certification of soil stabilizers used on gravel roads in terms of their fitness-for-purpose	7	8	3	3
A.3.8.6	Mix design procedures for chemical, pozzolanic and bituminous treatments	6	4	8	3
A.3.8.7	Cost-effective ways of upgrading gravel roads to low-volume surfaced roads	12	3	3	3
A.3.8.8	Framework for the implementation of a Gravel Road Improvement Programme	9	6	2	4
A.3.8.9	Other (specify):				

A.3.9 Alternative Materials		A	B	C	Blank
A.3.9.1	Identification of potential sources of alternative materials for use in roads	14	5	1	1
A.3.9.2	Production of guidelines on, and appropriate specifications for, the use of alternative materials in road construction	12	5	1	3
A.3.9.3	Other (specify):				

A.3.10 Optimising the Use of Local Materials in Road Construction		A	B	C	Blank
A.3.10.1	Development of a road material database	17	3	1	
A.3.10.2	Guidelines on the identification of aggregate sources and the assessment of their quality for use in road construction	12	8		1
A.3.10.3	Optimisation in the use of locally-available materials (e.g. high PI materials and sands) by means of modification and/or stabilisation techniques	15	6		
A.3.10.4	Other (specify):				

A.4 Structural Design of Road Pavements

A.4.1 Structural Design & Performance		A	B	C	Blank
A.4.1.1	Establishment of criteria for assessment of pavement layers (earthworks, capping layer, subbase and base) from layer moduli determined through Light Falling Weight Deflectometer (LFWD) testing	9	8		4
A.4.1.2	Development of a pavement performance database based on periodic road condition assessments as well as long-term pavement performance studies	7	9	4	1
A.4.1.3	Development of Mozambican road pavement design and analysis methods for all categories of roads (primary to tertiary; urban and rural; paved and unpaved)	13	4	1	3
A.4.1.4	Explore innovative concepts for incorporation of initial and life-cycle features in pavement design taking cognisance of constructability, durability and maintainability	5	12	2	2
A.4.1.5	Other (specify):				

A.4.2 Innovation in Road Design & Structural Design of Pavements		A	B	C	Blank
A.4.2.1	Explore feasibility and viability of implementing long-life pavement ("perpetual" pavement) concepts in Mozambique: * Concept development and economic viability of long-life pavements; * Construction and material requirements for long-life pavements; * Guidelines for design, construction and maintenance of long-life pavements	9	6	6	
A.4.2.2	Implementation of long-term pavement performance (LTPP) studies to monitor long-term performance of road designs in order to provide data to feed into the improvement of design and construction concepts	5	12	3	1

A.4.2.3	Other (specify): *Design, controlo de construção e monitoria de troços experimentais*	1			

A.5 Road Furniture, Structures and Drainage

A.5.1 Road Furniture

		A	B	C	Blank
A.5.1.1	Performance-based specifications and acceptance criteria for road markings	3	9	6	3
A.5.1.2	Road signage asset management	7	3	6	5
A.5.1.3	Guidelines for selection and installation of roadside safety equipment	5	6	7	3
A.5.1.4	Other (specify):				

A.5.2 Structures

		A	B	C	Blank
A.5.2.1	Development of durability index test methods and specifications for concrete bridges and other structures	11	3	2	5
A.5.2.2	Characterization of time-dependent behaviour of concrete bridges	6	8	2	5
A.5.2.3	Structural assessment of existing bridges	16	4		1
A.5.2.4	Strengthening and retrofitting of bridges to upgrade their capacity	11	8		2
A.5.2.5	Service life predictions	9	8	3	1
A.5.2.6	Assessment of the penetration of chlorides and carbonates into the cover of concrete structures, and identification of preventative treatments/designs	4	11	4	2
A.5.2.7	Prevention, diagnosis and mitigation of alkali-aggregate reaction (AAR) in concrete bridges	3	12	4	2
A.5.2.8	Best practices on the use of fly-ash and slag in the marine environment	2	10	4	5
A.5.2.9	Identification of Abnormal Load/Super Load Strategic Routes	3	9	7	2
A.5.2.10	Other (specify): *Elaboração de um catálogo de obras de arte tipo: culverts, box-culverts, drifts, tabuleiros até 15 m de vão*	1			

A.5.3 Innovative Approaches for the Preservation of Assets & Rapid Renewal

		A	B	C	Blank
A.5.3.1	Design concepts using advanced composites, steel and hybrid materials in pavements and bridge structures	3	7	8	3
A.5.3.2	Modern materials and composites to improve the service life of pavements and bridges with reduced maintenance	6	10	3	2
A.5.3.3	Advanced coating materials and corrosion protection processes to increase the service life of road structures including steel and reinforced concrete structures	6	9	2	4
A.5.3.4	Concrete durability test methods and specifications	9	7	2	3
A.5.3.5	Modular bridge systems	6	6	5	4
A.5.3.6	Other (specify):				

A.5.4 Drainage

		A	B	C	Blank
A.5.4.1	Development/revision of the road drainage manual, including methodology and criteria for the design of various drainage structures	11	8		2
A.5.4.2	Implementation of inspection procedures on road drainage structures	15	2	3	1
A.5.4.3	Investigation of moisture conditions in pavements and drainage requirements to ensure stable moisture regimes within pavement structural layers and subgrades	7	10	3	1
A.5.4.4	Other (specify):				

A.6 Management of Assets

A.6.1 Asset Management

		A	B	C	Blank
A.6.1.1	Development and implementation of an integrated asset management system	8	6	3	4
A.6.1.2	Recommendations for setting up asset inventories and registries, and for conducting asset valuations	6	9	3	3
A.6.1.3	Guidelines for asset condition assessments of pavements, structures and drainage systems	8	12	1	
A.6.1.4	Geographic Information System (GIS) applications for the management of roads, structures and drainage systems	12	5	1	3
A.6.1.5	Guidelines for situational analyses; need determination processes, and development of road asset management plans	6	6	5	4
A.6.1.6	Methods for prioritising investments in road maintenance, rehabilitation and construction based on multi-criteria analysis	12	2	4	3
A.6.1.7	Other (specify):				

A.6.2 Vehicle Characterization & Vehicle Overloading

		A	B	C	Blank
A.6.2.1	Implementation of a national/provincial vehicle overloading control strategy	18	1	1	1
A.6.2.2	Identification of (additional) sites for weigh bridges (regulatory) and control sites for Weigh-in-Motion	14	4	2	1
A.6.2.3	Installation of vehicle count/classification instrumentation on critical routes	13	4	2	2
A.6.2.4	Other (specify):				

A.7 Advanced Research Topics

		A	B	C	Blank
A.7.1	Impact of riding quality (i.e. dynamic loading effects) on the structural and functional life of pavements	4	10	5	2
A.7.2	Establishment of methodologies for use of Spectral Analysis of Surface Waves for the assessment of pavements structural behaviour (e.g., layer moduli, cracking)	6	11	3	1
A.7.3	Other (specify):				

A.8 General

		A	B	C	Blank
A.8.1	Standards and specifications: * Revision of national standard specifications and guidelines; * Rationalisation to one set of national standards; * Performance-based standards for the roads sector	10	6	3	2
A.8.2	Other (specify): *Utilização de normas regionais já aprovadas e elaboração de anexos com âmbito de aplicação local*				

B. INFRASTRUCTURE DELIVERY

B.1 Construction & Maintenance

B.1.1 Labour-Intensive Construction

		A	B	C	Blank
B.1.1.1	Study on labour-intensive construction to review the potential gains of a national labour-intensive road construction and maintenance programme	6	5	6	4
B.1.1.2	Review applicability of current best practices on labour-intensive construction and maintenance for the different classes of roads, and assess their potential to create employment	7	8	4	2
B.1.1.3	Labour-intensive methodologies for upgrading gravel roads to paved standards	4	9	5	3
B.1.1.4	Incorporation of labour-intensive road construction and maintenance methods in codes of practice	6	9	3	3
B.1.1.5	Innovative systems for involvement of local communities in the maintenance of low-volume rural roads	9	4	6	2
B.1.1.6	Other (specify):				

B.1.2 Conventional Construction

		A	B	C	Blank
B.1.2.1	Develop project evaluation procedures and techniques that ensure more equitable allocation of resources in accordance with community and user needs, while giving due consideration to social, environmental and quality-of-life issues	5	13	2	1
B.1.2.2	Standardised procedures and specifications for in-situ recycling with cement, foamed-bitumen and/or bitumen-emulsions	4	9	6	2
B.1.2.3	Best practice guidelines on the manufacturing, laying and compaction of hot, warm or cold asphalt	9	9	2	1
B.1.2.4	Best practice guidelines for concrete pavement construction and equipment requirements for: * Concrete batching and mixing; * Concrete placement; * Concrete pavement curing, texturing and jointing	5	11	2	3
B.1.2.5	Cost-effective maintenance methods for prolonging the functional service life of thin bituminous surfacings, focusing on aspects such as skid resistance, impermeability and flexibility	10	8	1	2

B.1.2.6	Techniques to reduce the impact of pavement construction, rehabilitation and maintenance activities (e.g. noise, safety, environmental pollution, vibration, land property impacts, availability of the road, etc.) on road users and adjacent	3	7	9	2
B.1.2.7	Geotechnical solutions for soil improvement and embankment construction	13	3	2	3
B.1.2.8	Other (specify):				

B.1.3 Contractor Development

		A	B	C	Blank
B.1.3.1	Development of guideline documents for the sustainable development of Small and Medium Enterprises (SMEs) through training, mentoring and incubation programmes	12	6		3
B.1.3.2	Other (specify):				

B.1.4 Maintenance

		A	B	C	Blank
B.1.4.1	Code of practice on maintenance	12	5	1	3
B.1.4.2	Development of processes that ensure sustainable maintenance strategies for gravel roads and their upgrading to paved standards	12	6	1	2
B.1.4.3	Advanced diagnostic technologies to enhance early detection of deterioration	11	6	1	3
B.1.4.4	The role of periodic maintenance versus rehabilitation in terms of cost-effectiveness	12	5	2	2
B.1.4.5	Time-cost implications of moving maintenance and rehabilitation actions to a date earlier/later than the planned date	9	6	3	3
B.1.4.6	Other (specify):				

B.1.5 Quality Control & Assurance

		A	B	C	Blank
B.1.5.1	Survey of factors and influencing issues that impact on quality in the road construction industry (e.g. which factors guarantee success or failure)	8	5	3	5
B.1.5.2	Development of quality control software	12	6	2	1
B.1.5.3	Improved test procedures for monitoring and controlling construction quality of road pavements, earthworks and structures	12	7		2
B.1.5.4	Other (specify):				

B.1.6 Minimise Disruption

		A	B	C	Blank
B.1.6.1	Ways to minimise disruption from road works on mobility and accessibility, including traffic management schemes	3	7	7	4
B.1.6.2	Rapid repair technologies that reduce the time between repair and resumption of service	7	8	4	2
B.1.6.3	High-speed pavement construction/rehabilitation technologies	8	6	4	3

B.1.6.4	Improve customer (road user) relationships: * Guidelines for improving public involvement in renewal strategy selection and for improving business relationships during renewal projects; * Context-sensitive designs and construction operations to minimize impact on road users and adjacent land users; * Feasibility study into the establishment of customer call centres countrywide to receive and act upon any deficiencies in road service delivery	5	1	11	4
B.1.6.5	Other (specify):				

B.2 Contracting Systems for Construction & Maintenance

B.2.1 Quality Assurance Systems

		A	B	C	Blank
B.2.1.1	Development and implementation of minimum standards for quality systems to be adopted by contractors	11	6	2	2
B.2.1.2	Other (specify):				

B.2.2 End-Performance Systems & Guarantees

		A	B	C	Blank
B.2.2.1	Methodologies for quantifying, optimising and manage the risk profile of projects	6	8	3	4
B.2.2.2	Innovative project management strategies for large, complex projects	8	5	3	5
B.2.2.3	Development of performance-based routine road maintenance principles while also securing alignment with labour-intensive and community-driven maintenance operations	7	11		3
B.2.2.4	Refinement of the concession model and optimisation of the role players' interests in order to obtain an equitable balance between product quality and service delivery on the one hand, and fair compensation and profit taking on the other hand	3	10	5	3
B.2.2.5	Other (specify):				

