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Hosted by Mozambique
National Road Administration

2nd AFCAP Practitioner's Conference
Maputo, Mozambique - 3rd to 5th July 2012

Africa's pre-eminent conference for rural transport professionals

VIP Grand Hotel

v1.0 22/06/12

AFCAP PRACTITIONERS CONFERENCE

Maputo 3rd to 5th July 2012

"Research and Innovation for Rural Mobility and Access"

Monday 2 July			
		Travel to the venue	
	17:00 – 18:00	Registration of Participants	
	18:00 – 20:00	**Meet and Greet**	

Tuesday 3 July		**DAY 1**	
	07:45 – 08:45	Registration of Participants	
1	09:00 - 09:20	Welcoming Address.	Host
2	09:20 – 09:30	Conference Objectives	Facilitator
3	09:30 – 09:50	Keynote Address	Camilla Lema - The World Bank/ SSATP
4a	09:50 - 10:15	AFCAP Headline Achievements	AFCAP CMG
4b	10:15 – 10:30	Update on Mozambique AFCAP activities	ANE
5	**10:30 – 11:00**	**Coffee/Tea**	
6	**Asset Management for Rural Roads**		
6.1	11:00 – 11:20	Starting From Scratch - Tertiary Road Maintenance	Steve Newport
6.2	11:20 – 11:40	Road Maintenance Management In Inhambane Province Mozambique	Kingstone Gongera
6.3	11:40 – 12:00	Private sector engagement in rural roads maintenance activities: a successful PPP experience in Cameroon	Guy Kemtsop
6.4	12:00 - 12:20	URRAP Implementation (Ethiopia)	Yetimgeta Asrat
6.4	12:20 – 13:00	Discussion	Facilitator
7	**13:00 – 14:00**	**Lunch**	
8	**Materials for Rural Roads**		
8.1	14:00 – 14:20	Spiral Wound U-PVC Pipe Culvert Trials in Uganda	Ted Bishop
8.2	14:20 - 14:40	Thermoplastic composites as a degradation-resistant material used for bridge construction and the use of recycled materials in pavement construction	Jim Bremner and John Bowker
8.3	14:40 – 15:00	Eco-Road Building for Emerging Economies: An Initial Scan for Promising Alternative Technologies	Rob Petts
8.4	15:00 – 15:30	Discussion	Facilitator
9	**15:30 – 16:00**	**Coffee/Tea**	
10	**Materials for Rural Roads**		
10.1	16:00 – 16:20	Comparison of Test Methods and Implications on Materials Selection for Road Construction	Mike Pinard
10.2	16:20 – 16:40	Research on characterization techniques of (sub) tropical road materials for rural access roads (repeated load CBR testing)	Alemgena A. Araya
10.3	16:40 - 17:00	Design, Construction and Monitoring of Demonstration Sites at Bagamayo District for District Road Improvement in Tanzania	James Mitchell and Robert Ayieko
10.4	17:00 – 17:40	Discussion	Facilitator

Wednesday 4 July		DAY 2	
11	**Beyond Roads**		
11.1	08.30 – 08.50	Developing indicators to assess rural transport services	Paul Starkey
11.2	08.50 – 09.10	Innovations in vehicle management platform	Daniel O'Farrell
11.3	09.10 – 09.30	Leapfrogging from Rural Hubs to New Markets	Mwehe Mathenge
11.4	09.30 – 09.40	Bicycles: an answer to mobility needs of rural children?	Regina Amoako-Sakyi and Samuel Owusu
11.5	09.40 – 10.30	**Discussion**	
12	**10:30 – 11:00**	**Coffee/Tea**	
11.6	11:00 – 11:15	Follow Up Social and Economic Impact Assessment of the Zambézia Feeder Roads Project	Gaye Thompson and Cecilia Pedro
13	**Field Exercises in parallel groups:** **Group 1:** Developing a Transport Services Indicator. **Group 2:** Developing a Transport Services Indicator. **Group 3:** The DCP Design Method for Low Volume Sealed Roads. **Group 4:** Axle Load Surveys and the determination of Average Equivalency Factors for different vehicle types. **Group 5:** Field Density Determination. **Group 6:** Road Condition Monitoring using the GPS Method.		 Paul Starkey Shedrack Willilo Mike Pinard Tony Greening Andrew Otto Dave Geilinger
13.1	11:15 - 11:40	Instructions to groups	
13.2	11:40 – 13:00	Travel to field and data collection	
14	**13:00 – 13:30**	**Packed Lunches**	
15	**Field Exercises**		
15.1	13:30 – 16:00	Data collection and return to venue	
16	**16:00 – 16:30**	**Coffee/Tea**	
17	**Data Analysis**		
17.1	16:30 – 18:00	Analysis of field data in groups	
18	**19:00 – 22:00**	**Social/cultural event**	All Delegates

Thursday 5 July		DAY 3	
20	**Meeting Community Needs**		
20.1	08:30 – 08:50	The N14 and N10 corridors along the Orange River in Siyanda District Municipalities, Northern Cape	Imelda Julies, Petronella Theron and Tiago Massingue
20.2	08:50 – 09:10	Training programme for Low-Cost Sealing of Low Volume Roads in Uganda by the Mount Elgon Labour-based Training Centre	Henry Komakech
20.3	09:10 – 09:30	Training Programme for Improved Performance of Surface Treatments in Ethiopia	Tom Falconer
20.4	09:30 - 09:50	PRRINN-MNCH experience on emergency transport scheme for maternal and child care emergencies	Fatima Adamu
20.5	09:50 – 10:20	Discussion	
21	**10:20 – 10:50**	**Coffee/Tea**	
22	**Group report back**		
22.1	10:50 - 12:00	Field group report back	
22.2	12:00 – 12:30	Discussion	
22.3	12:30 – 13:00	Developing a Regional Research Capacity for the Rural Transport Sector: Plenary Discussion	Facilitator
23	**13:00 – 14:00**	**Lunch**	
24	14:00 – 15.30	Conference wrap up - Summary of main issues arising and resolutions	Facilitator
25	15.30 – 15.45	Closing address	ANE
26		**Departure of Participants/Time at Leisure**	

AFCAP

2nd AFCAP Practitioners Conference, VIP Hotel, Maputo, Mozambique, 3-5 July 2012

AFCAP Core Management Team	
Paul Segal - Programme Manager	paul.segal@crownagents.co.uk
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Attendance Register

Reg No.	Title	Name Tag	Organisation
2	Mr	Mac Mashiri, South Africa	Freelance
3	Mr	Yetimgeta Maru, Ethiopia	
4	Mr	Dawit Fanta, Ethiopia	Freelance
5	Dr	Taye Berhanu, Ethiopia	
6	Mr	Assefa Addisu, Ethiopia	Freelance
7	Dr	Alemgena Araya, Ethiopia	Ethiopian Roads Authority
8	Mr	Rashid Abdulwahid, Ethiopia	Ethiopian Road Fund
9	Eng	Erastus Kariuki, Kenya	Kenya Rural Road Authority
10	Mr	Hillary Akwiri, Kenya	Kenya Rural Road Authority
11	Mr	Jackson Magondu, Kenya	Kenya Rural Road Authority
13	Mrs	Regina Amoako-Sakyi, Ghana	University of Cape Coast, Ghana
14	Mr	Meleck Silaa, Tanzania	Siha District Council, Tanzania
15	Mr	Abdul Awadh, Tanzania	

Reg No.	Title	Name Tag	Organisation
16	Mr	Kingstone Gongera, Zimbabwe	
18	Mr	Guy Kemtsop, Cameroon	IFRTD
19	Mr	Francisco Manheche, Mozambique	A.N.E.
20	Mr	Rob Petts, UK	Intech Consultants
21	Eng	John Nganga, Kenya	
22	Mr	Nelson Nyamao, Kenya	
24	Mr	Samson Kalesi, Tanzania	Bagamoyo District Council
25	Mr	Hailu Kitessa, Ethiopia	HZS Consulting Engineers Plc
26	Mr	Edward O' Connor, Ireland	Transaid
27	Mr	Romanus Otieno, Kenya	
28	Dr	Manuel Guerrero, USA	
29	Eng	Stephen Ajalu, Uganda	Danida
31	Mr	Per Christiansen, Denmark	
32	Mr	Henry Komakech, Uganda	Mt Elgon Labour Based Training Centre, Mbale
37	Mr	Mike Pinard, Botswana	InfraAfrica Consultants
38	Dr	Simon Gillett, UK	Roughton International
39	Mr	Robert Kuchioh, Kenya	Roughton International
40	Mr	James Mitchell, UK	Roughton International
41	Mr	Thomas Falconer, UK	Roughton International
42	Mr	Alemayehu Endale, Ethiopia	Ethiopian Roads Authority
44	Mr	Frew Bekele, Ethiopia	Ethiopian Roads Authority
45	Major	Jim Bremner, UK	Ministry of Defence, Royal Engineers
46	Captain	John Bowker, UK	Ministry of Defence, Royal Engineers
47	Mr	Paul Starkey, UK	Freelance

Reg No.	Title	Name Tag	Organisation
48	Mr	Jan Bijl, The Netherlands	Orion Consulting Associates
50	Mr	Ted Bishop, UK	COWI Ltd
51	Mr	Amare Asres, Ethiopia	
52	Mr	Bekele Kebede, Ethiopia	Ethiopian Roads Authority (ERA)
53	Mr	Emmanuel Wansibho, Tanzania	Appropriate Technology Training Institute (ATTI), Ministry of Works
54	Mr	Al Soko, South Africa	Department of Transport, Eastern Cape
55	Mr	Robin Workman, UK	TRL Ltd.
57	Mr	Joey Macmillan, Malawi	Malawi Roads Authority
58	Mr	Jonas Mugabe, Rwanda	Forum for Agricultural Research in Africa (FARA)
60	Mr	Aluko Oluwasegun, Nigeria	Institute for Transport Studies
61	Ms	Nite Tanzarn, Uganda	
63	Eng Dr	Anania Mbabazi, Uganda	Uganda Association of Consulting Engineers (UACE)
64	Mr	Joanes Atela, Unknown	School of Earth and Environment, University of Leeds
65	Mr	Charles Mtawali, Malawi	Roads Authority Malawi
66	Mr	Protasio Chipulu, Zambia	Ministry of Local Government & Housing
67	Mr	Edwin Matanga, Malawi	Roads Department, Malawi
68	Mr	Sangwani Gondwe, Malawi	Roads Fund Administration
69	Mr	Kelvin Mphonda, Malawi	Roads Department, Malawi
70	Mr	Benjamin Kapoteza, Malawi	Roads Authority Malawi
71	Dr	Fatima Adamu, Nigeria	PRRRINN-MNCH & Department of Sociology, Usmanyu Danfodiyo University
72	Mr	Ibrahim Ahmad, Nigeria	National Union of Road Transport Workers
73	Mr	Tete Tanko, Nigeria	Rural Access and Mobility Project, Ministry of Works & Transport

Reg No.	Title	Name Tag	Organisation
74	Mr	Benjamin Olobo, Uganda	Uganda National Roads Authority
75	Mr	Lucas Mwaisaka, Tanzania	Regional Secretariat, Regional Commissioner's Office
76	Mr	David Luyimbazi, Uganda	Uganda National Roads Authority
77	Mr	Joseph Haule, Tanzania	Road Fund Board
78	Mrs	Elina Kayanda, Tanzania	Prime Minister's Office, Ragional Administration and Local Government
79	Mr	Ronald Lwakatare, Tanzania	Roads Fund Board, Tanzania
80	Mr	Pempho Mwinjilo, Malawi	Ministry of Finance and Development Planning
82	Mr	Mwehe Mathenge, Kenya	Maseno University
83	Mr	Bill McMahon, UK	TRL Ltd.
84	Mr	Stephen Newport, UK	IMC Worldwide
85	Mr	Akram Ahmedi, UK	TRL Ltd.
87	Mr	Tony Greening, UK	
88	Mr	Asfaw Kidanu, Ethiopia	International Labour Organisation
89	Miss	Christine Nzai, Kenya	
90	Mr	Peter Makau, Kenya	
91	Mr	John Hine, UK	IT Transport
92	Mr	Hillary Cherop, Kenya	
94	Mr	Malijani Lungu, Zambia	Eastconsult Ltd
96	Mr	Shadrack Wililo, Tanzania	STET International
100	Mr	David Geilinger, Mozambique	
102	Ms	Petronella Theron, South Africa	South African National Roads Agency Limited
103	Mr	Tiago Massingue, Mozambique	South African National Roads Agency Limited
104	Mrs	Imelda Julies, South Africa	South African National Roads Agency Limited

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106	Eng	Salehe Juma, Tanzania	
107	Mrs	Liz Jones, UK	DFID
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109	Eng	Joseph Kimata, Kenya	Kenya Rural Road Authority
110	Ms	Camilla Lema, SSATP	Sub-Saharan Africa Transport Policy Program (SSATP), World Bank
111	Mr	Andrew Otto, Uganda	TRL Ltd.
113	Mr	Jeph Chagunda, Malawi	Pamodzi Consulting Engineers
114	Mr	Les Sampson, South Africa	Sampson Consulting cc
115	Ms	Pat Bosman, South Africa	Executive Focus cc
116	Mr	Paul Segal, UK	Crown Agents
117	Mr	Danny O'Farrell, Kenya	Riders for Health
119	Mr	Ernesto Correia, Mozambique	ANE
120	Mr	Belarmino Nota, Mozambique	ANE
121	Mr	Carlos Braz, Mozambique	ANE
122	Mr	Fernando Dabo, Mozambique	ANE
123	Mr	Silvestre Elias, Mozambique	ANE
124	Mr	Orestes Zezela, Mozambique	ANE
125	Mr	Palmiro Mavila, Mozambique	ANE
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132	Mr	Elcídio Parruque, Mozambique	ANE
133	Mr	Adamo Ali, Mozambique	ANE
134	Mr	Freitas Muyayane, Mozambique	ANE
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145	Mr	Marco Vaz, Mozambique	ANE
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148	Mrs	Aurora Mussa, Mozambique	ANE
149	Mr	Nacir Amir, Mozambique	ANE
150	Mr	Luís Alfinete, Mozambique	ANE
151	Mr	César Macuacua, Mozambique	ANE
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154	Mrs	Joana Guiuele, Mozambique	ANE
155	Mrs	Avelino Machava, Mozambique	ANE
156	Mrs	Manuel Cossa, Mozambique	ANE

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161		Romeu Rodrigues, Mozambique	Federação Moçambicana, De Empreiteiros
162		Justino Chemane, Mozambique	Federação Moçambicana, De Empreiteiros
163		Agostinho Vuma, Mozambique	Federação Moçambicana, De Empreiteiros
164		Carlos Cumbane, Mozambique	Laboratório De Engenharia De Moçambique
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169	Mrs	Maria Vicente, Mozambique	Administração Do Distrito
170	Mr	Augusto Fernando, Mozambique	Ordem dos Engenheiros de Moçambique
171	Mr	Marcelino Zango, Mozambique	Cotop
173	Mr	Harold Bofinger, UK	Roughton International
174	Mr	Dave Jennings, UK	IT Transport
175	Mrs	Rehema Myeya, Tanzania	Ministry of Works
176	Mr	Philip Waiwai, South Sudan	Ministry of Roads and Bridges, South Sudan
177	Mr	Jeremiah Bairiak, South Sudan	Ministry of Roads and Bridges, South Sudan
178	Mr	Michael Austin, Mozambique	Stange Consult
179	Mrs	Helena Cardoso, Mozambique	DHV
180	Mr	Dinis Juizo, Mozambique	Universidade Eduardo Mondlane
181	Mr	Carlos Quadros, Mozambique	Tecnica

AFCAP

Africa Community Access Programme

THE IMPORTANCE OF ACCESS

Reliable access is essential for rural communities in Africa. Access is required to reach basic services and all kinds of economic and social opportunities. Unreliable and difficult access reduces growth opportunities and negates the benefits from investments in other sectors designed to improve the livelihoods of poor communities.

WHAT IS AFCAP?

The Africa Community Access Programme (AFCAP) is addressing the challenges of providing reliable access for poor communities. AFCAP provides advice and undertakes research to facilitate the delivery of safe and sustainable access.

AFCAP is based around a portfolio of research, demonstration, advisory and training projects, which identify and support the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The outputs from these projects feed directly into regional and national rural transport policies and strategies for poverty reduction.

The Department for International Development (DFID) is supporting AFCAP through the provision of the AFCAP Core Management Group (CMG), operated by Crown Agents, as well as with funding for projects. The projects are also being supported by the participating governments and other development partners.

BUILDING ON EXISTING INSTITUTIONS

AFCAP started in 2008; however it is not a new institution and works with existing organisations and programmes funded by a range of development partners. AFCAP supports innovative field research and puts this knowledge into practical use and aims to achieve knowledge dissemination through the establishment of a Community of Practice.

WHO ARE BENEFITING FROM AFCAP?

The main beneficiaries are rural communities in Africa. They benefit from improved access to investments in other sectors; better access to health and education services, improved road safety and greater gender equality in how the transport sector operates. At the national level, Ethiopia, Kenya, Malawi, Mozambique, South Sudan and Tanzania are directly participating in AFCAP and implementing research and knowledge dissemination activities as well as the support of regional economic organisations in Africa.

AFCAP Community of Practice (CoP)

The CoP is an informal network of professional, policy makers and interested individuals who share a common interest, knowledge and experience in the provision of community access. This informal network will enhance communication between the members and will facilitate dialogue around key issues.

AIM:

The CoP is to connect practitioners, policy-makers, researchers and interested individuals around the issue of community access in rural Africa.

OBJECTIVE:

The CoP is to share experiences amongst those interested in community access, enhancing the professional ethic, raising the profile of community access as a key sector in national economies, and promoting enquiry and research in this area.

CORE MANAGEMENT GROUP

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This programme has been funded by UKaid from the Department for International Development.
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MANAGEMENT OF GRAVEL FEEDER ROADS IN INHAMBANE PROVINCE: MOZAMBIQUE

Author

Kingstone S Gongera

Maxixe,
Inhambane
Mozambique

Abstract

This paper describes a simplified road maintenance system that is based on the use of an agricultural tractor and labour as the main inputs. It provides an option into the management of feeder roads in developing countries and offers management possibilities to address different problems encountered in the maintenance of gravel feeder roads. The paper also identifies some of the challenges encountered by the small contractors during the execution of work.

1. INTRODUCTION

This presentation paper describes the implementation of a road maintenance approach used in Mozambique to maintain unpaved feeder roads in Inhambane province. Similar initiatives have been initiated in Sofala, Zambezia and Manica provinces of Mozambique. The system uses small scale contractors to execute road maintenance work. The maintenance system is based on management of small units equipped with all of the necessary resources for maintenance. Regular planned cyclic activities make it easy for supervision. A consultant supervises personnel from the contractor and from the client. On-the-job training for contractor and client personnel is provided by the consultant. The paper aims to share experiences in Mozambique and highlight some of the practical solutions to managing gravel roads.

2. LOCATION

Inhambane Province is located in the southern half of Mozambique Covering an area 68 615sq km. It borders to the north the Save River, separating it from Sofala and Manica Provinces to the west, Changane River separating it from Gaza Province and to the east is the Indian Ocean extending for 700km along the coast.

2.1 Climate

The Province has two distinct climatic zones: the eastern coastal region experiences a tropical humid climate and in the western inland region precipitation decreases progressively moving inland and the climate becomes semi-arid. The annual rainfall lies between 800 to 1000mm along the coastal region, while in the interior it varies between 600 to 800mm. This variation in rainfall has a direct impact on road condition and maintenance intervention needs.

2.2 Relief

The entire province presents a fairly flat and slightly undulating landscape with many hydromorphic depressions associated with the lagoons and rivers. Altitude barely exceeds 150m above mean sea level apart from the Urrongas plateau in the northern part of the province where altitude does not exceed 200m above mean sea level.

2.3 Soil Type

Soils in Inhambane Province are mainly the yellow/brown sands and calcaric brown loamy sands. Red clayey soils are also found along the plateau. The province has a variation of sand dunes, wetland and flood plains. The underlying calcareous formations close to the surface mainly in the central part of the Province provide the much needed calcrete which is being used as wearing coarse gravel.

3.0 PROJECT HISTORY

The project involves the rehabilitation of 276km of tertiary and vicinal roads (feeder) and to develop and install a maintenance system that will preserve the investment. Stange-Consult was commissioned by the KfW (a German development Bank) to supervise the implementation of the construction and maintenance of these roads.

Fig 1: Map showing implementation of ABMS in Inhambane province, 2011

Table (1): Core Roads selected for Rehabilitation in 2005

ORIGINAL CLASSIFICATION		RECLASSIFICATION		ROUTE	LENGTH (KM)
NUMBER	TYPE	NUMBER	TYPE		
EN209	Secondary	R483	Tertiary	Inharrime-Panda	58.5
EN210(a)	Secondary	R482	Tertiary	Maxixe-Homoine	20.8
EN210(b)	Secondary	R482	Tertiary	Homoine-Panda	48.7
EN257	Secondary	R918	Tertiary	Lindela-Homoine	16.8
ER413/ EV Mocumbi	Tertiary /unclassified	R480 R920	Tertiary Vicinal	Inharrime-Mocumbi Mocumbi jct-Coguno	65.1
ER416(a)	Tertiary	R481	Tertiary	Maxixe-Mocodene	22.8
ER418	Tertiary	R485	Tertiary	Homoine-Pembe	25.4
ER419	Tertiary	R911	Vicinal	Homoine-Pembe	19.6
TOTAL					**277.7**

3.1 Materials

Existing roads in Inhambane were constructed generally using red sandy materials with a very high plasticity index (up to 10). These roads deteriorate rapidly once the red soils mix with the sandy non plastic material. The bearing capacity of these soils is very poor.

A number of borrow pits were identified and sampled. Below is a laboratory analysis of the materials used in this project:

Table (2): Summary for calcrete borrow pits (bppts) used

SUMMARY FOR CALCRETE BORROW PITS (BPPTS) USED: ENGINEERING PROPERTIES												
	NATURAL						**BLENDED 50/50**					
BPPTS	LL	PI	GM	MDD	OMC	CBR@ 95%MDD	LL	PI	GM	MDD	OMC	CBR
MAIONE	98	28	2.2	1320	34	20	35	17	1.6	1700	11	24
MUBIQUE	24	15	1.5	1470	15	15	16	8	1.5	1720	13.2	44
MANHAUSS ANE	41	18	1.7	1505	20	20	22	9	1.3	1682	10	35
DOMO DOMO	52	21	1.4	1450	29.6	29.6	28	12	1.6	1660	11	17
MAVUME	34	15	2.4	1478	22.8	22.8	NP	NP	2	1690	10.9	62
INHASSUNE	80	43	2.3	1690	24	24	30	15	1.8	1950	12	40

Table (3): Sieve Analysis

	% PASSING SIEVE SIZE								Shrinkage Product	Grading Coefficient
	37.5	**26.5**	**19**	**13.2**	**4.75**	**2**	**0.425**	**0.075**	**100-360**	**16-34**
MAIONE NATURAL	100	99	96	93	83	47	46	18	138	18.3
MAIONE BLENDED	**100**	**97**	**91**	**83**	**56**	**42**	**23**	**12**	**278**	**31**
DOMO DOMO NATURAL	100	97	94	91	84	70	50	11	200	18
DOMO DOMO BLENDED	**100**	**96**	**88**	**83**	**71**	**66**	**58**	**34**	**580**	**21**
INHASSUME NATURAL	100	94	82	67	42	36	24	11	244	24
INHASSUME BLENDED	**100**	**95**	**90**	**86**	**75**	**71**	**44**	**9**	**114**	**18**
MAVHUME NATURAL	100	79	59	50	39	35	23	7	112	17.2
MAVHUME BLENDED	**100**	**89**	**80**	**77**	**71**	**68**	**27**	**4**	**47**	**14.9**
MUBIQUE NATURAL	100	98	93	90	80	78	49	28	162	20
MUBIQUE BLENDED	**100**	**98**	**96**	**93**	**86**	**84**	**46**	**14**	**32**	**12**
MANHAUSSANE NATURAL	100	97	93	89	70	59	48	21	230	26.6
MANHAUSSANE BLENDED	**100**	**98**	**97**	**95**	**86**	**80**	**70**	**16**	**119**	**15.5**

COMMENTS

1. INHASSUME BORROW PIT was used on Inharrime Panda road R483. The pit is located in a low lying flat land area. In its natural state the pit has a high plasticity index but was significantly reduced by blending the calcrete with non plastic sand and it produced a good wearing course.
2. MAIONE BORROW PIT is located in a low lying vlei and the calcrete in its natural form is powder like with few solid pebbles. This pit was rejected due to high plasticity even after blending with non plastic sand.
3. MOBIQUE BORROW PIT Was used on Panda Homoine Road R482. The pit is located along an inland lake. The material has a low plasticity index and high binding properties. After a year the material is performing well as a wearing course.

4. DOMO DOMO BORROW PIT was used on Maxixe Mocoudene. The pit is located on a river bank and it is a mixture of calcrete and mudstone. When it is dry it appears good but it loses cohesion when wet and the bearing capacity drops with increased moisture. The material is slippery when wet. However after continuous grading and mixing with natural sands it is binding and stabilising.

3.2 Inhambane Project

As shown above the roads on this project have been built using calcrete-sand mixtures. The deposits of calcrete being used comprise hard material surrounded by clayey soils. The calcrete is firstly screened after crushing. The crushed calcrete has PI ranges shown in table above. This calcrete is then blended with none plastic sands using varying proportions of 40: 60 and 50: 50 depending on the characteristic of the materials. Several experimental proportions have to be tried to achieve the desired outcome. Due to this variety of material the contractor constructed trial sections for the laboratory to carry out required tests (CBR, PI and Compaction). After the laboratory tests specific mixture rates were determined for specific sections of the road. The laboratory continued to monitor the quality of work and the compaction densities. The completed roads were then put out to tender for contractors to carry out maintenance work.

4.0 AREA BASED MAINTENANCE SYSTEM

This system was first developed in Zimbabwe and adapted and continued in Mozambique in Sofala, Manica and Zambezia Provinces. The rationale behind the system is that the road to be maintained has to be properly constructed and completed with all necessary drainage structures in place (i.e. it must be 'maintainable'). When the road is complete, then preserving the capital investment is justified through routine maintenance. The Area based maintenance system, as the name describes, is based on parcelling sections of the road network into manageable units of between 150 -200km. These sections are then managed from a base camp with a dedicated contractor to look after these roads, a budget for each road and specified equipment for the contractor.

The equipment required by each contractor is listed below:

- 1 X 80 Hp tractor
- 1 x 4ton towed grader
- 1 x water bowser
- Tyre drags one every 20km
- 1 x 4 wheel tractor drawn trailer
- Hand tools

5.0 PLANNING AND PROGRAMMING OF WORKS

Maintenance work on these roads can be split into labour intensive activities and equipment intensive activities. The table below provides the planning guidelines for the various activities.

Table (4) Planning Guideline for ABMS Activities

JAN-APRIL Cope with the rains and prepare roads for the dry season	**MAY-SEPT** Cope with the dry season and prepare drainage before the next rainy season	**OCT-DEC** Cope with the rains and reshape roads during the initial weeks of the wet spell
PLANNED EXPENDITURE**: 40%**	PLANNED EXPENDITURE**: 20%**	PLANNED EXPENDITURE**: 40%**
Main Activities	**Main Activities**	**Main Activities**
Grass cutting	Pot hole filling	Pot hole filling
Pot hole filling	Stock piling calcrete for patching	Opening mitre drains
erosion repairs	Painting of road signs	Erosion repairs
Opening of mitres	Repair of broken culverts	Cleaning of culverts
Cleaning of culverts	Sign maintenance	Bridge inspection
Towed grading	Tyre dragging	Towed grading

The planning calendar provides a general guide as to when each activity is supposed to be carried out and the frequency of maintenance. The planning guide is closely linked to the availability of resources and it helps in monitoring both the progress and expenditure. At a glance on the reports at the end of the month or quarter, one can deduce where shortfalls are. If the expenditure is low it is an indicator that some of the planned activities have not been done and equally if the expenditure is too high then it is also an indicator that the work programmes are not being followed or respected. The consultant monitors the performance of the contractors and provides training both in the field and in the formal 'classroom' based sessions.

The wet season in Inhambane stretches from October/ November to April/May and during this period the road surface is repaired and the profile restored. From the month of June to August the maintenance emphasis shifts to sign maintenance, repair of damaged culverts and preparing calcrete for the wet season. The road pavement is too dry for grading, but tyre dragging is effective in reducing the formation of corrugations. Repair of potholes is also done during this period to ensure safety to the road user and to minimise deterioration of the pavement. The table below shows the expenditure and progress during the first three months of the year.

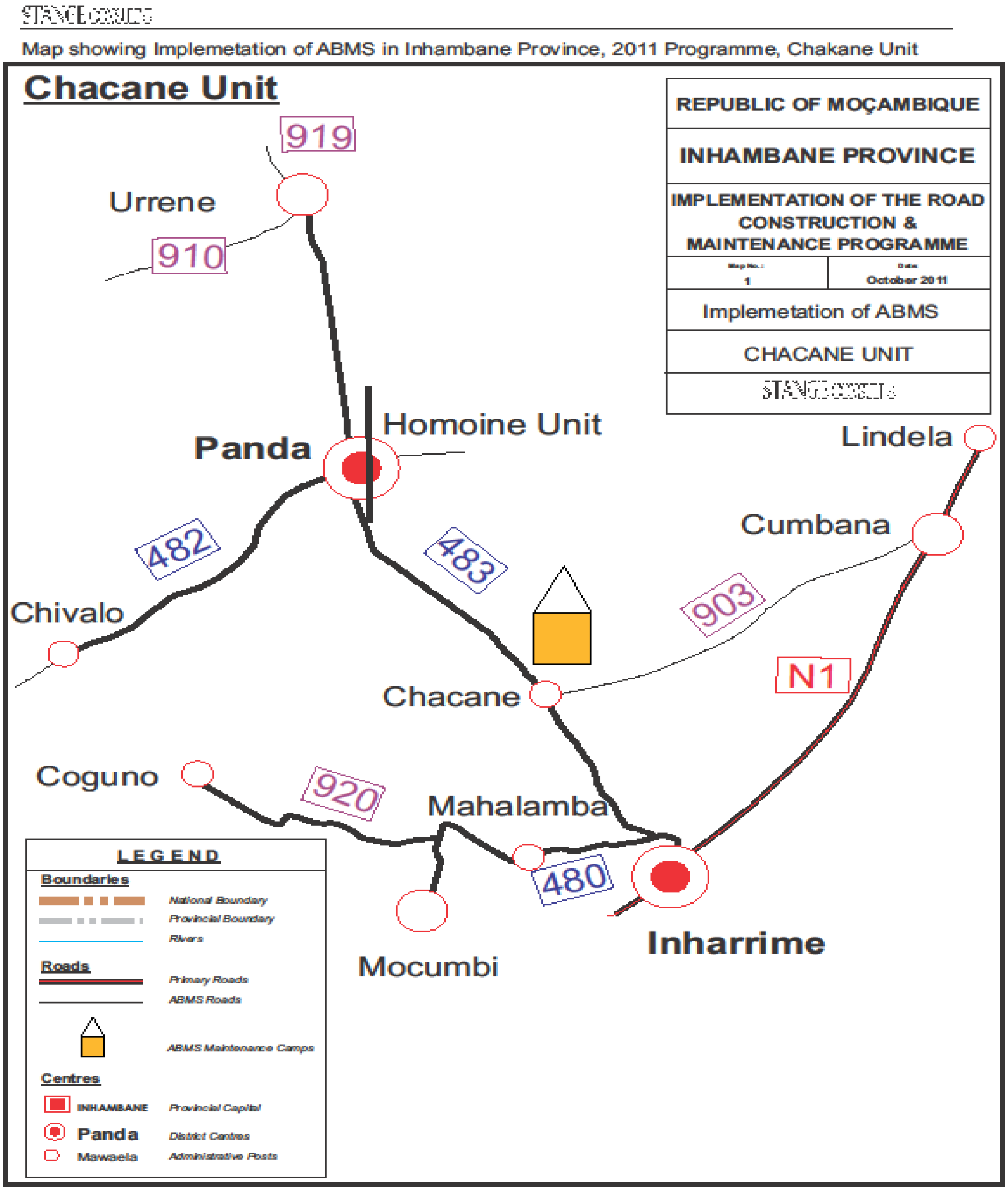


Fig 2: Map showing implementation of ABMS in Inhambane province, Chakane

As shown above, the unit maintenance camp is at Chacane, which is central to the road network managed from this camp. The unit personnel start maintenance operations from the camp and work southwards to Inharrime which is 25km from camp. This distance is achievable and economic enough to travel to and from in a day. Equally travelling north towards Panda and Chivalo, the distance is manageable so the contractor does not spend too much time travelling before getting to the worksite. Road maintenance units have dedicated equipment specifically meant for the roads under the maintenance unit. This makes maintenance intervention timely and effective.