B.3 Safety of Road Workers

		A	B	C	Blank
B.3.1	Implementation of technologies/solutions to reduce road workers' exposure to hazardous conditions and to warn road workers of impending hazards	10	6	1	4
B.3.2	Identify requirements that need to be incorporated into Health and Safety Plans prior to construction	11	6	1	3
B.3.3	Other (specify):				

C. ENVIRONMENT

C.1 Environmental Impact of Roads

		A	B	C	Blank
C.1.1	Development of a national strategy on sustainable construction	9	6	2	4
C.1.2	Procedures for performing environmental impact assessments whenever improvements to roads are planned, and for the selection of the least intrusive measures	6	11	1	3
C.1.3	Quantification of the cost of environmental impacts	8	7	3	3
C.1.4	Investigation into means for reducing noise pollution in urban areas	3	9	3	6

C.2 Preservation of Natural Resources

		A	B	C	Blank
C.2.1	Forms of contract that encourage recycling and the use of recycled and/or alternative materials	7	7	2	5
C.2.2	Cold in-place recycling of road construction materials	7	7	2	5
C.2.3	Means by which non-renewable sources of road construction material (e.g. regravelling of gravel roads) can be protected	8	6	1	6
C.2.4	Assess the potential for reusing waste materials in road construction	8	8	1	4
C.2.5	Minimise the environmental impact of borrow pits	7	7		7
C.2.6	Implement borrow pit management systems to optimise their use	6	8	1	6
C.2.7	Identify ways by which local water resources and receiving environment can be protected against leaching of pollutants (e.g. oil and fuel)	8	6	1	6
C.2.8	Other (specify):				

D.PLANNING & OPERATIONS

D.1 Land Use & Infrastructure Planning

		A	B	C	Blank
D.1.1	Land use/transport interaction modelling: * Review of alternative approaches and mechanisms for delivering integrated transport planning and land use; * Means by which land use developments can be monitored and controlled such that the road network is not unduly affected by unwelcome developments and in order to be able to plan timeously for possible upgrading or extensions to the network; * Tourism and events: Mapping of identified tourist routes and management thereof to ensure accessibility and safety	5	9	3	4
D.1.2	Strategic operational management of urban road networks	5	7	4	5
D.1.3	Integration of regional transport strategies with spatial planning policies	6	6	4	5
D.1.4	Other (specify):				

D.2 Accessibility & Mobility

		A	B	C	Blank
D.2.1	Development of a road master plan that will provide all rural communities in Mozambique with decent access roads to reduce rural isolation by connecting people with services and by increasing mobility	11	5	2	3

D.2.2	Identification of bottlenecks in transport networks that lead to traffic congestion, particularly in large metropolitan areas, and the development of a plan of action	10	8	1	2
D.2.3	The management of the transportation of Abnormal Loads	3	7	6	5
D.2.4	Identification of Strategic Routes and the management thereof	7	7	4	3
D.2.5	Impacts of planning policy on congestion reduction	9	4	5	3
D.2.6	Other (specify):				

D.3 Road User Information Systems

		A	B	C	Blank
D.3.1	Implementation of warning systems for hazardous conditions affecting road users	11	3	3	4
D.3.2	Other (specify):				

D.4 Road Infrastructure Safety Management

		A	B	C	Blank
D.4.1	Implementation of a safety information system for the main road network, centred in a road accident data base, including traffic and road data	11	4	1	5
D.4.2	Guidelines and best practice manuals for application of safety management procedures to every phase of the road life-cycle (e. g. safety audits, safety inspections and management of high-risk road sections)	10	5	3	3
D.4.3	Implementation of monitoring and evaluation procedures on the results of safety measures applied to the road infrastructure	7	7	3	4
D.4.4	Other (specify):				

E. POLICY, ECONOMICS & DECISION SUPPORT

E.1 Funding & Transport Economics

		A	B	C	Blank
E.1.1	Assessment of: * The relationship between transport infrastructure investment and productivity; * The relationship between transport costs and international trade; * The role of transport on the competitiveness of cities and regions, including mining and tourism	10	7	1	3
E.1.2	Development of models for vehicle operating costs in relationship to the quality of the assets	10	3	4	4
E.1.3	Development of guidelines, methods and tools for assessing impacts of road investment and for prioritising investments	7	7	4	3
E.1.4	Review of the toll road strategy taking cognisance of the current toll road strategy, policies on toll levies and impact on the economy and lower-income groups	9	5	4	3
E.1.5	Road-needs study to assess the current backlog with respect to road provision and maintenance needs based on uniform data and protocols	3	9	7	2

E.1.6	Other (specify): Estudo de custos unitarios dos trabalhos rodoviarios	1			

E.2 Performance Measures

		A	B	C	Blank
E.2.1	Development of strategic performance indicators and assessment of road sector performance against the indicators	5	9	4	3
E.2.2	Extend performance indicators to enable international benchmarking	6	8	4	3
E.2.3	Other (specify):				

F. RESOURCES

F.1 Human Capital

		A	B	C	Blank
F.1.1	Perform a skills audit to review the current skills base, the identification of capacity gaps and the formulation of plans of action to address these gaps. Formulate, develop and implement a strategy to: * Attract, develop and retain young scientists and engineers; * Provide science, engineering and technology education at all levels; * Build centres of excellence (e.g. at RRC and universities); * Establish virtual networks of excellence; * Foster greater public-private partnerships; * Create and maintain digital libraries; * Build regional and international networks of collaboration.	14	3	2	2
F.1.2	Other (specify):				

F.2 Management of Knowledge & Information

		A	B	C	Blank
F.2.1	Development/revision of national codes of practice, standards and specifications	6	9	2	4
F.2.2	Efficient management of national codes of practice, standards and specifications, including their implementation in practice	6	10	2	3
F.2.3	Other (specify):				

The next section presents a first overview of the collected replies.

3.2 Analysis of responses to the questionnaire

Taking into account the answers to the questionnaire concerning research priorities, it can be concluded that the topics presented in the questionnaire are in line with the needs perceived by the stakeholders, since a significant percentage of the topics were ranked as A or B (Figure 1).

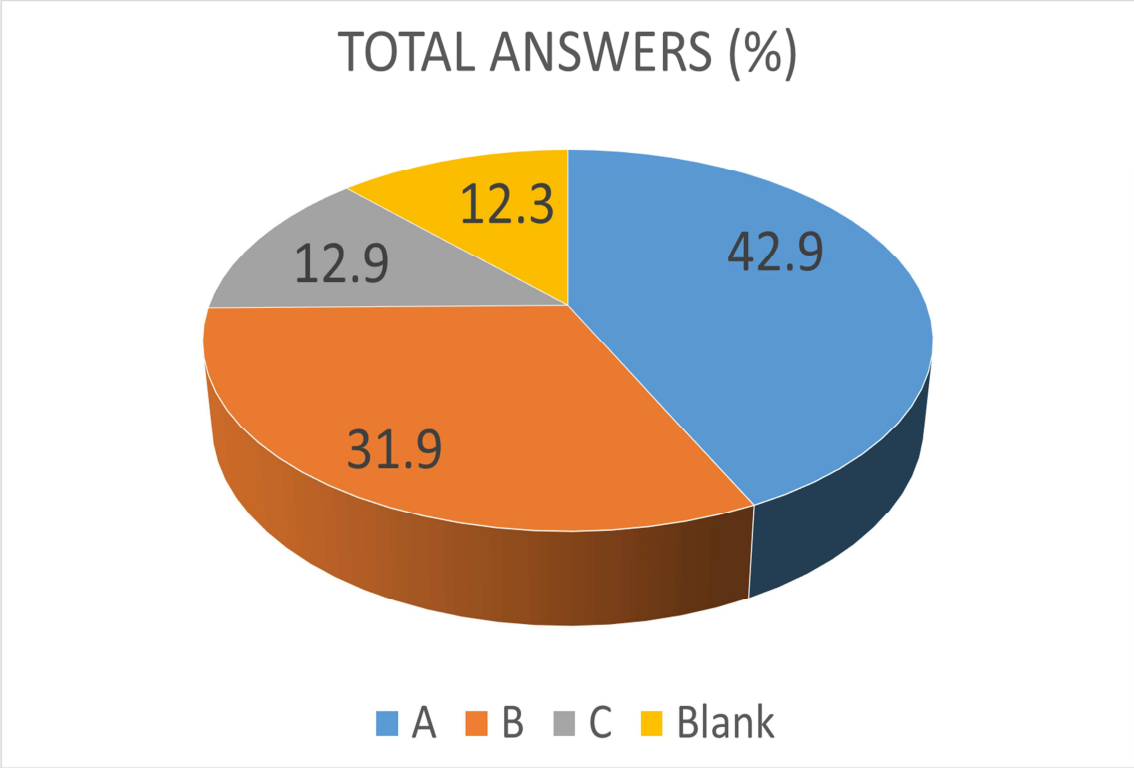

Figure 1 - Percentage of replies ranked as A, B, C and Blank

Figure 2 shows the percentage of "A"s for each main topic.

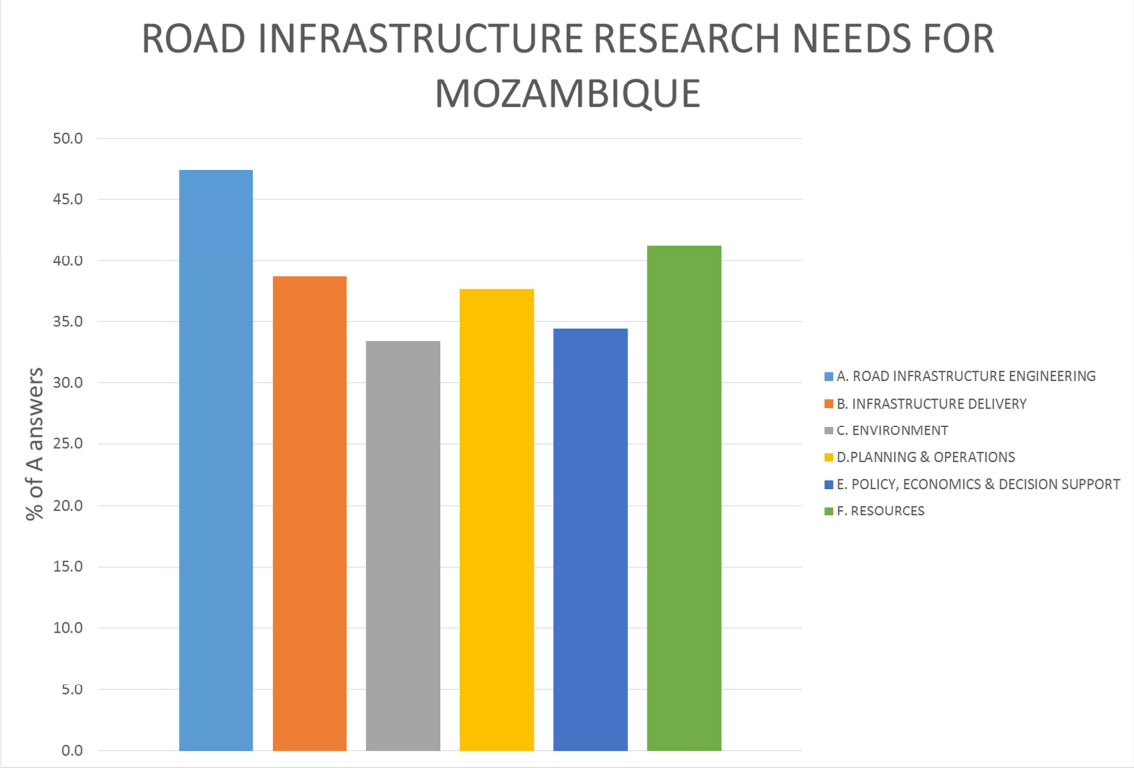

Figure 2 – Percentage of "A"s for each main topic

Figure 3 to Figure 8 present the percentage of replies giving “A” priority to each of the topics.

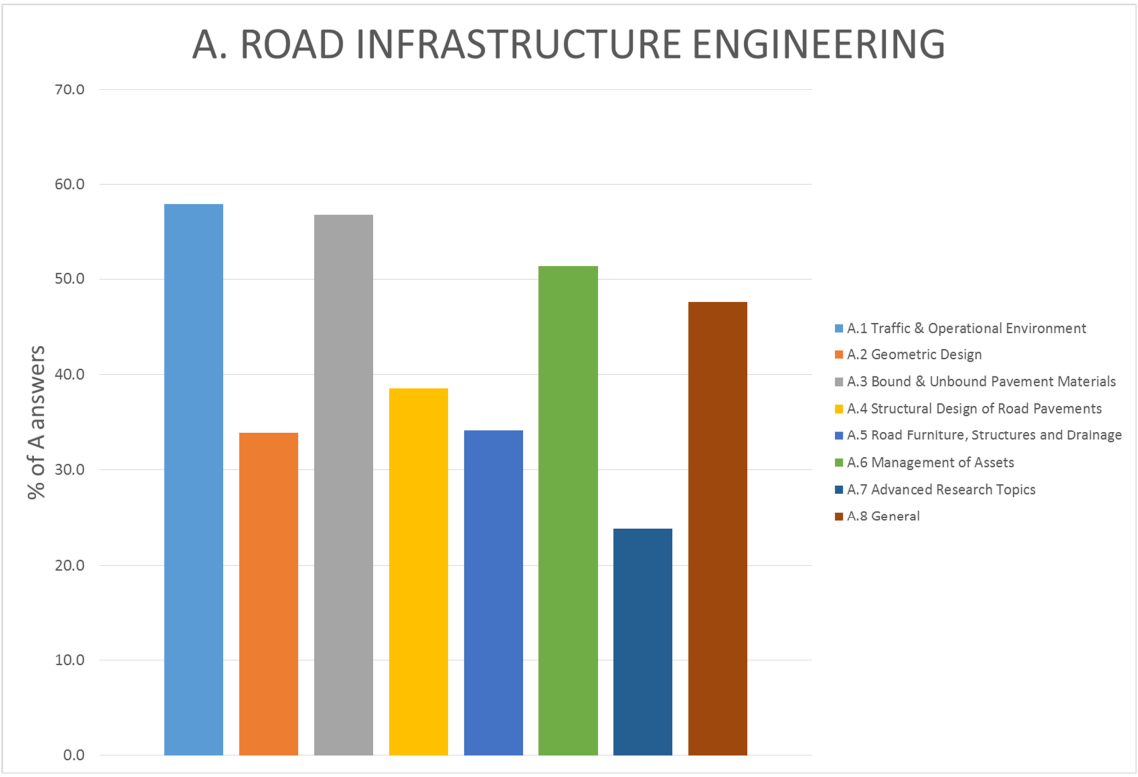

Figure 3 - Percentage of "A" replies for Road Infrastructure Engineering topics

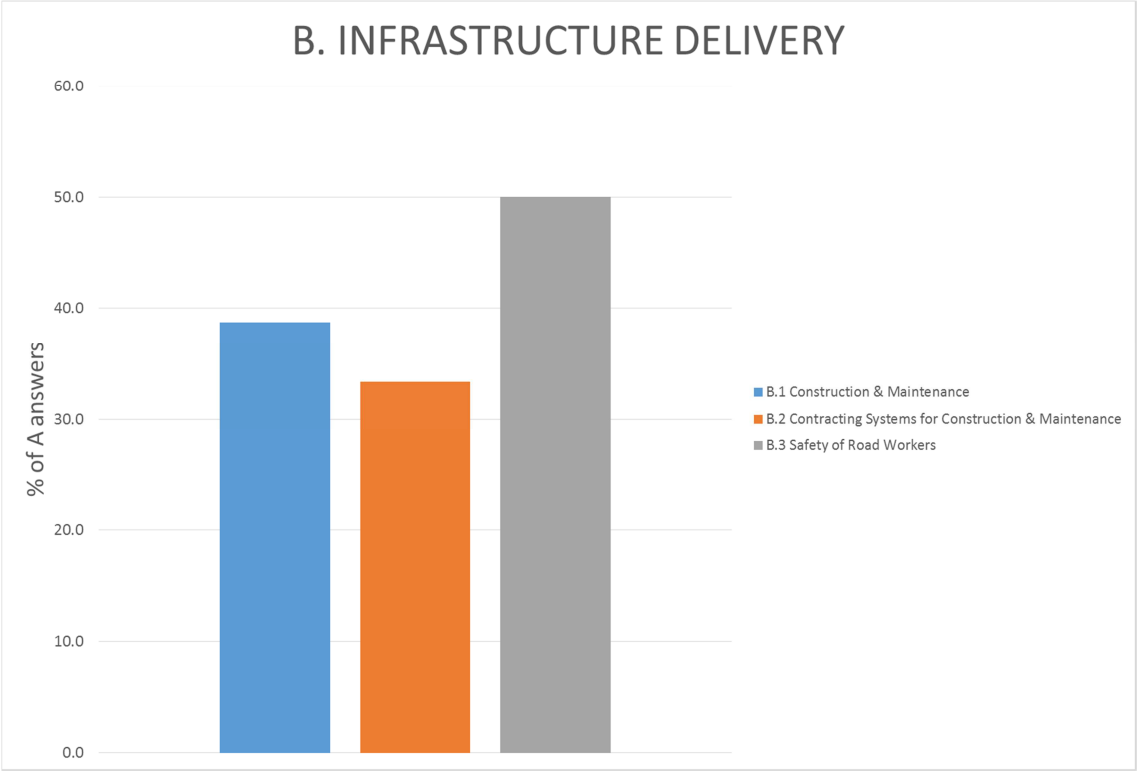

Figure 4 - Percentage of "A" replies for Road Infrastructure Delivery

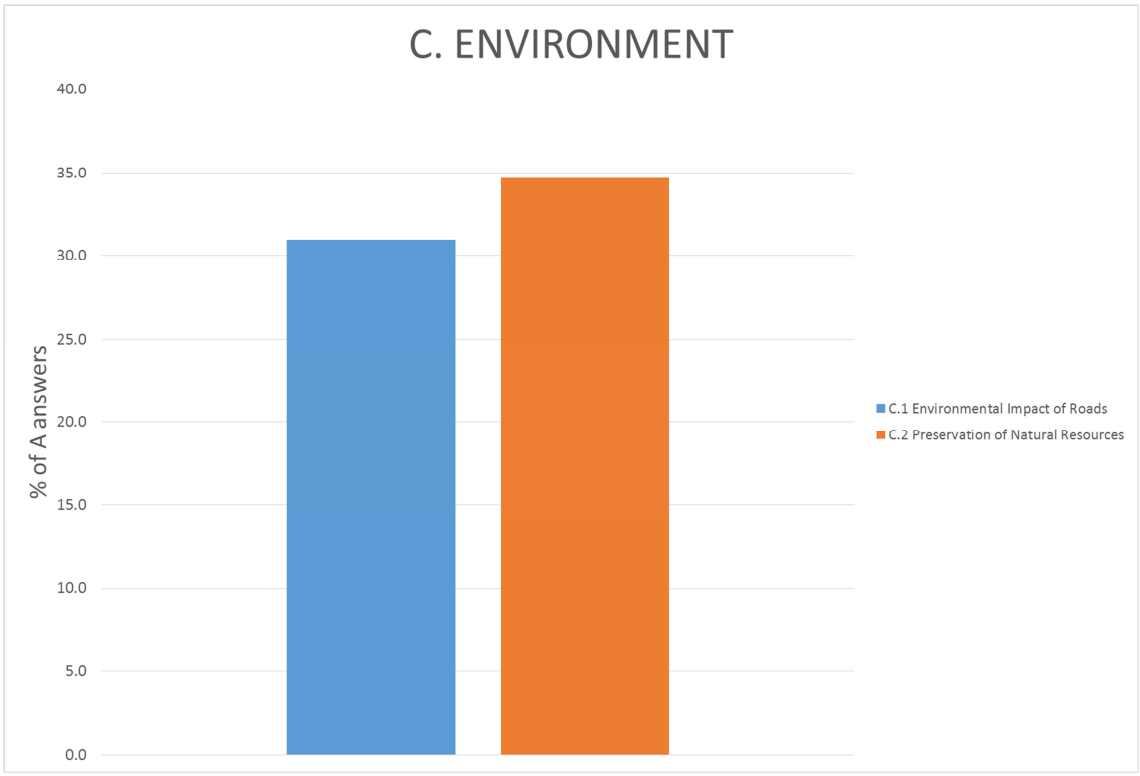

Figure 5 - Percentage of "A" replies for Environment

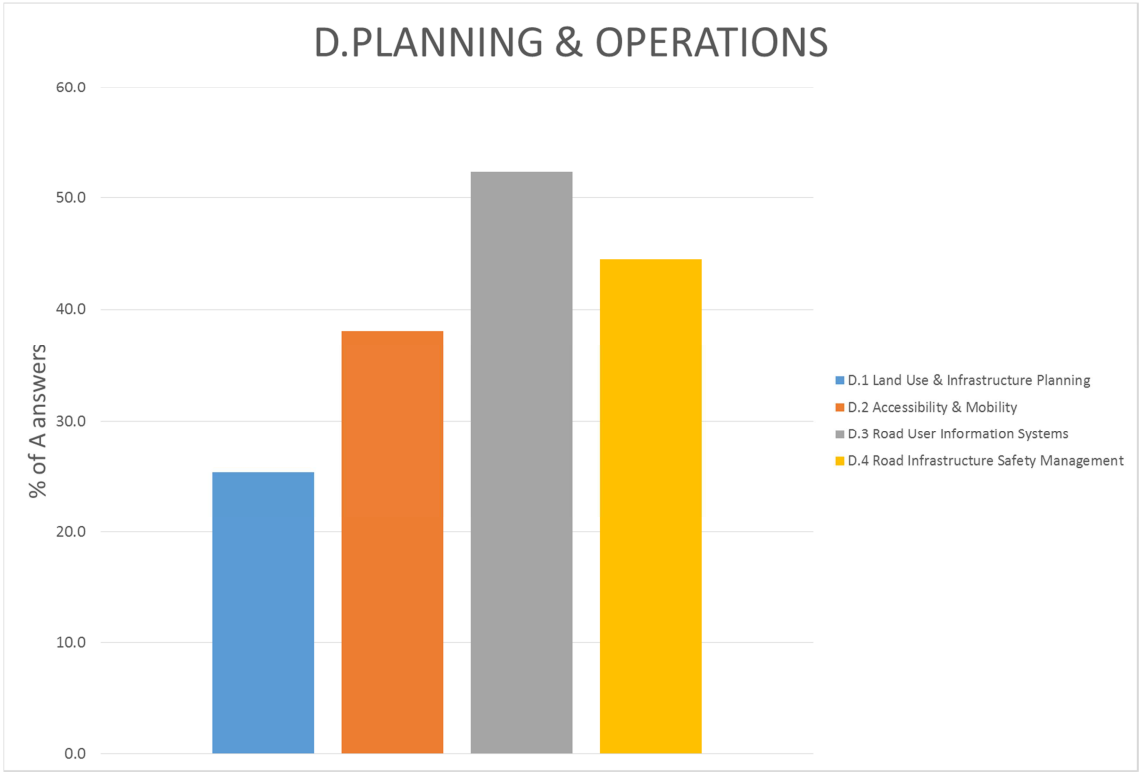

Figure 6 - Percentage of "A" replies for Planing & Operations

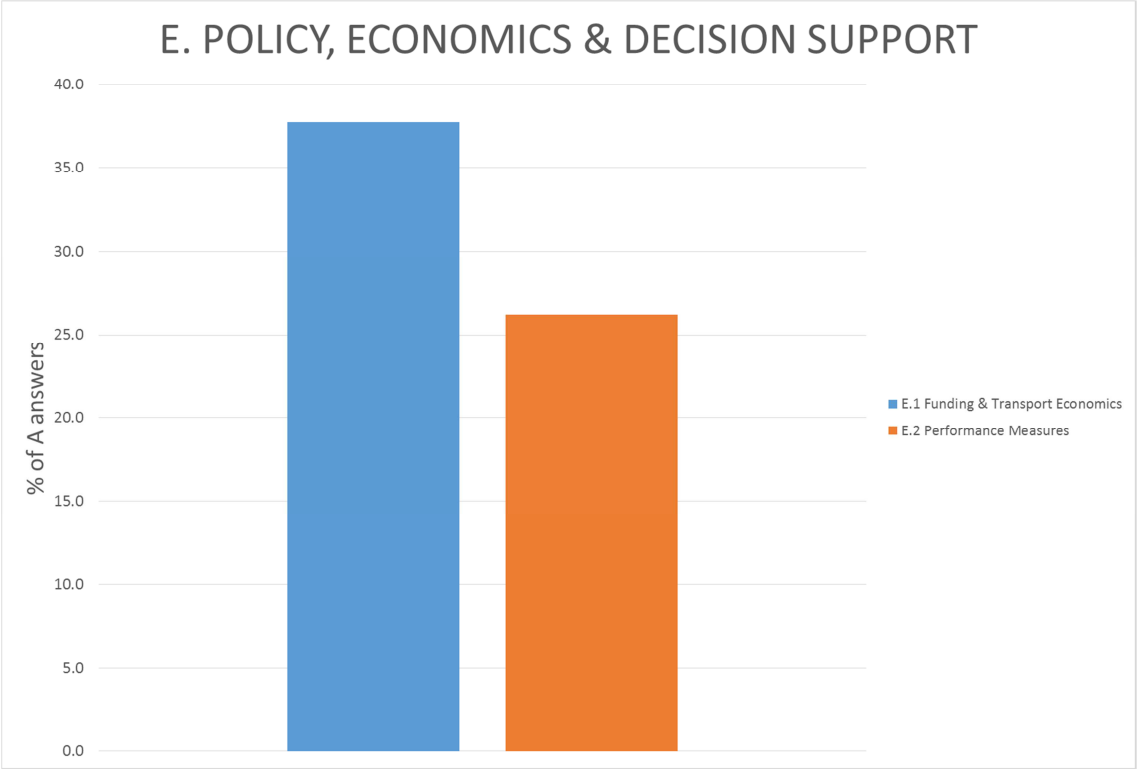

Figure 7 - Percentage of "A" replies for Policy, Economics & Decision Support

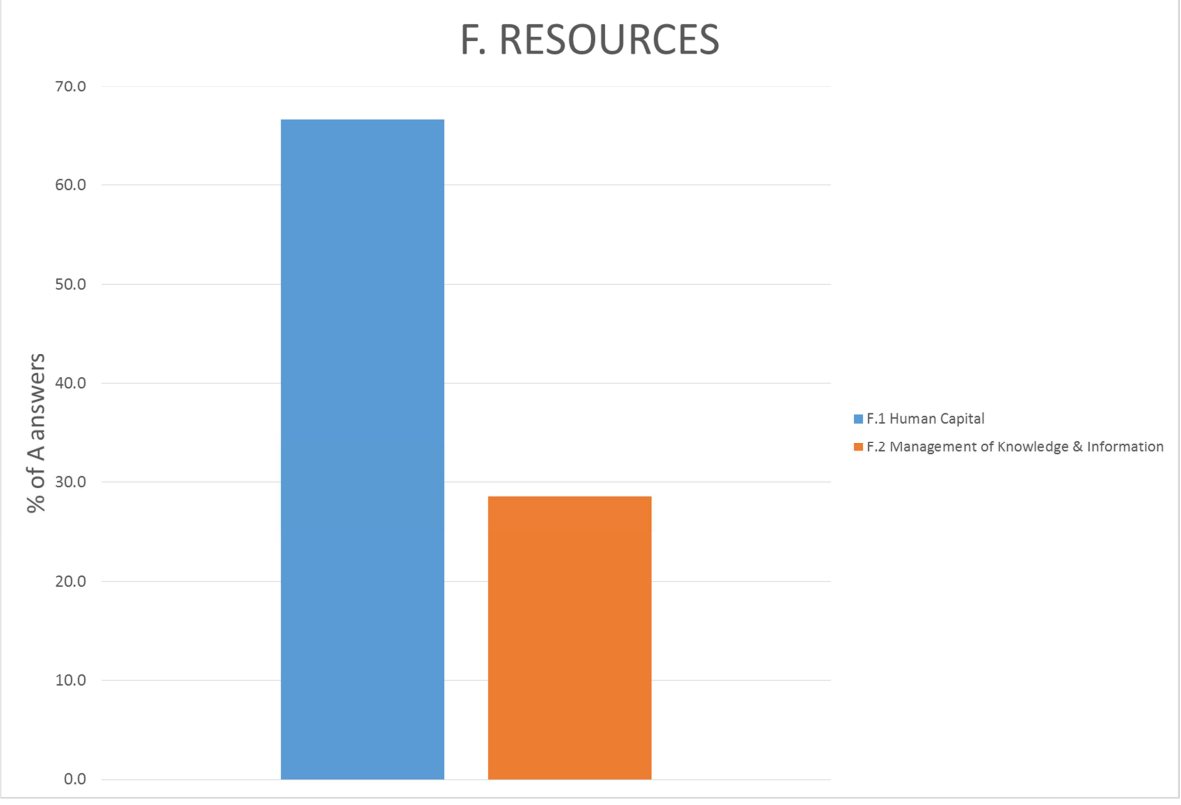

Figure 8 - Percentage of "A" replies for Resources

In order to rate the research topics by order of importance assigned by the respondents, a numerical value was attributed to each response, using the following scale:

Table 3 - Correspondance between Priority and number of points for analysis of questionnaires

Priority	Number of points
A	5
B	3
C	1
No interest (blank)	0

The statistical validity of this procedure has been confirmed by an independent expert statistician.

The total number of points for each topic was then converted into a percentage, where 100% corresponds to the maximum possible number of points. Figure 9 illustrates the distribution of the relative classifications for the full set of topics. The table below lists the topics with the highest ratings.

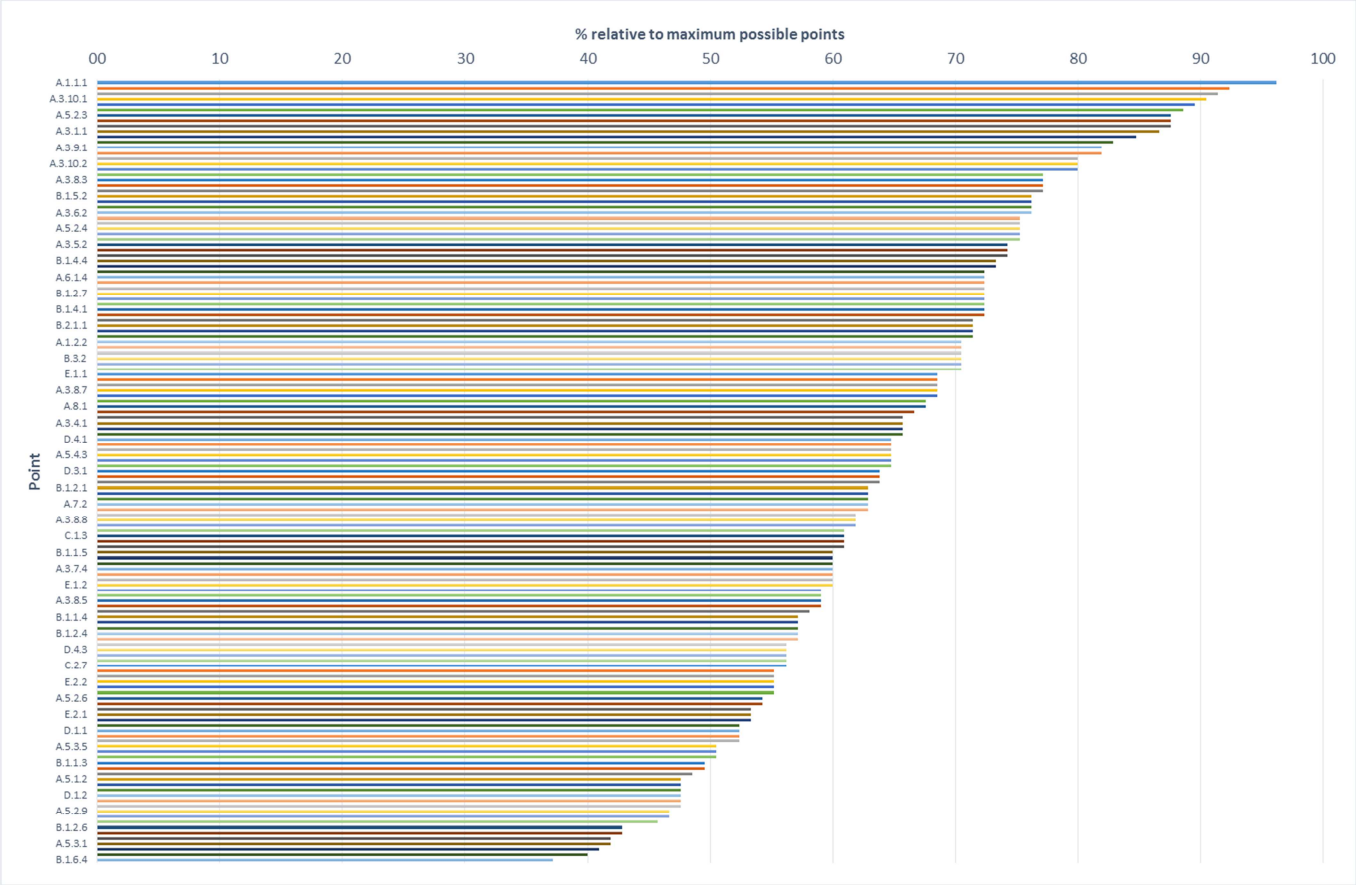

Figure 9 – Distribution of relative classifications for research topics

Table 4 – Top 20 rated research topics

Topics	Rating(%)	Description
A.1.1.1	96.2	Improved understanding of the effects of traffic loading on pavement performance: * Characterisation of distribution of axle load grouping and/or vehicle classes on the primary, secondary and tertiary road networks; * Updating of equivalent single axle loads (ESALs) per heavy vehicle factors for Mozambique
A.3.1.2	92.4	Identification of suitable and cost-effective binders and soil stabilizers, for use as cement and/or bitumen replacements
A.3.3.1	91.4	Development of hot, warm and/or cold-mix asphalt design guidelines (including binder specifications) for Mozambique
A.3.10.1	90.5	Development of a road material database
A.6.2.1	89.5	Implementation of a national/provincial vehicle overloading control strategy
A.3.10.3	88.6	Optimisation in the use of locally-available materials (e.g. high PI materials and sands) by means of modification and/or stabilisation techniques
A.5.2.3	87.6	Structural assessment of existing bridges