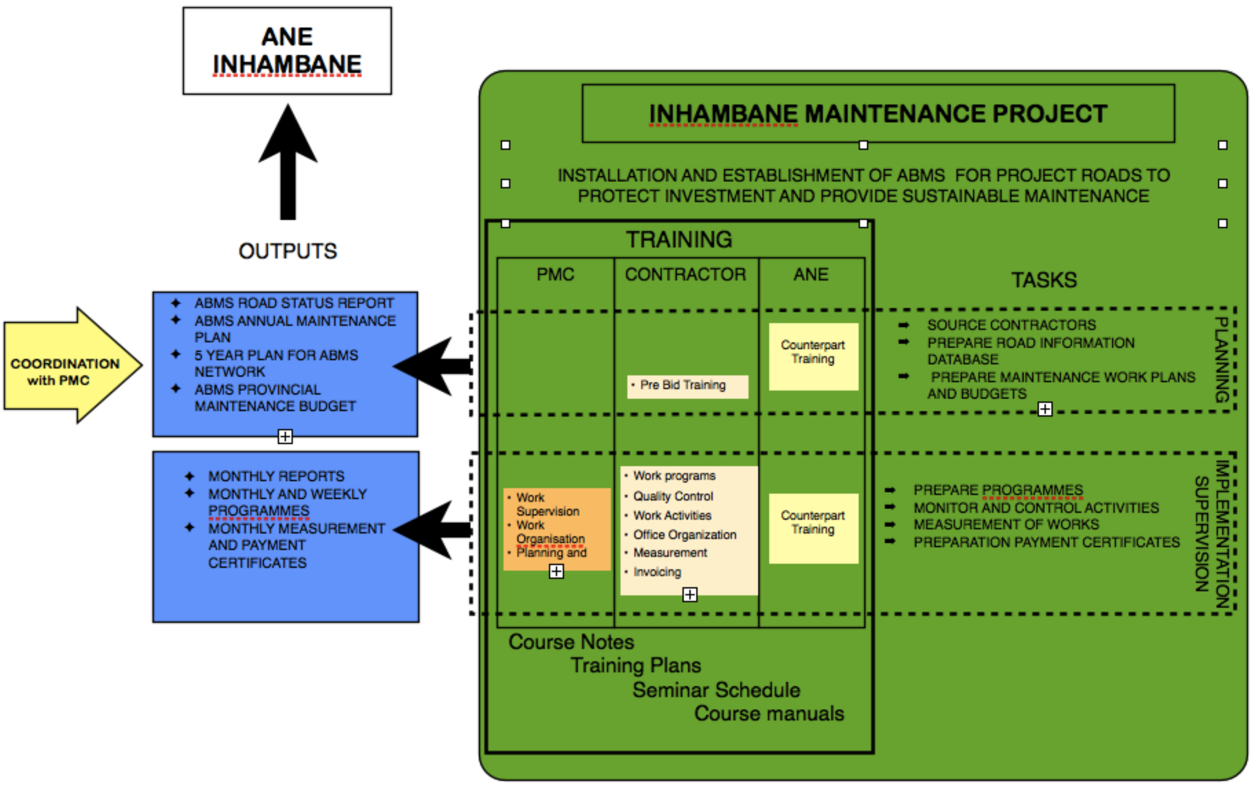
Each road has its own maintenance allocation and the programmed activities are related to the resources available. A detailed road inventory was carried out and a bill of quantities for the maintenance items was drawn up. These include all the mitre drains to be cleaned, the culverts to be maintained and all related drainage structures that require attention.

Pot holes and erosion damages are measured daily by the contractor supervisor and checker from the consultant. This information is collected on daily forms and summarised at the end of the week into a weekly return. The weekly return is further processed into a monthly summary. This summary is used to reconcile payments at the end of the month. This process provides the client with checks and balances for the use of resources and accountability.

6.0 REPORTING SYSTEM

One of the major weaknesses in management of feeder roads is the lack of historical data on the performance of roads. The ABMS system has a detailed reporting system that captures all activities on a daily basis and the resources used. This data helps the contractor to monitor and control his operations in a profitable manner. The data also helps the consultant in planning for the frequency of intervention within the budget and provision of acceptable level of service. The client is able to account for resources used through the analysis of this data.

DIVISION OF RESPONSIBILITIES-ABMS INHAMBANE PROVINCE



ROAD NAME	ALLOC	EXP	BALANCE	LABOUR	%		EQUIP	%
Mocumbi-Coguni	1914285.85	571348.77	1342937.23	587714.23 458831.96	76	P A	176000.00 176000.00	100
Panda-Urene	780820.14	177925.81	602894.33	257328.06 122000.00	48	P A	55000.00 55000.00	100
Panda-chivalo	1938684.33	294643.33	1644041.67	475473.74 294643.53	62	P A	300000.00 -	0
Inharrime Panda	4971398.49 850439.96		4120958.53	1812559.40 674459.96	38	P A	176000.00 176000.00	100
CHACANE BASE CAMP: SSJ REASONS FOR ABOVE PERFORMANCE: EXPENDITURE UP TO MARCH								
• LATE MOBILISATION								
• LOW PROGRESS ON LABOUR ACTIVITIES								
• EXCESSIVE RAIN								
ROAD NAME	**ALLOC**	**EXP**	**BALANCE**	**LABOUR**	**%**		**EQUIP**	**%**
Lindela homoine	1421454.60	464439.99	956994.61	415581.81 311439.99	74	P A	153000.00 153000.00	100
Maxixe Mocoduene	1613320.00	712249.20	901071.60	429328.20 390920.80	91	P A	216000.00 108000.00	50
Homoine Pembe	2464463.40	708580.00	1518827.60	605118.00 501618.00	82	P A	103000.00 103000.00	100
Homoine Mocoduene	1597407.60	464580.00		404963.40 287963.40	71	P A	234000.00 117000.00	50
HOMOINE BASE CAMP: CBC REASONS FOR ABOVE PERFORMANCE: EXPENDITURE UP TO APRIL								
• TIMELY MOBILISATION								
• ADEQUATE RECRUITMENT OF LABOUR								
• ADEQUATE EQUIPMENT								
ROAD NAME	**ALLOC**	**EXP**	**BALANCE**	**LABOUR**	**%**		**EQUIP**	**%**
HOMOINE PANDA	1945922.70	604515.30		420765.55 533265.55	127	P A	183750.00 71250.00	39
HOMOINE BASE CAMP: MAXI REASONS FOR ABOVE PERFORMANCE: EXPENDITURE UP TO MARCH								
• LATE MOBILISATION								
• INADEWQUATE LABOUR								
• INADEQUATE EQUIPMENT								
FUNHALOURO BASE CAMP: MARCLEUSA REASONS FOR ABOVE PERFORMANCE: NO INVOICES ISSUED								
• LATE MOBILISATION								
• QUALITY OF WORK BELOW STANDARD								
• INADEQUATE SUPERVISION								

7.0 ADVANTANGES OF USING THE AREA BASED MAINTENANCE SYSTEM

- The system is based on small road maintenance units making it easier to plan, programme and manage.
- The main equipment based activities are tyre dragging and towed grading, both done using an agricultural tractor as the only motorized piece of equipment. The tractor is also deployed for occasional haulage duties; i.e. one power source for a range of tasks.
- The cost of procurement, repair and maintenance of an agricultural tractor compared to a motorized grader plus haulage equipment is substantially cheaper. It is also relatively easier to repair and maintain, thereby reducing costs of importing expensive spares and use of highly qualified mechanics to manage the equipment.
- The flexibility of the tractor to be deployed productively for a range of tasks throughout the year produces high utilisation and cost effectiveness. This compares favourably with single task specialised equipment (such as motor graders) which generally have low utilisation in the annual maintenance cycle and consequential high ownership and operating costs.
- The bulk of the work is done by labour and this has the effect of creating local employment and also giving a sense of ownership to the local population who are employed along the road to do the labour activities

8.0 PROBLEMS ENCOUNTERED BY THE CONTRACTORS

- Delay in payment of invoices by the Road Fund affects cash flow and performance of the contractor
- Low and unrealistic tender rates by competing contractors
- Availability of equipment on the market
- Lack of skilled mechanics to maintain and service equipment

9.0 CHALLENGES FOR THE FUTURE

Some of the issues to be resolved to ensure the 'embedment' of a sustainable maintenance and asset management system include:

- Refinement of the training to improve supervisor and contractor training for weak areas such as pricing.
- General support for small enterprises to develop complementary business opportunities.
- Developing cost effective arrangements for periodic maintenance re-gravelling.
- Developing 'spot improvement' techniques/arrangements for sections of road that require particularly high levels of maintenance.
- Developing and 'embedding' the planning and financing system, to ensure that 'post-project' the maintenance system does not degenerate, and to ensure that the investments continue to be preserved.
- Quantifying the cost and benefits against alternative heavy equipment based and 'force account' maintenance systems.

Involvement of development companies in roads infrastructures rehabilitation works: Case study of an initiative for sustained rural roads in Cameroon

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Abstract

Rural roads (RR) in Cameroon account for more than 50% of the national network (54 000 km) and have suffered from lack of care from the Government since early 90s. This has resulted in a bad physical condition for 86% of the network. From 1996 there have been reforms in the roads sector included the creation of the Rural Road Direction (RRD) in 2000. This assignment focuses on the initiative of the RRD to partner with development companies through delegated forced account agreements for the rehabilitation and maintenance of rural roads. From just 40 km in 2005, the rehabilitated length of roads increased to more than 300 km in the following years, with a highly satisfactory level of performance by the RRD as far as the 'cahier de charge' is concerned.

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1 INTRODUCTION

This assignment intends to share an experience carried out by the Rural Road Direction (RRD) of the Ministry of Public Works (MPW) in Cameroon, as a Public Private Partnership initiative for the rehabilitation and maintenance works of Rural Roads (RR) in the country. The concerned initiative, which started in 2005 with one Development Company as a delegated forced account agreement between the two entities, has successfully been expended to several others in various regions, covering seven over the ten regions of the country. Targeted development companies are those either specialised in agricultural value chain (cotton, cocoa, coffee, palm oil, etc.) development or with specific missions of developing targeted areas, as a secular hands to the Government of Cameroon (GoC) The first ones include SODECOTON, SODECAO and the second categories concern MIDENO, SOWEDA.

This paper is structured around two main parts. The overall context of road sector in Cameroon is presented with emphasis on the regulatory framework and aspects related to road rehabilitation and maintenance, specifically for rural road network. Secondly, the delegated forced account for road rehabilitation and maintenance initiative is presented, with emphasises on its genesis, the targets achieved in the progress of the initiative and the key elements found as pillars for the success of this initiative.

It is hoped that through this experience that governments facing similar challenges with regards to keeping the rural network in good physical condition will be able to draw on the lessons learnt. Key success factors enumerated may be adapted and appropriated based on the concerned context (regulatory, potential existence of partners, etc.) for more efficiency and to reduce limiting factors.

2 THE ROAD SECTOR IN CAMEROON

2.1 The regulatory framework

The overall dynamic of the road regulatory framework in Cameroon has gone through three main phases. Until early 90s, the GoC was the main actor in the road sector, intervening through projects and programmes with support of bi- and multi-lateral financial and technical partners. All road rehabilitation and maintenance works were carried out by the MPW based on a system involving government equipment pools found in all the country's regions. According to the MPW staff, this rehabilitation and maintenance system based on the principle of force account resulted to relatively better all weather road networks throughout the country.

With the global economic crisis of 90s, the country was put under a structural adjustment plan. The scarcity of available funds for roads maintenance contributed to worsen the physical condition of road network. Hence, the GoC initiated a series of reform process to its regulatory framework, which led to the adoption of the Transport Sector Programme (PST) in 1996. The new PST aimed at more efficiency in the management of funds for the maintenance and development and road networks. Its objective was to reinforce road maintenance capacity for a greater effectiveness in the use of available financial resources, through a balance between relevant investments and road maintenance expenses. The PST was established around the following pillars: i) the liberalisation/outsourcing of the execution and the control of road maintenance works in favour of private companies; ii) setting up a sustainable mechanism to finance the maintenance of the priority road network that ensure permanently available funds; iii) setting up a rapid and efficient mechanism for payment of private companies; iv) reforming procurement procedures for more transparency and efficiency; v) the definition of the new institutional framework that takes into account the new roles (planning, programming, budgeting, supervision/control) to be played by the Ministry of public works (MPW) in the road maintenance works.

The design and adoption of the New Strategy for Rural Road Maintenance (NSERR) in 2000 by the GoC was in line with the implementation of the PST, taking into account the poverty level of the rural population. The adoption of this strategic document in rural road maintenance aimed at reducing the effects of poverty through an adjustment of challenges in rural areas development to the actual and future macro economic conditions of the country. Anchored on the principles of community involvement and decentralised responsibilities in road assets management in favour of local councils, the NSERR requires a share of roles among the State, local councils and communities along roads. Consequently on the priority road network, the GoC should finance rural road rehabilitation works, and the two other stakeholders ensure post rehabilitation routine maintenance works; whereas on the non priority road network, local councils and communities will finance both rehabilitation and routine maintenance works.

This NSERR is based on the following pillars:

i) the design of an institutional and regulatory framework that guarantees sustained investments through enforcement of regulations on road assets protection;

ii) the decentralisation of rural road management to local councils;

iii) a greater participation of beneficiaries to the protection and the routine maintenance of rural roads, including their ownership;

iv) the promotion of local PW companies through the enforcement of procurement' regulatory framework;

v) beneficiaries' capacity building by PW companies in view of their participation to maintenance works;

vi) the clarification of road network classification (priority, non priority and private roads);

vii) the enforcement of objective criteria for selection of priority roads in view of their maintenance;

viii) the execution of rehabilitation and periodic maintenance works by PW companies;

ix) the design and application of an action plan for environment protection during roads construction works;

x) greater privatisation/outsourcing of works and the use of labour based approaches.

2.2 The national road network

In order to meet the existing demand for roads, Cameroon has different types of network (urban, interurban and rural) at its disposal, which involves tarred and untarred/earth roads with crossing infrastructures (bridges, culverts, ferries, etc.). The existing road infrastructure results from efforts by the government, development companies and to some extend private individuals/farmers. However, considering its primary duties, the State is the main provider of roads, through new openings or the rehabilitation and maintenance of existing roads created by others. Tarred roads are the least important of the total network, followed by the earth and rural roads (**Table 1**). The overall road network condition is poor.

Table 1 : Road infrastructures and their physical condition in Cameroon

Types of infrastructures	Quantity	Ratio	Network condition		
			Good or normal	Fairly good	Bad
Roads					
Tarred	4918 km	9%	26%	26%	48%
Untarred/earthen	19688 km	36%	11%	80%	9%
Earthen rural	30 000 km	55%	14%	10%	76%
Total roads	54 606 km	100%			
Crossings					
Bridges	1196	98%	26%	28%	46%
Ferries	29	2%	28%	31%	41%
Total crossings	1225	100%			

Source : MINTP/DIER/DRR 2008

In terms of density, the road network in Cameroon is estimated at around 3 km per 1,000 inhabitants and 100 km of road per 1,000 km². Roads are classified following the presidential decree N° 79/093, which includes the following (**Table 2**):

i) National roads, as are the main network backbone. They link regional capitals together and to the country's political and business capitals (Yaoundé and Douala), and the neighbouring countries;

ii) Regional road links, within regions, divisional capitals t the regional one;

iii) Divisional roads link together sub divisional capitals to the divisional one, within a divisional administrative area and;

iv) Rural roads serve rural areas, farms, local industrial areas. They link productive areas to local markets or trade centres.

With the global economic crisis that affected the national economy, the GoC could no more ensure its commitment towards roads infrastructures. Both unavailable and insufficient funds dedicated to roads rehabilitation and maintenance have severely impacted the physical conditions of existing roads. Consequently, the total length of servicable road has reduced. To face this challenging situation and for a more efficient use of available funds, the road network has been allocated different levels in terms of priority for maintenance and rehabilitation works, with the definition of priority and non priority road networks (**Table 2**).

Table 2 : Road classification in Cameroon

Categories of roads	**Distance (Km)**
1) Priority network for main roads	
Earthen priority network (1)	
National	3 799
Regional)	3 958
Divisional	3 616
Unclassified roads	228
Sub-Total	11 601 Km
Tarred priority road network (2)	
National	3 377
Regional	796
Divisional	590
Unclassified roads	155
Sub-Total	4 918
Total (1 + 2)	16 519 km
2) Total rural priority network	**12 338 km**
3) Non priority network	
Classified earthen roads	8 087
Rural roads	17 662
Total	25 750 km
Overall total	54 606 km

<u>Source</u> *: MINTP/2008*

2.3 The rural roads sector in Cameroon

Rural roads as defined in the current MPW' strategy document for the rehabilitation and maintenance of rural roads in Cameroon (NSERR) are ways of communication constructed in rural councils excluding those of the core network made up of national, regional and divisional classified roads. They include road infrastructures used daily by inhabitants of rural areas. This network is made up of:

i) Roads linking access areas to the core road network, accessible to motorized traffic;

ii) Pathways which are seasonal roads that are not improved, but cleared for use by light vehicles and carts;

iii) Tracks which are ways accessible only to two-wheeled vehicles, bicycles and motorcycles including pedestrians and animals and;

iv) Footpaths which are ways open for pedestrians, in some cases for bicycles and motorcycles.

2.3.1 The road network

The classified rural road network in Cameroon is about 30 000 km (there exists no updated inventory on this) which constitutes 55% of the total national road network (**Table 2**). Among this, about 14% is in good or normal state, 10% in fair state and over 76% in poor state (**Table 1**), requiring serious rehabilitation works. These statistics indicate a critical need for an "all-weather" connectivity between the rural communities or agro-production zones to a well-integrated and reliable road transport system through a sustainable rehabilitation and maintenance scheme of a strategic backbone road network composed of rural roads connecting primary and secondary roads to main economic and social centres. This would help remove several bottlenecks that are constrains to road transport services in rural areas.

Table 3 : Distribution of roads according to the various regions of Cameroon

Regions	Area (km²)	Tarred roads	Priority classified earthen roads	Non priority earthen roads	Priority rural roads	Non priority rural roads	Total rural roads	Total
Adamaoua	63 701	441	1350	707	645	1 553	2 198	4 696
Centre	68 953	921	1555	1 665	3765	4 249	8 014	12 155
East	109 002	346	1590	1 581	888	920	1 808	5 325
Far North	34 263	589	1011	1 182	1195	1 931	3 126	5 908
Littoral	20 248	478	773	328	748	924	1 672	3 251
North	66 090	645	1044	1 178	887	1 475	2 362	5 229
North-West	17 300	205	841	73	1271	2 778	4 049	5 168
West	13 892	459	983	386	1483	1 442	2 925	4 753
South	47 191	574	1512	799	706	1 263	1 969	4 854
South West	25 410	260	942	188	750	1 127	1 877	3 267
TOTAL	466 050	4918	11601	8087	12338	17 662	30 000	54 606

Source : MINTP/DIER 2008

Rural roads are unequally distributed in the country (**Table 3**). Half of the total rural road network is concentrated in four regions. The Centre region has the greater share among all (27%), following by the North West (13%), West and Far North (10% each) regions.

Table 4 : Physical condition of rural roads in Cameroon

Physical condition	1999		2000		2002		2003		2007		2010	
	length (km)	%	length (km)	%	length (km)	%	length (km)	%	length (km)	%	Length (km)	%
Good	397	10%	617	6%	1080	11%	520	12%	230	2%	TC	TC
Normal	1390	35%	975	10%	982	10%	606	14%	3939	36%	TC	TC
Bad	2184	55%	8337	84%	7759	79%	3206	74%	6745	62%	TC	TC
Total	3971	100%	9929	100%	9821	100%	4332	100%	10914	100%	TC	TC

***Source:**: DIER/DRR/MINTP 2008*

TC : To be completed

At least half of the total rural road networks in Cameroon have been in bad physical condition since 1999. This overall condition of road network is in line with the national dynamic of the sector, in the sense that from 1999, road maintenance suffered from lack of funds, and 2007 (with improvement of good condition roads) coincides with the creation of the rural road direction in the MPW.

2.3.2 Rural roads rehabilitation and maintenance

From 2001 to 2007, road maintenance budget increased from USD 62 million to USD 96 million with an annual increase rate of 8% (**Table 5**). During the same period, the network expanded from 49 048 km to 52 770 km. Of the 3 722 km of expanded network, 17.7% constituted paved roads, 78.6% unpaved road and only 3.7% for the rural roads with a corresponding average annual rates of 2.42%, 2.72% and 0.08% respectively.

Table 5 : Rural roads maintained between 2001 and 2007

Designations	2001	2002	2003	2004	2005	2006	2007	Av. Annual increase rate (%)
Length of rural road maintained (km)	0	0	3499	0	2075	4742	7156	19.6
Total length of national road network maintained	13 528	7 777	14 123	11 682	17 468	21 922	22 408	8.8
% of rural road maintained	0	0	25	0	12	22	32	
Total maintenance cost, rural roads *(Millions FCFA)*	0	0	2 461	0	1 422	3 312	413	-26.5
Total maintenance cost, national roads *(Millions FCFA)*	29 773	22 951	17 557	13 311	34 840	29 874	35 890	3.2
% cost for rural roads maintenance	0	0	14	0	4	11	1	
Unit maintenance cost, rural roads *(Millions FCFA)*	0.8	-	0.7	-	0.7	0.7	0.1	
Unit maintenance cost, Classified earth roads *(Millions FCFA)*	1.9	1.4	1.2	1.2	1.5	0.7	1.9	
% of unit cost for rural road to classified earth road	42	-	58	-	47	100	5	

Source: Rapport diagnostique étude d'opportunité et de faisabilité de la création d'une Agence routière au Cameroun

As a result, the lack of continuity in rural road maintenance and expansion as well as its sustainability, has led to a significant impact on the general economic growth both at the rural and national levels given the major role appropriate rural road investment plays in fulfilling this (post-harvest losses sometimes can result to more than 30% due to lack of access to market). This inadequate attention to the rural road network led to eventual adverse deterioration and catastrophic pavement failures of some sections of the network which will require much resource to re-instead. Hence, a continuous deterioration of the general service level and state of the network.

The share of rural roads maintenance works in the overall execution of the country' road network is far away less important between 2001 and 2007 (**Table 5**). The most important road length maintained is done in 2007, year of creation of the rural road direction at the MPW. Construction works costs are the lest of all others.

Types of works carried out on rural roads include maintenance (routine and periodic) and rehabilitation, each of them happening at a certain frequency (**Table 6**). Such rotation should guarantee a good level of service on the targeted roads, which ensure a fluid traffic for people and their goods as well as connecting with the rest of the country.

Table 6 : Standardised unit costs of various works according to each type of roads in Cameroon

Type of roads	Types of work	Frequencies	Average unit cost (000 USD / km)
Tarred roads	Routine maintenance	Annual	4,7
	Periodic maintenance	5 - 7 years	57
	Rehabilitation	if IRI > 5m/km	230
Earthen roads	Routine maintenance	Annual	4
	Periodic maintenance	5 – 7 years	30
	Rehabilitation	12 years	41
Rural roads	Routine maintenance	Annual	2
	Periodic maintenance	3 - 5 years	10
	Rehabilitation	8 years	20

Source: Annuaire statistique du secteur des BTP, 2007/DRR-MINTP

** Doesn't take into account the level of degradation of earthen roads*

2.3.3 Assessment of rural roads demand in Cameroon

The trend of rural roads length has globally increased by 0.5% over 7 years

Table 7**)**

Table 7 : Trends of rural roads network in Cameroon per region

Road network	Regions	Rural roads network			
		Length (km)		Variation	
		2001	2007	km	%
North	Far North	2 696	2 696	0	0
	North	2 079	2 034	-45	-2.2
	Adamaoua	1 813	1 853	40	2.2
South	East	2 033	2 053	20	1
	Centre	4 625	4 665	40	0.9
	South	2 580	2 588	8	0.3
West	Littoral	2 326	2 366	40	1.7
	South West	2 516	2 526	10	0.4
	North West	3 841	3 881	40	1.0
	West	3 517	3 502	-15	-0.4
	Total	28 026	28 164	138	0.5

The average yearly increase of length of rural road can be estimated at about 20 km. Everything being equal, the possible total increase of rural road network on 2011 could be around 217 km, which represent additional length of road to be maintained.

Improving rural road infrastructures is a pre-requisite and critical need because of their essence as an indispensable requirement for the modernization and growth of agriculture which contributes to about 20% of Cameroon's GDP and which remains the main source of revenue to rural households (*about 50% 0f the population leaves in rural areas and 90% of rural households population are in one way or the other implicated in an agricultural activity*).

Table 8 : Road network by demand and supply

Designation		Paved Roads	Earth Roads	Rural Roads	Total (km)
Demand (in km)		4 918	19 688	30 000	54 606
Supplied : (network in good condition)	Proportion *(%)*	26%	21%	14%	8 890
	Length *(km)*	1 279	4 135	4 200	
Regular intervention *(km)*		4 918	11 000	3 500	19 500
Gap between demand & Supplied	Length *(km)*	3 639	15 554	25 800	41 110
	Proportion *(%)*	74%	79%	86%	

Source: Stratégie du secteur des BTP, Rapport provisoire 2005/MINTP

In addition to the annual increase in length, the need for rural roads can be assessed through the gap between the demand and the supply; the supply being the total road network effectively rehabilitated. For rural roads, this gap is estimated at 86% of the existing network. With the same amount of financial resources, and given the urgent necessity of improving the living condition of people in rural areas through the provision of all weather roads, the challenge of the MPW is to maintain all the increasing length of roads.

3 PUBLIC PRIVATE PARTNERSHIP FOR RURAL ROADS MAINTENANCE

3.1 Genesis

In view of implementing the New Strategy for Rural Maintenance and Rehabilitation (NSERR), the Ministry of Public Works (MPW) initiated in 2003 delegated force account agreements with local development companies for rehabilitation of rural roads in their respective areas. The signature of these agreements was done with a special approval (through the letter N°B574/SG/PM of 14/08/03) of the Prime Minister.

These agreements aimed at mobilising local resources for the development of economic activities through the improvement of the physical state of the rural road network and the reduction of road maintenance costs taking advantage of the use of their own equipment in their area.

The required duties include:

i) carrying out technical studies,

ii) sensitising people to the New Strategy of Roads Rehabilitation and Maintenance,

iii) carrying out rehabilitation works,

iv) ensuring routine maintenance of post-rehabilitated roads by road committees;

v) participatory follow up/ assessment.

Box 1 : Development companies: key partners in rehabilitating rural roads

In Cameroon, the development of some agricultural value chains (cotton, coffee, cocoa, palm oil tress, etc.) is ensured by specialised companies which shares are owned by the GoC and other privates. Some of them include: Société de développement du cotton (SODECOTON), Société de développement du Cacao (SODECAO). In the other hands, based on its national strategy for rural development, the GoC has created development authorities, covering around four of the ten national regions. Their main mission is to serve as levier and cornerstone for the overall development of the targeted areas. Those include: Mission de development du Nord Ouest (MIDENO), South West development authority (SOWEDA), which are public agencies with special regime.

Given their objectives dealing with rural development which include among others roads infrastructures, these companies are permanently involved in construction, rehabilitation and maintenance works. For companies falling in the first category, they have their own road network that plays an indispensable role in the transportation of agricultural inputs and outputs by liaising existing farms to processing sites and storage facilities. They perform mainly in maintaining existing roads, and they also open new ones where the need be. The total road network being maintained by SODECOTON each year is around 6 000 to 6 500 km, all of which are spread in three different regions (North, Far North and southern part of Adamaoua). Apart from maintaining roads, SOWEDA deals with opening of new roads in the South West region (one of the must productive agricultural areas of the country, with limited access).

Given that they are used to carry out roads infrastructures works, these companies are found to have good resources to perform requested works. Their equipments are in good quality and sufficient fleet. The personnel involved in these works are among the company's staff, with good experience and knowledge of the covered areas. All these aspects and characteristics count a lot and are comparative advantages in their selection process in view of their involvement in this initiative.

Support to roads committees involves organisation and structuring, training and distribution of light equipment (wheel barrows) for roads maintenance purposes through the establishment of small task contracts.

Effectively started in 2005 with the South West Development Authority (SOWEDA), this initiative has progressively been implemented, targeting development companies with relevant capacities (human resources and equipment) for implementing roads rehabilitation works. At the origin of this, no preliminary assessments were carried out by the RRD when offering these contracts, based on the assumption of the good results produced in managing their own work. The public investment budget is the main source of funds for these works, and a total of seven companies have been used, distributed in different agro ecological areas (**Table 9**).

Table 9 : Distribution of targeted development companies in the country

Companies	Targeted regions	Starting year	Total road network (km)
SOWEDA	South West	2005	1 877
Cocoa development company (SODECAO)	Centre, East	2006	9 822
Agricultural mechanisation national centre (CENEEMA)	South	2006	1 969
Cotton development company (SODECOTON)	North, Far North	2008	5 488
North West development authority (MIDENO) and Upper Noun Valley Development Authority (UNVDA)	North West	2008	4 049

3.2 Implementation of the initiative

In 2006, two other companies were contracted, namely the Cocoa Development Company (SODECAO) and the Agricultural Mechanisation National Experimentation Centre (CENEEMA). However in 2007, an internal assessment of this initiative was carried out by the RRD, which led to the revision of these agreements. It was noticed from this assessment that sensitisation effort/actions and training of beneficiaries on routine maintenance are yet to be mastered by the technical staff of some of these private companies. Other improvements to be made included the following:

i) a summary of expenses engaged by the targeted private companies are not easy to produce; this is due to the fact that they don't make available invoices on time. This doesn't allow an appreciation of the consumption rate of the budget;

ii) external services of the MPW are not fully involved in the follow up and the progress of work on the field, with serious consequences on the administrative management (production of monthly reports) of agreements and the assessment of physical execution rate;

iii) useful funds are not always disposed on time by the MPW to the private companies. consequently, there is a postponement/delay in carrying out the expected works (apart from SODECOTON who has enough funding to cover this).

Based on the satisfactory results obtained in the partnership with these companies, this initiative was extended in 2008 to several other companies with proved competence in rural road maintenance (**Table 9**). Targeted areas through this initiative include seven of the ten regions of the country and represent a total of 23 205 km (77% of the total rural road network) of existing rural road network.

Each year, agreements are signed between the MPW and the concerned development companies, providing details of the total targeted length (distributed on various routes) to be rehabilitated and maintained. As an additional but indispensable document to the signed agreement, there is a 'cahier de charge' in which all relevant issues of the regulatory framework for the targeted interventions by the executing agency are defined. Roles and responsibilities of stakeholders are also clearly mentioned. Other issues provided by this document include the following: targeted objectives and outputs/outcomes, selection of targeted roads and their field visit, programme consistency, technical studies, works start and execution programme, road geometric characteristics, execution and quality control documents, deadline of execution, reception and guarantee of work, site signalisation, land occupation and management, administrative management aspects, follow up of sensitisation activities and supervision missions, programme assessment, indicators, routine maintenance, roads committee management and equipment, regulation on labour, etc.

It is explicitly mentioned that technical studies are carried out by external services of the MPW, based on which technical specifications and guidelines are provided. These specifications serve as a baseline for assessment purposes at the end of works. The follow up of works is also ensured by these external staff of the MPW.

3.3 Progress made in the initiative

According to the staff of the RRD and MPW, this partnership with private companies is having positive impacts on the physical condition of targeted roads, hence on improved living condition of people in the area and therefore poverty alleviation.