A.3.2.2	87.6	Appropriate standards for surfacings on low-volume roads taking cognisance of operating conditions, base types and drainage design
A.3.3.2	87.6	Development of specifications and quality control/assurance standards for hot, warm and/or cold-mix asphalt
A.3.1.1	86.7	Test methods and criteria for the assessment of aggregate durability
A.3.7.1	84.8	Recommendations on modification/treatment options for marginal aggregate in order to render them suitable for road construction
A.3.6.3	82.9	Production of guidelines for the selection of the most appropriate modifier to treat high Plasticity Index (PI) materials
A.3.9.1	81.9	Identification of potential sources of alternative materials for use in roads
A.3.6.1	81.9	Development of best-practice guidelines on the beneficiation of sandy materials through the addition of cement stabilisers, and identification/specification of most appropriate cement types to suite local conditions
A.5.4.2	80.0	Implementation of inspection procedures on road drainage structures
A.3.10.2	80.0	Guidelines on the identification of aggregate sources and the assessment of their quality for use in road construction
A.6.2.2	80.0	Identification of (additional) sites for weigh bridges (regulatory) and control sites for Weigh-in-Motion
F.1.1	77.1	Perform a skills audit to review the current skills base, the identification of capacity gaps and the formulation of plans of action to address these gaps. Formulate, develop and implement a strategy to: * Attract, develop and retain young scientists and engineers; * Provide science, engineering and technology education at all levels; * Build centres of excellence (e.g. at RRC and universities); * Establish virtual networks of excellence; * Foster greater public-private partnerships; * Create and maintain digital libraries; * Build regional and international networks of collaboration.
A.3.8.3	77.1	Development of design models for the use of granular materials of varying quality in pavements
B.1.5.3	77.1	Improved test procedures for monitoring and controlling construction quality of road pavements, earthworks and structures

Many of the past and ongoing AFCAP funded projects in Mozambique have resulted in useful conclusions but have generally left many of the important questions and issues unanswered. The proposed research programmes for the RRC should ensure that the problems and shortcomings identified during these projects are addressed in order to bring these projects to some degree of finality.