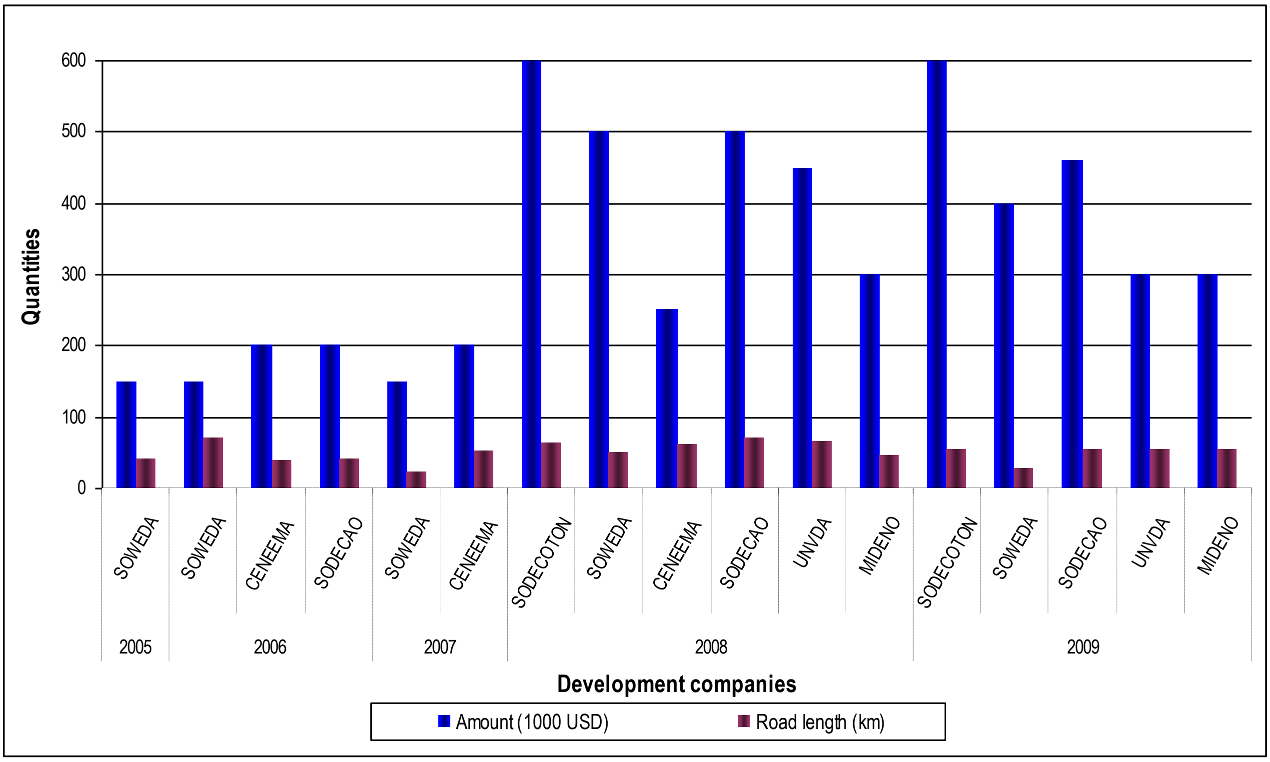
Among all agreements signed up to 2009, SOWEDA and SODECOTON have the most important share in terms of budget allocated (

Figure 1) followed by UNVDA and SODECAO. Longest lengths of roads to be rehabilitated are attributed to SOWEDA, SODECOTON and CENEEMA with respectively 208, 165 and 155 km (**Source:** *RRD, 2008*

The overall unit cost of rehabilitation for one kilometre of rural road is around USD 6 860. Only SODECOTON and SOWEDA are provided with higher unit costs of rehabilitation (Error! Not a valid bookmark self-reference.). However, from the perspective of the RRD staff, the level of satisfaction is higher and important when one considers the quality and technical level of executed works and the overall management of these agreements.

Table 11). The correlation between fund and road allocation can be explained, when we consider the total rural road existing in the concerned regions (**Table 9**), for it appears that more attention is given to regions with most important road network.

Figure 1 : Road lengths and amount object of signed agreement between MPW and companies



The execution of the agreement components is spread around various activities, for which road rehabilitation works constitute the most important share with up to 85% (**Table 10**). Costs of carrying out studies and follow up of rehabilitation works are around 9.3% of the cost of executing the works, which is standard for this kind of activity.

Table 10 : Distribution of expenses with regard to the execution of the delegated forced account agreement between MPW and SODECAO in 2007 for 50 km of road

Expenses	Amount (USD)	Ratio (%)
Studies (technical and socio economic)	7 800	3,12
Beneficiaries' capacity building for ownership of the NSEER (7 road committees constituted, trained and equipped)	16 804	6,72
Rehabilitation and maintenance works	213 194	85,27
Follow up/supervision/control and assessment by the MPW	12 200	4,88
Total	250 000	*100*

Source: RRD, 2008

The overall unit cost of rehabilitation for one kilometre of rural road is around USD 6 860. Only SODECOTON and SOWEDA are provided with higher unit costs of rehabilitation (Error! Not a valid bookmark self-reference.). However, from the perspective of the RRD staff, the level of satisfaction is higher and important when one considers the quality and technical level of executed works and the overall management of these agreements.

Table 11 : Yearly distribution of execution of rehabilitation works accounting for signed agreements

Companies	Convention' year	Amount (000 USD)	Length (km)	Units costs (000 USD/km)
CENEEMA	2006	200	39,3	5,08
	2007	200	51,7	3,86
	2008	250	59,8	4,18
Total/Average		650	150,8	4,38
MIDENO	2008	300	45	6,66
	2009	300	55	5,46
Total/Average		600	100	6,06
SODECAO	2006	200	41	4,88
	2008	500	70,1	7,14
	2009	460	54,8	8,4
Total/ Average		1160	165,9	6,8
SODECOTON	2008	600	63	9,52
	2009	600	55	10,9
Total/ Average		1200	118	10,22
SOWEDA	2005	150	41	3,66
	2006	150	69	2,18
	2007	150	22	6,82
	2008	500	50,5	9,9
	2009	400	26	15,38
Total/ Average		1350	208,5	7,58
UNVDA	2008	450	66	6,82
	2009	300	55	5,46
Total/ Average		750	121	6,14

Source: RRD, 2010

Compared to the standard unit costs for the same type of work on typical roads (**Table** 12), the execution costs of these companies are much lower. A consideration of the content of their 'cahier de charge' gives us an idea of the important workload they are dealing with.

Table 12 : Standard average unit cost per km for various works on road in Cameroon

Types of interventions	Average cost out of tax (000 USD)
Periodic/routine maintenance (rural roads)	3,58
Rehabilitation of earthen roads	18,55
New opening of earthen roads	32,94
Periodic/routine maintenance of tarred roads	7,87
Heavy 'cantonnage' (tarred roads)	0,55
Semi heavy 'cantonnage' (tarred roads)	0,45
Light 'cantonnage' (tarred roads)	0,22
New improvement works for tarred roads	520

Source : EGIS CAMEROUN (Rapport de l'étude en vue de la définition des coûts des différents standards des travaux routiers au Cameroun)

3.4 Analysis of key successful factors of this initiative

This initiative could not be carried out without some comparative advantages to consider, which served as key pillars in order to achieve the actual results and outcomes. Some of them can be cited here, and one should recognise that, in order to replicate it in different situation, considering the prevailing environment would be indispensable for scaling up purposes.

3.4.1 Institutional anchorage

The creation and functioning of a Rural Road Direction (RRD) has been crucial, as an incentive to this initiative. It is clear that before the existence of the RRD the rural roads sector suffered from a lack of attention and investment from the MPW, with no importance accorded to this network. This happened mostly not because of lack of capacities available at the MPW, but mainly because of the absence of a relevant organ serving as interface and specialised in the concerned subject. The evidence of this is based on the fact that with the creation and functioning of the RRD in 2007, the physical conditions of RR began improving. Hence, as an independent body under the MPW, the RRD could bring more attention to RR, and take the lead in matters aimed at improving the network.

Though the NSEER opened enough doors for possible collaboration with other entities like local government and private individuals in keeping the RR in good condition, a special support from the Prime Minister's office was indispensable, as a regulatory pillar to expect good collaboration with these companies. However, despite this two years was needed to implement the Prime Minister's decree (the decree was signed in 2003 and the first company was contracted in 2005), not too many years were needed to expand the experience with other companies. This special measure was indispensable to allow complementarities (not competitiveness) among the two systems (tenders with private firms and agreements with development companies) in achieving the goals.

3.4.2 Existence of a demand for roads to be maintained

The partnership with development companies was based on a real, quantifiable and existing demand in terms of roads to be rehabilitated. Many factors contributed to the existence of the situation that prevailed before the intervention of these private companies, which led to rural road networks in very poor physical conditions. Added to non negligible increase in length of this network, this network to be rehabilitated and maintained constitutes an important critical mass for which the involvement of the private companies will contribute to achieve the overall goals. The existence of the two systems (tendering process with private firms and this initiative) are hence complementary.

3.4.3 Existence of qualified companies at regional level

The success of this initiative was founded on the fact that the targeted companies have many comparative advantages that contributed to their good deployment for the tasks encountered:

i) All the targeted companies have very good technical capacities that allow them to carry out the job. These resources include: equipment, technical staff, finances, etc. Since they have their own road network (to evacuate agricultural produces) to maintain at a certain level of service in the year, these companies are generally equipped with at least essential equipments (trucks, graders, etc.). Also, the personnel involved are recruited by their companies during which recruitment their capacities are assessed, according to their job description;

ii) The fact that these companies have their own equipment is a comparative advantage as there is no need of mobilisation/de-mobilising for the equipment required;

iii) The partnering companies have a very good knowledge of the area where they work. This knowledge concerns all required information that is useful and contributes to good technical results (location of material sites, types of soil, etc.). Hence they have exact and specific answers to technical difficulties (soil treatment, protection measures, etc.);

iv) Using the companies existing level of equipment this initiative can remain successful where there is no competition between the volume of work received from the MPW and that of the targeted companies own network. Otherwise new equipment (and additional staff) are to be acquired by these companies to meet with the objectives.

3.4.4 Qualified MPW staff at regional level

The implementation of an initiative such as this requires that the MPW (as the body responsible for application of national standards, harmonisation and coordination of activities, etc.) and its staff play effectively their roles. This can only be done if these staff are present in the targeted areas, and also possess the appropriate skills and knowledge. In Cameroon, the MPW is present in all administrative areas of the country. They are responsible of the supervision of the targeted works, in close collaboration with the contracted development companies. Supervision missions, which are contractual arrangement, are frequently taking place (**Table** 10). Costs of carrying out studies and follow up of rehabilitation works are around 9.3% of the cost of executing the works, which is standard for this kind of activity.

Table 10 under the initiative of the RRD staffs. Progress reports on technical and administrative management aspects of the contract are regularly made available by each party, to the attention of central services, with reference to the 'cahier de charge'.

4 CONCLUSION

The delegated forced account agreements signed with the concerned private companies have greatly contributed to improved rural roads network. As a step by step process built based on self assessment of the process, the overall management has been improved, to meet difficulties met, to ensure it is efficient and sustainable. The objectives couldn't be achieved without the provisions of the regulatory framework and the support of the Prime Minister. The willingness and the determination of the RRD and the MPW and its staff have also been indispensable. Despite the results obtained in filling the existing gap in the need for rural roads, some efforts are yet to be considered for more efficiency of the initiative, as well as its sustainability. An overall assessment of the socio economic and technical aspects of this initiative is needed at national level. This will help in identifying the assets, the efficiency, the sustainability (creation and functioning of road management committees) of this initiative.

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2nd AFCAP PRACTITIONER'S CONFERENCE 3rd to 5th July 2012

SPIRAL WOUND U-PVC PIPE CULVERT TRIALS IN UGANDA

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ABSTRACT

A pilot project to demonstrate innovative technologies for Low Traffic Volume (LTV) bitumen sealed roads commenced in Uganda in January 2009. The project researched techniques for reducing construction costs, through the incorporation of construction trials in a Contract for upgrading a rural road. The results of this research will be used to assist in the development of Design Manuals, Specifications and Guidelines for Sealed LTV Roads in Uganda. This paper describes trials of spiral wound U-PVC culvert pipes manufactured on site. This technology has been widely used in China on LTV roads, but appears not to have been used in Africa. The trials have indicated that this technology combines good performance with both significant practical and financial advantages over traditional concrete or steel culverts.

1 INTRODUCTION

1.1 Project Background

The Implementation of a Pilot Demonstration Project (PDP) involving Innovative Technologies for the Construction of Low Traffic Volume Roads on the Matugga - Semuto - Kapeeka Road in Uganda involved construction trials using spiral would U-PVC culvert pipes manufactured on site instead of the originally specified segmental precast reinforced concrete culvert pipes.

The project contractor (China Chongqing International Corporation – CICO) proposed the change in pipe culvert type after contract award as an economical and innovative way of constructing the replacement cross drainage structures. The manufacturer of the U-PVC pipe materials was China Chongqing Baoercheng Zhaoliang Science & Technology Ltd and the manufacture's technical publications were submitted to the Engineer as justification for introducing the construction trials.

The Contractor indicated that the product would have the following advantages:

- The finished product can be easily manufactured on site from rolls of 130mm wide U-PVC, economising on transport costs;
- The U-PVC culvert pipes can be assembled to exactly the required dimensions;
- The finished product is light so installation is quick and easy;
- The product is very waterproof and can incorporate recycled PVC with positive environmental impact;

- The U-PVC pipes have a 50 year life associated with excellent anti-corrosion and anti-wear properties;
- The product gives low water resistance;
- The flexible pipe will not suffer breakage or leakage when subjected to 30% deformation.

Following initial materials testing and the successful use of the pipes in the temporary works (borrow pit access road) a permanent works trial was constructed. Based on the success of this trial the Contractor was allowed to substitute 600mm U-PVC pipes at all access culvert locations and to construct eleven 900 mm U-PVC cross culvert pipe trials. The Contractor agreed to a 10% discount for 600mm pipes and an 8% discount for 900mm pipe culverts.

Samples of both 600mm and 900mm U-PVC pipes were sent to Denmark for full testing in accordance with appropriate European Standards and the test results were satisfactory, although the requirement for some additional testing before general acceptance was identified.

Construction of the U-PVC culverts proved to be a much quicker and easier activity than construction using segmental reinforced concrete culvert pipes. In fact, taking account of the large increase in number of house access culverts required, the Consultant concludes that culvert construction using the on site manufactured 600mm spiral wound culvert pipes contributed significantly to the contractor being able to finishing the road construction within the approved time for completion.

The suitability of U-PVC culvert pipes is compared against traditional concrete and steel culvert pipes in this paper.

The U-PVC culvert construction trials have all performed well to date and will be monitored over a six year period. Whilst such U-PVC pipes appears to have no history of previous use in the region to support their introduction in Africa, it should be noted that the central government of China has made relevant regulations that encourage the use of spiral wound U-PVC culvert pipes to replace concrete pipes (<800mm).

U-PVC culvert pipes do appear to have the advantages promoted by the Project's Chinese Contractor and the good "in service" performance of these culverts on the PDP should remove uncertainty concerning their suitability for further use in the region, particularly with respect to the economical construction of low traffic volume sealed roads. Indeed, the Consultant is encouraging the Uganda National Roads Authority (UNRA) to actively promote furthertrials and use of thistechnology in lowvolumeroadconstruction in Uganda.

1.2 Project Location

The project road was a gravel road starting in Matugga on the Kampala - Bombo - Luwero - Gulu Road, about 20 km north of Kampala and is 41.1 km long (refer Figure 1).

The project road was selected as being representative of typical environmental conditions found in many part of Uganda in terms of climate, drainage, topography and locally available natural construction materials.

The project area is located in a wet and humid region with a mean annual rainfall generally in the range of 1,100 to 1,200 mm. There were a total of 88 existing cross drainage structures along the road, all of which required replacement with new pipe or box culverts.

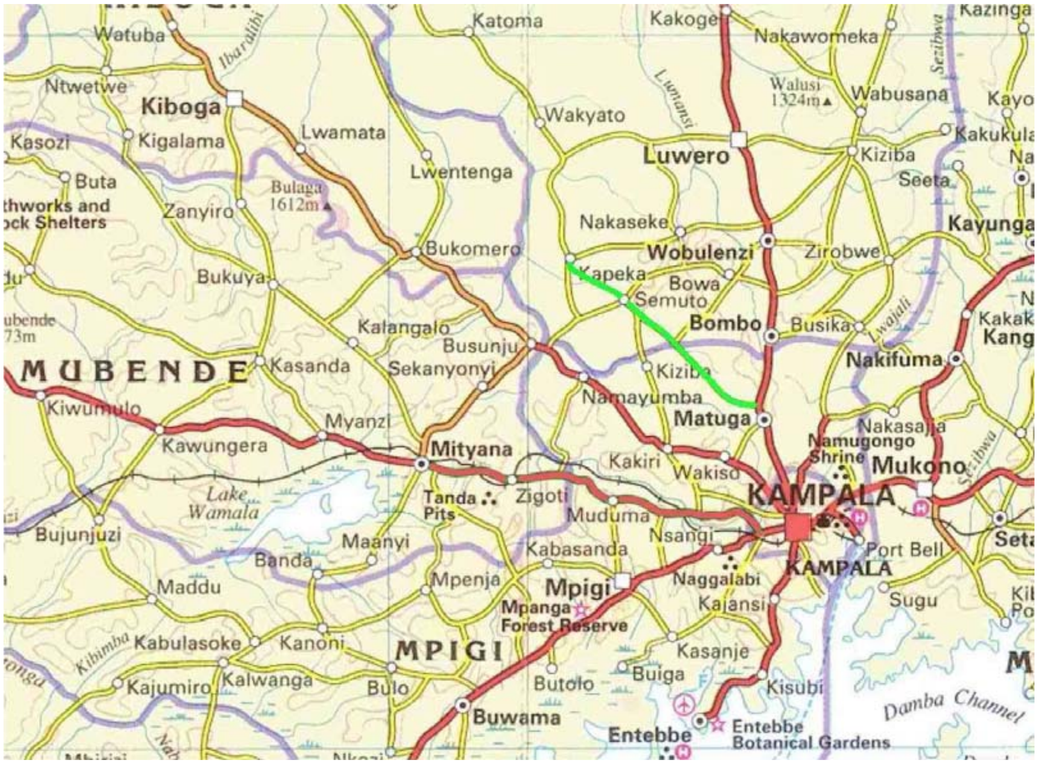


Figure 1 Location Map. (Project Road Shown in green)

The design traffic loads were light and were as follows:

Matugga to Kirolo (km 0 to 15) - 1.5 to 3.0 Mill. ESA;

Kirolo to Semuto (km 15 to 29) – 0.7 to 1.5 Mill. ESA;

Semuto to Kapeeka (km 29 to 41) – 0.3 to 0.7 Mill ESA.

The Project comprised a number of trial constructions to demonstrate innovative and appropriate construction technologies for low volume roads. These included:

- Pavement construction trials;
- Culvert construction trials;
- Swamp construction trials.

1.3 Project Objectives

The three main research goals of this Pilot Demonstration Project are as follows:

- Pioneer the development of innovative construction technologies for the construction of Sealed Low Volume Traffic Roads in Uganda;
- Through research (before, during and after construction) establish on a scientifically acceptable level a basis for the development of Design Manuals, Specifications and Guidelines for Sealed Low Volume Traffic Roads;
- Demonstrate the cost-effectiveness of the innovative technologies and their potential contribution to sustainable rural road infrastructure development in Uganda.

1.4 Aim of the U-PVC Pipe Construction Trials

The Construction of the U-PVC culvert trials is fully in line with the research objectives of the Pilot Demonstration Project (PDP).The U-PVC pipe system tested on the PDP is creative and innovative in its design. It involves an easy assembly technique which requires passing 130 mm U-PVC strips through a simple spiral coiling machine that applies glue at the joints. This pipe assembly that can be implemented in any rural construction camp to produce a strong light weight culvert pipe that is expected to be well suited for use in the construction of low traffic volume sealed roads, where the emphasis must be on utilising the most economical construction materials that involve simple low cost techniques for construction.

Whilst the product is reported to be widely accepted and used in China no reports have been found concerning the use of similar spiral wound U-PVC culvert pipes in Africa. This project therefore provided an ideal opportunity to demonstrate the suitability of this product and to evaluate the advantages and any disadvantages that might be associated with the introduction of this new technology.

As a result of the implementation of the controlled construction trials followed by long term performance monitoring it is intended that any uncertainty concerning the suitability and performance of these spiral wound U-PVC culvert pipes will be eliminated and that confidence in the product will lead to its adoption as a viable and cost effective alternative to the use of traditional concrete and steel pipe culverts.

2 TESTSAND STANDARDS FOR U-PVC PIPE CULVERTS

2.1 The Manufacturer's Test Results

The manufacturer's publication states that the U-PVC materials and pipes satisfy the National Standards of the People's Republic of China. The testing requirements for the Chinese standards are summarised below in Table 1.

Table 1: Summary of Manufacturer's U-PVC Test Standards

	Property	Requirement
1	Density, g/cm^3	≤ 1.60
2	Vicat Softening Temperature. ^{o}C	≥ 75
3	Tensile Yield strength, MPa	≥ 25
4	Bending Modulus of Elasticity, MPa	≥ 2000
	After heating state	Free from bubbles spots or cracks
5	Charpy Impact Strength, kJ/m^2	
	For 23 ^{o}C	≥ 40
	For -10 ^{o}C	≥ 20
7	Corrosion Resistance	
	10 % HCL	No corrosion
	10 % HNO_3	No corrosion
	10 % H_2SO_4	No corrosion
	10 % NaOH	No corrosion
8	Stiffness, kN/m^2	S1 to S8 (nominal stiffness of 1 to 8 kN/m^2)
9	Impact Strength, %	TIR ≤ 10
10	Ring Flexibility	The test pieces shall be smooth and round. There shall be no contraflexure crack or any peeling on either wall.
11	Leak resistance	No leaking

The above data are requirements according to the Chinese standards. The Contractor was not able to produce test results for the pipe materials delivered to site. Hence, it was required that tests should be performed on the pipes to define physical and chemical properties of the pipes. Initially pipe samples were sent to the Uganda National Bureau of Standards (UNBS) for testing.

2.2 Ugandan National Bureau of Standards Test Results

Ugandan National Bureau of Standards (UNBS) performed tests on samples of U-PVC pipe culverts. The UNBS test result shows the manufactured pipes satisfy the requirements of American Standard Testing Methods (ASTM) F 949 -06:Standard Specification for Poly(Vinyl Chloride) (PVC) CorrugatedSewerPipe With a SmoothInterior and Fittings.

Table 2 Summary of UNBS U-PVC Test Results

1	Basic materials— PVC	Materials made of PVC
2	Pipe dimensions: minimum Average Inside & wall thickness	Satisfies ASTM F 949 -06
3	Impact Strength	NOT tested by UNBS
4	Pipe Stiffness	Satisfies ASTM F 949 -06
5	Flattening Test	No cracks observed during test

UNBS used ASTM F 949 -06 Specification as a reference. The specification of ASTM F 949 -06 as quoted in UNBS is a relaxed specification compared to the requirements of American Association of State Highway Transport Officials(AASHTO) M 304 -03 : Poly(Vinyl Chloride) (PVC) Profile Wall Drain Pipe and Fittings Based on Controlled Inside Diameter Requirement.

Also, it should be noted that some tests including material type details and impact strength were not included in UNBS test results. It was therefore required to further test the pipes to get additional details at the Danish Technological Institute.

2.3 Danish Technological Institute Test Results

A sample of both 600 and 900 mm U-PVC pipes were shipped to Denmark, near the end of the project.

The Danish Technological Institute performed the following tests:

- Identification by means of infrared spectroscopy, ASTM D 2124
- Ring stiffness, ISO 9969
- Impact strength, EN 13476-2 which refers to EN 744

Table 3: Summary of Danish Technological Institute U-PVC Test Results

1	Basic Materials (ASTM D 2124)	Manufactured from PVC added calcium carbonate ($CaCO_3$). Based on infrared spectroscopy is it not possible to state the amounts of PVC and calcium carbonate ($CaCO_3$).
2	Impact Strength (EN 13476-2/ EN744)	U-PVC ø600 mm and U-PVC ø900 mm fulfil the demands, as no visible cracks or damages observed in the outer surface during the impact test.
3	Ring Stiffness (ISO 9969)	EN ISO 9969 relevant ring stiffness classes are SN 4, SN 8 or SN 16 (nominal stiffness 4 to 16 kN/m^2) U-PVC pipe ø600 mm can be characterised to SN 8 (ring stiff-ness = 8.45 kN/m^2) U-PVC pipe ø900 mm was below SN 4 (Test Result 1.56 kN/m^2)

2.4 Comments on the Test Results

i) Basic Materials

The manufacturer's brochure states that the materials for fabricating wound pipe strips shall be composed of not less than 64% polyvinyl chloride resin. The filling additives such as active $CaCo^3$ shall be maximum 30%, the rest are auxiliary materials.

The manufacture also reports that recycled materials may be used to produce the pipe winding strips. White strips are the best quality "virgin material" and that recycled strips "non-virgin material"(which still conform to the manufacturer's standards) are black in colour.

ii) Impact Strength

The Danish Technology Institutetested the pipes in accordance with EN 744: Plastic Piping and ducting systems –Thermoplastic Pipes – Test Method for Resistance to External Blows by the Round-the-Clock Method.Both the 600mm and 9000mm pipe samples suffered no visible damage during the test. The pipes were tested at 23 degree C because temperatures in Uganda are normally not in proximity of 0 degrees C.

iii) Flattening Test

The sample tested at UNBC showed no evidence of splitting or cracking during the test procedure specified in ASTM F 949. The manufacturer reports that their products are flexible and their typical ring flexure ratio is 30%. This property means that their pipes will be found to be free from breakage, cracking and contraflexure.

iv) Pipe Stiffness

The pipe sample tested at UNBS satisfied the requirement of ASTM F949.

The Manufacturer states that the U-PVC pipes have a stiffness of S1 to S8 (nominal stiffness 1 to 8 kN/m^2).

When tested in accordance with ISO 9969 (Thermoplastics pipes - Determination of Ring Stiffness), the 600mm pipe sample was classified as SN 8 since the stiffness value obtained was 8.45 kN/m2.

The 900mm pipe produced a stiffness value of 1.56kN/m^2, which seems somewhat lower than expected. However, according to Draft EN 13476-3, pipes of diameter more than 500 mm, shall be designated as SN 2, SN 4, SN 8 or SN 16. Hence, the 900 mm diameter can be approximately designated as SN 2.

Due to reluctance by the Contractor for further testing of the pipe after receipt of the UNBS test certificate, the sampling of the pipes for the additional testing was done near the end of the project and at that time there were only leftover U-PVC pipes which had not been properly stored as shown in the Photograph No1 below.

Photograph No 1
The sampled 900 mm diameter
U-PVC Pipe sent to Denmark

The samples tested by UNBS were from freshly produced U-PVC pipes and the results for ring stiffness were satisfactory, but the Danish Technological Institute ring stiffness test results on the 900mm pipe sample were relatively low. Generally, PVC materials deteriorate under exposure to direct sunlight and the manufacturer's guide advises that the pipes and raw materials (U-PVC strips) be stored away from direct sunlight (even though the U-PVC pipe material is reported to be ultra violet resistant by the manufacturer).

It is concluded that due to the poor storage of the 900mm sample tested in Denmark, additional testing is required on fresh samples of 900 mm U-PVC pipes to accurately determine their representative ring stiffness.

It should be noted that the U-PVC technology is different from other technologies which focus more on circle rigidity; U-PVC pipes are flexible by design and share the load with the surrounding soil. They can tolerate relatively high deformation before failing (quoted as more than 30% by the manufacturer). The manufacturer's literature notes that the pipe ring stiffness Sp shall satisfy the Spangler formula, namely Sp shall be determined according to the overall modulus of deformation of the backfilled soil in the trench.

Future studies on U-PVC pipes should include additional tests not covered in the above discussions. For example, if the AASHTO Specifications is to be pursued, additional tests including cell classification (ASTM Cell Class) and Acetone Immersion Tests need to be carried out.

Currently there are different standards and terminologies concerning the strength requirement for PVC pipes. Structural assessment will be required to clearly define site and project specific requirements.

3 MANFACTURE AND CONSTRUCTION OF U-PVC PIPE CULVERTS

3.1 Raw Materials for Pipe Manufacture

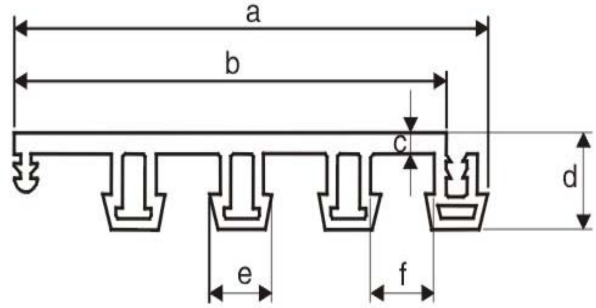
The U-PVC used on the PDP was virgin U-PVC (i.e. the pipes were not produced from recycled materials).

The pipes are manufactured from 130mm wide strips of U-PVC piping which are delivered to the user in large rolls as shown in Photograph No 2

Photograph No 2
Rolls of U-PVC strips stored on site at the construction camp.

The strips are designed to have a self locking mechanism between strips and glue is required to reinforce the joints.

Figure 2 shows the patented transverse section dimensions of the U-PVC strips used for culvert pipe manufacture for the PDP.



a (mm)	b (mm)	c (mm)	d (mm)	e (mm)	F (mm)
129.5	118	5	23	17	17.51

Figure 2 Transverse Section Dimensions of U-PVC Strips

3.2 On Site Assembly of U-PVC Pipes

The assembling of the pipes is done easily on site using a simple machine as shown in the Photograph Numbers 3 and 4.

Photograph No 3
Assembling spiral wound U-PVC Pipes from the 130mm rolls at the Construction camp (July 2009).

A single person can assemble the pipe from the 130mm wide strips with a simple machine (spiral coiling machine) which applies glues at the joints in accordance with the manufacturers patented system. Only simple training is required to operate the machine. The pipes can be of any length, an advantage over concrete or metal culverts which are usually manufactured in standard one metre. Also, different diameters of pipe can be assembled by adjusting the slot (within the range of the slot) as indicated in Photograph No 4.

One roll of U-PVC strip can be joined with another along the length of a culvert pipe and the contractor achieved this by wiring the ends of the rolls together and then patching the joint with fibreglass matt and resin (refer Photograph No 5).

Photograph No 4
Spiral winding machine set up to manufacture 900mm culvert pipe at construction camp). Maximum size for this machine.

Photograph No 5
Culvert pipe showing a joint at which the strips have been wired together and strengthened with fibreglass matt and resin.

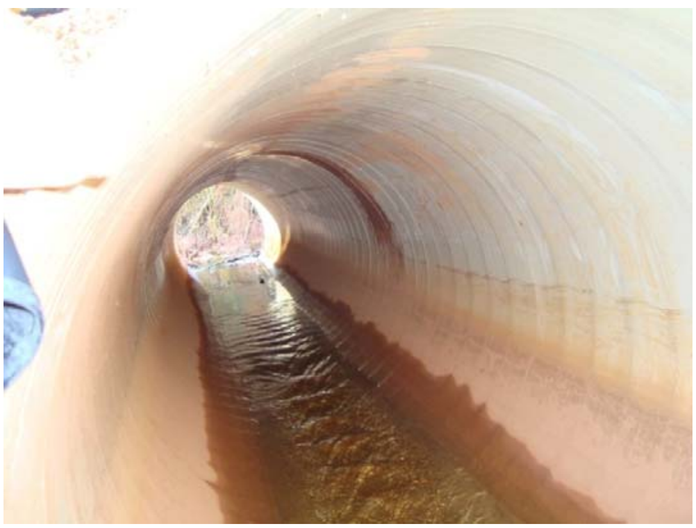
3.3 Construction of U-PVC Culverts

3.3.1 Initial Construction Trial in Temporary Works

The contractor implemented an initial U-PVC culvert trial at a swamp crossing on one of his borrow pit access roads (km 3 LHS) as shown in Photograph Numbers 6 to 8.

Photograph No 6
Initial U-PVC culvert trial in swamp crossing on borrow pit access road at km 3 LHS (July 2009).

Photograph No 7
U-PVC culvert Construction trial. Note that cover to culvert is about 300-400mm and that it survived the passage of hundreds of loaded tipper tucks delivering gravel to the project road without any damage. The manufacturer recommends that when the pipes are placed under a road there should be a minimum 700mm cover).



Photograph No 8
Culvert pipe on borrow pit access road some three months after installation and after passage of hundreds of gravel tippers. Note no observable deformation from time of installation

3.3.2 Construction Trial in Main Works

Following the receipt of the test certificate for the product from the Uganda National Bureau of Standards (UNBC) it was agreed with the Uganda National Road Authority (UNRA) that a trial construction would be made in the permanent works.

The first trial in the permanent works was made in March 2009at km 3+365 using a 900mm U-PVC culvert (refer Photograph No 9). It was noted that this pipe became a little deformed during backfilling, but the Consultant concluded that a lack of care during the backfilling process explained the observed deformation of the pipe. The flexible pipe become slightly oval with the long axis near vertical due to pressures arising during the backfilling (refer Photograph No 10).

Photograph No 9
U-PVC Culvert construction trial at km 3+365 in permanent works.

Photograph No 10
Note slightly oval shape (long axis vertical) at culvert outlet.

3.3.3 Construction Procedures Adopted

The manufacturer's Technical Specification contains guidelines for the construction and installation of the U-PVC pipes. The procedures described for placing of U-PVC pipe culverts on site are basically the same as "best practice" to be used for the placing of corrugated metal pipe culverts.

To avoid the deformation observed in the construction trial at km 3+365 the pipes were supported on the inside by timber before backfilling was commenced as shown in Photograph No 10.

Photograph No 11
U-PVC culvert pipe supported inside with timber prior to backfilling. Although testing has shown that the U-PVC pipes are very tolerate of minor deformation.

The project specification requires all culverts to be constructed in trenched conditions. Hence, all the U-PVC pipe culverts were constructed in excavated trenches.

If the *in situ* foundation materials were soft or weak, they were replaced with G30 (CBR >30) materials. The foundation was compacted to 90 % maximum dry density (MDD).

The materials used for bedding of the pipes were coarse sand with Fineness Modulus of 3.3. The sand was extracted from a local sand borrow pit.

The backfill materials used were subbase quality materials, G20 (CBR >20). The backfill up to the top of fill horizon were compacted to 93% MDD in 150mm layer using a rammer.

The procedure used by the Contractor for joining the lengths of U-PVC during manufacture involved using fibre glass matt and resin (refer Photo No 5). However, the Manufacturer's guide indicates that reparation of the pipes is to be carried out using a thin plate of the same pipe material. As a precaution the Engineer instructed the Contractor that joints in the installed pipes were to avoided, but must be restricted to within 1m of the inlet or outlet of the pipe.

3.4 Location of U-PVC Culvert on the Project

Eleven 900 mm U-PVC cross culvert pipe trials have been constructed along the length of the PDP road.

Most of the access road culverts on the project were constructed using 600 mm U-PVC pipes (refer Photograph No 12).

Photograph No 12
Example of U-PVC access culvert construction at km 29+600 (October 2010).

3.5 Monitoring of U-PVC Pipe Culvert Trials

To date all of the U-PVC culverts constructed on the PDP are performing well, there has been no observed "in service" deformation or any other kind of deterioration.

As flexible pipes made from U-PVC they can accommodate a certain amount of deformation during their service without it affecting the service life. The deformation of buried flexible pipes increases with time. However, the manufacturer's documents note that almost all deformation typically occurs during the first or second year after the pipeline is put into service. European Standard prEN 13476-3 stipulates that the average initial deformation shall be within 5% when the ring stiffness is 2kN/m2 and 8% when the ring stiffness increases.

All the trial constructions are to be regularly inspected at 6 monthly intervals during the 6 year post construction monitoring period.

Photograph No 13
At km 3+845 a replacement U-PVC cross culvert was constructed after joints in the initially installed 900 mm concrete pipe developed cracks. The replacement U-PVC pipe is performing well

4 COMPARISON WITH OTHER TYPES OF PIPE CULVERT

The traditional pipe culverts in road construction are either pre cast reinforced concrete or corrugated metal culverts. A brief summary of comparative analysis of U-PVC pipe culverts to those traditional culverts is presented below.

4.1 Diameter and Length of Pipe

U-PVC pipe culverts can be manufactured to any diameter; it only requires getting an appropriate type of spiral winding machine for large diameter pipe manufacture. Pipe sizes can be designed to different diameters instead of the standard 600 mm, 900mm, etc for concrete and metal pipe culverts.

The length of U-PVC pipe does not have to be rounded to full metre length as is the case for concrete and metal pipe culverts. For example U-PVC pipe of diameter of 825 mm and of a length of 11.650m can be produced, but in traditional culvert design the diameter is rounded to 900 and the length to 12m.

4.2 Workmanship, Assembling and Construction

This is the area where U-PVC pipe culverts have particular advantages over both concrete and metal pipe culverts.

Concrete pipe culverts require mortar joints which normally are the weakest links in the performance of the pipes. Metal culverts also require rivet or bolt connections. For U-PVC pipe culverts the connections are glued without seams.

The U-PVC are light weight materials which can be easily and quickly manufactured on site, can be manually loaded onto a light truck and manually dropped into position.

4.3 Service Life

Concrete and metal culverts can give a service life of more than 50 years under normal conditions. The U-PVC pipe manufacturer has reported that they are designed for a service life of 50 years.

4.4 Fire Resistance of the U-PVC Pipes

Bush fires are common in Africa. In this regard, resistance to fire/ heat may be one of the desired properties of pipes. The fire resistance properties of U-PVC needs further studies. In the mean time, the construction of protective headwalls, wing walls and aprons is important along with clearance of bushes from the inlet and outlet of the pipe to reduce the risks of damage to the pipe from a bush fire.

4.5 Resistance to Chemicals

Well produced concrete pipes manufactured from high quality concrete with adequate cover to reinforcement will have good resistance to corrosion, but ordinary concrete can be expected to suffer greater affect from long term exposure to an acid or alkali environment than a U-PVC pipe. Any workmanship problems during manufacture of concrete pipes may leave them prone to attack.

For metal pipe culverts damage from chemicals could be severe if the water or soil has high presence of corrosive chemicals or if there are undetected defects in the galvanising.

U-PVC pipes show good resistance to chemicals that are likely to be found in soils or streams (refer Table 4). The manufacturer reports that according to relevant tests the capacity of U-PVC pipelines to withstand corrosion is four times that of reinforced concrete.

Table 4 Resistance of PVC to Chemical Reagents

Resistance of Plastic PVC and High-density Polyethylene to Chemical Reagents
Excerpt from Volume 1, Industrial Code 312 (1973), UK

chemical	consistence	PVC		high-density polyethylene	
		20℃	60℃	20℃	60℃
fuel oil		S	S	S	S
chlorine hydride		S*	S*	S	S*
hydrogen peroxide	30%	S	S	S	S*
	12%	S	S	S	S*
	30%	S	S	S	S
	90%	U	U	U	U
hepatic gas		S	S	S	S
nitric acid	5%	S		S*	S*
	10%	S	D	S*	S*
	25%	S	D	S	S
	50%	S	U	D	U
potassium hydroxide	1%	S	S	S	S
	10%	S	S	S	S
	浓缩	S	S	S	S
potassium permanganate	10%	S	S	S	S
	20%	S	S	S	S
seawater		S	S	S	S
sodium nitrate		S	S	S	S
sodium chloride		S	S	S	S
caustic soda	1%	S	S	S	S
	10%	S	S	S	S
	40%	S	S	S	S
vitriol	10%	S	S	S	S
	20%	S	S	S	S
	50%	S	S	S	S
	60%	S	S	S	S
	80%	S	S	S	
	90%	D	D	S	
	98%	U	U	S	U

S-satisfaction U-unsatisfaction
D-distorted or absorbed ★ -result

4.6 Abrasion Resistance

U-PVC pipe culverts perform well in abrasion resistance compared to other type culverts. As shown in Figure 3extracted from the manufacturer's publication.

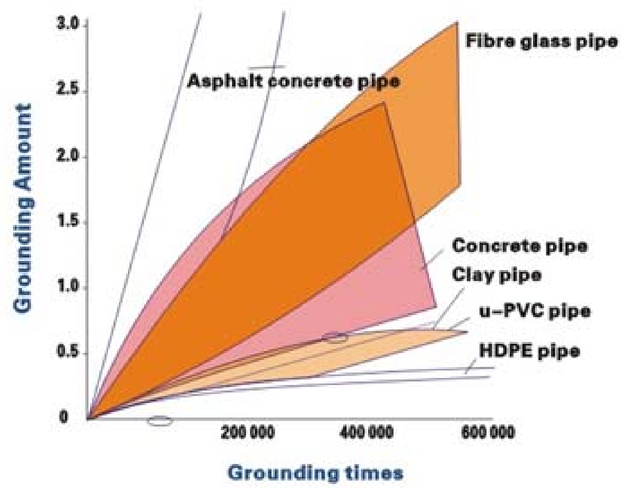


Figure 3 Effect of Abrasion (Grounding) on U-PVC Pipe &Other Types of Pipes

Of the materials compared in Figure 3 only high density polyethylene (HDPE), performed better than U-PVC in abrasion tests.

The manufacturer reports that in a sand blasting test high density PVC pipes have four times greater resistance than steel pipes.

4.7 Smooth Inner Surface

U-PVC pipes will typically have a smoother inner surface than metal or concrete pipes, this helps to reduce energy loss due to friction and helps to prevent accumulation of sediment in the pipe (i.e. the pipes have a low Manning coefficient).

4.8 Construction Cost

It is difficult to carry out a comparative cost evaluation of U-PVC pipes against traditional culvert pipes when there appears to be no other experience of the use of this technology in the region.

However, the Project Contractor (CICO) is in the business of road building for profit not for research. It was CICO's proposal to replace the concrete pipe culverts, as designed, with U-PVC pipes. CICO had imported the U-PVC strips without reference to the Employer or Engineer, as a measure of their confidence that the change would be accepted and would be profitable for them (the material quantities were much larger than required for his temporary works).

When pressed to give a cost discount for the U-PVC pipes (material cost/metre), the Contractor included recovery of the cost of buying and importing the spiral binding machine within his rate build-up and still agreed to a 10% discount on the supply of 900 mm U-PVC pipes and an 8% discount on 600mm U-PVC pipes. A summary of the Contractor's bid rate build up (2008) and agreed discount (October 2009) is included in Table 5.

Table 5 Summary Calculation for Supplying U-PVC Pipe Culvert Materials in Place of Concrete pipes

	Concrete Pipe Culverts (Bid rate build up per m length material only)	
	600mm dia.	900mm dia
Construction Cost (USD)	177	276
Exchange Rate (1 USD=1,800 UGX)	1,800	1,800
Construction Cost (UGX)	318,600	496,800
Contractor's overheads & profits (%)	15.7%	13.3%
Contractor's overheads & profits (UGX)	50,108	65,965
Bid Rate (UGX/m)	**368,708**	**562,765**
	U-PVC Pipe Culverts	
	600mm dia.	900mm dia
Agreed discount on U-PVC pipes	8%	10%
Revised Rate (UGX/m)	**339,211.36**	**506,488.50**

It is not known how the Contractor evaluated the reduced installation costs associated with U-PVC pipes, or whether this was just their profit bonus (no discount was applied to the installation cost). However, the ease and speed of installation compared with segmental reinforced concrete pipes must have had a considerable impact on the overall cost of culvert construction to CICO.

Based on the above, it has to be concluded that if U-PVC pipe materials were to be procured in bulk or preferably produced locally, the cost of spiral wound U-PVC pipe culverts would be significantly less than the alternatives of concrete or steel pipe culverts.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i) Laboratory Investigations

The spiral wound U-PVC pipes have been assessed based on the Chinese manufacturer's publication and tests conducted by Uganda National Bureau of Standards (UNBS) and Danish Technological Institute. For 600 mm diameter pipes all the data submitted show the pipe is of an acceptable standard. For 900 mm diameter pipe all parameters of the publications and tests show acceptable standard, but there are conflicting test results for the ring stiffness, one showing a relatively low test result and another reporting acceptable standard.

ii) In Service Performance

The cross drain and access culvert U-PVC pipes installed as PDP construction trials are performing well to date, but they will be inspected regularly at 6 monthly intervals during the six year post construction monitoring period (under a Consultancy Service agreement with the Uganda National Road Authority).

iii) Apparent Main Advantages of Using Spiral Wound U-PVC Culvert Pipes:

- Because the finished product can be easily manufactured on site from light weight rolls of 130mm wide U-PVC, the costs associated with transportation and handling of these culvert pipes is dramatically reduced when compared with traditional concrete culvert pipes;
- The U-PVC culvert pipes can be assembled to exactly the required dimensions;
- The finished product is light, therefore installation is quick and easy and so would be particularly suitable for emergency replacements;
- The product is very waterproof;
- The product has a 50 year life associated with excellent anti-corrosion and anti- wear properties;
- The product gives low water resistance to keep smooth water flow (low Manning coefficient);
- The pipe may not suffer breakage or leakage when subjected to over 30% deformation;
- When mass produced spiral wound U-PVC culvert pipes are expected to be significantly cheaper to manufacture and install than traditional concrete or steelpipes.

5.2 Disadvantages

- A disadvantage of using U-PVC pipes will be associated with the material's resistance to fire, this will require construction of protective end structures and regular clearing of vegetation from around the end structures. However this is not expected to significantly increase construction and maintenance costs over and above normal good practice for such drainage structures.

5.3 Recommendations

- The Uganda PDP studies and preliminary conclusions indicate that the innovative use of spiral wound U-PVC culvert technology is a suitable and cost effective construction procedure to be introduced in relation to the construction and maintenance of low volume roads;
- The easy constructability and economy of U-PVC seems to give them an overall advantage over concrete and metal pipe culverts;
- Whilst such U-PVC pipes have no history of use in the region to support their general introduction, it should be noted that the central government of China has made relevant regulations that encourages the use of U-PVC spiral wound pipes to replace concrete pipes (<800mm);
- Further test results and investigations are required to define the representative ring stiffness of the 900 mm diameter spiral wound U-PVC culvert pipes;
- The tests done for this project are the basic ones, but are not comprehensive. Further studies should include some additional tests as outlined in AASHTO and European Standards;
- Project and site specific structual analysis is required for assessing strength requirements;

- The good performance of the PDP construction trials and the expected competitive cost of spiral wound U-PVC culvert pipes lead the Consultant to encourage UNRA to actively promote further trial constructions and use of this technology in road construction in Uganda. One option might be to allow tenderers for the construction of low traffic volume roads to price for both concrete or steel culvert pipes and for U-PVC culvert pipes as an alternative.

ACKNOWLEDGEMENTS

The Uganda Pilot Demonstration Project was jointly funded by the Government of Uganda and the Nordic Development Fund. The authors wish to thank the Uganda National Road Authority (UNRA) for their support throughout the implementation of this research project and in particular we acknowledge the important contributions to the success of the project provided by Engineer James Okiror (Project Director, UNRA) and Engineer Charles Naita (Project Manager, UNRA). We also thank CICO's Project Manager, the late Mr Deng Shi Wei for his commitment to the research aspects of this construction contract.

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ASTM D 1784, Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and ChlorinatedPoly(Vinyl Chloride) (CPVC) Compounds

ASTM D 2122, Method of Determining Dimensions of ThermoplasticPipe and Fittings

ASTM D 2152, Test Method for Degree of Fusion of ExtrudedPoly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion

ASTM D 2412, Test Method for Determination of ExternalLoadingCharacteristics of Plastic Pipe by Parallel PlateLoading

ASTM D 2444, Test Method for ImpactResistance of ThermoplasticPipe and Fittings by Means of a Tup (Falling Weight)

ASTM F679Specification for Poly(Vinyl Chloride) (PVC) Large-Diameter Plastic GravitySewerPipe and Fittings

ASTM F949 - 10 Standard Specification for Poly(Vinyl Chloride) (PVC) CorrugatedSewerPipe With a SmoothInterior and Fittings

ASTM F1057Practice for Estimating the Quality of ExtrudedPoly (Vinyl Chloride) (PVC) Pipe by the Heat ReversionTechnique

AASHTO Code

AASHTO M 304-03: Poly(Vinyl Chloride) (PVC) Profile Wall Drain Pipe and Fittings Based on Controlled Inside Diameter

European Codes and Testing Standards

prEN 13476 Plastic piping systems for non-pressure underground drainage and sewerage - Structured-wallpiping systems of unplasticized polyvinyl chloride (PVC-U), polypropylene (PP) and polyethylene (PE):

— Part 1: General requirements and performance characteristics
— Part 2: Specifications for pipes and fittings with smooth internal and external surface and the system, Type A
— Part 3: Specifications for pipes with a smooth internal surface and profiled external surface and the system, Type B
— Part 4: Assessment of conformity (CEN/TS)
— Part 5: Guidance for installation (CEN/TS)

EN ISO 9969:2007: Thermoplastic pipes — Determination of Ring Stiffness

DS/ EN 744: Plastic Piping and ducting systems -ThermoplasticPipes – Test Method for Resistance to External Blows by the Round-the-Clock Method

Chinese Codes and Testing Standards

CECS122-2001 Technical Specifications of Buried PVC-U Pipeline for Sewer Engineering.

GBJ14-Code for Design of Outdoor Wastewater Engineering.

GB50268-Code for Construction and Acceptance of Water Supply and Sewerage Pileline Engineering

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THERMOPLASTIC COMPOSITES AS A DEGRADATION-RESISTANT MATERIAL USED FOR BRIDGE CONSTRUCTION AND THE USE OF RECYCLED MATERIALS IN PAVEMENT CONSTRUCTION

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Abstract

This paper examines the role played by recycled materials when used in road pavement construction and structural bridge components and the possible application of such technology and benefits of incorporating this initiative in rural Africa. The research comes from a combination of live project data, proven application of products, consideration of suitability and an assessment of market demand. The results show that the technology behind recycled products has advanced considerably in recent years. Africa needs a sustainable solution to both its disposal of waste material and the deficiency of rural road networks. The use of recycled materials offers unskilled and skilled employment, technological development opportunities and a way to improve rural transport infrastructure. The paper concludes by outlining some of the second order effects and benefits of utilising recycled materials.

1. INTRODUCTION

This paper will explore the benefits of utilising recycled materials as a construction medium for use within a rural transportation development environment. It will identify a selected number of existing initiatives where recycled materials have been used and present the benefits of incorporating this type of initiative into African rural transportation development.

The scope and purpose of the research paper is to outline the benefits of using recyclable materials for pavement construction. It will examine the existing market, quantities and type of waste produced in order to demonstrate its suitability and wider community benefits. It will examine the advantages and cost benefits and propose a development plan that covers the use of non-conventional recycled materials (glass, rubber tyres) for use within road pavement construction, and the use of recycled thermoplastic structural components for use in bridge construction.

It is intended that the reader will gain a sufficient understanding of utilising recycled materials in developing countries as a means to enhance rural development. This paper should stimulate further reader interest in the subject matter, generate creative thinking and encourage further discussion of the topic.

1.1. Background

Agriculture forms the backbone of the African economy. In order to encourage and develop agricultural growth a sound rural road and bridge network is required. This infrastructure must be within existing economic constraints, must be sustainable, have low maintenance costs, be durable and generate employment opportunities for both unskilled and skilled local labour. Quality aggregates and construction materials within rural areas are rare and expensive to extract. The production of recycled plastic building materials would utilise waste materials arising in Africa and provide Africans with much needed employment, manufacture, and design and building opportunities.

As countries become more developed and globalized one of the effects is an increase in the quantity of municipal solid waste that is produced. It is assessed that whilst a city may spend 20-50% of its budget on the collection of waste, only 20-80% of the waste is collected, with illegally dumped or disregarded waste constituting potential dangers for human health and environmental damage (Achankeng, 2003). One study has shown that Doula, Cameroon, produces 10 tons of glass and 20 tons of plastic waste per day (United-Nations, 2010); currently all of this waste is destined for land fill, if indeed it is collected at all. It is therefore obvious that this problem must be tackled; however there must be a market for reclaimed products in order to generate revenue for the process. This paper will address the potential market for some of these products within the road and bridge construction industry.

Plastic in different forms is found to be approximately 5% of municipal solid waste and is toxic in nature. Due to its limited biodegradability plastics stagnate and cause associated hygiene problems. In order to contain this problem successful experiments and practical application have been carried out using waste plastic in the construction of roads and thermoplastic bridges. The use of recycled materials for road construction within Europe, India and the USA is fast becoming an economic and environmental solution for rural road development.

2. **Rubber Tyres in Asphalt**.

The use of rubber tyres in asphalt has increased over the last 30 years within the developing world. In many countries, manufacturers and contractors are encouraged to include more recycled material such as rubber as an initiative to reduce the volume of raw products such as aggregate and bitumen. The USA commonly uses rubber tyres, in the form of a 'crumb' in road pavement construction ranging from the deep cold environment in Alaska to the hot southern states of Arizona, Florida, Texas, and California. This crumb can be produced by cryogenically freezing the tyres until brittle. The tyres are then crushed before further shredding and subsequent grading occurs. Alternatively tyres can simply be shredded from a raw state prior to grading. It should be noted that there are two types of Crumb Rubber Modifier (CRM). Normal CRM is obtained from a number of sources, ranging from car tyres, up to and including truck and bus tyres; rubber obtained through the re-treading process. The other type is the High Natural Rubber (HNR) type. This differs as the product includes 40 – 48% natural rubber and a minimum of 50 % rubber hydrocarbon Sources of (HNR) include scrap tire rubber from some types of heavy truck tires, but are not limited to scrap tires. Other sources of high natural rubber include scrap from tennis balls and rubber mats. (IWMB, n.d.)

2.1. Methods.

There are generally two recognized methods of using rubber in road construction; a wet and a dry method. Other studies have been completed that examine the interaction of a dry method of construction, and the interaction of the heat and the bitumen products in order to ascertain if any wet method process occur during the construction process.

2.1.1. Wet Method.

2.1.1.1. General. This method uses the rubber as a binder agent as opposed to a bulk fill material and uses material ranging in size from 0.075 to 1.2mm. The crumb is heated to high temperatures, typically 175 to 190°C for a period of 30 to 60 minutes with the bitumen, prior to the addition of aggregate. (Buncher, 1995). The rubber absorbs some of the lighter fractions from the bitumen and forms a thick viscous gel. It is this gel which then acts as the binder when the aggregate is added.

2.1.1.2. Standards.

In the USA, the ASTM definition of asphalt rubber is

"a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 % by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles" (ASTM D 8-02, Vol. 4.03, "Road and Paving Materials" of the Annual Book of ASTM Standards 2005).

Additionally the ASTM definition of rubber binder is

"a blend of paving grade asphalt cements, ground recycled tire (that is, vulcanized) rubber and other additives, as needed, for use as binder in pavement construction. The rubber shall be blended and interacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles prior to use."ASTM D 6114 - Standard Specification for Asphalt Rubber Binder

This 15% of weight constitutes scrap tires that have been ground down to sizes ranging from 0.075 to 1.2 mm in size.

2.1.1.3. Advantages.

There are a number of advantages of using the wet method, and the use of rubber within asphalt road construction. These include

- Improved durability as surface layer
- Resistance to fatigue cracking
- Resistance to reflection cracking
- Resistance to aging
- Can be used in reduced thickness
- Reduced noise
- Lower life cycle costs
- Environmental benefits

Disadvantages.

The disadvantage of this system is that the initial cost of the project is increased by approximately £22 per tonne. (IWMB, n.d.). This is primarily due to the increased binder content, addition of rubber, increased energy requirements due to elevated temperatures and extending mixing time, additional plant personnel/equipment for handling and blending, and additional personnel/equipment at the construction site. Studies by CLATRANs showed an increase in price of one and a half to two times the price per ton. This however can be mitigated by a reduced pavement thickness. (Van Kirk, 1997). The process requires specialist plant and knowledge of the process in order to produce the correct mix. The laying process must use a high mechanical process as the material is not suitable for hand working.

2.1.2. Dry Method.

This involves the use of a larger size of rubber crumb, nominal size typically 0.4 to 9.5mm. It is mixed with the aggregate and is normally about 3 to 4% of the placed road base. It can be used during the construction of new roads but it can also be used as a temporary repair to roads with a worn wearing surface but still with suitable sub-grade.

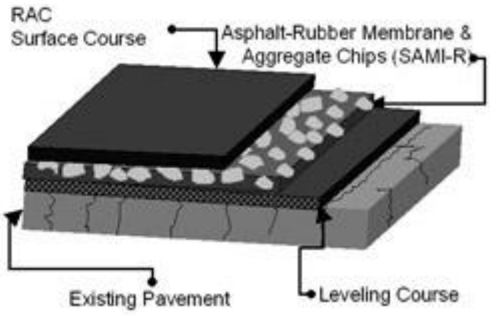

Figure 1: Typical stress absorbing membrane with interlayered rubber.

Figure 1 shows a Stress Absorbing Membrane Interlayer-Rubber. This is simply an asphalt rubber chip seal which is then overlaid with either conventional asphalt or Rubber Asphalt.

2.1.2.1. Advantages.

The above scheme shows a method of rapidly repairing tired road surfaces which may allow rural areas to continue to be connected by a maintained road. This may allow time for additional donor contributions to be raised or for a re-prioritisation of road maintenance. From a technical stance the material is very flexible and elastic and has a low modulus as it flexes and creeps to relieve stresses and to heal many of the cracks that do occur. Interlayers can act to interrupt crack propagation and have been shown to be highly effective in minimizing reflective cracking in overlays of existing distressed asphalt and jointed Portland cement concrete pavements. Finally the seal prevents further water egress into the sub-base and stabilises the roads foundations.

2.1.2.2. Disadvantage

The use of rubber in the dry method of road construction requires the aggregate to be mixed to a special composition which will increase the price per ton approximately 15 – 20 % (Corporation of the County of Grey, 2012).

3. **Glass in Road Construction**.

An alternative substitute to rubber is crushed glass, which was been developed in Europe and the USA in the 1960s where the glass replaces between 5 and 15% (up to 40% in the USA) of the aggregate in dense graded asphalt. Medium and fine recycled glass exhibits geotechnical behaviour similar to natural aggregates. Shear strength tests indicate that the fine and medium glass encompass shear strength parameters similar to that of natural sand and gravel mixtures comprising angular particles. Research in the USA and Australia has accepted crushed glass as a suitable medium in road pavement construction. The Glass Recycling company in South Africa now indirectly supports 30,000 individuals (The Glass Recycling Comapny, 2011) who earn an income from the collection of waste glass.

It can be used for low to heavy traffic volume of light weight (300 vehs per day of residential traffic) vehicles in applications such as residential streets or distributor roads. One could agree that many of the rural roads in Africa, whilst major, do not see the heavy traffic weight expected or seen in some of the more developed countries. Whilst glass should predominately be recycled back into glass products, there are occasions when this is not possible. One such case study is from Australia where the cost of shipping the glass to a recycling plant was too prohibitive. This cost benefit analyses has also seen glass collected as recyclable material, but taken to land fill due to a down turn in the market.

Fulton Hogan (Fulton, 2008) has conducted extensive trials on the use of glass as a component of asphalt. It was concluded that the addition of a 5% glass to the asphalt had no effect on the design parameters of the road.

4. THE USE OF THERMOPLASTIC BRIDGES FOR RURAL TRANSPORTATION

The use of thermoplastics for the construction of bridges is a relatively new initiative developed in the USA over the last 20 years. The initial rationale behind this research was to produce a high quality sustainable bridge that could withstand high imposed loads, require minimal maintenance, have sufficient longevity and have limited impact on renewable resources. In early 2009, the world's first vehicular bridges made of 100% recycled plastic composites were built at Fort Bragg in North Carolina. The bridges were designed to support 80 tonne M1 Abram's Tank. Figure 2 shows a typical thermoplastic bridge being used by a 70 tonne military battle tank. These bridges confirmed the anticipated benefits, surpassed the expected performance and in addition highlighted the benefits of not requiring any maintenance. This technology was introduced to the UK in late 2011 to build the world's longest single span recycled plastic bridge and the first recycled plastic bridge in Europe. There are approximately 100 million tonnes of plastics consumed worldwide each year (Kim, et al., 2010). The use of recycled plastic offers a viable innovation to address the mass of waste plastic produced worldwide.

Figure 2: A 70 tonne tank crossing a plastic bridge at Fort Bragg, USA.

4.1. Thermoplastic Composites

Thermoplastic (also known as a thermo softening plastic) is a polymer that turns to a liquid when heated and freezes to a rigid state when sufficiently cooled. Most thermoplastics are heavy weight polymers that can be re-melted and remoulded and have an elastic modulus (stiffness) at least 10 times less than the most common timber used in construction. Subsequent research has shown that certain immiscible blends of thermoplastics can address this weakness and enable the manufacture of cost-efficient, formed structural components that are theoretically capable of replacing treated timber, steel and reinforced concrete. These structural shapes can be moulded as single integrally-formed components such as I-Beams, T-Beams and C-Beams. A further benefit is the resultant reduced cross-sectional area of such shapes which in turn represents a significant cost savings in terms of material usage, without sacrificing any mechanical properties. A photograph of typical piles and I-Breams being prepared for transportation to site is shown at Figure 3. These components have been used on a range of structurally demanding applications included joists, railroad ties and marine piles. In the USA recycled thermoplastic composite materials already present an alternative to chemically treated timber. These structural composites are used commercially as replacements for creosoted railroad ties and other rectangular cross-sectioned materials. The US has developed ASTM test methods to evaluate and compare the properties of plastic composites in commercial use.

Figure 3: Plastic piers and I Beams prepared for transportation to site.

4.1.1. Material Properties of Thermoplastics

As previously mentioned, integrally-formed thermoplastic components weigh comparatively less than other commonly used construction materials such as concrete and steel. Thermoplastics weigh roughly the same as oak wood and are far less dense than similar sized concrete and steel components. A typical comparison of densities is shown in Table 1.

Table 1: Weight Comparison of Thermoplastic and other Construction Materials

Material	Pounds per cubic foot	Density
Thermoplastic	55 pcf	881.015 Kg/m^3
Wood	60 pcf	961.102 Kg/m^3
Concrete	150 pcf	2402.77 Kg/m^3
Steel	490 pcf	7849.047 Kg/m^3

Various material properties including elastic modulus were tested based on ASTM **D6111** and shown in Table 2. A comparison showing some of the typical values for mild steel are shown in table 3.

Table 2: Properties of Thermoplastic Material

Specific Gravity	0.85-0.90	
Elastic Modulus (ASTM D6108)	350,000 psi	2.413 X 10^3 N/mm^2
Allowable Tensile Stress (ASTM D638)	600 psi (Ultimate = 3,000 psi)	4.137 N/mm^2 (Ultimate = 20.648 N/mm^2)
Allowable Flexural Stress (ASTM D6109)	600 psi (Ultimate = 2,500 psi)	4.137 N/mm^2 (Ultimate = 17.237 N/mm^2)
Allowable Compressive Stress (ASTM D695)	600 psi (Ultimate = 2,500 to 4,300 psi)	4.137 N/mm^2 (Ultimate = 17.237 N/mm^2 to 29.647 N/mm^2)
Allowable Shear Stress (ASTM D6109)	350 psi (Ultimate = 1,500 psi)	2.413 N/mm^2 (Ultimate = 10.342 N/mm^2)
Coefficient of Thermal Expansion (ASTM D696)	0.0000282 in/in/deg F	M/M-K 0.0000508

Table 3: Properties of mild steel

Specific Gravity	7.86
Elastic Modulus (ASTM A36)	200 x 10^3 N/mm^2
Ultimate Tensile Stress (ASTM A36)	400 N/mm^2
Yield Strength	250 N/mm^2

The ultimate tensile strength of thermoplastic material can reach 31 N/mm^2. A fraction of the ultimate strength (4.137 N/mm^2) is utilized for an allowable stress in bridge design because of conservatism and creep control. As long as the applied stress is within 4.137 N/mm^2. This material is predicted to avoid any creep effect over a 25 year period of constant loading.

4.1.2. Typical Types of Material Suitable for Thermoplastic Component Construction

The most common plastic material used for thermoplastic components is Polypropylene (PP) and High Density Polyethylene (HDPE). This can be easily obtained from recycling plastic bottles, discarded plastic containers and it is also possible to use waste plastic bags.

4.2. Recent Examples of Thermoplastic Bridge Construction

In November 2011 a landmark bridge was built over the river Tweed, at Easter Dawyck in Peeblesshire. Figure 4 shows a photograph of the existing bridge prior to being replaced. The existing bridge had seriously degraded and had been downgraded from 28 Tonnes to 5 Tonnes. It was a 27 meter, three section, twin pier, simply supported bridge. The decking timber was rotten through and the steel sub-structure was severely rusted. According to a Post Exercise Report written by an Officer of the Royal Engineers the bridge consisted of three 9 meter long pre-assembled bridge deck units, the trafficable bridge deck surface, railings and vehicle guide walls; these are all made of recycled thermoplastic. Each section of the bridge was a 9 metre span. The existing bridge was demolished and new bridge constructed in a total of 11 days by the Royal Engineers. (Aconley, 2012)

Figure 4: Dilapidated composite bridge at Easter Dawyck, Peeblesshire, Scotland.

The replacement bridge was the first recycled thermoplastic road bridge to be built outside the United States. It was designed to carry heavy goods vehicles of up to 44 tonnes (11.5 Tonne single axle weight). Its individual spans, at over 9 m, are the longest ever constructed from recycled plastic. Being manufactured from plastic it will not rot or rust, it does not require painting, treating or regular maintenance. It has made very effective use of over 50 tonnes of waste plastic, e.g. from kerbside collection of household bottles and plastic waste from end of life vehicle recycling, which might otherwise have been sent to landfill. The bridge is also 100% recyclable. Figure 5 shows a section of the replacement bridge being craned into place. Figure 6 shows a longitudinal photograph of the bridge during the construction process.

Figure 5: Typical 9 metre decking section being craned into place.

Figure 6: Longitudinal view of bridge during construction.

The construction had valuable academic oversight from Cardiff University. The value and benefits of this bridge construction project were succinctly quoted by Professor Robert Lark (Deputy Director, Cardiff University School of Engineering):

"*A unique opportunity to contribute to the development and assessment of a truly sustainable construction material for the nation's transport infrastructure. This initiative has the potential to deliver durable, low maintenance alternatives to traditional structures manufactured from recycled waste, the benefits of which, particularly to rural communities, should be far reaching both economically, socially and environmentally*." (Mainwaring, 2012)

One of the key aspects of this construction task was that none of the engineers involved had ever constructed a thermoplastic bridge before and had not received any specific training to do so. Only one engineer from the manufacturing company provided oversight and guidance during the process.

4.3. Advantages of using Recycled Plastics

The use of recycled plastics as a structural thermoplastic construction medium is a relatively new innovation in both the USA and UK. Even at this early stage the advantages are very apparent and disadvantages are sparse. Some of the advantages and disadvantages of using recycled material for the production of thermoplastics are as follows:

4.4. Advantages

The advantages of regenerating recycled plastics as a structural construction medium are clearly apparent. Some of the specific advantages relating to thermoplastic structures are as follows:

Minimal ultraviolet degredation of less than 0.003 inches/ year (0.0762 mm).

The fire resistant ignition point of termoplastics is 660^0 F (349^0 C). A composite flame retardent coating is available that prevents ignition completely.

The range heat deflection range is between $+250^0$ F and -250^0 F ($+121^0$ C and -157^0 C).

The skid resistance and coefficient of friction can be modified by surface texturing during manufacture. It is also highly resistant to wear and abrasion.