Examples of these issues are:

- The development of specifications for calcretes in the Inhambane Province based on monitoring and back-analysis of as many roads constructed using calcrete in the province as possible;
- As calcrete occurs in other provinces as well, the Inhambane Province findings should be extended to these areas in order to enlarge the data and knowledge base and extend the area of implementation of the findings;
- Re-evaluation of the back-analysis data in order to provide a full suite of specifications (currently only plasticity and grading issues are discussed although the CBR values indicate that a significant relaxation in this area is possible);
- Mechanisms for improving the use of calcrete in Otta seals based on revisiting and assessing the Inhambane trials.

The RRTC should take these issues and recommendations into account when finalising the proposed research programme. As much of the groundwork has already been completed, some of these roads have been in service for a number of years and significant information regarding their construction and performance already exists, such projects should yield relatively short-term results and the accompanying benefits for justification of the RRC.

4. Summary conclusions and recommendations

Most of the research studies reviewed concerned road pavement design, construction and rehabilitation using locally available materials in Mozambique. This is, in fact, an important topic, due to the fact that many regions in the country have scarce sources of quality aggregates for road construction. The projects have been predominantly funded through the AFCAP programme and are thus primarily targeted towards low volume roads specifically related to improved community access.

Most of the work reported in previous refers to the construction techniques for using these local materials. The main difficulties are related to the fact that many of these local materials do not comply with the local standard specifications for road works, although there is a perception that, if properly treated and placed, they can provide pavement structures with adequate durability.

The following recommendations have been developed from the experience gathered:

- Research projects should be carefully planned, taking into account issues such as:
  - Objectives;
  - Financing and programming of the activities;
  - Available resources;
  - Practical implementation of results.
- Research projects involving local materials and construction techniques should be carefully prepared taking into account relevant site constrains, such as:
  - Contractor capabilities (equipment, human resources and know-how);

  - Climatic conditions;
  - State condition of the materials;
  - Quality control procedures.
- In order to consolidate the knowledge, the test sections should be monitored, the results fully documented and archived and the results should be analysed.
- The experience gathered should be translated into specifications and best practice guides.
- Dissemination of the research results to the appropriate stakeholders should be a priority.

Taking into account the answers to the questionnaire concerning research priorities, it can be concluded that the topics presented in the questionnaire are in line with the needs perceived by the stakeholders.

The analysis of the questionnaire replies shows that the following research topics have higher priority:

- Traffic loading and its effect on pavement performance;
- Use of available local materials
- Materials database
- Material specifications
- Thin surfacings
- Assessment of bridges and drainage structures
- Research skill enhancement.

It is recommended that the RRTC places on the list of proposed projects for the RRC that the experimental and test sections constructed during the ongoing and earlier AFCAP funded projects should be fully evaluated in order to derive specifications for these marginal quality base and surfacing materials that can be implemented. This could be a short term output for the RRC.

Appendix 1 / Summary of documents reviewed

Report title	Report number	Abstract	Author (s)	Date	Issuing organisation	Receiving organisation
AFCAP Project Phase 4: Back Analysis of Previous Low Volume Rural Roads in Mozambique: DRAFT PROJECT INCEPTION REPORT	CPR 1410	The Mozambican National Roads Administration (ANE) has embarked on a Regional Roads Investment Programme (RRIP). The programme is being supported by the Swedish International Development Agency (ASDI), which is providing the funding for construction works, including site supervision, and by the UK's Department for International Development (DFID) through its African Community Access Programme (AFCAP) 1 which is providing technical assistance for research, application of innovative solutions, development of guidelines, communication, and mainstreaming. TRL has been commissioned by Crown Agents to carry out Phase 4 of the AFCAP programme in Mozambique to undertake a back analysis of previously constructed low volume roads (LVRs) and monitor their historic and current performance.	Kenneth Mukura, and John Rolt	September, 2012	TRL	ANE/AFCAP
Analysis of Performance of Previous Low Volume Rural Roads in Mozambique: Monthly Progress Report No. 1	N/A	This report covers the work carried out in the month of October, providing information on activities and technical aspects of the project. Sample data and illustrated photographs are provided in the Appendix	Kenneth Mukura	October, 2012	TRL	ANE/AFCAP
Targeted Interventions on Low Volume Roads in Mozambique: Monitoring Report	N/A	This report presents some interim findings from the monitoring data collected at intervals to measure the performance of the sites constructed under the second phase of the AFCAP project in Mozambique. A preliminary discussion is made under sub-heading of the performance of each trial site. A more detailed analysis of the monitoring data will be provided once the final monitoring period has been completed in February 2013. Final recommendations will be made in the Final Report in consideration of these results and those to be obtained from the AFRCAP project "Analysis of PerfoRMANCE of Previous Low Volume Rural Road (AFCAP/MOZ/001/G)"	Andrew Otto	November, 2012	TRL	ANE/AFCAP

Back Analysis of Previous Low Volume Rural Roads in Mozambique: Final Report	RPN2585	This is the Final Report for the Back Analysis Project. The report provides information on the activities carried out and the data that was collected during the execution of the project. The report gives a brief on the preliminary activities and the reconnaissance surveys carried out during the early stages of the project. More details of these early stages are given in the Inception Report. The report also gives a detailed of the field surveys particularly the data that was collected from the measurements carried out in the field and the materials tests results. Finally, the report provides results of the analysis and the recommendations and conclusions from the results of the analysis	John Rolt, Kenneth Mukura, Francis Dangare and Andrew Otto	June, 2013	TRL	ANE/AFCAP
Back Analysis of Previous Constructed LowVolume Rural Roads in Mozambique: Final Report	CPR1612	This is the Final Report for the Back Analysis Project. The report provides information on the activities carried out and the data that was collected during the execution of the project. The report gives a brief on the preliminary activities and the reconnaissance surveys carried out during the early stages of the project. More details of these early stages are given in the Inception Report. The report also gives a detailed account of the field surveys particularly the data that was collected from the measurements carried out in the field and the materials tests results. Finally, the report provides results of the analysis and the recommendations and conclusions from the results of the analysis	John Rolt, Kenneth Mukura, Francis Dangare and Andrew Otto	June, 2013	TRL	ANE/AFCAP
Targeted Interventions on Low Volume Rural Roads in Mozambique: Consolidated Construction Report	N/A	This report provides information on the implementation of the AFCAP/RRIP pilot projects covering works carried out during Phases 1, 2 and 3. The report provides information on the nature of the projects, the materials used, the site organisation, the work methods used or developed, the challenges faced and recommendations. The information from this document and lessons learnt will be incorporated in the user documents such as the Guideline on Specifications and Work Norms for Low Volume Roads in Mozambique and the future manual, the New Version of the Normas de Execucao.	Kenneth Mukura, John Rolt, and Andrew Otto	,2013	TRL	ANE/AFCAP
Targeted Interventions Under the Rural Roads Investments Programme in Mozambique (Phase 1): Construction/Progress Report	CPR 470	This report concerns the construction stage of the first phase of targeted interventions on low volume rural roads in Mozambique (2008-2009) under the Rural Road Investment Programme	K Mukura, S Done and J Rolt	September, 2009	TRL	ANE/AFCAP

Targeted Interventions on Low Volume Rural Roads in Mozambique: Construction Report	N/A	This report covers the construction of the Phase 2 projects under the AFCAP/RRIP	K Mukura	,2012	TRL	ANE/AFCAP
Targeted Interventions on Low Volume Rural Roads in Mozambique, AFCAP/RRIP Project Phase 3: DESIGN REPORT	CPR 1258	This report covers the design stage of the RRIP/AFCAP Project Phase 3. This project follows on from the execution of Phase 2 where several sites were designed by TRL in collaboration with the provincial consultants and built mostly by local contractors. Most of the works were carried out successfully and this lead to the commissioning of Phase 3. The designs for the Phase 2 projects were based on the development of sustainable designs and construction techniques to resolve passability problems experienced on some important rural roads. The project therefore focussed not only on providing all weather access but also on research and development. A number of design solutions were trialled but, due to the limited scope of the project, some design options that were proposed were not included. Phase 3 provided the opportunity to design and trial some of these other possible options.	Kenneth Mukura, John Rolt, and Andrew Otto	February, 2012	TRL	ANE/AFCAP
Targeted Interventions on Low Volume Rural Roads in Mozambique – RRIP: Phase 3 - Supervision and Monitoring: Inception Report	CPR 1207	This report covers the inception stage of the RRIP Phase 3 covering supervision of the projects being constructed by contractors in 5 provinces. The project is a continuation of the work being undertaken under Phase 2 of the RRIP. The project was necessitated by the need for additional resources to cover the supervision and monitoring of the additional projects that were commissioned under Phase 3.	Kenneth Mukura	October, 2011	TLR	ANE
Targeted Interventions on Low Volume Rural Roads in Mozambique – RRIP Phase 4: RRIP Phase 4 Supervision and Monitoring, Inception Report	N/A	This report covers the inception stage of the RRIP Phase 4 for projects to be constructed by contractors in various provinces. The project is a continuation of the work being undertaken under Phase 3 of the RRIP. The project was necessitated by the need for additional resources to cover the supervision of the additional projects that were commissioned under RRIP Phase 4.	Kenneth Mukura	May, 2013	TLR	ANE

Targeted Interventions on Low Volume Rural Roads in Mozambique Phase 2: Final Report	N/A	This is the Final Report for AFCAP/RRIP Phase 2 and it covers the work carried out which includes planning, design, construction, construction costs, monitoring, performance overview and general recommendations. The report gives detailed of the individual pilot projects recommendations on innovative designs and work norms for the execution of works on site. The successes in using locally available materials, development of appropriate specifications for pavement structures, base materials and Otta seal surfacingIt also covers the challenges faced with problematic materials, lack of capacity within the road sector in Mozambique and matters relating to quality assurance among others	Kenneth Mukura, John Rolt, and Andrew Otto	,2013	TRL	ANE/AFCAP
Targeted Interventions on Low Volume Rural Roads in Mozambique: Draft Construction Report	RPN 2172	This report covers the construction of the Phase 2 projects under the AFCAP/RRIP	K Mukura	, 2012	TRL	ANE/AFCAP
Targeted Interventions for Low Volume Roads in Mozambique: Quarterly Progress Report No.7	N/A	This quarterly report provides details of the work carried out by TRL on Mozambique AFCAP/RRIP Phase 2 for the past 3 months from August 2012. This project has been ongoing for over 2 years and a lot of work has been accomplished. The report provides an insight into the activities carried out during this reporting period, the achievements and challenges that have been faced and the plans for the next reporting period.	Kenneth Mukura	October, 2012	TRL	ANE/AFCAP
Targeted Interventions for Low Volume Roads in Mozambique:AFCAP Project Phase 2, Quarterly Project Progress Report No.3	N/A	The repor t gives details of the work carr ied out , including the challenges and lessons learnt during its execution. TRL s role on the project is to provide technical assistance in developing adequate designs and specificat ions which will enable ANE to ut ilise the non-conventional materials that are abundant ly available in Mozambique to deal with the problem of shortages	A Otto and K Mukura	February, 2011	TRL	ANE/AFCAP