Thermoplastics are virtually impervious to moisture, resistant to marine borers, corrosion, insects and rot.

Thermoplastics do not leach any poisons into the surrounding soil or water as there are no carciogenic chemicals present.

Thermoplastics offer a sustainable solution to reduce the current excessive levels of plastic waste produced worldwide.

4.5. Disadvantages

Recycled thermoplastic technology is a relatively new and specialised process. It is yet to be fully embraced in the developed world and is currently only manufactured by one known company. The technology is patented and can not be easily replicated without licence, however, with the correct licensing arrangements this could be over come. The cost of thermoplastic components from an established plant are comparable to those of traditional concrete and steel bridge components. The cost of establishing a plant, collection of materials, training of operators and other associated costs may make the use of thermoplastic technology initially seem extortionate but whole life costs, due to a the deminised requoirement for maintenance, brings makes these bridges a viable alternative. The establishing of such a manufacturing plant within Africa would require a deliberate operation with viable financial return but bridges and other component parts could be imported until demand makes this option of cost benefit.

4.6. Feasibility of Using Thermoplastic Bridges in Rural Africa

There are a number of factors that must be considered regarding the use of thermoplastic bridges. A summary of the main requirements placed into a simple table is as follows:

Requirement	Description	Feasibility	Remarks
Is there sufficient plastic waste available in the target location?	One tonne of plastic waste produces one tonne of product	There are numerous waste disposal sites within all countries and cities in Africa that contain suitable plastic waste products such as plastic bottles and redundant plastic components	This would generate a second order effect by the generation of multiple business opportunities; recycling, reduced litter, new manufacturing opportunity
How expensive is a typical bridge?	What is the cost per M^2?	As a guide a thermoplastic bridge costs approximately £1000 per M^2 (the cost may vary considerably due to the complexity of the design and ground conditions)	A typical 4 meter wide, single span bridge crossing a 9 meter gap would cost approximately £36,000, not including transportation and labour
How much land would a typical production plant require?	The exact details of the process and composition is commercially confidential	Approximately 30-40,000 Sq./ft. is required	
What are the skills required and size of workforce?	What level of training is required for the workforce?	A shift of 5-6 semi-skilled workers is sufficient and a main plant operator	All workers would require training, the main plant operator requires more advance training
Is there any waste product from the manufacturing process?		No, all plastic components are utilised in the procedure	

5. Second Order Effects.

The proposals for the use of recycled materials in the construction of roads in Africa may seem unnecessary as the quantity of raw material that they replace does not seem to be significant in both cost and supply. However the secondary effects of this recycling should be considered. In the case of the rubber, whilst entrepreneurs have recycled tyres as sandals, their use in roads offers a viable and ecological resting place for the bulk of tyres that have exceeded their natural life. If one looks at South Africa, where an estimated 95 000 tons of waste tyres are generated each year, the South African Tyre Recycling Process Company **(**SATRP) - a not for profit tyre recycling scheme - has been initiated to reduce the ecological aspect of waste tyres. However one of the main uses specified in the information literature, (STARP, 2010) is the use of rubber crumb in road surfacing and construction. It appears that once a market for a waste product is created then individuals will start to gather old tyres and sell them on to the waste companies.

South Africa has also created a market for the collection and sorting of glass through the setting up of the Glass Recycling Company. This has allowed over 30,000 individuals to gain income through; collecting waste bottles, setting up their own collection service or servicing the glass collection banks that have been placed around the country. Again, once viable market conditions are set, and then entrepreneurial activity is sure to follow.

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COMPARISON OF TEST METHODS AND IMPLICATIONS ON MATERIALS SELECTION FOR ROAD CONSTRUCTION

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Abstract

The purpose of this paper is to raise awareness of the inherent differences between similar soil tests carried out in accordance with different testing standards that are commonly used in the Eastern and Southern African region. The paper reviews the requirements for some basic tests used for assessing the suitability of soils for incorporation in road pavements and finds that there are significant differences in procedure which produce quite different results leading to inconsistencies in the quality of materials incorporated in the road works. It is concluded that a more comprehensive review should be undertaken of all the commonly used soil and aggregate test methods so that the differences can be taken into account when setting specifications and, ultimately, that testing standards in a common transport region such as Southern Africa should be gradually standardized and, importantly, that all testing laboratories should be properly accredited.

1. INTRODUCTION

1.1 Background

The constituent materials used in the construction of roads – soil, gravel or rock - should be "fit for purpose", i.e. they should possess certain fundamental engineering properties that allow them to provide satisfactory and cost-effective performance in service. Ultimately, and to varying degrees, depending on the position they will occupy in the pavement, the materials used should be sufficiently strong, stiff and durable under all climatic conditions and traffic stresses to spread traffic loads to the underlying pavement layers and subgrade without deforming. Strength, stiffness and durability are correlated to varying extents with such soils parameters as grading and plasticity, which, either individually or collectively, affect the moisture sensitivity of the material – a key parameter governing pavement performance in the road environment.

In order to determine the properties of road building materials, they need to be subjected to various laboratory tests – a critical activity that is central to cost-effective road design, construction and performance and, as such, is integral to any road project. These tests are generally governed by strict procedures that, in the main, have been derived primarily from American (AASHTO or ASTM) and British Standards (BS). In many cases, they have been incorporated, with some adaptation, into national standards such as the South African TMH1 (Standard Methods of Testing Road Construction Materials (NITRR, 1979, 1986)) and the Zimbabwean Central African Standards (CAS) (1974).

Currently, a number of different testing standards are used in the African region such as TMH1 (e.g. in South Africa, Namibia, Botswana), BS (e.g. in Malawi, Tanzania, Kenya), AASHTO (e.g. Ethiopia). It is also not uncommon to find that the testing standards used in undertaking research work in a particular country are tied to the country of origin of the research organization which may well be different to the national testing standards.

There can be significant problems associated with the use of multi-standard testing systems in a geographic region such as Southern Africa. These problems may be seen as falling within two overlapping areas of concern. Firstly, there are problems concerned with differing test equipment and/or procedures and, secondly, there are difficulties associated with extrapolating test results from one country to another in the same region. In both cases, the results may not be comparable and this can lead to much confusion because the differences in test procedure alone are sufficient to explain the difference in material quality apparently tolerable by roads agencies in different Southern African countries. This has resulted in inconsistency of the designed works and, in some cases, failures because of the use of misleading test results for design purposes.

The problem of applying mixed testing standards in the region is all the more serious because of an apparent lack of appreciation of the differences in test results emanating from these different testing standards. There have been instances where contractors and supervising consultants have been at loggerheads over the acceptability of a particular material simply because they were undertaking the same test using different testing standards and, as a result, were obtaining different results.

1.2 Purpose and Scope

Against the above background, the main purpose of this paper is to raise awareness of the inherent differences between similar soil tests carried out in accordance with the various soil testing standards that are commonly used in the Southern African region. By so doing, it is hoped that soil testing in the region will be carried out in a more discriminating manner than hitherto and, moreover, that the results of the tests will be interpreted in light of the test method employed so that, in turn, appropriate specifications can be set in relation to the type of soil and prevailing road environment.

The paper reviews the requirements of a few basic soil tests that are used for assessing the suitability of soils for incorporation in road pavements. Although just as important, tests for stabilized soils, including durability, and aggregate tests are not covered in the paper. However, some mention is made of the accuracy and precision (repeatability and reproducibility) of various soil tests as well as the sampling procedures adopted and the calibration of equipment– all of which contribute significantly to the large variance in results typically associated with soil testing.

1.3 Approach

The approach adopted has been to broadly compare and contrast the test procedures adopted for a selection of soils tests as stipulated by different testing standards and to highlight how these differences in the procedures can influence the test results and the implications in practice.

1.4 Significance of paper

Currently, there are a disconcerting number of premature road failures that have occurred in the region. Although not specifically cited, it seems likely that one of the reasons for such failures has been due to poor characterization of the soils, in large part due to misleading test results. It is hoped, therefore, that a better understanding of the various factors that affect the results of soil tests and the variability of the results obtained will reduce the likelihood of such failures in future.

2. COMPARISON OF TEST METHODS

2.1 Introduction

There are underlying reasons why tropical soils are very sensitive to the testing procedure adopted. This is largely because the well known BS or AASHTO standards prescribe good practice that, particularly in the case of AASHTO, are in the main based on "normal" experience with temperate zone sedimentary soils, i.e. soils laid down by the action of water or ice. However, it is now widely recognized that tropically weathered material behaviour can be noticeably different from temperate sedimentary soils from which the standard principles of soil mechanics were derived (e.g. Terzaghi and Peck, 1967; De Mello, 1971; Gidigasu, 1988). Table 1 lists some of these differences.

Table 1: Differences between temperate and residual soils (Adapted from Netterberg, 1985)

Property	Temperate sedimentary Soils	Tropical residually weathered soils
Climate	Temperate to cold	Arid, tropical, warm temperate
Composition	Natural or crushed	Varies from rock to clay
Aggregate	Solid, strong rock	Sometimes porous, weakly cemented fines
Fines	Rock particles with or without clay	Cemented, coated and aggregated clay and/or silt fines
Clay minerals	Mostly illite or smectite	Wide variety, e.g. halloysite, attapulgite (palygorskite)
Cement	None (usually)	Iron oxides, aluminium hydroxide, calcium carbonate, etc
Chemical reactivity	Inert	Reactive
Grading	Stable	Sensitive to drying and working
Solubility	Insoluble	May be soluble
Weathering	Weathering or stable	Forming or weathering
Consistency limits	Stable	Sensitive to drying and mixing
Salinity	Non-saline	May be saline
Self-stabilization	Non-self stabilizing	May be self-stabilizing
Variability	Homogeneous	Extremely variable

When dealing with tropical residually weathered materials, special procedures are often necessary to obtain reliable, relevant and consistent results. This applies particularly to the handling and treatment of samples before testing (Head, 1992; Geological Society, 1990). The approach to the laboratory investigation of tropical materials in terms of the range of tests employed, their detailed procedures and their interpretation should derive principally from the following (TRL, 2000).

- Chemically bonded materials (e.g. affects assessment of strength)
- Mineralogical complexity (e.g. influences volume change)
- Fragile relict fabric (e.g. leads to particle breakdown)
- Very heterogeneous soil-rock masses (e.g. influences statistical reliability of data)
- Variable climate (e.g. moisture susceptibility)

2.3 Soil preparation for Atterberg limits and grading

The differences in test procedures appertaining to TMH1, BS and AASHTO standards for the soil preparation for Atterberg limits and grading determinations, as applied to pavement materials specifications such as COLTO, 1998; TRL Overseas Road Note 31,1993 and AASHTO M147-65 1996, are summarized in Table 2.

Table 2: Differences in soil preparation methods for Atterberg limits and grading

TMH1 Method A1(a) (1986)	BS 1377-2 (1990)	AASHTO T87-86 (1996)
(i) No provision made for testing soils in their natural state (natural moisture content).	(i) Provision made for testing natural soil samples. Where practically the whole sample passes the 0.425 mm sieve it is tested without any previous treatment.	(i) No provision made for testing soils in their natural state.
(ii) Oven drying at a temperature of 105-110°C required.	(ii) Air drying preferred but oven drying at 50°C or less allowed.	(ii) Oven drying at a temperature not exceeding 60°C allowed.
(iii) Wet sieving method used. The material retained on the 0.425 mm sieve after dry sieving is boiled or allowed to soak overnight. The -0.425 mm slurry is not decanted but dried off at 105 to 110°C.	(iii) Wet sieving method used. Granular soils wet sieved through a 0.425 mm sieve. The soil/water mixture is allowed to stand. When the water clears, it is decanted and the remaining sample is air dried.	(iii) Dry sieving method used. The material is dry sieved through a 0.425 mm sieve. All the material retained is rubbed down in a mortar with a pestle and re-sieved.

2.3.1 Differences in test methods

As is readily apparent from Table 2, there are a number of differences in the soil preparation procedures for Atterberg limits and grading determinations that relate to the differing moisture conditions during pretreatment for testing and type of sieving undertaken as summarized below.

(a) Moisture condition

- As received: (i.e. at natural moisture content)
- Soaked: immersed in water for varying periods up to 24 hours
- Air dried: dried under normal site temperature
- Oven dried: oven dried at 105 to 110°C, or at some other lower temperatures e.g. 60°C.

(b) Grading

- Dry sieving – used only by AASHTO, but wet sieving of material passing 0.075 mm sieve.
- Wet sieving – used by TMH1 Method A1(a) and A1(b) and BS1377.

2.3.2 Implications of different test methods

Tropical residual soils are particularly sensitive to the effects of drying and, more specifically, to the actual drying temperatures followed in the different test procedures used in the preparation of soils for determination of Atterberg limits, grading and shrinkage (Terzagi, 1958; Newill, 1961; Wesley, 1973). Even partial drying at moderate temperatures may change the structure and physical behaviour of some materials such as laterites, some times irreversibly from quite high PIs to non-plastic, due to the mineralogical changes in soil (e.g. LNEC et al, 1959, 1969; Morin and Todor, 1976; Gidigasu, 1976; Charman 1988; Fookes, 1997).

Comprehensive studies on tropical residual soils (e.g. Morin and Ayety, 1971; Morin and Todor, 1976) concluded that changes in properties, even with air drying at room temperature, can be significant and that erroneous values for Atterberg Limits, grading and density may be applied unless the soils are similarly dried during construction.

There are also significant differences in grading results depending on whether dry or wet sieving procedures are followed. Wet sieving is more thorough as the soil fines are obtained by a three-stage process designed to remove all clay adhering to the aggregate, but is slower and the fines are oven dried by heating to 105 to 110°C (TMH1 Method A1(a)). Wet sieving is the preferred method of particle size analysis because it gives more reproducible results and a more accurate representation of the engineering characteristics of the soil (Millard, 1993). This is particularly important with some tropical residual soils because the fines tend to adhere to the larger particles.

Dry sieving should not normally be permitted (e.g. Yoder, 1959) unless the soils contain insignificant amounts of silt and clay (BS 1377: 1990) as, otherwise, the results will understate the amount of fines passing the sieves on which the Atterberg limits and linear shrinkage are carried out and, as a result, influence other specification criteria such as the Plastic Modulus (PI on the 0.425 mm sieve x percentage fines passing the 0.425 mm sieve) and the Fineness Index (FI) (PI on 0.075 mm sieve x the percentage passing the 0.075 mm sieve).

The Grading Modulus (GM) (GM = [300-(P2+P425+P075]/100 where P2, etc., denote the percentage passing through that sieve size) which is often used as a specification criterion is also affected by the type of sieving carried out. The dry method tends to give significantly higher GMs than the wet method with the result that the shape of the grading curve is also different with the dry method tending to yield results lying outside (coarser than) the coarse half of the grading envelope typically specified for a base course material and the wet method giving results lying outside (finer than) the fine half of the envelope.

Although the use of the dry sieving method may be used for reasons of expediency, there are known cases in Botswana (Pinard, 2005) where this method was used unwittingly for assessing the grading and plasticity of base course materials on roads which have subsequently believed to have failed because misleadingly coarse gradings and/or low PIs were obtained during testing. Thus, it is clear that although both wet and dry sieving are catered for in the standard procedures, dry sieving should only be used for materials containing little or no silt or clay and, in all other cases, wet sieving should be mandatory. Moreover, the compliance specifications used, ideally on the basis of research and investigation, should also generally be based on the wet sieving method.

As regards the particle size analysis of soils, it is also noteworthy that the purpose of this analysis is to determine the proportional *volume* occupied by the particles of different sizes. Since the proportions are determined by weighing the dried material retained between each sieve, this involves the assumption that the bulk relative density of the particles is constant over the range of sizes. With most soils this is a valid assumption (Millard, 1993) but with some soils, notably calcretes (Netterberg, 1969, 1971) and laterites (Charman, 1998), there can be large differences between the bulk relative density of the coarse and fine fractions and a correction to the grading curves is necessary on this account. This is illustrated in Figure 2.

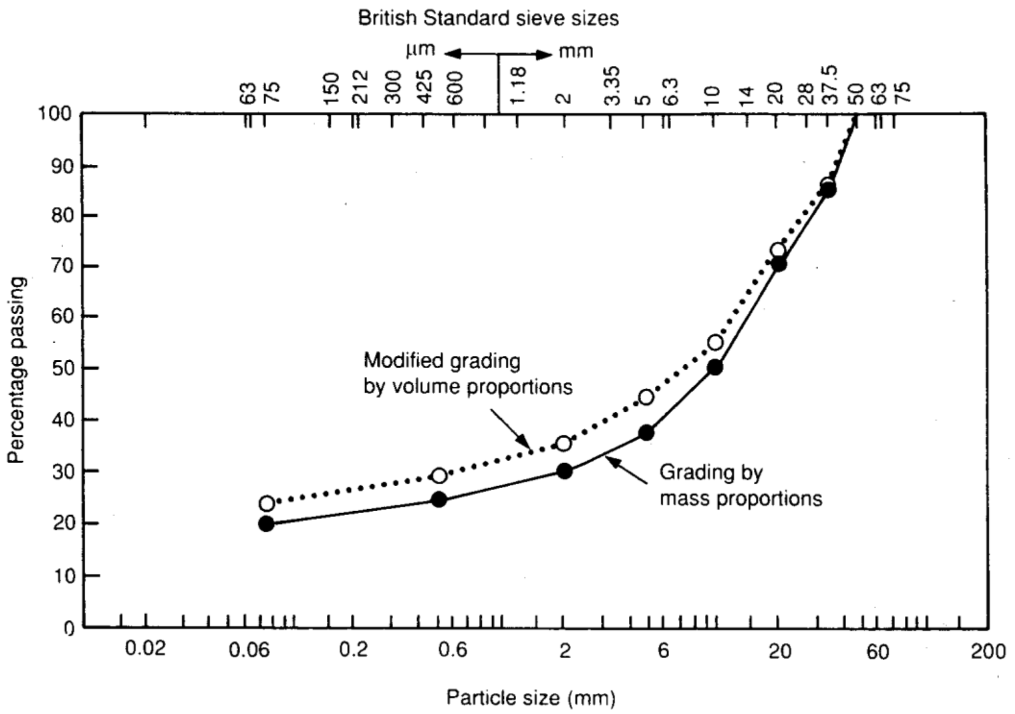

Figure 2: Modification to particle size distribution required with lateritic gravels (Charman, 1988)

In practice, corrections to grading curves for tropical residual soils in the Southern African region are seldom carried out. As a result, as indicated in Figure 2, the resulting grading curve tends to underestimate the amount of fines in the soil sample, thereby incorrectly estimating any soil parameters such as Grading Modulus, Plastic Modulus and Fineness Index, that all include the use of the particle size on a particular sieve as part of the parameter determination.

2.4 Liquid limit, plastic limit and linear shrinkage

The differences in test procedures appertaining to TMH1, BS and AASHTO standards for the determination of the Liquid Limit (LL) and Plastic Limit (PL) and the linear shrinkage (LS) of a soil are summarized in Tables 3 and 4 respectively.

Table 3: Differences in determination of the liquid limit of a soil

TMH1 Method A2	BS 1377-2 (1990)[1]	AASHTO T89-96 (1996)
Casagrande cup method. (i) No pre-soaking (ii) Soil mixed with water for 10 minutes. (iii) Groove closure about10 mm. (iv) Provides for 3 point flow curve method standard but also provides for 2- and 1-point methods. (v) Non-plastic material: (a) Cup tapped a few times before groove is cut, several strokes are used for cutting the groove–normally only one used. (b) Portions should not slide together but flow. (vii) Casagrande cup operation not repeated for a single point. (vi) No provision made for material to be tested in its natural condition.	**Casagrande cup method.** (i) Overnight moisture equilibration recommended (24 hours). For soils with a low PI this is not considered necessary. (ii) Groove closure 13.0 mm. (iii) Four determinations made (from dry to wet). (iv) Different grooving tool. TMH1 type used for non-plastic materials. (v) Casagrande cup operation carried out in duplicate for determination by the one point method. (vi) Provision is made for material to be tested in natural condition (only when whole or almost whole sample passes 0.425 mm sieve.	**Casagrande cup method**. (i) No pre-soaking specified. (ii) No mixing or moisture equilibration time specified. (iii) Groove closure about 13 mm. (iv) Provides for both 3-point and 1-point methods (v) Several strikes (up to six) permitted when cutting the groove (vi) No provision made for testing material in its natural state..

Table 3: Differences in determination of the liquid limit of a soil

TMH1 Method A2	BS 1377-2 (1990)1	AASHTO T89-96 (1996)
Apparatus: Casagrande cup: Base hardness= Shore D 85-95 @ 23 ± 2 °C Hard rubber feet usual. ASTM grooving tool.	**Apparatus**: Casagrande cup: Base hardness = 84-94. IRHD @ 20 °C (± 3% Shore D value. Resilience 20–35%. No rubber feet. Casagrande grooving tool (different shape to ASTM tool).	**Apparatus:** Casagrande cup: Base resilience of 80-90%. "Resilient" feet. Grooving tool as for TMH1 usual.

1 – Cone penetrometer method preferred

Table 4: Differences in determination of the plastic limit and linear shrinkage of a soil

TMH1 Method A3 (1979)	BS 1377-2: (1990)	AASHTO T90-96 (1996)
Plastic limit (i) No pressure specified. (ii) No curing time specified for either the PL or LS.	**Plastic limit** (i) Approx. rolling pressure specified (i.e. the pressure required to reduce the thread from 6 mm to 3 mm in 5-10 backward and forward movements when the soil is close to the PL. .	Plastic limit (i) A rolling rate of 80-90 strokes per minute is given (a stroke is one complete motion of the hand forward and backward).
Linear shrinkage (Method A4-1979) (i) Material from LL test used and number of taps required for groove closure for this material is recorded as this information is required for LL determination. (ii) The material is put into an oven at 105 °C to dry. (iii) If the specimen has curled during drying it is pressed back into the mould and measured. Detailed measuring instructions given.	**Linear shrinkage** (i) Material is mixed with water until it becomes a smooth homo-geneous paste with a moisture content approximating the LL. (ii) The mould is first air-dried until the material has shrunk away from the walls of the mould, then at 60-65 °C and then at 105 – 110 °C to complete drying. (iii) If specimen has curled during dry-ing, top and bottom are measured and the average is used.	**Linear shrinkage** Determined from shrinkage factors (T92-91). No bar trough method.
Apparatus: LS trough inside dimensions = 150 x10 x 10 mm (rectangular trough).	**Apparatus** Semi-cylindrical LS trough inside dimensions = 140 mm, dia. = 25 mm.	**Apparatus** Not applicable.

2.4.1 Differences in test methods

There are a number of differences in the procedures stipulated by the various standards for carrying out the LL, PI and LS tests as well as differences in the type of equipment specified as summarized below:

Liquid Limit

(a) Procedure
- Time of mixing and moisture equilibration
- Width of groove closure
- Number of moisture/blow determinations
- Speed of cup operation

(b) Equipment
- Hardness of Casagrande cup base

Plastic Limit

(a) Procedure

- Type of pressure applied

Linear Shrinkage

(a) Procedure

- Material preparation
- Material used
- Drying method
- Measurement of shrinkage

(b) Equipment

- Type of trough

2.4.2 Implications of different test methods

Although not fundamental material properties, the Atterberg limits are key index parameters that have become an integral part of all specifications used for controlling soil used in pavements. As indicated in the previous section, there are numerous differences in the test methods embodied in the various testing standards. Even for a given standard, the subjective nature of the test procedure can introduce significant imprecision in carrying out the test. Not surprisingly, therefore, the results obtained from these very basic but, nonetheless, critical tests can be highly variable.

It is not uncommon in engineering practice in the Southern African region to assume that the determination of the LL is independent of the test method used. In fact, this is not the case and at least a qualitative difference has been highlighted for over 50 years! (Dos Santos, 1955; Casagrande, 1958; Norman 1958; Netterberg, 1969). This difference is simply due to the softer base of the BS cup device. It has now been established with a high degree of reliability (correlation coefficient of 0.989; number of results = 89; number of laboratories = 6; 95% CI limits ± 4 units) (Sampson and Netterberg, 1984) that, ***all other factors being equal, the LL and, hence, PI determined using the BS LL device are 4 units higher than those determined using a TMH1 ASTM-type LL device (similar to AASHTO LL device).*** The same investigation also found that a factor of 1 unit should be subtracted from the linear shrinkage at 20 mm penetration to give an indication of the linear shrinkage at the LL if direct linear shrinkage measurements are required.

The LL test, as currently recommended by BS, utilizes the cone penetrometer (BS1377: Part 2: 1990). However, since this device has been designed to give the same results as the BS Casagrande cup device, then it, too, also produces LL (and PI) results 4 units higher than the ASTM type LL device. In view of the superior precision (both repeatability and reproducibility) of the British cone penetrometer method, it has been recommended that it should replace the Casagrande method (Sampson and Netterberg, 1984).

The significance of the differences in LL and PI obtained from the LL devices specified in the different testing standards is that similar specifications for a pavement base course material of a maximum LL of 25 and PI of 6 are used worldwide***. The far-reaching implications of adopting these index specification limits irrespective of the testing standard used is that countries using a BS device are actually specifying equivalent, and probably unnecessarily conservative, AASHTO maximum LL of 21 and PI of 2*** *(Netterberg, 1997).* These facts are probably insufficiently appreciated in the Southern African region. It would seem prudent, therefore, to ensure that only one type of LL device should be used in any one country and, moreover, that the testing standard followed should be the same as that used to derive the specification.

2.5 Optimum moisture content (OMC) and maximum dry density (MDD)

The differences in test procedures appertaining to TMH1, BS and AASHTO standards for the determination of the OMC and MDD of a soil are summarized in Table 5.

Table 5: Differences in determining the OMC and MDD of a soil

TMH1 Method A7	BS 1377-4 (1990)	AASHTO T180-74 (1990)[1]
Material (i) -19 mm material used. **All** + 19 mm material crushed to pass 19 mm sieve and added to -19 mm. (ii) Material not usually re-used. .	**Material (4.5 kg hammer method)** (i) -20 mm material used % +20 mm stone recorded. (ii) material not susceptible to crushing may be re-used. **Material (2.5 kg hammer method)** As for 4.5 kg hammer method .	**Material (Method D)** (i) -19.0 mm material used and +19.0 mm material discarded; or + 50 mm material discarded and -50 mm + 19 mm material removed and replaced with an equal amount of -19 mm +4.75 mm material sieved out from the remainder of the sample as also required for the CBR test.
Method (iii) Minimum moisture equilibration period of 30 mins. Overnight recommended. (iv) 5 layer compaction. 55 blows per layer distributed in cycles of 11. In each cycle 8 blows are applied to the outside circumference and 3 at the centre. (v) Moisture content specimen taken from material remaining in the basin after 2nd layer has been compacted. (vi) Minimum of 5 points used.	**Method (4.5 kg hammer method)** (iii) 16 hrs. moisture equilibration period suggested for soils with high plasticity. (iv) 5 layer compaction. 62 blows per layer uniformly distributed. (v) Moisture content specimen taken from centre of moulded sample. **Method (2.5 kg hammer method)** (i) As for 4.5 kg hammer method (ii) 27 blows. 3 layer compaction.	**Method (AASHTO 180)** (ii) No moisture equilibration. (iii) 12 h minimum moisture equilibration. (iv) 5 layer compaction. Each layer compacted with 56 evenly distributed blows. (v) Moisture content sample taken from specimen after test.
Apparatus (i) 4.536 kg hammer, fall 457.2 mm (ii) Specimen dia. = 152.4 mm; height = 127 mm.	**Apparatus (4.5 kg hammer method)** (i) 4.5 kg hammer; fall 450 mm (ii) Specimen dia. = 152.4 mm height 115.5 mm **Apparatus (2.5 kg hammer method)** (i) 2.5 kg hammer; fall 300 mm (ii) Specimen dia. = 105 mm height 115.5 mm	**Apparatus** (i) 4.536 kg hammer, fall 457.2 mm (ii) Specimen: Dia. = 152.4 mm; height = 116.4 mm.

Four alternative procedures provided for as follows: (1**) Method A**: 102 mm mould; -4.74 mm material**;** (2) **Method B**: 152 mm mould; -4.75 mm material. (3) **Method C**: 102 mm mould; 19.0 mm material. (4) **Method D**: 152 mm mould; 19.0 mm material. No guidelines given for choice of method. **Method D** is discussed as it is closest to the TMH1 method.

2.5.1 Differences in test methods

There are a number of differences in the procedures stipulated by the various testing standards for carrying out OMC and MDD tests as well as differences in the type of equipment specified as summarized below:

(a) Material

- Method of compensation for oversize
- Proportioning of material sizes
- Material re-use

(b) Procedure
- Moisture equilibration
- Distribution of blows on layer
- Location of moisture content specimen

(c) Equipment
- Compactive effort

2.5.2 Implications of different test methods

One of the significant differences in the various test methods for determining the MDD/OMC relationship of a soil is the compactive effort used. This varies from 2,415 kJ/m^3 for TMH1 (the old Mod. AASHO effort), as against 2,670 kJ/m^3 for BS 1377:1990 and 2,700 kJ/m^3 for AASHTO T180. Despite the significant differences in energy between TMH1 and the BS and AASHTO methods, the difference in dry densities obtained is relatively small, of the order of ±0.5% for the latter methods (DOT, 1970).

In practice, the effect of using the greater AASHTO T180 MDD on twelve, mostly coarsely graded, calcretes was, on average, to increase all the CBRs by 7 units at 98%, decreasing to only 2 units at 90% (Netterebrg, under preparation).

Even more significant that the differences in energy of the various compaction standards is the maximum particle size allowed in the 152 mm diameter mould and the method of compensation for oversize particles prescribed for the determination of compaction characteristics and CBR as highlighted below.

(a) TMH1 test standard: In the TMH1 procedure, all the material coarser than 19 mm is supposed to be lightly crushed to pass 19 mm and added in with no restriction being placed on the amount. Although it is generally accepted that the addition of large amounts of +19 mm material will alter the material, the operator is nonetheless expected to use his discretion as to the “extent” to which particles should be lightly crushed, a subjective factor that can cause much variation amongst different operators.

(b) BS test standard: In the BS procedure, the soil is scalped at 20 mm without any compensation for oversize and, if the fraction coarser than 20 mm exceeds 25% the test is considered to be unreliable.

(c) AASHTO test standard: In the AASHTO T 180-74 procedure the soil is scalped at 50 mm and the 19-50 mm fraction replaced with similar 4.75 – 19 mm material so as to maintain the maximum particle size of 19 mm permitted in the mould. A method of correcting the MDD according to percentage coarser than 4.75 mm found in an in-place density test is also provided..

The practice of compensating for oversize material as allowed in the TMH1 and AASHTO test methods is intended to reflect actual construction practice where a maximum particle size well in excess of 20 mm is specified (for a natural gravel, typically up to about 40% retained on 19 mm sieve). For example, it is common construction practice to breakdown oversize material with a grid roller to ensure compliance with specified grading. The effect of compensating for oversize on the laboratory CBR value of the material can be very significant. For example, the addition of 45% of lightly crushed 4.75 - 19 mm material would have the effect of increasing the MDD by 5-20% (average 12%) and the soaked CBR by a factor of 1.5 – 3.3 (average 2.2) (National Roads Board, 1946). Subsequent tests on the fraction passing the 19 mm sieve without compensation, as in the BS 1377 test method, yielded much lower results.

The failure of a road in Botswana and also in Kenya has been ascribed to the misleadingly high CBR of the material assumed for control purposes due to the inclusion of too much crushed +19 mm material in the CBR test (authors personal communication with supervising consultants).

2.6 California Bearing Ratio (CBR)

The differences in test procedures appertaining to TMH1, BS and AASHTO standards for the determination of the CBR of a soil are summarized in Table 6. The material requirements and equipment are largely as per Table 5 and are not repeated in Table 6 where only the more significant differences in test methods are indicated.

Table 6: Differences in determining the CBR of a soil

TMH1 Method A8	BS 1377-4 (1990)	AASHTO T193-81 (1990)
Method (i) The penetration surcharge weight is 5.56 kg which is equal to the surcharge weight and swell plate used in soaking. (ii) A penetration rate of 1.27 mm/min is used. (iii) A moisture content after penetration is not required. . (iv) The CBR values for the pen-etration depth of 2.54 mm and 5.08 mm are 13.334 kN and 20.016 kN respectively. (v) The CBR at 2.54 mm penetration is used. (vi) Soaking for 4 days is standard..	**Method** (i) The minimum weight for the penetration surcharge is 4.5 kg which is equal to the surcharge weight used in soaking. (ii) A penetration rate of 1.0 mm/min is used. (iii) A moisture content sample from below the plunger is taken after testing. (iv) The higher of the CBRs at 2.54 or 5.08 mm is used. (v) Soaking is optional (OMC or 4 days depending on climate).	**Method** (i) The minimum weight for the penetration surcharge is 4.5 kg. This weight has to be equal to the surcharge weight in soaking. (ii) A penetration rate of 1.3 mm/min is used. (iii) The moisture content of the top 25 mm may be determined if desired (after penetration). (iv) The higher of the CBRs at 2.54 or 5.08 mm is used. (v) Soaking for 4 days is standard.

2.6.1 Differences in test methods

There are a number of differences in the procedures stipulated by the various testing standards for carrying out CBR test as well as differences in the type of equipment specified as summarized below:

(a) Material (from Table 5)
- Method of compensation for oversize (TMH1 and AASHTO compensate but BS does not).
- Proportioning of material sizes
- Material re-use

(b) Procedure
- Penetration rate and depth for measuring the CBR
- Moisture content determination

(c) Equipment
- Penetration surcharge
- Compactive effort

2.6.2 Implications of different test methods

The major difference in the procedure prescribed by the various test standards for reporting of the CBR results is related to the penetration at which such reporting is made. In the TMH1 procedure, only the CBR at 2.54 mm penetration is used. However, both BS and AASHTO standards state that the higher of the 2.54 mm or 5.08 mm CBRs can be used.

From investigations carried out in the region (Netterberg in preparation), except in the case of cemented materials, the 5.08 mm CBR was found to be nearly always higher than the 2.54 mm value. From these investigations the following average relationships between the two penetrations for all 154 results on 54 samples tested with a 2.54 mm CBR between 2 and 175%.

$$CBR_{2.54} = 0.79\ CBR_{5.08} \qquad (Eq.1)$$

or

$$CBR_{5.08} = 1.27\ CBR_{2.54} \qquad (Eq.2)$$

The major significance of the above findings is that***, all other factors being equal, CBRs determined by the TMH1 or AASHTO methods are, on average, about 20% lower that the same material tested by the BS test method. Ironically, the same minimum soaked CBR of 80% for granular base course which originated in the United States is used on a worldwide basis***.

As illustrated in a hypothetical example in Table 7, the combination of the manner in which oversize material is dealt with in the sample preparation for CBR testing (inclusion or exclusion of oversize), coupled with the penetration depth at which the CBR is measured (2.54 mm or 5.08 mm), is likely to have a significant influence on the result obtained from the test.

Table 7: Hypothetical illustration of CBR determinations by different test methods

CBR Penetration depth (mm)	CBR % by test method			
	TMH1 and AASHTO		BS	
	Oversize compensation	No oversize compensation	Oversize compensation	No oversize compensation
2.54	80[1]	35[2]	140[3]	65[4]
5.08	100[5]	45[2]	180[3]	80[1]

Notes: 1- Assumed soaked CBR value of 80% as measured by the prescribed testing standard
2- Based on a CBR reduction factor of 0.45 to compensate for removal of oversize (ref. Section 2.5.2)
3- Based on a CBR increase factor of 2.2 to compensate for addition of oversize (typically 45% compensation)
4- Based on $CBR_{2..54} = 0.79\ CBR_{5.08}$
5- Based on $CBR_{5.08} = 1.27\ CBR_{2.54}$

By way of broad comparison, if it is assumed that a CBR of 80% is obtained from the TMH1 test method (compensation for oversize material and CBR penetration depth of 2.54 mm), such a material, if there was no compensation for oversize, would be expected to exhibit a 2.54 mm CBR of the order of 35%. In contrast, if it is assumed that a CBR of 80% is obtained from the BS test method (no compensation for oversize and CBR penetration at 5.08 mm) such a material, if there was compensation for oversize, would be expected to exhibit a CBR of the order of 180%. In practice, soaked CBRs of 80% are typically specified for base course material by either the TMH1, BS or AASHTO methods. However, as indicated in Table 7, the materials used will be of vastly different quality, strength-wise. The upshot of this anomalous situation is that, all other design factors being equal, either the TMH1 and AASHTO test methods produce grossly under-designed pavements or the BS design method produces grossly over-designed pavements. Because of all the variables involved in pavement design, it is difficult to determine which is the case. This uncertainty is compounded further when the accuracy and precision of test methods, particularly the CBR test method, is considered as discussed below.

3. ACCURACY AND PRECISION OF TEST METHODS

3.1 Introduction

The accuracy and precision of various test methods vary significantly (Lee et al, 1983). The accuracy of a test method is such that the *reported value* of the soil parameter is the same as the *true* value. For example, if the true value of a soil parameter, such as specific gravity is 2.65, then an accurate measurement would be one which reported a value of 2.65. In contrast, a precise measurement might record an apparent relative density value of 2.683, i.e. it reports not necessarily the *true value*, although the measurement has been made with great care and precision. When such a measurement differs from the true value, it may do so either because of random or systematic errors. In general, the true value of any soil is never known, and it can only be estimated from a number of measurements all of which are subject to error.

3.2 Repeatability and reproducibility

All of the soils tests considered in this paper are used in contractual situations to specify the properties required in the construction of roads. This does raise the issue of the confidence limits that can be placed on test results in terms of the repeatability (also known as single-operator precision) which is the ability of a single operator, and the reproducibility (also known as multi-laboratory precision) of more than one laboratory to obtain the same results on split samples. With other more homogeneous materials such as rock, bitumen, asphalt and concrete, the confidence limits on test results are usually known and can be employed in checking compliance with specifications. However, due to their heterogeneous nature, this is more difficult in the case with soils. Their natural variability is one cause of scatter in the results and, in addition, some of the tests involve procedures that are not easy to reproduce with precision. Nonetheless, some idea of the variation in measurement of soil parameters, as considered below, is required so that results obtained can be interpreted sensibly. The issue of variation of test results is discussed.

3.2 Variation in measurement of soil parameters

Table 8 shows the coefficient of variation for the various tests considered in this paper. Because of the many sources of variability in soils, it is not to be expected that these coefficients of variation will be the same.

Table 8: Coefficient of variation (CV) for common soil tests (Lee, 1983)

Test	Reported CV (%)	Recommended CV (%)	Sources in Lee (not consulted)	Comments
CBR	17-58	25	1,4	Wide variation
Compaction (OMC)	11 - 43	20, 40	1,6,12	Lower value, clay soils; Higher value, sands & gravels
Compaction (MDD)	1 - 7	5	2,4,6,12,22	
Linear shrinkage	57 - 135	100	1,6	Refers to gravel & crushed rock; will be lower for soils.
Liquid limit	2 - 48	10	2,4,10,12,14, 15,20,22	
Moisture content	6 - 63	15	4,5,9,20,21,22	
Plastic limit	9 - 29	10	2,12,14,15,20	
Plasticity index	7 - 79	30, 70	1,4,6,10,12,15, 20	Lower value, clay soils; Higher value, sands & gravels

Sources:1. Ingles and Nobel (1975); 2. Lumb (1974); 3: Hoeg and Muraka (1974); 4. Kuhn (1972); 5. Ingles and Metcalf, 1972; 6. Leach and Goodran (1976); 7. Auff (1978); 8. Knight (1978); 9. Wu (1974); 10. Mitchell and Smith (1974); 11. Murphy and Grahame (1976); 12. Sherwood (1970); 13. Hode-Keyser (1970); 14. Minty et al (1979); 15. Corotis et al (1975); 16. Cranley (1969); 17. Otte 91978); 18. Kennedy (1978); 19. Morse (1971); 20. Singh (1975); 21. Schultze (1975); 22. Stamatopolous and Kotzias (1975).

What is of considerable significance from Table 8 is that it is not uncommon to find a coefficient of variation of about 10-25% in the measurement of soil properties and, according to Lund (1968) ***“values exceeding 25% should suggest caution, or even avoidance, since for the same mean value, a greater proportion of the material than usual is inferior to any value given below that mean”.***

3.3 Other factors affecting variability in soil test results

In addition to the various reasons indicated above for the lack of precision and accuracy encountered in testing soils, other errors in the value of a soil parameter can arise, as follows:

- The sample measured is not representative of the whole soil (*soil variability*)
- The sample properties have been altered or disturbed in the process of sampling and transportation to the laboratory (*sampling errors*)
- The tests themselves were not scrupulously performed according to the prescribed standard (*testing errors*).
- The test equipment has not been properly calibrated.
- Insufficiently trained and skilled personnel are used for undertaking the tests.

3.4 Appropriateness of the CBR method for selecting natural gravels

Since the CBR test is used as a principal means of selecting gravels for use in low volume road pavements, its suitability for this purpose would merit comment as follows, based on the outcome of a four country workshops held in Southern Africa (Gourley and Greening, 1999)

- The CBR test is an empirical test that was originally developed using empirical observations of satisfactory pavements over a number of subgrades with the objective of establishing subgrade bearing capacity, *not the adequacy of the pavement material.* However, its use has evolved to become the standard fine-grained soil test for the approval of base course materials. It is a test designed for homogeneous subgrade soils, not highly granular base course material. Attempts to modify the test for granular soils have led to a number of different practices in conducting the test, this explaining the poor repeatability and reproducibility of CBR test results.
- The test was designed as an indicator test for soils. It is not a performance-related test. This explains the frequent anamolous behaviour of road pavements constructed with materials with low CBR. Thus, although the test is used as an indicator for material selection, materials tested in the soaked condition do not necessarily rank in the same order at the moisture contents prevalent in the road pavement.
- The test does not measure any of the fundamental engineering properties of soil that critically influence its performance, such as elastic stiffness (Er) and resistance to permanent deformation or resilient modulus (Mr). As indicated in Figure 2, materials with the same CBR could have very different elastic stiffnesses and, as a result, in similar service conditions, could perform quite differently because of their different load–spreading ability.

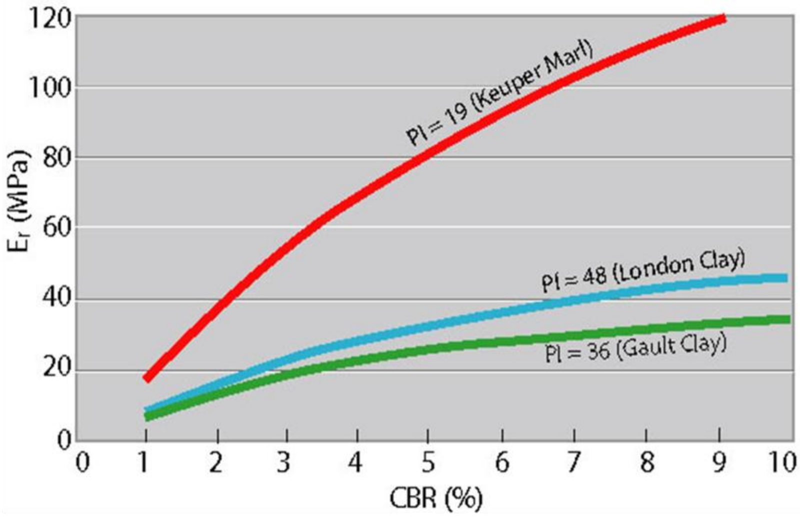

Figure 2: Relationship between elastic stiffness and CBR for a stress pulse of 40 kPa (Brown et al, 1987).

- The test is often carried out in the soaked condition (TMH1 and AASHTO) intended to typify sub-grade conditions for much of the year in many parts of Europe and other countries in the northern hemisphere. Subgrade conditions are often much drier for much of the year in Southern Africa.

- The same soaked condition is often used for design, not only for the subgrade, but for the subbase and even the base course, in which moisture conditions in the region are rarely above optimum.

- The test has a poor reproducibility with an overall coefficient of variation of the order of 25 per cent**.** This characteristic makes the interpretation of test results, especially for inherently variable natural gravels, very imprecise. For example, for a mean CBR value of 80, based on 10 CBR determinations,10% of the results would be expected to exhibit CBRs less than 55 and 10% more than about 105 (based on a T-distribution) – a range that can lead to vastly differing interpretations of the suitability of the soil for use as a pavement material. With a lesser number of tests, the variability would, of course, be even higher.

Despite its notoriously poor reproducibility, the CBR test is still one of the most widely used tests for evaluating the mechanical strength of pavement materials in Southern Africa. Alternative tests exist, such as the Texas Triaxial test which is used successfully in Zimbabwe, Australia and Texas. This test is based essentially on the relative stiffness of the material in the form of stress strain characteristics and measures the fundamental strength parameters – cohesion and angle of internal friction. It is less empirical than the CBR test in that more of the coarse fractions of gravels can be subjected to test. Moreover, in the test, the sample is tested as a whole, and the results are less prone to specific conditions under the CBR plunger (Reeves, 1989).

Despite the advantages of the Texas Triaxial test, it seems unlikely that the CBR test will be discarded largely because the industry is unlikely to re-invest in new laboratory equipment. Fortunately, however, there are very promising alternatives to the use of laboratory derived CBRs for the design of road pavements. These include the DCP design method which does not rely on the CBR test as a primary means of material selection (van Zyl and Kleyn,1987) and is currently being further developed by AFCAP for use in the Southern African region for upgrading unpaved roads to a paved standard.

3.5 Revision of TMH1

It is noteworthy that TMH1 is being revised in order to comply with the format required of South African national standards. During the revision process an opportunity was provided for roads agencies in SADC member states to comment on what were essentially minor improvements and clarifications to the original document, resulting in the production of a suite of South African National Standards (SANS) for use in the construction industry.

4. FINDINGS AND CONCLUSIONS

The following findings and conclusions are drawn from this paper.

1. A number of different soil testing standards are used in the African region and, in some instances, more than one standard is used in the same country.

2. There are significant, inherent, differences between similar soil tests using different testing standards as a result of which the test results are not comparable.

3. Some of the most significant differences in test methods which yield very different results include:

   a. The Liquid Limit (LL) and, hence, Plasticity Index (PI) of soils determined from the

BS LL which, all other factors being equal, yields LL and PI results 4 units higher than the ASTM/AASHTO-type LL device.

b. There are significant differences in grading results depending on whether dry or wet sieving procedures are followed. Although both procedures are catered for in the standard test procedures, dry sieving should only be used for materials containing little or no silt or clay. In all other cases, wet sieving should be mandatory.

c. The CBR of soils determined from the BS and AASHTO tests which, due to higher 5.08 mm penetration depth at which the CBR is measured, produces CBRs that are almost 30% higher than the TMH1 testing standard in which the CBR is measured at a penetration depth of 2.54 mm.

d. Due to the test procedure requirement of not compensating for oversize material in the sample preparation for CBR testing, the BS tests would yield lower CBRs than the TMH1 and AASHTO test which does compensate of oversize in the test sample.

e. When both the penetration depth at which the CBR is measured and the manner of compensating for oversize material are considered, the use of the BS 1377 test will produce in practice, i.e. in the pavement where particle sizes larger than 20 mm are allowed (up to 40% on the 20 mm sieve) far superior quality material to that produced when applying the TMH1 and AASHTO CBR testing standards.

4. The variability of test results obtained from all testing standards is relatively high with coefficients of variation of the order of 10-25%.

5. The CBR test, despite its notoriously poor reproducibility (coefficient of variation of 25%), is one of the most widely used tests for evaluating the strength of materials. However, its correlation with performance is poor, especially for materials tested in the soaked condition.

6. The differences in test results produced for a given test but using different testing standards appear not to be sufficiently appreciated in a number of countries as a result of which the interpretation of the test results is often the cause of much confusion.

7. Soil testing laboratories in some countries in Southern Africa have not been nationally accredited, including the certification of laboratory testing personnel and regular calibration of equipment, as a result of which the quality of the outputs cannot be guaranteed.

5. RECOMMENDATIONS

1. A much greater awareness needs to be engendered in the industry in the Eastern and Southern Africa region regarding the issue of testing standards and the implications on the results obtained.

2. Compliance specifications used in the region should, ideally, be on the basis of research and investigation, and should be tied to the test methods used in undertaking such work.

3. Alternative design methods which do not rely on the use of laboratory CBRs as an input to the design, such as the DCP method, should be considered in the design of low volume roads.

4. A comprehensive review of all materials (soils, aggregates, bitumen, etc.) testing standards should be undertaken with a view to ascertaining the implications of the

differing test procedures on the results obtained so that due account of this can be taken in practice, particularly with regard to the setting of specifications.

5. There should be a move to ensure that national accreditation of all materials testing laboratories and personnel in the Southern African region is in line with internationally recognized standards.

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KEY WORDS

Soils, testing, methods, standards, variability

RESEARCH ON CHARACTERIZATION TECHNIQUES OF (SUB) TROPICAL ROAD MATERIALS FOR RURAL ACCESS ROADS

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Abstract

Most rural road pavements in developing countries are low-cost unpaved structures or paved with thin asphalt surfaces. In such pavements the granular base and sub-base are the main load bearing layers. The strength and quality of granular (sub)base road materials is most commonly characterized by California Bearing Ratio (CBR) test which is practiced throughout the world and widely available in developing countries. A new characterization technique, repeated load CBR has been developed based on the CBR test to characterize the fundamental behavior of unbound granular materials such as stiffness and resistance to deformation. The repeated load CBR test is not only a powerful tool to characterize the stress dependent characteristics of the resilient and permanent deformation behaviors but also characterize the influence of degree of compaction and moisture content on the material behavior.

1 INTRODUCTION

Rural access roads provide communities with transportation infrastructure and services that ensures permanent accessibility to social and government services, economic and business services, and better opportunities for employment and income generation. To provide such access to rural communities in a more sustainable way, a realistic and achievable technique of infrastructural development has to be enhanced at an appropriate standard and affordable cost. One of these developmental techniques that have to consider the local realities is the way the access roads are designed, constructed, maintained and overall management of the transport network.

Most rural access road pavements are low-cost unpaved structures or paved with thin asphalt surfaces. In such pavements the granular base and sub-bases are the main load bearing layers. Those layers are mostly built from locally available natural or crushed stone aggregate materials. These granular materials are often obtained from nearby quarry along the road. Quarry sources on geologically vulnerable slopes can trigger erosion, mass wasting and sedimentation. This often leads to excessive land degradation of areas adjacent to the road. These effects have a direct bearing on the livelihoods of people who survive by subsistence farming in developing countries.

Proper utilization and characterization of these materials results in developing sustainable and cost-effective rural access roads. This can be done through characterization techniques that fit the workmanship involved and available laboratory facilities. The strength and quality of granular road materials is most commonly characterized by California Bearing Ratio (CBR) test which is practiced throughout the world and is widely available in developing countries. To exploit the available testing equipment in these countries and make use of local skills and experience, a new characterization technique. Repeated load CBR (RL-CBR) has been developed based on the CBR test but with repeated loading.

RL-CBR provides the fundamental material properties such as resilient modulus (M_r) which is an input in design methods such as AASHTO design method and the South African mechanistic pavement design procedure. The RL-CBR test is not only a powerful tool to characterize the stress dependent behavior of the resilient and permanent deformation behaviors but also characterize the influence of degree of compaction and moisture content on the material behavior. This paper presents the result of research carried out on the new testing mechanism developed mainly for developing countries. More than 30 tons of granular road base and sub-base materials such as natural weathered basalt gravel from Ethiopia, natural Ferricrete gravel and crushed Hornfels rock from South Africa has been transported to Delft, the Netherlands. The RL-CBR testing technique was then verified and validated by characterizing these granular road materials and others by means large scale cyclic load triaxial test at the Road and Railway Engineering Laboratory of the Delft University of Technology.

Historically, flexible pavement design practices were typically based on empirical procedures, which recommend certain base, sub-base and surface layer types and thicknesses based on the strength of the subgrade. The oft-used soil strength parameters in these empirical pavement design practices are California Bearing Ratio (CBR), Hveem R-value and Soil Support Value (SSV). All these soil parameters are based on failure of subgrade soil specimens in laboratory conditions (Huang 1993, NCHRP 2008). Because most flexible pavements do not fail as a result of soil strength failure, the 1986 AASHTO and subsequently the 1993 AASHTO Pavement design guide recommended the use of a soil parameter known as Resilient Modulus (M_R) to replace strength based parameters such as CBR and SSV (Brickman 1989). Several other investigations also refer to this modulus parameter as M_R in their studies.

The main reason for using the resilient modulus or stiffness as the parameter for subgrade, subbase and bases is that it represents a basic material property and can be used in mechanistic analyses for predicting different distresses such as rutting and roughness. The major drawback of empirical based design of pavements and characterization of materials is that the performance of the materials under different or changing conditions (climate, increasing traffic loads, tire pressures, etc) and applications (other type of pavement structures) is uncertain. Furthermore the use of such mechanical properties of materials allows the introduction of alternative or marginal, but possibly suitable, materials and their use to the fullest extent, which in itself will play a significant role in optimizing the use and conservation of natural resources.

The method of characterizing the mechanical behavior of unbound granular materials such as the resilient modulus, however, is commonly done using cyclic load triaxial tests which are considered to be advanced and costly to implement in routine road construction projects particularly in developing countries. The repeated load CBR test is therefore introduced to provide a more practical and simpler method for characterization of unbound materials. The following sections describe the principle of the test, the materials and methodologies used as well how the test technique is effective in determining the effect of moisture content, degree of compaction and load level on the resilient and permanent deformation characteristics of unbound granular materials.

2 MATERIAL

The materials used in the study range from a very good quality Grade 1 (G1) crushed Hornfels rock base course material of South Africa to a recycled mix granulate of the Netherlands. This paper however will deal mainly with weathered basalt (WB) natural gravel sub-base material obtained from a borrow pit in Ethiopia.

Beavenet. al(1998)presented a detailed analysis of the formation and weathering of basalt in Ethiopia. In their study they described basalts as the most common form of volcanic rock which are widely used in the production of crushed aggregates from quarries. However, where the rock has been weakened by physical disintegration or chemical weathering basalt gravels can be dug from pits. The composition can vary both within a pit and between pits, the most important features being the size and strength of the aggregates and the quantity and plasticity of the fines.

Typically, WB in Ethiopia are predominantly gravel with a low portion of sand. In practice it is difficult to find materials which, when excavated, meet the specification requirements for grading. This limitation is treated by crushing the oversized cobbles, coarser than 45 mm, and mix the crushed material with the natural gravel.

The material shipped from Ethiopia to Road and Railway Engineering Laboratory of Delft University of Technology is from a quarry source in the Bole suburban area of Addis Ababa, Figure 1, used as a subbase material for a road construction project in Addis Ababa city. To satisfy the Ethiopian road material specification (ERA, 2002) for gradation the oversize cobbles are mixed with the natural gravel after being run through a crusher. The material particles are characterized by their elongated and flaky shape so that they can be easily crushed during compaction. The fine grains, which can also be influenced by the surrounding soil nature as they are dug pit material, are characterized by a high plasticity index

Figure 1: Ethiopian Weathered Basalt source and material details

The material was first examined for its gradation (Figure 2) and its basic physical properties such as modified Proctor density, apparent (pycnometer) density, soaked and unsoaked CBR strength etc. The modified Proctor dry density (MPDD) vs. moisture content curve and the standard CBR for unsoaked and soaked samples for the material are shown in Figure 3.As a reference the modified Proctor dry density at its respective optimum moisture content is chosen to be 1950 kg/m^3 at 7% moisture content (MC) for the Weathered Basalt. These dry densities are considered to be100% degree of compaction (DOC) and are taken as reference for the variation of DOC of specimen production.

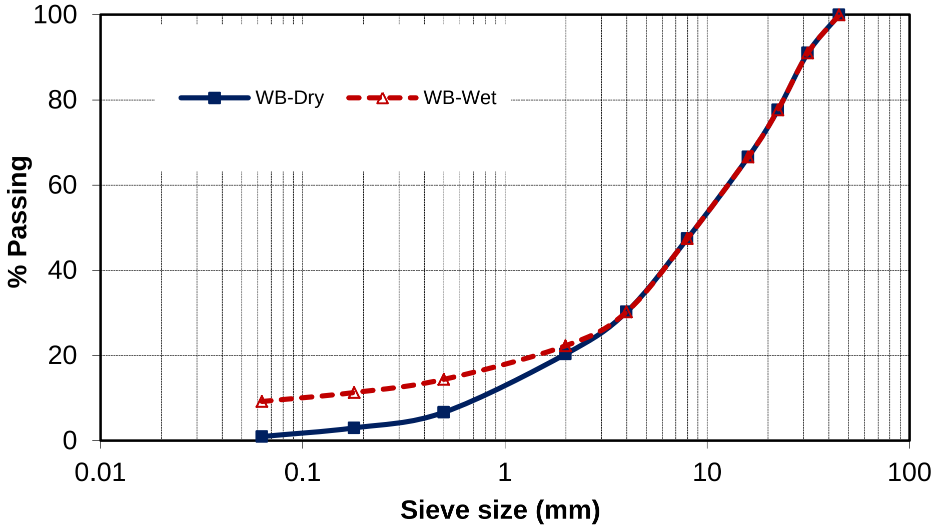

Figure 2: Dry & wet sieving particle size distribution of the Weathered Basalt.

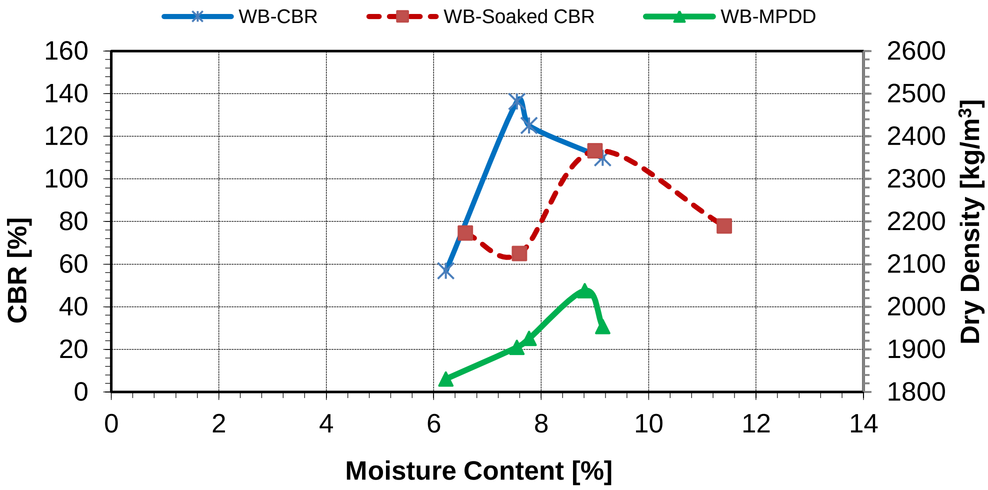

Figure 3: CBR and modified Proctor dry density vs. moisture content.

3 TEST SETUP AND METHODS

Specimens are prepared for both the RL_CBR and triaxial testing in a similar way using a vibratory compaction hammer which better simulates the vibration compaction in the field. For both tests the granular materials at required grading were obtained by recombination of various fractions of sieved materials to the grading shown in Figure 2. The quantity of water to bring the material to the required moisture content was added and mixed using a mechanical mixer. Having obtained the sample material at the target moisture content, the RL-CBR specimens were compacted in three layers in a 250 mm dia. 200 mm height mould, whereas the triaxial specimens were compacted in four layers in a 300 mm dia. 600 mm height split mould. For each layer the exact amount of material is weighed to obtain the target degree of compaction (measured in terms of modified Proctor dry density, % MPDD) after compaction. The material of the first layer is pre-compacted by hand tamping then by means of the vibratory compactor to the required density until the target layer thickness is achieved. The same procedure is followed for the subsequent layers. The surface of each layer was mechanically scarified before adding the next layer on top to obtain a good layer interlock and a homogeneous sample.

3.1 The Repeated Load CBR (RL-CBR)

3.1.1 Test Principle

The principle of the RL-CBR test is similar to the standard CBR test but repeated loads are applied. Upon multiple repetitions of the same magnitude of loading granular materials comes to a state in which almost all strain under a load application is recoverable. The permanent (plastic) strain ceases to exist or becomes negligible and the material behaves basically elastically i.e. with stable recoverable deformation (Araya et. al., 2012). From the applied stress and the measured strain an elastic modulus can be estimated. By recording the load and displacement and plotting in x-y axes, graphs similar to Figure 3 are obtained from which load levels and total, resilient (elastic) and permanent (plastic) deformations under the penetration plunger can be determined.

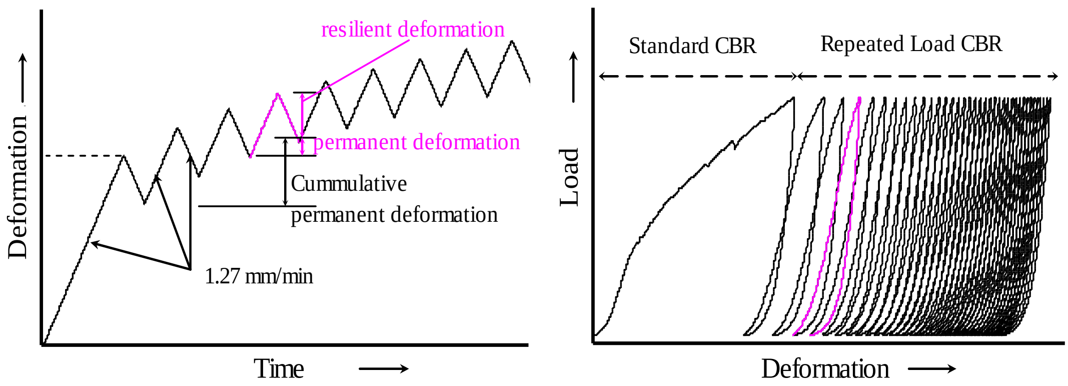

Figure 3:RL-CBR test principle and load-deformation pattern.

3.1.2 Test Setup

As illustrated in Figure 1 the grading of the weathered basalt is 0/45 mm. For such coarse granular material the standard 150 mm dia. mould is not suitable unless the material is downgraded i.e. by removing all particles coarser than 22.4 mm and replaced by materials in the 5.6 – 22.4 mm range. To avoid downgrading the material, which completely changes the gradation commonly found in the field, a bigger mould 250 mm (10 inch.) diameter and 200 mm height is adopted for all the RL-CBR tests in the project. Proportionally a bigger penetration plunger of 81.5 mm dia. is used instead of the standard 49.64 mm dia..

To apply the test method in a standard CBR test machine in routine road project tests the standard CBR loading rate i.e. 1.27mm/min is adopted for both loading and unloading and the following procedure is used:

- The specimen is loaded, at the standard CBR test rate (1.27 mm/min), to a predetermined load level or deformation, e.g. 2.54 mm. The load is recorded and unloaded to a minimum contact load of about 100kPa.
- The specimen is re-loaded to the same load at the same rate of loading and released once more to the minimum contact load. The load level for each cycle is therefore kept constant.
- These cycles are repeated for about 60 – 100 load cycles at which the permanent deformation due to the last 5 loading cycles will be less than 2% of the total permanent deformation at that point. The elastic and plastic deformation is measured as shown in Figure 3.

The test loading system is equipped with an actuator (MTS controller) so that the increase and decrease of load and development of deformation can be monitored along with a work station for storing and retrieving the test data.

3.1.3 RL-CBR Equivalent Modulus

The equivalent modulus E_{equ} is computed from the stabilized elastic deformation after 100 cycles. The term equivalent modulus is used because it reflects the overall stiffness of the sample as a bulk rather than the resilient modulus of the material. A Finite Element analysis was carried out on a model of the CBR mould using ABAQUS, a comprehensive finite element analysis software, assuming linear elastic behavior of the granular material (Araya, 2011). A wide range of material stiffness 100 – 1000 MPa and Poisson's ratio 0.15 - 0.45 was used for the granular material with different deformation and force levels in a total analysis of 240 combinations. From these analyses equation 1 has been developed that relates the elastic modulus of the material tested (referred to as equivalent modulus of the whole sample) and the load and elastic deformation that were measured from the RL-CBR tests.

$$E_{equ} = \frac{1.513(1-\upsilon^{1.104})\sigma_p \cdot a}{u^{1.012}} \qquad \text{(Eq. 1)}$$

Where:	E_{equ}	=	Equivalent modulus	[MPa]
	ν	=	Poisson's ratio	[-]
	σ_p	=	Plunger average stress	[MPa]
	u	=	elastic deformation	[mm]
	a	=	radius of the load circle /the plunger/	= 81.5[mm]

When using this equation one has to make an estimate for the Poisson's ratioν. Normally a value between 0.35 and 0.45 is taken. The choice depends on the type of material (fine grained soil or granular) and moisture conditions (Molenaar 2008).

3.2 Cyclic Load Triaxial Test

Similar to the RL-CBR test a large scale triaxial setup with a diameter of 300 mm and a height of 600 mm was used in the study for testing the full 0/45 mm coarse materials. The triaxial apparatus is equipped with a hydraulic loading system actuator and MTS controller capable of cycling the axial stress and with a Constant Confining vacuum Pressure (CCP). The loading signals used are a haversine at a loading frequency of 10 Hz for the first 20,000 load cycles of conditioning phase and 1 Hz for the series of short loadings 100 cycles each. The stress range used is a ratio of axial stress to their respective failure axial stress,$\sigma_1/\sigma_{1,f}$ = 0.05 to 0.6 for all the materials. The objective of the cyclic conditioning is to stabilize the permanent strains of the material and attain a practically elastic behavior. Generally the conditioning is performed with a stress level corresponding to the maximum stresses applied in the test. The triaxial cell is equipped with transducers measuring the axial and radial strains on the middle third of the specimen, see Figure 4. The resilient modulus is then expressed as:

$$M_r = \frac{\Delta\sigma_1}{\Delta\varepsilon_1} \qquad \text{(Eq. 2)}$$

Both the RL-CBR and resilient deformation test (RDT) testing were carried out for the three materials WB, FC and G1 in a similar way with varying the moisture content (MC) and degree of compaction (DOC as %MPDD) conditions.