Targeted Interventions for Low Volume Roads in Mozambique:AFCAP Project Phase 2, DRAFT PROJECT INCEPTION REPORT	CPR 607	A recent World Bank report has given poor accessibility as one of the main causes of high transport costs and slow development in Africa to the extent that Africa is lagging behind all other continents in term of development. Accessibility is a major issue in Sub-Saharan Africa and Mozambique is no exception. The main objective of the AFCAP Project is to contribute to the Rural Road Investment Programme (RRIP) being carried out by the National Road Administration (ANE) aimed at improving Mozambique's unpaved road network by increasing passability and all-weather access and reducing long-term maintenance costs. RRIP is managed by the Department of Maintenance (DIMAN) with assistance from the provincial delegations (DIPANE). DIMAN provides the coordination and overall control of the programme and DIPANE, with the assistance of the provincial consultants, look after the contract management aspects of the construction.	K Mukura	January, 2010	TRL	ANE/AFCAP
Identification and Mapping of Calcrete Deposits in Inhambane Province and Preparation of a Calcrete Classification System and Specifications for the Use of Calcrete in Road Construction in Mozambique	RPN 2326	Road-building materials meeting conventional specifications are scarce along much of the coastal and inland areas of Mozambique and, in particular, in Inhambane Province. Road bases for sealed roads have conventionally been constructed by stabilizing local sands with high proportions of cement. Stabilisation of the sand can also be achieved using bitumen. Both of these options are expensive, thereby constraining the expansion of the paved road network. The non-availability of good natural gravels for the construction of wearing courses on unpaved roads has resulted in high maintenance costs for roads in the province, and unreliable access during the rains. Hence, the innovative use of locally available materials, which are considered marginal or rejected by traditional specifications for road construction, needs to be investigated for use in the construction of roads in the province.	N/A	September, 2012	TRL, in Association with InfraAfrica (Pty) Ltd, Botswana	ANE/AFCAP
Identification and Mapping of Calcrete Deposits in Inhambane Province and Preparation of a Calcrete Classification System and Specifications for the Use of Calcrete in Road Construction in	RPN 2277	The project is part of the Africa Community Access Programme (AFCAP) which is a research programme supported by the Department for International Development (DFID) of the Government of the UK. AFCAP has been approached by the Mozambique National Road Administration (ANE) to support a research consultancy for the mapping of calcrete deposits in Imhambane province, preparation of a classification system for Mozambique calcretes and specifications for the use of calcrete in road construction.	N/A	August, 2012	TRL	ANE/AFCAP

Mozambique: Inception Report						
Development of a Road Research Strategy for Mozambique: Inception Report	RPN 2402	The project is part of the Africa Community Access Programme (AFCAP) which is a research programme supported by the Department for International Development (DFID) of the Government of the UK.AFCAP was approached by the Mozambique National Road Administration (ANE) to support a consultancy for developing indigenous capacity for carrying out research in the transport sector in Mozambique. This led to the project to 'Develop a Road Research Strategy for Mozambique', for which TRL has been appointed as consultant.		November, 2012	TRL	ANE/AFCAP
FEEDER ROADS PROJECT ZAMBÉZIA: FOLLOW-UP ASSESSMENT, Mozambique	N/A	The British government's support to rural development in Mozambique included funding feeder road rehabilitation to help improve the living conditions of rural communities with better access to markets and services. The Zambézia Feeder Roads Project rehabilitated over 900 km of rural feeder roads in Zambézia Province from 1996 to December 2001, using labour-based methods.	Gaye Thompson and Cecília Pedro	December, 2012	SCDS	ANE/AFCAP
AFCAP: Follow Up Assessment of The Feeder Roads Project, Zambézia Province, Mozambique: Inception Report	N/A	The follow-up Study of the Social and Economic Impact of the Feeder Roads Project in Zambézia province is designed to assess the outcomes and consequences of the project upon communities and people living in the vicinity of the road, ten years after the project's final socio-economic impact study. The study's specific objective is to evaluate the outcomes of three principal impacts of the project upon rural livelihoods in Zambézia ten years ago:		May, 2012	SCDS	ANE/AFCAP
Mozambique RRIP Phase 3 Supervision and Monitoring: Final Report	RPN 2139	This project is an extension of the AFCAP/RRIP Phase 2 with the same aims and objectives	K Mukura	Mrach, 2012	TRL	ANE
Mozambique RRIP Phase 4 Supervision and Monitoring: Progress Report	RPN 002	This report covers the work that was carried out during the reporting period up to end of May. The main focus was the monitoring that was carried out on sections which were complete recently as a continuation of the monitoring exercises which were carried out during Phase 2 and Phase 3.	K Mukura	May, 2013	TRL	ANE

Mozambique RRIP Phase 4 Supervision and Monitoring: Progress Report No. 2	RPN 002	This report covers the work that was carried out during the reporting period (May – June 2013) and focuses on the technical issues relating to the pavement and material designs. While TRL was not involved in the project before the tender processes it is important for TRL to provide advice on the materials selection and the pavement designs that are already in place for the projects which are at the early stages of execution.	K Mukura	June, 2013	TRL	ANE
Mozambique RRIP Phase 4 Supervision and Monitoring: Final Report	RPN 002	This is the final report on the work carried out under the Rural Road Investment Programme (RRIP) Phase 4. This programme consists of a number of projects that are being carried out in Mozambique as a continuation of the RRIP which was initiated in 2008.	K Mukura	September, 2013	TRL	ANE
Mozambique RRIP Phase 3 Supervision and Monitoring: Progress Report No. 2	N/A	This report covers work carried out in the period from December 2011 to January 2012 detailing supervision and monitoring activities carried out by TRL in collaboration with DIMAN, ANE Provincial Delegations and the Provincial Consultants.	K Mukura	January, 2012	TRL	ANE
TRAINING CONTRACTORS FOR TARGETED INTERVENTIONS ON LOW-VOLUME ROADS IN MOZAMBIQUE: DRAFT FINAL REPORT	N/A	The National Roads Administration (ANE) of Mozambique has embarked on a Regional Roads Investment Programme (RRIP) whose objective is to improve the standard of important unpaved low volume roads through the “targeted interventions” (spot improvements) approach, with an overall budget of US$10 million over three years starting in 2008. The programme is being managed by ANE Directorate of Maintenance (DIMAN) in Maputo. Projects are being administered by provincial delegations of ANE (DPANE) together with provincial consultants in the various provinces. Technical support is being provided to ANE by TRL Limited of UK. Scott Wilson Mozambique was engaged as the Training Consultant to Support the Execution of Targeted Interventions on Low Volume Rural Roads in Mozambique. The pilot projects and the current contractor training are financed by the Swedish International Development Agency (SIDA) through the SDMRR-2 Project. The African Community Access Programme (AFCAP), a DFID-funded programme, is assisting ANE with the implementation of the pilot projects.		May, 2011	Scott Wilson Mozambique Lda	ANE

TRAINING CONTRACTORS FOR TARGETED INTERVENTIONS ON LOW-VOLUME ROADS IN MOZAMBIQUE: MONTHLY REPORT	N/A	The National Roads Administration (ANE) of Mozambique has embarked on a Regional Roads Investment Programme (RRIP) whose objective is to improve the standard of important unpaved low volume roads through the "targeted interventions" (spot improvements) approach, with an overall budget of US$10 million over three years starting in 2008. The programme is being managed by ANE Directorate of Maintenance (DIMAN) in Maputo. Projects are being administered by provincial delegations of ANE (DPANE) together with provincial consultants in the various provinces. Technical support is being provided to ANE by TRL Limited of UK. Scott Wilson Mozambique was engaged as the Training Consultant to Support the Execution of Targeted Interventions on Low Volume Rural Roads in Mozambique. The pilot projects and the current contractor training are financed by the Swedish International Development Agency (SIDA) through the SDMRR-2 Project. The African Community Access Programme (AFCAP), a DFID-funded programme, is assisting ANE with the implementation of the pilot projects		April, 2011	Scott Wilson Mozambique Lda	ANE
AFRICA COMMUNITY ACCESS PROGRAMME: USE OF ROAD WORKS TO ENHANCE COMMUNITY WATER SUPPLIES IN MOZAMBIQUE, PRE-INCEPTION REPORT	N/A	Following a competitive bidding process, Stange Consult GmbH were appointed as Consultant in a Contract dated 13th July 2012 for *Use of Road Works to Enhance Community Water Supplies and Climate Resilience in Mozambique (Phase 2a – Design of Water Pilots)*, Contract Reference AFCAP/MOZ/054.	N/A	November, 2012	STANCE CONSULT	ANE/AFCAP

USE OF ROAD WORKS TO ENHANCE COMMUNITY WATER SUPPLIES IN MOZAMBIQUE: Phase 1 Final Report	N/A	Access to water supply is poor in rural Mozambique particularly in the dry season. Efforts are being made by the Government of Mozambique to increase access to water supply in the rural areas. At the same time, the government is also striving to improve road infrastructure to facilitate better connection between rural urban areas and hence increase the economic development. These road networks being constructed or improved require construction materials such as sand and stones and as a result, excavations are made along the roads to extract these materials. These excavations known as borrow pits tend to store water during the rains and are referred to as 'road ponds'. Road ponds can also be formed by building road crossing structures on water courses that retain storm water. Communities that are in close proximity to these road ponds use them as a source of water supply for domestic purposes, watering animals, irrigation and for recreation.	N/A	February, 2011	Department of Civil Engineering, Eduardo Mondlane University	ANE/AFCAP

Developments Towards a Mechanistic Design Method for Mozambique	N/A	Mozambique is upgrading its roadway infrastructure with the financial support of the World Bank. In the past, extensive use has been made of foreign consulting engineers and contractors that were not necessarily familiar with Mozambique materials. The objective of this research was to develop guidelines for a mechanistic-empirical design method for cement stabilized sand bases in Mozambique with the aids of Accelerated Pavement Testing (APT). Both reduced-scale and full scale APT have been applied in the laboratory and in the field using the MMLS3 and MLS10, respectively. Six sections were comprehensively trafficked and tested using the full-scale machine in Mozambique. The MMLS3 testing was primarily used to scope the study and to provide guidelines for the construction of full-scale test sections. The combination of the MMLS3 and MLS10 testing programs proved very effective and efficient and the findings have provided the basis for developing transfer functions for use in the proposed mechanistic design procedure. Comparative results between MMLS3 and MLS10 tests indicated that the distress mechanisms were similar. Performance in terms of load applications provided the necessary information for modelling the performance of the pavements and for developing a design procedure with appropriate transfer functions. It was apparent that the decision by ANE to embark on an APT program to address some of the concerns and constraints with their current mechanistic design approach is likely to be cost effective. The procedure that was developed has provided the necessary tools for conducting sensitivity tests for analysing the different variables that affect the performance of the alternative pavement structures. The end product is expected to provide a sound basis for design decisions by ANE and its consultants. To obtain the highest economic benefit out of this research investment, ANE should continue to fund research in the area as outlined in the Path Forward	A. Prozzi, A. d. F. Smit, K. Fults, A. Hefer, F. Hugo, P. J. Strauss and E.R. de Vos	April, 2009	The University of Texas at Austin	ANE

Appendix 2 / Questionnaire

ROAD RESEARCH TECHNICAL COMMITTEE

ROAD INFRASTRUCTURE RESEARCH NEEDS FOR MOZAMBIQUE

Questionnaire prepared by the Africa Community Access Programme (AFCAP)

December 2013

1. Introduction

1.1 Purpose of the Questionnaire

Following a road sector workshop held on 8 February 2013 in Maputo, the executive decision was made to establish a Road Research Centre (RRC) in Mozambique. Key to the establishment of the RRC is the identification and prioritisation of the road infrastructure research needs and the formulation of a Strategic Research Plan that will direct the operations of the RRC.

The implementation of a successful research plan will yield many benefits, which could include: a reduction in the life-cycle cost of infrastructure; improved delivery and better services, contributing to social wellbeing and economic growth; and supporting industries and regions to achieve their economic potential.

The purpose of this questionnaire is to identify the road infrastructure research needs for Mozambique. The feedback received on the questionnaire will be used as a point of departure for the prioritisation process, which ultimately will result in the development of the Strategic Research Plan that will be integrated in the Business Plan of the RRC.