Figure 4: RL-CBR specimen during compaction (left), RL-CBR during testing (middle) and instrumented triaxial specimen ready for testing (right)

4 RESULTS AND DISCUSSION

4.1 Repeated Load CBR (RL-CBR)

Most of the RL-CBR specimens are tested first at a load level, P, which results in a 2.54 mm (0.1 inch) penetration, similar to the standard CBR, and the repeat loading cycles use the same load. However as granular materials are known for their stress dependent behavior, the tests at various material conditions are carried out with different load levels on a virgin specimen. Figure 5 shows the resilient deformation of six Ethiopian WB specimens with varying material condition and tested at two load levels, 32 kN for varying the DOC and 15 kN for varying the MC. The resilient deformation decreases for the WB with moderate MC and increase of the DOC at the same load level, 32 kN. At 95% DOC and 15 kN load the resilient deformation increases with the increase of the MC.

To obtain stress dependent behavior from the RL-CBR, large numbers of tests have been carried out at various plunger load levels. The equivalent modulus is estimated using equation 1 developed by the author from finite element modeling of the RL-CBR. Figure 6 shows stress dependent equivalent modulus of the weathered basalt analyzed using a Poisson's ratio of 0.35. It is to be noticed that the RL-CBR equivalent modulus is stress dependent and generally the stiffness of the WB increases with an increase in DOC and decrease in MC.

In the results presented here for each individual loading, the value of the resilient strain and stress are the average of the last ten load cycles. The values of M_r are not generally very sensitive to MC and DOC. When we compare the M_r values, the range is 100 – 500 MPa for the WB.

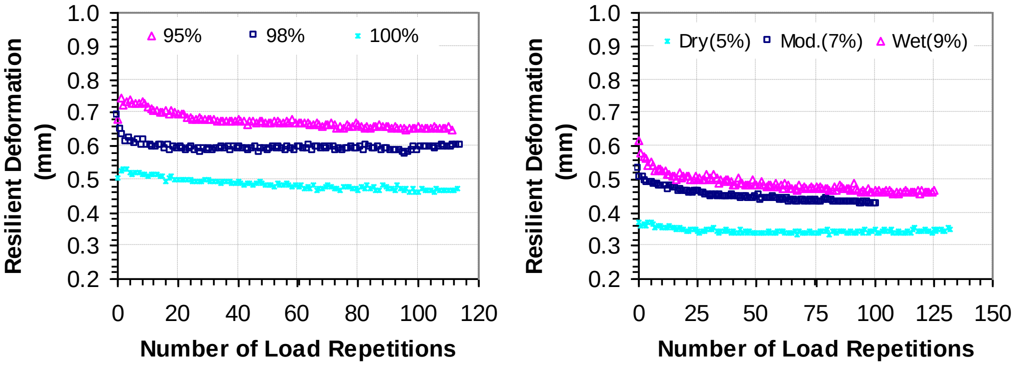

Figure 5: Effect of DOC at moderate MC and effect of MC at 95% DOC for WB material

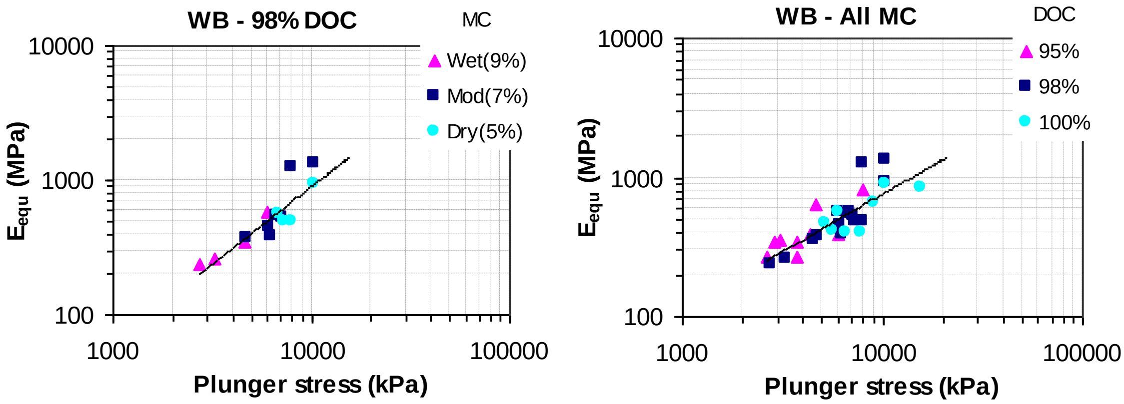

Figure 6: Stress dependent equivalent modulus for the WB at various MC & DOC

4.2 Triaxial Resilient Deformation

The resilient modulus triaxial testing has been carried out for the weathered basalt at varying mixture and compaction condition. The stress dependency of the resilient modulus was analyzed using different models, however for comparison with the result of the RL-CBR tests the isotropic non-linear $M_r - \theta$ model is presented in Figure 7.

$$M_r = k_1 \theta^{k_2} \qquad \text{(Eq. 3)}$$

Where:
- M_r = resilient modulus [MPa]
- θ = sum of principal stresses $(\sigma_1+\sigma_2+\sigma_3)$ [kPa]
- k_1 & k_2 = model parameters

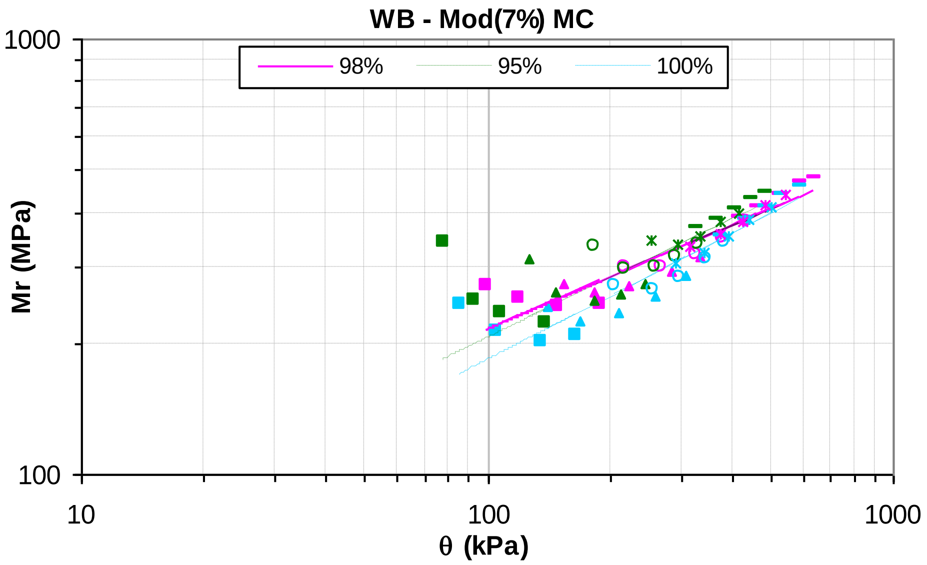

Figure 7: Examples of resilient modulus behavior; variation of M_r with bulk stress θ DOC and MC.

5 VERIFICATION OF RL-CBR EQUIVALENT MODULUS BY TRIAXIAL RESILIENT MODULUS

The equivalent modulus obtained from the RL-CBR test can't be used directly for analysis and design of pavements as the test load level and the stresses in the specimen are quite high compared to the triaxial test loadings and practical traffic loading. Figure 8 shows the trend of the modulus varies with respective stress levels (bulk stress for the triaxial and plunger stress for the RL-CBR) for a typical example. Thus to use the output of the RL-CBR test for pavement analysis and design a correlation to the triaxial test results of the same material and test condition is necessary. Araya (2011) has made a correlation between the results of the two test techniques using test results of various granular materials, South African crushed rock, South African ferricrete, Ethiopian weathered basalt, Netherlands recycled mix granulate and two Austrian natural limestone gravels. This has been done by finding a corrected or reduced plunger stress to get a modulus that is comparable to the triaxial test result and that can be used for lost-cost pavement design and analysis.

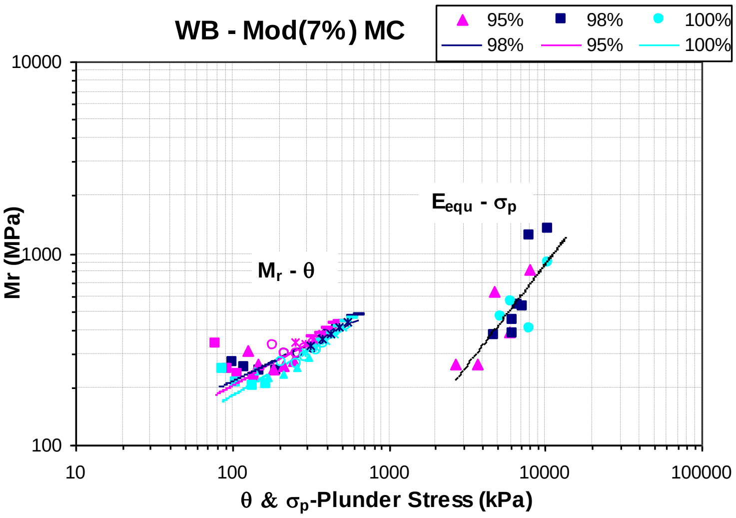

Figure 8: Comparison of resilient modulus vs. equivalent modulus typical example

For $E_{equ} \cong M_r$ from equations (1) and (3):

$$\frac{1.513(1-\nu^{1.104}) \cdot \sigma_p \cdot a}{u^{1.012}} = k_1 \theta^{k_2}$$ for ν = 0.35, and r = 40.75 mm

$$\sigma_p = \frac{u^{1.012} \cdot k_1 \theta^{k_2}}{42.312}$$ (Eq. 4)

The recoverable deformation, *u*, is measured from the RL-CBR test illustrated in Figure 3 above. The parameters k_1 and k_2 are known from the triaxial test M_r- θ model, Figure 7 above. The corrected plunger stresses are computed for a range of triaxial bulk stress levels, θ, 100 – 800 kPa and the effects of DOC and MC for each material condition are incorporated. Using a non-linear multidimensional least square regression technique, equation 5 is developed for estimation of the corrected plunger stress for the three materials. A regression analysis was done for each of the various materials individually and for all the materials as a whole, shown in figure 9 and 10 respectively, to obtain a general representative equation. However the correlation of the regression fit for the general one is smaller as shown in table 1.

$$Log(\sigma_{cp}) = a_1 + a_2 MC + a_3 DOC + a_4 Log(\theta) \quad \text{(Eq. 5)}$$

Where σ_{cp} = corrected plunger stress [MPa]

MC = moisture content [%]

DOC = degree of compaction [%/100]

θ = bulk stress $(\sigma_1+\sigma_2+\sigma_3)$ [kPa]

a_1 to a_4 = regression model parameters [-]

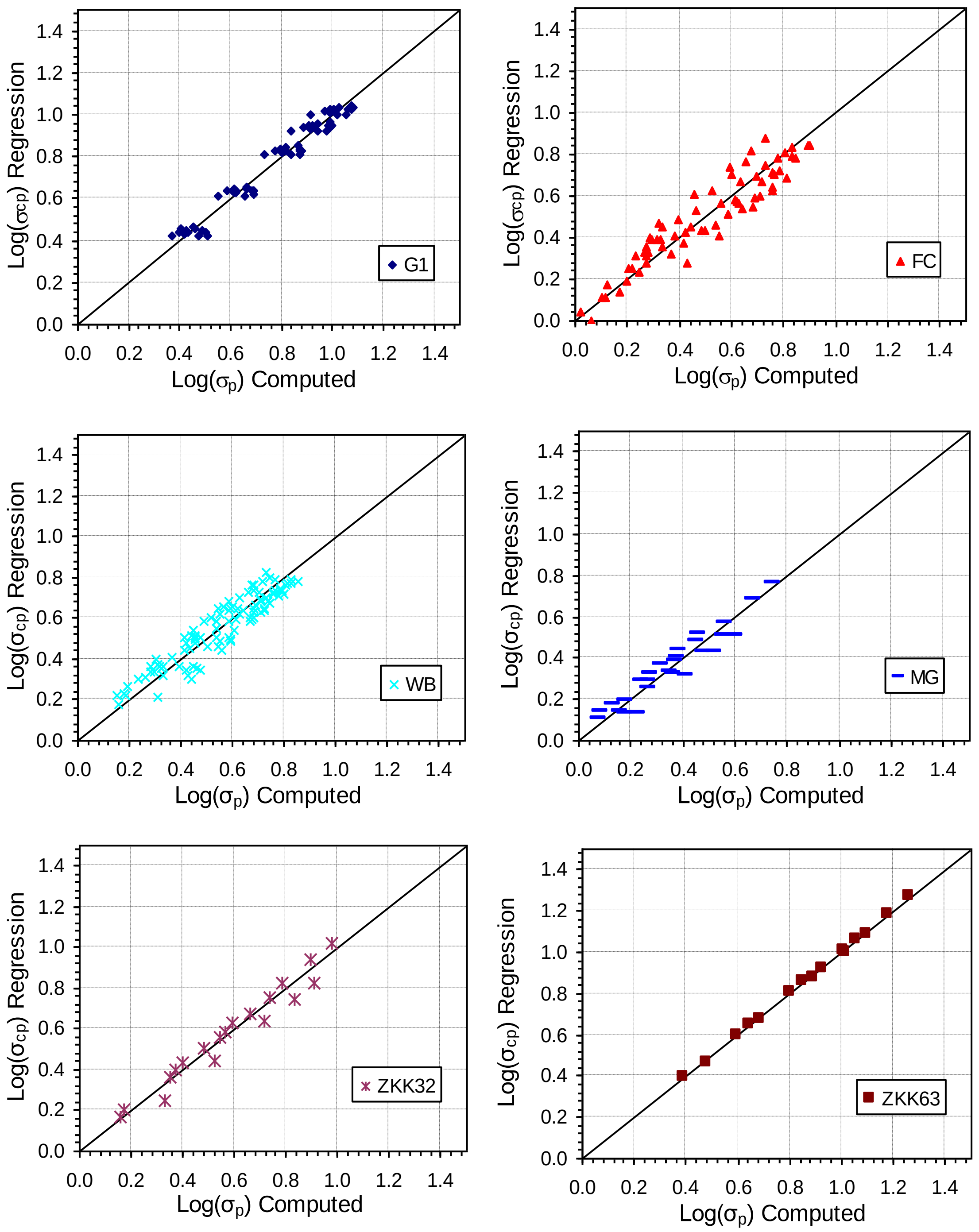

Figure 9: Comparison of the regression fit of equation 5 for each material with the computed values from equation 4

In practice to get an equivalent modulus comparable to the triaxial resilient modulus one can conduct a RL-CBR test at different load levels and carrying out a pavement analysis for an assumed modulus to estimate the stress level in different layers. The DOC and MC are estimated from the compaction level and moisture content of the base layer in the road. The corrected equivalent modulus, comparable to the triaxial resilient modulus, can then be estimated in an iterative way from RL-CBR test.

Table 1: Model parameters for equation 5

Material	a_1	a_2	a_3	a_4	R^2	*No. data*
G1	0.077	0.012	-0.957	0.641	0.962	65
FC	4.429	-0.149	-3.960	0.452	0.896	70
WB	***-3.910***	***-0.006***	***3.399***	***0.474***	***0.865***	***100***
ZKK32	-23.788	0.036	22.242	0.642	0.968	20
ZKK63	21.622	-1.021	-18.887	0.684	0.998	15
MG	-6.189	0.059	-4.345	0.626	0.960	55
All materials	0.314	-0.063	-0.726	0.543	0.686	305

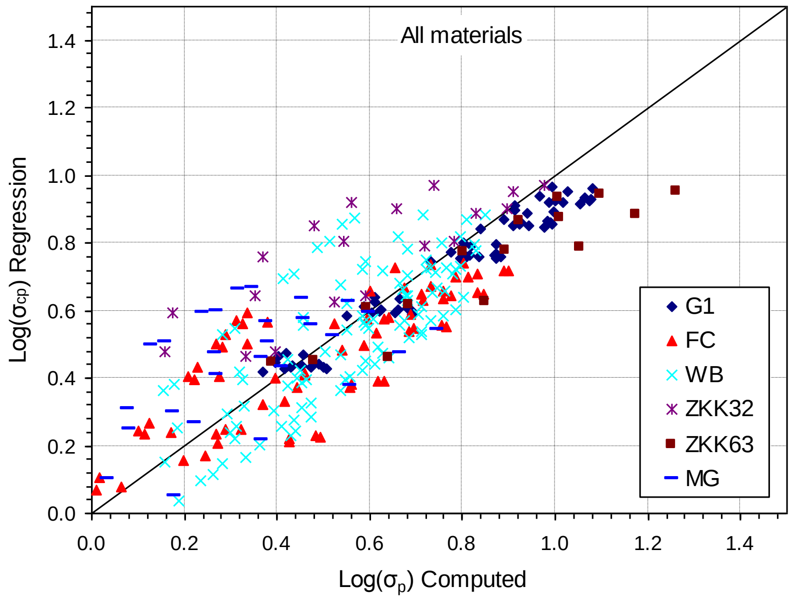

Figure 10: Comparison of the regression fit of equation 5 for all materials together with the computed values from equation 4

6 CONCLUSIONS

The RL-CBR test is a realistic and affordable technique and gives a reasonably good estimate of the resilient modulus, when large scale triaxial testing for coarse granular materials is too complex to be used in low-cost road pavements. The verification and validation of the RL-CBR equivalent modulus is made using resilient modulus triaxial test results. The RL-CBR is calibrated against the triaxial resilient modulus through a relation that provides a reduced or corrected plunger stress. The corrected plunger stress can be used to iteratively estimate the modulus, equivalent to the triaxial resilient modulus, for a stress level occurring in the real pavement structure. A good general relationship is developed by the reduced plunger load for the equivalent stiffness modulus of RL-CBR tests. This relation significantly improves if individual materials are considered; which implies that the RL-CBR characterization technique can be used in practice for ranges of materials grouped based on their characteristics. Moreover, the RL-CBR test is a useful technique to evaluate the effect of moisture, compaction and stress level on the modulus.

As the standard CBR test is the most popular testing technique and the test equipment widely available in many countries in Africa, the new characterization can easily be adopted in these countries. This can be done first through dissemination of the testing techniques and the advantage of characterizing road materials in terms of their mechanical behavior in comparison to their index properties. Further research and elaboration is essential on tropical materials to use this semi-mechanistic characterization technique for various class/group of road materials.

ACKNOWLEDGEMENT

The research was funded by Delft University of Technology and conducted at the Road and Railway Engineering Laboratory of the Delft University of Technology. The author wishes also to acknowledge the full support of the promoter Prof. Dr. Ir. A.A.A. Molenaar and the Core Consulting Engineers P.L.C. Ethiopia for supporting the transportation of the weathered basalt.

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EXPERIENCE IN THE NOVEL USE OF THE DYNAMIC CONE PENETROMETER AND MARGINAL MATERIAL IN THE DESIGN AND CONSTRUCTION OF DEMONSTRATION SITES FOR LOW VOLUME RURAL ROAD IMPROVEMENT IN TANZANIA

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Abstract

Two demonstration roads in Tanzania are undergoing upgrading to an all weather level utilising Environmentally Optimised Design principles, incorporating the use of locally sourced marginal materials and a Dynamic Cone Penetrometer (DCP) design method. The intention is to monitor the performance of these roads and develop new design methods and strategies to be incorporated into current design standards to specifically address pavement design for low volume roads. Results thus far are encouraging; however the detailed knowledge of the performance of unconventional materials and methods required to make future recommendations will only be discovered through future monitoring of these sites. Roughton International is working closely with AFCAP and the Districts to carry out this monitoring over the next 10 years.

1 INTRODUCTION

The Africa Community Access Programme is designed to address the challenges of providing reliable access for poor communities. Improving the reliability of rural access will lead to improved economic mobility, and access to health and education services for the rural poor; thereby creating opportunities for pro-poor growth and poverty alleviation. The objectives for the AFCAP project in Tanzania aim at identifying low-cost, locally resource-based methods of improving problematic lengths of road to provide sustainable rural access.

Low volume rural roads should be maintained to an appropriate and affordable standard which allows year round access to vital community facilities. Current design philosophies and ideologies promote rehabilitation of continuous road sections – on rural roads; this generally involves frequent re-gravelling of the entire road length. This is inefficient, costly and environmentally un-sustainable in the long term.

Maintaining year round access need not involve providing a blanket solution to the entire road length. The proposed Environmentally Optimised Design (EOD) methodology being implemented involves “variable longitudinal design, i.e. a design which may vary along the length of the road with, for example, a sealed surface up a hill or gravel along a level section. In addition, these works should incorporate locally sourced materials; labour and labour based construction methods wherever possible. This should, in theory, allow the road to be easily maintained by the local residents throughout its lifetime. The specification for construction materials may not always meet current standards set out by the Tanzanian Pavement and Materials Design Manual (TPMDM), but on these roads, as traffic levels and pavement stresses are low, material specifications can be relaxed. This approach is imperative to the success and sustainability of this methodology, as locally sourced materials cannot always meet the standards required by current specifications which are more appropriate for relatively high volume roads.

It is necessary to understand how well these roads, constructed with marginal or unconventional materials, perform and their durability in order to maximize investments and meet sustainability criteria.

Construction and monitoring of these demonstration sites will aid the research for development of design guides, methods of best practice and specifications for marginal materials for use on low volume rural roads across Tanzania and East Africa.

1.1 Project Background

Two sites have been selected in Tanzania representing the varying sub-grade soil and road environment characteristics apparent across the country. One located near Bagamoyo, approximately 60km north of Dar es Salaam and the other on the foothills of Mt. Kilimanjaro in Siha District. Both experience low volumes of traffic (less than 50 vehicles per day) and exhibit different challenges in the design of low volume roads.

Current pavement design in Tanzania does not address the need for an appropriate design methodology, or standard, for low volume rural roads. The TPMDM details the design of major trunk and arterial roads. The TPMDM uses a combination of axle loading and subgrade strength to allocate pavement designs to specific road sections. These pavement designs determine the entire pavement structure, material type and specification for each layer.

However, arterial and trunk roads have a much higher traffic volume than is experienced on many rural roads, thus material quality and specifications must be of a much higher standard. In the case of low volume roads, these specifications for material may be relaxed to allow the use of readily available, locally sourced materials. These materials may not meet the specification for arterial or trunk roads, but, where lower traffic volumes are involved; stresses and deteriorating factors are generally lower. This would facilitate the consideration of materials such as natural gravels including volcanic cinders, calcrete and coral rocks., which may be readily available but due to specifications in current design manuals and local engineering principles, are not given consideration in pavement construction. Current design beliefs held by many engineers regard these materials as being substandard. While this may be the case for high volume roads, many of these materials are suitable for rehabilitating lower volume roads, but are not given consideration as little information is available on their performance. As Engineers we should be asking ourselves the question 'What appropriate road can I build with these materials?', rather than 'Where can I find materials to meet these general specifications?' In other words, we should be making the specifications fit the materials rather than the materials fit the specifications.

Research on an improved design approach for low-volume roads has been completed by TRL under the SEACAP project (DFID, 2009) and the South African Development Community (SADC) project on Guidelines for Low-Volume Sealed Roads (Gourley and Greening, 1999). The research has shown that sealed roads built in accordance with conventional specifications are generally overdesigned resulting in inefficient use of the financial resources available. Also proven is that, with appropriate designs, some so-called marginal materials can be used successfully in the construction of sealed roads. This is a particularly important development for Tanzania considering the availability of marginal natural gravels for base course. With careful adherence to good workmanship and provision of adequate drainage coupled with appropriate specifications and design, labour based upgrading and sealing of low volume district and local roads can be undertaken in Tanzania.

EOD ensures that specifications and designs support the functions of different road sections - assessing local environment and limited available resources. This requires analysing a broad spectrum of solutions to rectify different road sections depending on their individual requirements, ranging from engineered natural surfaces to bituminous pavements. A key cornerstone of this method is that the chosen solution must be achievable with materials, plant and contractors available locally (Petts, 2008).

EOD has been defined as a system of road design that considers the variation of different road environments along the length of the road such as steep gradients, wet and marshy areas as well as passage over easy terrain (Roughton International, 2009).

So the EOD philosophy challenges the standard rural access road design of applying a gravel wearing course from start to finish. The EOD method asks if the standard design is sufficient for problematic areas and is the standard design necessary for the good areas. The correct design needs to be undertaken for the different sections of the road as they are assessed. An under-design of poor sections can lead to premature failure of problematic areas and an over-design will often be a waste of funds which would be better spent on the problematic sections.

The EOD design philosophy proposes using minimal resources on the good sections, some resources on the standard sections and the majority of resources on the problematic sections. Viable and permanent rural road networks are essential for sustainable rural development and the implementation of the EOD approach can be a key element of the solution. Whole-life costing of roads, built using results of research over the last two decades, has shown that it is often cheaper to build and maintain sealed roads and other types of durable road surfaces than gravel roads.

Different pavement and surface treatments will be used on the sites in order to demonstrate alternative technologies for district roads that will hopefully lead to increased durability, lower costs and lower long term maintenance. Where new construction techniques and standards are established these will add to the knowledge base. The pavement types selected for demonstration cover a number of different forms of construction including concrete geocells, concrete strips, surface dressing, Otta seals, sand seals, slurry seals, hand packed stone and engineered natural materials.

The construction of the demonstration sections in Bagamoyo is now complete and monitoring of pavement performance has begun. Construction in Siha commenced in March 2012 and is expected to take 8 months. Following completion a set of base line data is collected from each road and then further monitoring trips are carried out at 6 months intervals for a period of 2 years by the consultant and a further 8 years by the respective districts. With this future monitoring schedule it is hoped sufficient data can be captured to draw conclusions and make recommendations for design guides, methods of best practice and use of materials for low volume rural roads.

1.2 Scope and Purpose

The background of EOD methodology has been widely covered in the past as well as the details of the specific demonstration sections, costs and construction issues of the Bagamoyo project site. This paper covers in more technical detail some of the methods and materials used in the design and construction of the two demonstration sites selected for the AFCAP Tanzania project that relate to the objectives of researching marginal materials and employing non traditional construction techniques. The ways in which these roads have been designed and constructed is appraised in order to facilitate the development of research into methods of best practice, design guides and material specifications for use on low volume roads.

More specifically this paper looks into the use of Marly Limestone as a non traditional construction material for rural roads along the east coast of Tanzania and the use of Dynamic Cone Penetrometer (DCP) equipment to facilitate the design of low cost pavement structures for rural roads.

Marly Limestone is a raised reef deposit thought to be abundant along the east coast of Tanzania. This locally sourced material was used widely in the construction of the project road in the coastal Bagamoyo district. By looking at past experiences with coralline materials, and utilising the material test samples and monitoring data collected from the Bagamoyo project it is hoped that recommendations can be made for the widespread use of this material.

The use of the DCP method of road design is discussed following its use in the design of the project road located on the foothills of Mt. Kilimanjaro in the Siha district. The methodology behind the design is briefly described, highlighting the benefits achievable and the assessed risks associated with this approach.

These two subject areas are important in the development of design standards for low volume roads both in Tanzania and across East Africa. The purpose of this paper is to highlight ways that non-standard techniques and materials are being implemented in order to further our knowledge and aid the development of sustainable methods to improve district roads to all weather standards. Through this it is hoped to illustrate that the upgrading of district roads in this way can provide a more sustainable solution to frequent re-gravelling, and facilitate economic growth and social mobility in these communities.

2 BAGO – TALAWANDA ROAD

The road from Bago to Talawanda is in the coastal region of the Bagamoyo District of Tanzania and illustrates typical problems of coastal regions such as sandy sub-grades and flat marshy areas of black cotton soils. The road, connecting the two small villages of Bago and Talawanda, passes through a number of small settlements, is 20.24km long and was completed in September 2012. The map in Figure 1 illustrates the geographical location of the road.

Figure 1 - Location of Bago - Talawanda Road

2.1 Use of Marginal Materials

The project road in Bagamoyo looks to promote the use of locally sourced marginal materials, presently considered substandard, but which, if incorporated within an appropriate low volume road design and construction philosophy, can actually perform satisfactorily on low volume roads whilst providing a significant cost saving.

A thorough investigation was carried out to source local materials for construction of the selected sub-grade, sub-base, base and surfacing layers. Materials were tested to determine their suitability to the project objective of utilising marginal material in construction of the selected pavement layers.

2.1.1 Marly Limestone

Two borrow pits were located along the road in Bagamoyo yielding a material that was identified as Marly Limestone. Marly Limestone is a sedimentary rock formed from a mixture of clay (5%-15%) and carbonate (85%-95%) largely derived from the skeletal deposits of coral reef organisms. This material is thought to be abundant along the East coast of Tanzania.

One of the AFCAP objectives for this project is to utilise and research the performance of marginal and unconventional materials on low volume rural roads which would otherwise be discarded as unsuitable under the TPMDM. Marly Limestone exhibits a number of different material characteristics, the benefits of its use as a road construction material along the Bago – Talawanda road are examined in more detail here.

Formation

The borrow pits were identified as raised reef deposits of Marly Limestone. Raised reef deposits comprise a variety of dead corals and algae in the aragonite form of calcium carbonate that has been cemented together when the coral reef is exposed to the air. Under exposure to air and lightly acidic rainwater any aragonite deposits go into solution, this can cause the structure of the reef deposit to break up. The aragonite solution however, causes the present groundwater to become highly carbonate charged and as this permeates through the reef material it deposits coarse and fine grained crystalline calcite. This process will, over time, bond the reef structure together forming a limestone.

Raised reef deposits and other coralline materials exhibit a number of seemingly undesirable engineering qualities such as low particle strength and non-standard grading; despite this it is has been possible to achieve high levels of compaction and strength for use in road construction (Cardno and Davies, 1993).

Particle Size

Due to the method of formation of coralline materials, deposits experience a huge variation in particle size and shape. Despite the low strength of Calcite deposits when used in road construction the material exhibits good interlocking characteristics due to the range of particle sizes. Distinguishing the acceptance of particle size for coralline gravels like Marly Limestone is further affected by its degradation and breakdown during compaction. Experience in use of these materials and knowledge of its likely grading following compaction is important in order to determine its performance in service. A strong mechanical interlock, formed through heavy compaction is important in the performance of Marly limestone.

It can be seen from Figure 2 and Figure 3 below that the samples of Marly Limestone taken from the borrow pits in Bagamoyo indicate the material does not meet the traditional grading requirements specified for a base course layer in the TPMDM and that they contain too high a percentage of fines.

Despite this the material was deemed satisfactory for use on the Bago – Talawanda road due to the low levels of traffic experienced and the research purposes of the project.