Feedback on the questionnaire will be processed by a project team appointed by the Africa Community Access Programme (AFCAP), which is a research programme supported by the Department of International Development (DFID) of the Government of the United Kingdom and managed by Crown Agents Ltd on behalf of DFID. This project team, consisting of representatives from the CSIR and LNEC, has been appointed to support and provide assistance with the establishment of the RRC.

The consolidated results from the questionnaire will be presented and discussed at the first meeting of the Road Research Technical Committee (RRTC) in January 2014. The purpose of the RRTC is to provide advice to the Road Research Steering Committee (RRSC), to be established in January 2014, on the nature and scope of research projects and activities to be undertaken in the road infrastructure domain. Although the terms of reference of the RRTC still need to be agreed to by its members, the RRTC could be tasked with providing, inter alia:

- Advice on road infrastructure research needs and priorities;
- Assistance with technology foresight studies;
- Advice on the development of strategic plans and research portfolio plans for the research programme;
- Assistance with project portfolio analysis;
- Assistance with the review of research outcomes, and
- Assistance with the assessment of the impact of research outcomes.

1.2 Structure of the Questionnaire

The orientation and work of the RRTC will enable the RRSC to provide strategic oversight and steer research projects, programmes and activities that will:

- Address the road infrastructure needs of Mozambique;

- Promote sustainable development;
- Enhance socio-economic impact;
- Support asset preservation;
- Strengthen Mozambique's industry competitiveness;
- Support the interests of the road construction industry's stakeholders, and
- Position Mozambique to address current and future challenges in road provision and maintenance.

Given these considerations, the questionnaire has been structured in terms of the following six broad areas of research:

A: Infrastructure engineering;

B: Infrastructure delivery;

C: Environmental impact of roads and the preservation of natural resources;

D: Planning and operations;

E: Policy, economics and decision support, and

F: Resources which support the above.

Potential research topics are listed under each of the above headings in the questionnaire, but space has been provided to include additional research topics.

In the questionnaire, cells are provided to rate the importance of each topic. Each topic should be rated as follows:

- Insert 'A' for topics that are considered to be of High Priority: topics that are of critical importance and that should be undertaken as soon as possible
- Insert 'B' for topics that are considered to be of Medium Priority: topics that are still important but it not essential that they be undertaken immediately
- Insert 'C' for topics that are considered to be of Low Priority: they are of less immediate importance and could be placed 'on hold' for now
- Leave Blank (i.e. do not rate) if there is no interest in the topic.

1.3 Completion date

The questionnaire needs to be completed before Friday, 17 January 2014.

Responses should be emailed to:

Benoît Verhaeghe of the CSIR (bverhaeg@csir.co.za), and/or

Maria Lurdes Lantunes of LNEC (mlantunes@lnec.pt).

2. Details of Participant

The questionnaire responses received the participants will be kept confidential. Hence, it will be appreciated if each participant could at least provide information on the organisation they represent and their position within the organisation. This will enable the project team to group the responses in accordance with the sectors they represent (e.g. funding agencies, road authorities, consulting engineers, contractors, material suppliers, academic institutions, etc.).

Providing the name and the contact details of the participant is optional. However, by providing this information, the project team will be able to contact participants in case more clarity is needed, and it will also enable the participants to receive feedback on the outcomes of the questionnaire.

ORGANISATION: _____

POSITION IN ORGANISATION: _____

NAME AND SURNAME: _____

(Optional)

CONTACT TELEPHONE NO.: _____

(Optional)

EMAIL ADDRESS: _____

(Optional)

A. ROAD INFRASTRUCTURE ENGINEERING

A.1 Traffic & Operational Environment

A.1.1	Traffic Loading & Contact Stresses	Rating
A.1.1.1	Improved understanding of the effects of traffic loading on pavement performance: • Characterisation of distribution of axle load grouping and/or vehicle classes on the primary, secondary and tertiary road networks; • Updating of equivalent single axle loads (ESALs) per heavy vehicle factors for Mozambique	
A.1.1.2	Development of guidelines for the collection of traffic data	
A.1.1.3	Guidelines for estimating attracted and generated traffic resulting from new road construction and road upgrades	
A.1.1.4	Other (specify):	

A.1.2	Impact of Climate	Rating
A.1.2.1	Quantification of the influence of temperature and moisture variation on pavement performance, and development of design methodologies to mitigate their impact	
A.1.2.2	Impact of climate change (e.g. increased intensity of storms, effects of sea level rise on coastal roads) on the integrity and safety of road infrastructure and the development of adaptation strategies	
A.1.2.3	Other (specify):	

A.2 Geometric Design

		Rating
A.2.1	Geometric design guidelines for rural and urban roads, reflecting best international practice, adopted for the Mozambican environment	

A.2.2	Geometric design guidelines for unsurfaced roads and upgraded unsurfaced roads to sealed standards so as not to compromise driver safety	
A.2.3	Geometric design guidelines for unsurfaced roads and upgraded unsurfaced roads to sealed standards so as not to compromise driver safety	
A.2.4	Relationship between design speed, operating speed and road alignment for surfaced and unsurfaced roads	
A.2.5	Other (specify):	

A.3 Bound & Unbound Pavement Materials

A.3.1	**Mix Components & Characterisation thereof**	Rating
A.3.1.1	Test methods and criteria for the assessment of aggregate durability	
A.3.1.2	Identification of suitable and cost-effective binders and soil stabilizers, for use as cement and/or bitumen replacements	
A.3.1.3	Other (specify):	

A.3.2	**Thin Bituminous Surfacings**	Rating
A.3.2.1	Capturing of long-term performance data on roads with thin bituminous surfacings	
A.3.2.2	Appropriate standards for surfacings on low-volume roads taking cognisance of operating conditions, base types and drainage design	
A.3.2.3	Performance of thin bituminous surfacings using marginal aggregates	
A.3.2.4	Study into the causes and mechanisms of premature failure of thin wearing courses	
A.3.2.5	Other (specify):	

A.3.3	**Hot, Warm and Cold-Mix Asphalt**	Rating

A.3.3.1	Development of hot, warm and/or cold-mix asphalt design guidelines (including binder specifications) for Mozambique	
A.3.3.2	Development of specifications and quality control/assurance standards for hot, warm and/or cold-mix asphalt	
A.3.3.3	Other (specify):	

A.3.4	**Cement Concrete**	Rating
A.3.4.1	Performance-based concrete mix design system integrated with structural design and field quality control for pavements and/or structures	
A.3.4.2	Study into the use of: • low-cost reinforcement, • self-compacting concrete, • self-curing concrete, • one-pass paving, • (ultra) high-strength concrete (and others) to make concrete pavements and/or structures more economical to construct, to speed up the construction process to reducing traffic delays, and to provide safeguards to ensure that the pavement and/or structure will meet the design objectives without resulting in premature distress	
A.3.4.3	Other (specify):	

A.3.5	**Recycled Materials**	Rating
A.3.5.1	Development of codes of practice for cold in-place recycling with bitumen-emulsion, foamed-bitumen and/or cement	
A.3.5.2	Development of standard specifications for cold in-place recycling with bitumen-emulsion, foamed-bitumen and/or cement	
A.3.5.3	Other (specify):	

A.3.6	Lime & Cement Stabilised Materials	Rating
A.3.6.1	Development of best-practice guidelines on the beneficiation of sandy materials through the addition of cement stabilisers, and identification/specification of most appropriate cement types to suite local conditions	
A.3.6.2	Evaluation of the effects of high quality cements on the behaviour and long-term performance of cement-treated/stabilized materials	
A.3.6.3	Production of guidelines for the selection of the most appropriate modifier to treat high Plasticity Index (PI) materials	
A.3.6.4	Assess the effects of pre-cracking cement stabilised layers on pavement performance and life-expectancy	
A.3.6.5	Other (specify):	

A.3.7	Unbound Materials	Rating
A.3.7.1	Recommendations on modification/treatment options for marginal aggregate in order to render them suitable for road construction	
A.3.7.2	Assessment of the ability of the Dynamic Cone Penetrometer (DCP) method, and its correlation to triaxial testing, to predict shear responses in unbound granular layers	
A.3.7.3	Guidelines for characterisation of lateritic soils for use in road construction, taking into account the effect of water and drying processes on their behaviour	
A.3.7.4	Behavioural analysis of mixtures of soil and coal ash	
A.3.7.5	Development of procedures for assessing the permeability of sandy soils	
A.3.7.6	Other (specify):	

A.3.8	Gravel Wearing Courses (Unsurfaced Roads)	Rating
A.3.8.1	Improved deterioration models for gravel roads	

A.3.8.2	Review of specifications for gravel wearing courses	
A.3.8.3	Development of design models for the use of granular materials of varying quality in pavements	
A.3.8.4	Development of appropriate tests and criteria for assessing the durability of bituminous and pozzolanic treatments	
A.3.8.5	Development of appropriate tests and criteria for the certification of soil stabilizers used on gravel roads in terms of their fitness-for-purpose	
A.3.8.6	Mix design procedures for chemical, pozzolanic and bituminous treatments	
A.3.8.7	Cost-effective ways of upgrading gravel roads to low-volume surfaced roads	
A.3.8.8	Framework for the implementation of a Gravel Road Improvement Programme	
A.3.8.9	Other (specify):	

A.3.9	**Alternative Materials**	Rating
A.3.9.1	Identification of potential sources of alternative materials for use in roads	
A.3.9.2	Production of guidelines on, and appropriate specifications for, the use of alternative materials in road construction	
A.3.9.3	Other (specify):	

A.3.10	**Optimising the Use of Local Materials in Road Construction**	Rating
A.3.10.1	Development of a road material database	
A.3.10.2	Guidelines on the identification of aggregate sources and the assessment of their quality for use in road construction	
A.3.10.3	Optimisation in the use of locally-available materials (e.g. high PI materials and sands) by means of modification and/or stabilisation techniques	

A.3.10.4	Other (specify):	

A.4 Structural Design of Road Pavements

A.4.1	Structural Design & Performance	Rating
A.4.1.1	Establishment of criteria for assessment of pavement layers (earthworks, capping layer, subbase and base) from layer moduli determined through Light Falling Weight Deflectometer (LFWD) testing	
A.4.1.2	Development of a pavement performance database based on periodic road condition assessments as well as long-term pavement performance studies	
A.4.1.3	Development of Mozambican road pavement design and analysis methods for all categories of roads (primary to tertiary; urban and rural; paved and unpaved)	
A.4.1.4	Explore innovative concepts for incorporation of initial and life-cycle features in pavement design taking cognisance of constructability, durability and maintainability	
A.4.1.5	Other (specify):	

A.4.2	Innovation in Road Design & Structural Design of Pavements	Rating
A.4.2.1	Explore feasibility and viability of implementing long-life pavement ("perpetual" pavement) concepts in Mozambique: • Concept development and economic viability of long-life pavements; • Construction and material requirements for long-life pavements; • Guidelines for design, construction and maintenance of long-life pavements	
A.4.2.2	Implementation of long-term pavement performance (LTPP) studies to monitor long-term performance of road designs in order to provide data to feed into the improvement of design and construction concepts	
A.4.2.3	Other (specify):	

A.5 Road Furniture, Structures and Drainage

A.5.1	Road Furniture	Rating
A.5.1.1	Performance-based specifications and acceptance criteria for road markings	
A.5.1.2	Road signage asset management	
A.5.1.3	Guidelines for selection and installation of roadside safety equipment	
A.5.1.4	Other (specify):	

A.5.2	Structures	Rating
A.5.2.1	Development of durability index test methods and specifications for concrete bridges and other structures	
A.5.2.2	Characterization of time-dependent behaviour of concrete bridges	
A.5.2.3	Structural assessment of existing bridges	
A.5.2.4	Strengthening and retrofitting of bridges to upgrade their capacity	
A.5.2.5	Service life predictions	
A.5.2.6	Assessment of the penetration of chlorides and carbonates into the cover of concrete structures, and identification of preventative treatments/designs	
A.5.2.7	Prevention, diagnosis and mitigation of alkali-aggregate reaction (AAR) in concrete bridges	
A.5.2.8	Best practices on the use of fly-ash and slag in the marine environment	
A.5.2.9	Identification of Abnormal Load/Super Load Strategic Routes	
A.5.2.10	Other (specify):	

A.5.3	Innovative Approaches for the Preservation of Assets & Rapid Renewal	Rating

A.5.3.1	Design concepts using advanced composites, steel and hybrid materials in pavements and bridge structures	
A.5.3.2	Modern materials and composites to improve the service life of pavements and bridges with reduced maintenance	
A.5.3.3	Advanced coating materials and corrosion protection processes to increase the service life of road structures including steel and reinforced concrete structures	
A.5.3.4	Concrete durability test methods and specifications	
A.5.3.5	Modular bridge systems	
A.5.3.6	Other (specify):	

A.5.4	**Drainage**	Rating
A.5.4.1	Development/revision of the road drainage manual, including methodology and criteria for the design of various drainage structures	
A.5.4.2	Implementation of inspection procedures on road drainage structures	
A.5.4.3	Investigation of moisture conditions in pavements and drainage requirements to ensure stable moisture regimes within pavement structural layers and subgrades	
A.5.4.4	Other (specify):	

A.6 Management of Assets

A.6.1	**Asset Management**	Rating
A.6.1.1	Development and implementation of an integrated asset management system	
A.6.1.2	Recommendations for setting up asset inventories and registries, and for conducting asset valuations	
A.6.1.3	Guidelines for asset condition assessments of pavements, structures and drainage systems	

A.6.1.4	Geographic Information System (GIS) applications for the management of roads, structures and drainage systems	
A.6.1.5	Guidelines for situational analyses; need determination processes, and development of road asset management plans	
A.6.1.6	Methods for prioritising investments in road maintenance, rehabilitation and construction based on multi-criteria analysis	
A.6.1.7	Other (specify):	

A.6.2	**Vehicle Characterization & Vehicle Overloading**	Rating
A.6.2.1	Implementation of a national/provincial vehicle overloading control strategy	
A.6.2.2	Identification of (additional) sites for weigh bridges (regulatory) and control sites for Weigh-in-Motion	
A.6.2.3	Installation of vehicle count/classification instrumentation on critical routes	
A.6.2.4	Other (specify):	

A.7	**Advanced Research Topics**	Rating
A.7.1	Impact of riding quality (i.e. dynamic loading effects) on the structural and functional life of pavements	
A.7.2	Establishment of methodologies for use of Spectral Analysis of Surface Waves for the assessment of pavements structural behaviour (e.g., layer moduli, cracking)	
A.7.3	Other (specify):	

A.8	**General**	Rating

A.8.1	Standards and specifications: • Revision of national standard specifications and guidelines; • Rationalisation to one set of national standards; • Performance-based standards for the roads sector	
A.8.2	Other (specify):	

B. INFRASTRUCTURE DELIVERY

B.1 Construction & Maintenance

B.1.1	Labour-Intensive Construction	Rating
B.1.1.1	Study on labour-intensive construction to review the potential gains of a national labour-intensive road construction and maintenance programme	
B.1.1.2	Review applicability of current best practices on labour-intensive construction and maintenance for the different classes of roads, and assess their potential to create employment	
B.1.1.3	Labour-intensive methodologies for upgrading gravel roads to paved standards	
B.1.1.4	Incorporation of labour-intensive road construction and maintenance methods in codes of practice	
B.1.1.5	Innovative systems for involvement of local communities in the maintenance of low-volume rural roads	
B.1.1.6	Other (specify):	

B.1.2	Conventional Construction	Rating
B.1.2.1	Develop project evaluation procedures and techniques that ensure more equitable allocation of resources in accordance with community and user needs, while giving due consideration to social, environmental and quality-of-life issues	
B.1.2.2	Standardised procedures and specifications for in-situ recycling with cement, foamed-bitumen and/or bitumen-emulsions	
B.1.2.3	Best practice guidelines on the manufacturing, laying and compaction of hot, warm or cold asphalt	
B.1.2.4	Best practice guidelines for concrete pavement construction and equipment requirements for: • Concrete batching and mixing; • Concrete placement; • Concrete pavement curing, texturing and jointing	

B.1.2.5	Cost-effective maintenance methods for prolonging the functional service life of thin bituminous surfacings, focusing on aspects such as skid resistance, impermeability and flexibility	
B.1.2.6	Techniques to reduce the impact of pavement construction, rehabilitation and maintenance activities (e.g. noise, safety, environmental pollution, vibration, land property impacts, availability of the road, etc.) on road users and adjacent land use	
B.1.2.7	Geotechnical solutions for soil improvement and embankment construction	
B.1.2.8	Other (specify):	

B.1.3	**Contractor Development**	Rating
B.1.3.1	Development of guideline documents for the sustainable development of Small and Medium Enterprises (SMEs) through training, mentoring and incubation programmes	
B.1.3.2	Other (specify):	

B.1.4	**Maintenance**	Rating
B.1.4.1	Code of practice on maintenance	
B.1.4.2	Development of processes that ensure sustainable maintenance strategies for gravel roads and their upgrading to paved standards	
B.1.4.3	Advanced diagnostic technologies to enhance early detection of deterioration	
B.1.4.4	The role of periodic maintenance versus rehabilitation in terms of cost-effectiveness	
B.1.4.5	Time-cost implications of moving maintenance and rehabilitation actions to a date earlier/later than the planned date	
B.1.4.6	Other (specify):	

B.1.5	Quality Control & Assurance	Rating
B.1.5.1	Survey of factors and influencing issues that impact on quality in the road construction industry (e.g. which factors guarantee success or failure)	
B.1.5.2	Development of quality control software	
B.1.5.3	Improved test procedures for monitoring and controlling construction quality of road pavements, earthworks and structures	
B.1.5.4	Other (specify):	

B.1.6	Minimise Disruption	Rating
B.1.6.1	Ways to minimise disruption from road works on mobility and accessibility, including traffic management schemes	
B.1.6.2	Rapid repair technologies that reduce the time between repair and resumption of service	
B.1.6.3	High-speed pavement construction/rehabilitation technologies	
B.1.6.4	Improve customer (road user) relationships: • Guidelines for improving public involvement in renewal strategy selection and for improving business relationships during renewal projects; • Context-sensitive designs and construction operations to minimize impact on road users and adjacent land users; • Feasibility study into the establishment of customer call centres countrywide to receive and act upon any deficiencies in road service delivery	
B.1.6.5	Other (specify):	

B.2 Contracting Systems for Construction & Maintenance

B.2.1	Quality Assurance Systems	Rating
B.2.1.1	Development and implementation of minimum standards for quality systems to be adopted by contractors	

B.2.1.2	Other (specify):	

B.2.2	**End-Performance Systems & Guarantees**	Rating
B.2.2.1	Methodologies for quantifying, optimising and manage the risk profile of projects	
B.2.2.2	Innovative project management strategies for large, complex projects	
B.2.2.3	Development of performance-based routine road maintenance principles while also securing alignment with labour-intensive and community-driven maintenance operations	
B.2.2.4	Refinement of the concession model and optimisation of the role players' interests in order to obtain an equitable balance between product quality and service delivery on the one hand, and fair compensation and profit taking on the other hand	
B.2.2.5	Other (specify):	

B.3	**Safety of Road Workers**	Rating
B.3.1	Implementation of technologies/solutions to reduce road workers' exposure to hazardous conditions and to warn road workers of impending hazards	
B.3.2	Identify requirements that need to be incorporated into Health and Safety Plans prior to construction	
B.3.3	Other (specify):	

C. ENVIRONMENT

C.1	Environmental Impact of Roads	Rating
C.1.1	Development of a national strategy on sustainable construction	
C.1.2	Procedures for performing environmental impact assessments whenever improvements to roads are planned, and for the selection of the least intrusive measures	
C.1.3	Quantification of the cost of environmental impacts	
C.1.4	Investigation into means for reducing noise pollution in urban areas	

C.2	Preservation of Natural Resources	Rating
C.2.1	Forms of contract that encourage recycling and the use of recycled and/or alternative materials	
C.2.2	Cold in-place recycling of road construction materials	
C.2.3	Means by which non-renewable sources of road construction material (e.g. regravelling of gravel roads) can be protected	
C.2.4	Assess the potential for reusing waste materials in road construction	
C.2.5	Minimise the environmental impact of borrow pits	
C.2.6	Implement borrow pit management systems to optimise their use	
C.2.7	Identify ways by which local water resources and receiving environment can be protected against leaching of pollutants (e.g. oil and fuel)	
C.2.8	Other (specify):	

D. PLANNING & OPERATIONS

D.1 Land Use & Infrastructure Planning

		Rating
D.1.1	Land use/transport interaction modelling: • Review of alternative approaches and mechanisms for delivering integrated transport planning and land use; • Means by which land use developments can be monitored and controlled such that the road network is not unduly affected by unwelcome developments and in order to be able to plan timeously for possible upgrading or extensions to the network; • Tourism and events: Mapping of identified tourist routes and management thereof to ensure accessibility and safety	
D.1.2	Strategic operational management of urban road networks	
D.1.3	Integration of regional transport strategies with spatial planning policies	
D.1.4	Other (specify):	

D.2 Accessibility & Mobility

		Rating
D.2.1	Development of a road master plan that will provide all rural communities in Mozambique with decent access roads to reduce rural isolation by connecting people with services and by increasing mobility	
D.2.2	Identification of bottlenecks in transport networks that lead to traffic congestion, particularly in large metropolitan areas, and the development of a plan of action	
D.2.3	The management of the transportation of Abnormal Loads	
D.2.4	Identification of Strategic Routes and the management thereof	
D.2.5	Impacts of planning policy on congestion reduction	
D.2.6	Other (specify):	

D.3	Road User Information Systems	Rating
D.3.1	Implementation of warning systems for hazardous conditions affecting road users	
D.3.2	Other (specify):	

D.4	Road Infrastructure Safety Management	Rating
D.4.1	Implementation of a safety information system for the main road network, centred in a road accident data base, including traffic and road data	
D.4.2	Guidelines and best practice manuals for application of safety management procedures to every phase of the road life-cycle (e. g. safety audits, safety inspections and management of high-risk road sections)	
D.4.3	Implementation of monitoring and evaluation procedures on the results of safety measures applied to the road infrastructure	
D.4.4	Other (specify):	

E. POLICY, ECONOMICS & DECISION SUPPORT

E.1	Funding & Transport Economics	Rating
E.1.1	Assessment of: • The relationship between transport infrastructure investment and productivity; • The relationship between transport costs and international trade; • The role of transport on the competitiveness of cities and regions, including mining and tourism	
E.1.2	Development of models for vehicle operating costs in relationship to the quality of the assets	
E.1.3	Development of guidelines, methods and tools for assessing impacts of road investment and for prioritising investments	
E.1.4	Review of the toll road strategy taking cognisance of the current toll road strategy, policies on toll levies and impact on the economy and lower-income groups	
E.1.5	Road-needs study to assess the current backlog with respect to road provision and maintenance needs based on uniform data and protocols	
E.1.6	Other (specify):	

E.2	Performance Measures	Rating
E.2.1	Development of strategic performance indicators and assessment of road sector performance against the indicators	
E.2.2	Extend performance indicators to enable international benchmarking	
E.2.3	Other (specify):	

F. RESOURCES

F.1 Human Capital		Rating
F.1.1	Perform a skills audit to review the current skills base, the identification of capacity gaps and the formulation of plans of action to address these gaps. Formulate, develop and implement a strategy to: • Attract, develop and retain young scientists and engineers; • Provide science, engineering and technology education at all levels; • Build centres of excellence (e.g. at RRC and universities); • Establish virtual networks of excellence; • Foster greater public-private partnerships; • Create and maintain digital libraries; • Build regional and international networks of collaboration.	
F.1.2	Other (specify):	

F.2 Management of Knowledge & Information		Rating
F.2.1	Development/revision of national codes of practice, standards and specifications	
F.2.2	Efficient management of national codes of practice, standards and specifications, including their implementation in practice	
F.2.3	Other (specify):	

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