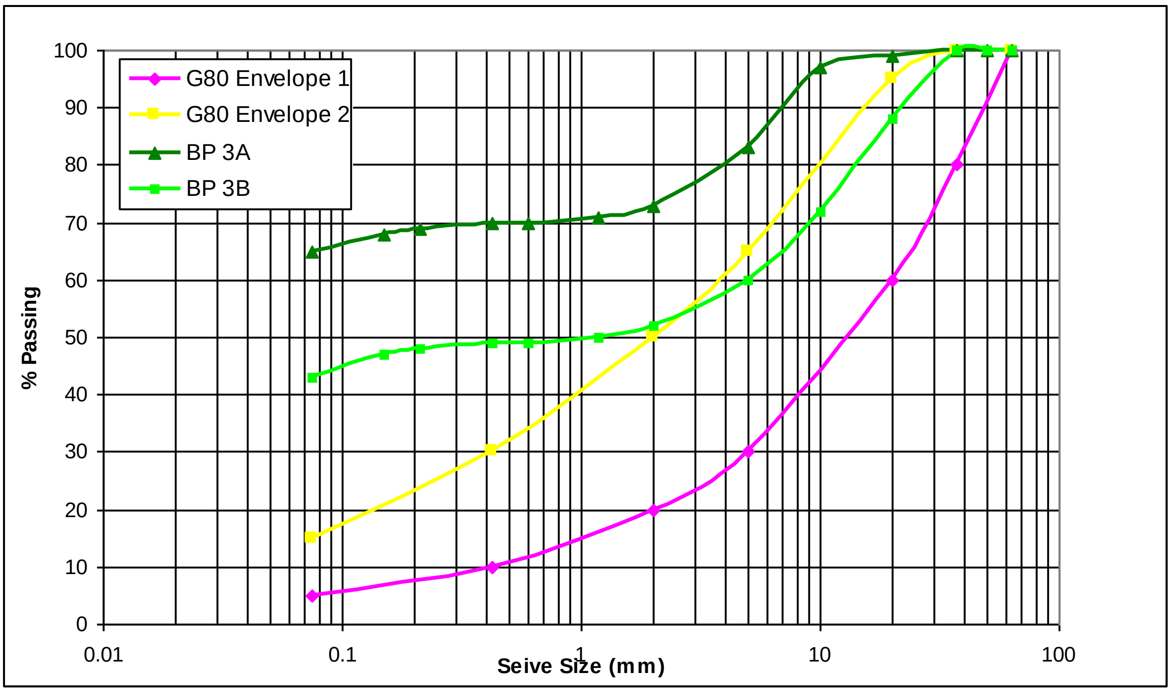

Figure 2 - Particle Grading of Borrow Pit 3 (Ch. 13+860km)

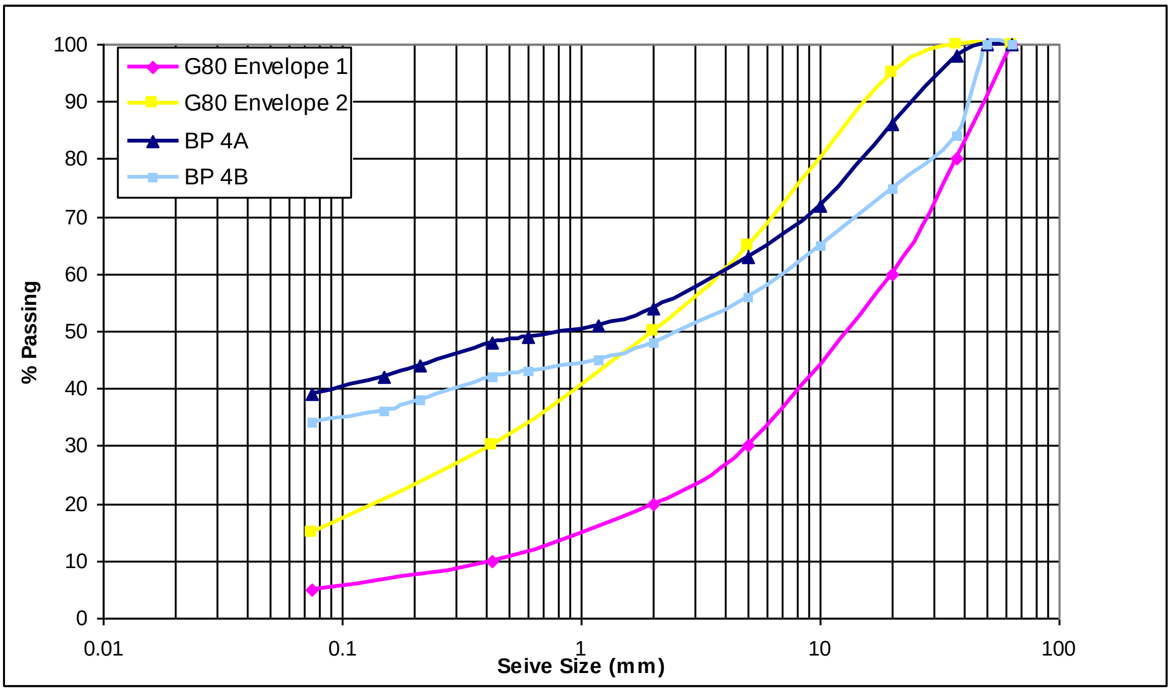

Figure 3 - Particle Grading of Borrow Pit 4 (Ch. 8+030km)

<u>Plasticity</u>

Cardno and Davies (1993) discovered that materials with high plasticity and poor grading were difficult to place and compact. Placing material in a very wet state was ineffective with highly plastic material causing plant to bog and non plastic material forming an inconsistent layer of fines on the surface that can cause problems with sealing. The climate of the project road in Bagamoyo is deemed as moderate, in this case the material test results proved marginal for the Atterberg Limits requirements as set out in the TPMDM for a traditional base course layer achieving a CBR of ≥80% for use in a dry or moderate climatic zone. This is highlighted in Table 1.

Table 1 - Atterberg Limit Results for Borrow Pit 3 and 4

Atterberg Limits	TPMDM Specification Dry or Moderate Climate	BP 3A	BP 3B	BP 4A	BP 4B
Liquid Limit	Max 40	30	33	35	34
Plasticity Index	Max 14	12	14	14	14
Linear Shrinkage	Max 7	6	7	7	8
Plasticity Modulus		840	686	624	588
Shrinkage Modulus		420	343	336	336

Cardno and Davies (1993) also states that coralline materials exhibiting higher Plasticity Index values than those traditionally accepted for natural gravel materials have been found to perform well in service. This is due to the importance of the quantity of fines and not just their plasticity. Low values of Plasticity Modulus (100-800) and Shrinkage Modulus (0-350) were found to give a good indication of the ability to achieve high CBR values from a material.

Results from the CBR testing carried out on the samples collected from the borrow pits along the project road are shown in Table 2. Results were highly variable between samples and pits and indicate a strong correlation with density. CBR results also support the notion proposed by Cardno and Davies (1993) that Plasticity Modulus and Shrinkage Modulus give a good indication of material strength. The sample from borrow pit 3A, characterised by the highest values of Plasticity Modulus and Shrinkage Modulus, also exhibited the lowest CBR values as seen in Table 2.

These values show that even with unconventional marginal materials, high CBR values can be achieved through high levels of compaction. Traditional levels of compaction recommended in design manuals fail to achieve the maximum strength potential from construction materials and it is recommended for future projects that pavement layers are compacted to "refusal" to achieve this potential from material otherwise considered as substandard. In this case, the Marly Limestone from the two borrow pits in Bagamoyo would be acceptable as a wide range of pavement layers and provide an ideal low cost alternative to traditional materials.

Table 2 - CBR Results of Marly Limestone from Borrow Pit 3 and 4

	Compaction	BP 3A	BP 3B	BP 4A	BP 4B
CBR % (Unsoaked)	90% Heavy DD	16	31	59	26
	95% Heavy DD	45	60	106	79
	100% Heavy DD	58	94	132	104
CBR % (4 Day Soaked)	90% Heavy DD	10	10	10	15
	95% Heavy DD	15	26	48	61
	100% Heavy DD	27	36	83	91

Self Cementation

Marly Limestone and other coralline materials exhibit the interesting ability of self cementation. The use of salt water to aid this process has also been promoted by some in the past (Perry, 1945; Luce, 1945). Despite this, field studies in Papua New Guinea by Cardno and Davies (1993) suggest it was not possible to correlate between benefits of self cementation and laboratory tests and that such strength gains do not contribute significantly to warrant further investigation.

Samples from the borrow pits along the Bago – Talawanda road were left in a mould for one month and then tested using a 4 day soaked method. The results in Table 3 loosely support the notion that self cementation occurs in the material with the material from borrow pits 3 and 4 achieving a 5% and 19% CBR increase respectively. However the current lab testing of this is not sufficient to make conclusions on extent of self cementation. The increases in CBR experienced are within the traditional variability of CBR testing, to determine the viability of these results further study would be required.

Further laboratory and field testing into the intrinsic increase in strength displayed by Marly Limestone and other pedogenic materials will help to determine if CBR values increase reliably and uniformly in order to promote their use as a marginal material. The use of DCP testing in the future monitoring of the constructed demonstration sections will indicate if the self cementation properties of this material have a significant effect on in-situ strength over a longer time period.

Table 3 - Marly Limestone CBR Results

	Normal CBR Procedure		CBR After 1 Month	
Borrow pit no.	**Borrow pit 3**	**Borrow pit 4**	**Borrow pit 3**	**Borrow pit 4**
CBR (%) (100% BS-Heavy)	30	58	35	77

Performance

The Marly Limestone excavated from the two borrow pits along the project road were used on a variety of different aspects of the road. Gravel from borrow pit 3 and 4 was used as improved subgrade, sub-base and base course layers and as a gravel wearing course. Material from borrow pit 4 was used in the construction of the hand packed stone as the material's naturally cubic shape provided an ideal block for the surfacing. This stone was also used in construction of headwalls, wing walls and side drains. The gravel and stone blocks extracted from the borrow pits can be seen in Figure 4 and Figure 5.

During the construction phase the Marly Limestone performed well and was able to be compacted sufficiently and when checked with a Troxler Nuclear Density Gauge, achieved compaction values exceeding the requirements for each specific layer.

Figure 4 - Marly Limestone from BP 4

Figure 5 - Marly Limestone from BP 3

The road is currently undergoing monitoring at 6 month intervals following the completion of construction in September 2011. A set of base line data was collected in September/October 2011 and further data was collected 6 months after construction, in April 2012. The monitoring data being collected includes:

- Surface Profile Measurement;
- Rut Depth Measurement;
- Surface Roughness (MERLIN);
- Surface Texture (Sand Patch);
- Visual and Photographic Recording;
- Traffic Counts;
- DCP Testing.

This information will be collected by Roughton International for the first two years, working closely with the local district engineers to be handed over for monitoring by the districts for a further 8 years. Given the short time scale of the current data few clear conclusions can be drawn. It was observed during the most recent monitoring period that motorcycle drivers were frequently using the gravel shoulder of the hand packed stone section. This is due to erosion of gravel material between the blocks which has led to loose blocks and a very rough running surface. This use of the shoulder is causing excessive wear of the material and is illustrated in Figure 6 and Figure 7.

For this reason, it is recommended that hand packed stone is used as a surfacing option on only the most problematic, short sections that cause severe access problems during the wet season. Bicycle and motorcycle riders will no doubt prefer to make use of the gravel shoulder when it is dry and they provide a smoother running surface, however during periods of heavy rain the hand packed stone running surface will provide a sufficient and accessible route for basic access to communities along the road when a gravel shoulder may become less desirable. It should be noted that sections of hand packed stone are recommended to be limited to 200m in length due to their inherent roughness.

Figure 6 - Hand Packed Stone Shoulder Wear

Figure 7 - Motorcycle Using Gravel Shoulder

All other surfacing is performing well with the qualitative data collected showing no significant areas of erosion, as would be expected over such a short time scale. The Marly Limestone gravel wearing course sections and shoulders are performing acceptably with only the expected minor gravel loss evident. Future DCP monitoring of gravel and bituminous demonstration sections is expected to provide further data to investigate the self cementing and strength properties exhibited by Marly Limestone and its use as sub-grade, sub-base, base course and wearing course layers.

3 LAWATE – KIBONGOTO ROAD

The road from Lawate to Kibongoto is in the Siha District of Northern Tanzania. The road is characterised by steep gradients and clayey red soils on the foothills of Mt. Kilimanjaro. The road exhibits some natural volcanic gravel which provides a good gravel wearing course however rainfall can quickly render the road inaccessible due to the slippery clayey soils prevalent along most of the 13.4km length. A busy agricultural landscape surrounds the road facilitated by the areas high rainfall of up to 2000mm per year. A map illustrating the geographical location of the road is shown in Figure 8.

Figure 8 - Location of Lawate - Kibongoto Road

3.1 DCP Design Method

The objectives of the design process were to review the appropriateness of the approach adopted by the TPMDM in the design of the road within the EOD philosophy and ensure the application of the most efficient pavement structure. This will allow us to provide a design solution that will enable reliable year round access along the challenging road environment of this project location, characterised by steep and narrowing winding sections.

A review of our initial pavement design based on the current TPMDM identified that he resultant multi-layered pavement structure will provide a much higher bearing capacity than required for the projected design loads encountered between Lawate and Kibongoto. Based on recent experience in Malawi (Pinard, 2011) and other Southern African countries, the use of a DCP based design method was identified as appropriate. The DCP has been developed to a stage where it can be used for the design of low volume roads. The testing approach allows for a quick, non-destructive method of estimating the in-situ strength of base, sub-base, sub-grade and weakly cemented pavement layers.

The DCP design process consists of utilizing the in-situ strength profile data collected from testing on the alignment material and comparing this profile with minimum specified DCP design profiles. These profiles have been adopted based on investigation and previous experience on Low Volume Roads (LVRs) carried out in the region and calibrated by results undertaken in a number of countries, most recently, Malawi (Pinard, 2011). These design profiles, characterized by DN values calculated as number of mm penetrated per blow, are presented in Table 4 for different LVR categories. It is important to note the pavement class applicable for the Lawate to Kibongoto road is that of LV 0.03.

Table 4 - Pavement design profile for different LVR categories

Pavement Class E80 x 106	LV 0.01 0.003 – 0.010	LV 0.03 0.010 – 0.030	LV 0.1 0.030 – 0.100	LV 0.3 0.100 – 0.300	LV 1.0 0.300 – 1.000
150mm Base ≥ 98% BSH	DN ≤ 8	DN ≤ 5	DN ≤ 4	DN ≤ 3.2	DN ≤ 2.5
150mm Sub-base ≥ 95% BSH	DN ≤ 19	DN ≤ 14	DN ≤ 9	DN ≤ 6	DN ≤ 3.5
150mm Sub-grade 93% BSH	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 12	DN ≤ 6

DCP testing was carried out at 100 m intervals, alternating between the outer wheel path, centre line and inner wheel path, in order to obtain sufficient level of data to assess the in-situ strength profiles of the road. Following completion of the DCP survey, the data was used in a cumulative sum analysis to identify uniform sections based on the three uppermost 150 mm layers. The cumulative sum analysis identified six uniform sections along the road. Three trial pits per uniform section were excavated and soil samples taken for laboratory testing in order to support the DCP survey results. Based on the in-situ moisture conditions at the time of the DCP survey and the annual rainfall data in the Siha region, 80th percentile DN values were determined for each of the identified sections as well as values for bearing capacity. The results of the DN values for each of the six uniform sections are presented in Table 5.

Table 5 - Existing Pavement DCP Characteristics

Pavement Depth (mm)	DN (mm/blow)						
	DN for LV 0.01-0.03	Section No.					
		1	2	3	4	5	6
0 - 150	≤ 5	5.8	9.5	7.7	9.0	11.0	6.9
150 - 300	≤ 14	8.1	11.9	4.4	9.7	18.3	7.8
300 - 450	≤ 25	7.1	19.6	7.9	12.9	31.0	11.3

Inadequate strength at design moisture content (shaded cells)
Adequate strength at design moisture content

The results from the DCP survey and subsequent analysis indicate that the existing uppermost layer of the road does not meet the required DN value for any of the six sections, with section 5 identified as the weakest in which required DN values are not met to a depth of 450 mm.

In order to achieve a pavement structure that meets the required DN values for the design traffic loading along the Lawate-Kibongoto road it is necessary to import a 150 mm thick layer of material meeting the requirements of DN ≤ 5 for sections receiving a bituminous surfacing, the equivalent of a material with a CBR ≥ 60%. This approach would then render the existing running surface as the new sub-base layer, the existing sub-base layer as sub-grade and so on. The new pavement design structure is illustrated in Table 6.

Table 6 - New Pavement DCP Characteristics

Pavement Depth (mm)	DN (mm/blow)						
	DN for LV 0.01-0.03	Section No.					
		1	2	3	4	5	6
0 - 150	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5
150 - 300	≤ 14	5.8	9.5	7.7	9.0	11.0	6.9
300 - 450	≤ 25	8.1	11.9	4.4	9.7	18.3	7.8
450 - 600		7.1	19.6	7.9	12.9	31.0	11.3

Adequate strength at design moisture content

The pavement design where concrete surfacing options are to be implemented will require a 100 mm layer of base course material exhibiting a CBR value of 30% or greater to be imported, unless it is possible to achieve this in the existing in-situ running surface. Laboratory testing of material obtained from the trial pits excavated has identified a CBR value of 30% or greater can be achieved on the first 1.5 km of the road.

It is now widely recognized that the strength potential of the road base materials and the underlying sub-base and sub-grade layers as well, can be maximized by compacting. This can be achieved not necessarily by compacting to a pre-determined relative compaction level, as is traditionally done, but to the highest uniform level of density practicable by employing the heaviest rollers available. Compaction to this level ensures that the soil has reached its near elastic state at which point the near-zero air void condition is reached with the significant benefit of reduced pavement deflection, increase in pavement life, reduced susceptibility to rutting and reduced permeability, making the material strength less moisture sensitive. This is known as compaction to refusal.

The compaction requirements specified for the original multi-layered pavement system are in accordance with the TPMDM, i.e. 93% BS heavy in the sub-grade, 95% BS heavy in the sub-base and 98% BS heavy in the base. However, in view of the two layer pavement system as a result of the DCP design method, the existing running surface can achieve far better performance through proof rolling to refusal. The use of the DCP method obviates the need to meet the traditional multi-layered density requirements which are often inferior, in bearing capacity terms, to the strength-balanced pavement achieved by prior traffic consolidation, coupled with wetting and drying cycles.

This design approach has resulted in an efficient, relatively well balanced, pavement structure which is much more suitable for LVRs than a traditionally constructed multi-layered pavement structure. In comparison to the previous pavement design, this approach has facilitated the replacement of an expensive multi-layered pavement structure, as required by the TPMDM, with a cost effective single layer of natural gravel achieving a CBR strength value of ≥60% to be imported for bituminous surface sections and ≥30% for concrete surface sections. This is illustrated in Figure 9.

The use of more appropriate design methods and marginal materials in place of the TPMDM standards and specifications should not ultimately mean there is an increased risk of road failure. These methods have been proved to perform as well as expensive multi-layer pavement systems in Malawi over a number of years. Instead it requires that a greater degree of pavement engineering knowledge, local experience and judgment is applied and that engineers spend significant time in the field to obtain a sound understanding of the road environment in relation to the design requirements.

The principal requirement for mitigating risk when utilizing these methods of design and construction is to ensure that drainage is adequate to keep the in situ material at or below its optimum moisture content. In addition construction quality should be tightly controlled, high compaction standards must be achieved and the road effectively maintained.

If construction is carried out to a high quality then this method of pavement design has significant benefits for use on low volume rural roads most notably a substantial cost saving due to the removal of a number of pavement layers. Based on the rates of this contract the cost per m^2 and per 1km standardised 4m wide section for the various surfacing options of the original TPMDM design and the new DCP design are compared in Table 7.

Table 7 - Cost of Demonstration Sections in Siha

Surfacing Option	TPMDM	DCP	TPMDM	DCP
	USD ($)/km		**USD ($)/$m^2$**	
Double Surface Dressing	61,125	45,125	15.28	11.28
Bituminous Penetration Macadam	128,875	112,875	32.22	28.22
Unreinforced Concrete Slab (100mm)	91,000	73,500	22.75	18.38
Unreinforced Concrete Slab (75mm)	73,500	56,000	18.38	14.00
Lightly Reinforced Concrete Slab (100mm)	136,000	118,500	34.00	29.63
Lightly Reinforced Concrete Slab (75mm)	118,500	101,000	29.63	25.25
Flexible Geocells (75mm)	84,875	71,000	21.22	17.75
Concrete Paving Blocks	83,875	68,250	20.97	17.06
Concrete Strips	60,176	46,301	15.04	11.58

It can be seen from this information that the use of the DCP design method has facilitated a saving of up to US$17,500 per km for each demonstration section through the use of a single layer pavement design as opposed to a multi layer design which is illustrated in Figure 9. These cost savings not only brought the project below the adjusted budget but allowed for improved drainage to be incorporated into the design in an area where high rainfall can cause substantial damage to the road environment.

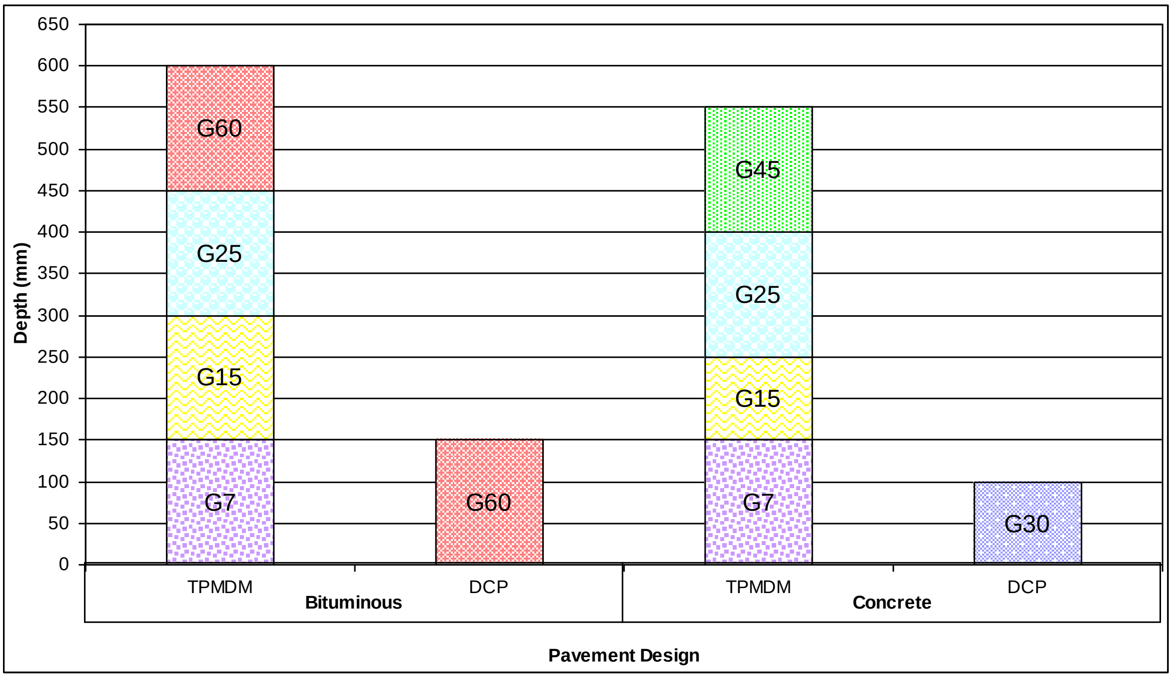

Figure 9 - TPMDM and DCP Pavement Design Comparison

4 CONCLUSIONS

The work carried out so far covers two rural roads in Tanzania which represent the access challenges faced by rural poor communities over a range of different environmental conditions.

4.1 Bago - Talawanda

The use of Marly Limestone as a construction material holds great potential for rural roads along the eastern coast of Tanzania. Due to the short time scale of the monitoring processes carried out it is difficult to draw strong conclusions about its performance. Thus far it has performed adequately in the range of forms it has been implemented along the Bago – Talawanda road. Where motorcycles are using the gravel shoulder of the hand packed stone section is more due to the inherent roughness of hand packed stone surfacing and not due to poor performance of the Marly Limestone blocks used.

During upcoming monitoring stages DCP testing will be carried out to analyse the in-situ strength of the various pavement layers along the road. This will give an insight into the long term effects of the self cementing properties exhibited by Marly Limestone and enable us to determine if this will provide any significant strength gains in the material.

The current performance of the road illustrates that the use of marginal materials not completely complying with the TPMDM can prove very effective in use on rural roads, providing significant cost savings in the process. This, coupled with the EOD approach can present an affordable and sustainable alternative to gravelling rural roads across East Africa.

4.2 Lawate – Kibongoto

The DCP method for designing rural roads has proved a highly beneficial and cost saving activity to the project road located in Siha district of northern Tanzania.

Through experience from previous work on low volume roads across Africa it was possible to transfer this knowledge and implement a pavement design not supported by the TPMDM, which will tend to overdesign for a road with low volumes of traffic (less than 0.2 MESA). The use of DCP equipment to determine the in-situ strength of the pavement structure has facilitated a reduction in the number of pavement layers representative of the prevalent subgrade and traffic conditions. Combining this with the compaction to refusal approach to each pavement layer the maximum inherent material properties can be exploited to achieve an efficient, low cost design using locally sourced marginal materials. This project clearly shows that through non traditional methods of design and construction significant cost savings can be achieved to implement a road carrying low volumes of traffic.

The cost saving of implementing a design using only a single layer of imported material has resulted in reductions of up to US$17,500 per km for some demonstration sections. These costs have been relocated to provide improved drainage along the road in a challenging and high rainfall environment.

The success of the pavement structure implemented through the DCP design process will only be verified following completion of the road and through future monitoring. The performance of these sections will be monitored using the same methods as the project road in Bagamoyo and will help to contribute further to the advancement of the use of the DCP and the development of design manuals for low volume roads.

The long term success of the research component of this project is dependent on thorough monitoring to observe the performance of these materials. Roughton International is working closely with AFCAP and the respective District Engineers to ensure that this information is properly recorded and logged to ensure we collect reliable data to enable us to make recommendations for the future and meet the objectives set out at the start of this process.

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KEYWORDS

DCP, Environmentally Optimised Design, Marginal Material, Marly Limestone, Rural Access

DEVELOPING INDICATORS TO ASSESS RURAL TRANSPORT SERVICES

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Abstract

Road investments are justified by improved transport services that allow people to access markets, services and socio-economic opportunities but there are no indicators to 'measure' the adequacy of transport services. Indicators should measure parameters relevant to stakeholders (passengers, operators, regulators) which can be improved. Indicators should be reliable, sensitive and meaningful. Since April 2012, a team working in Tanzania and Kenya has been developing methodologies to obtain indicator data through rapid surveys of users, operators, regulators and development personnel. The surveys, combined with observations and triangulation, will result in standardised summaries of statistics (costs, frequencies, loads), user satisfaction, operator margins, compliance with regulations and developmental impact for each transport mode. Subsequently, component indicators may be combined into overall rural transport services indicators.

1 INTRODUCTION

The International Forum for Rural Transport and Development (IFRTD) in conjunction with Paul Starkey has been awarded a research contract by the African Community Access Programme (AFCAP) to develop and test indicators that can be used to assess how good rural transport services are at providing access for rural people. The envisaged outcome of the research will be appropriate rural transport services indicators that are tested and disseminated to the transport sector in various African countries. The research aims to identify, develop, test and share rural transport services indicators relevant to the key stakeholders, including rural people, transport operators, regulators, planners, roads authorities and development agencies. This will be achieved using participative methodologies involving local stakeholders and sector experts. Since April 2012, initial studies have been carried out in Kenya and Tanzania. The research team includes Paul Starkey (Team Leader), Peter Njenga (Project Manager), Dr Kenneth Odero, Guy Kemtsop, Shedrack Willilo and Dr Musyimi Mbathi. The project website is http://www.ruraltransport.info/RTSi.

This paper reports the initial work on indicator develop. As the research is on-going, it is a work-in-progress document that introduces the aims of the project, the initial methodology developed and the lessons learned so far. The paper discusses the requirements of indicators and reviews some previous work relating to indicators. The paper then presents the suggestions of the research team for the types of data that need to be collected to develop rural transport services indicators. These are grouped by the four different perspectives from which the rural transport services are to be assessed: those of the users, the operators, the regulators and the authorities or organisations concerned with rural development. Some of the lessons from the surveys are highlighted. The paper concludes with possible ways in which the survey data can be summarised to facilitate the development of transport services indicators. This will be undertaken in the coming weeks and months. The paper provides the reader with an understanding of the complexity of trying to 'measure' the very diverse range of rural transport services. It also suggests a methodology that can be used to obtain the necessary information that could be used to develop indicators for rural transport services.

FIVE INNOVATIVE TRANSPORT MANAGEMENT SOLUTIONS TO INCREASE RURAL ACCESS TO HEALTH CARE IN AFRICA

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Abstract

Despite a recent focus on improving health in the developing world, rural populations in sub-Saharan Africa often do not have access to health care due to lack of transport management. Riders for Health (Riders) was founded as a not-for-profit social enterprise to improve management of transport for health care delivery. Using 20 years of experience, Riders has identified five key transport challenges and corresponding solutions to increase rural access to health care: selection of appropriate vehicles for usage and terrain, preventive maintenance, training of vehicle users, outreach maintenance, and predictable budgeting tools. Evaluations conducted by Riders' team and external sources have validated Riders' models in improving health-related outcomes. Riders continually seeks innovative ways to improve transport management and health care delivery models for hard-to-reach, rural populations in Africa.

1. INTRODUCTION

In rural areas across Africa, men, women, and children often lack access to vital health care services as a result of poor transport management. In the past decade, aid organisations have invested billions of dollars in supplying medicines, building new clinics and hospitals, and creating new diagnostic technologies. However, in spite of these developments, millions of Africans still do not have access to health care, often because of long distances, difficult terrain, or lack of infrastructure to link their community to the health system. In many regions throughout Africa, vulnerable populations who are living on less than $1 per day may be highly dispersed throughout the country, meaning that health care delivery must reach all the way down to the “last mile.” However, because these “last miles” are difficult to navigate and manage due to high-cost and oftentimes challenging terrain, the result is usually that many vulnerable populations are left underserved.

Riders for Health (Riders) was founded to address this challenge: the organisation’s vision aspires for “a world in which no one will die of an easily preventable or curable disease because barriers of distance, terrain or poverty prevent them from being reached.” Riders believes that the key to solving this issue is effective and well-managed motorised transport, which is often neglected in development, but enables equitable distribution of outreach health care services to vulnerable populations. As a result, Riders was formally established as a not-for-profit social enterprise in 1996 to focus on improving health care delivery through transport management, defined as a comprehensive system that focuses on maintenance and all elements related to a vehicle running to maximise productivity and reduce downtime while preserving the asset. Today, Riders manages transport for organisations as varied as community-based organisations (CBOs) to entire ministries of health (MoHs).

When Riders was founded, few organisations were focusing on vehicle management in Africa. The predominant mindset at that time, and which is still widespread today due to short-term planning, was to procure vehicles and to use them until they broke down. In rural areas, reliable parts can be in short supply and skilled technicians can be rare, resulting in many parked vehicles that should be vital in health care delivery to hard-to-reach populations. In its first years of operation, Riders observed these challenges first-hand and developed an innovative vehicle management platform that is based on five core principles. These competencies form the basis of Riders’ vehicle management systems that keep more than 1,300 vehicles and motorcycles operating across seven African countries today.

This paper explores five major challenges that impede community access to the health system and the corresponding core competencies of Riders’ transport management systems that address these challenges. These innovative solutions are: selection of appropriate vehicles for usage and terrain, preventive maintenance to replace vehicle components before breakdowns occur, training of vehicle users in defensive driving and daily preventive maintenance, outreach maintenance from vehicle maintenance units, and predictable budgeting tools.

2. FIVE INNOVATIVE SOLUTIONS FOR COMMON TRANSPORT CHALLENGES

2.1 Selection of appropriate vehicles for usage and terrain

While there have been improvements in road infrastructure in many African countries, the percentage of roads that are paved in sub-Saharan Africa still remains low, estimated at 18.8% by World Bank in 2009 (World dataBank, 2010). As a result, there is a need for transport that has been rigorously tested and is able to traverse difficult terrain and sustain high utilisation given the long distances. In some cases, motorcycles may be more appropriate to reach very rural areas, especially where single tracks may be the only path to certain communities. Moreover, vehicle managers should review the cost effectiveness of certain types of transport or makes/models of vehicles to ensure long-term sustainability.

Riders' team has been managing vehicles in African countries since the 1990s and in the process have collected 20 years worth of operational data on vehicles and motorcycles. Using these data, Riders' technical team often assists health-focused partners who are not automotive experts in two ways: 1) procurement of new vehicles and 2) assessment of current vehicle fleets.

Riders can assist with the selection of appropriate vehicles and the procurement process. Prior to procurement, Riders reviews the transport needs of the organisation and advises partners on the most appropriate types and makes/models of vehicles and motorcycles for the expected routes. For example, given the significantly reduced cost of operating motorcycles, Riders has advised some organisations to invest in motorcycle fleets to increase the ability of the organisation to cover more area with a fixed operating cost. Beyond types of transport, Riders also recommends makes/models that have proven more reliable over time. For example, Riders has managed more than 100 motorcycles of one particular make and model for several years. During this time, Riders' technical team has noted above average repair costs and breakdowns compared with other makes/models of motorcycles and has since recommended other partners not use this motorcycle for work involving rough terrain. This knowledge helps other partners avoid unnecessary repair costs and downtime.

Riders' operations team can also assist with the procurement of vehicles. Given Riders' position as a manager of significant fleets of vehicles, the operations team has built relationships with many of the largest vehicle and motorcycle manufacturers. As a result, Riders may be able to negotiate reduced pricing for partner organisations, resulting in procurement cost savings that can be reallocated to vehicle maintenance or other health service delivery activities.

Riders also assesses current fleets of vehicles and motorcycles that are already operating to determine viability for vehicle management systems that allow Riders to predict maintenance needs. During these on-site assessments, Riders' technician uses four criteria to determine whether the vehicle qualifies for these preventive maintenance systems: condition, make/model, mileage, and availability of replacement parts. First, the technician uses a checklist to closely examine the vehicle's condition and estimate refurbishment costs to bring it to a standard that allows for preventive maintenance. Second, the make/model and mileage are considered, as certain makes/models have been shown under Riders' systems to last longer periods. Finally, the local availability of replacement parts is considered to ensure guaranteed quality of local parts supplies if import of parts directly from the supplier is not possible or delayed. These assessments inform the vehicle owner whether the vehicle can be managed in a predictive maintenance system, or should be maintained on a regular servicing schedule that cannot predict parts replacement. A third option is to retire the vehicle, as it may be more costly to continue running the vehicle than to dispose of the asset.

2.2 Preventive maintenance to replace vehicle components before breakdowns occur

From ambulances to trucks carrying medical supplies, vehicles that are used in health care delivery must be reliable so that they are available when needed. If a vehicle in the health system breaks down, medicines may not reach a patient or a woman may die in childbirth on the side of the road. If one such instance occurs, a patient's faith in the health system may erode, which reduces the likelihood that he/she will seek health care the next time illness occurs.

However, many health-focused organisations may choose to operate vehicles in a manner that allows for reactive maintenance, or repairs, only when the vehicle breaks down. As a result, there may be significant downtime if parts or skilled technicians are scarce, resulting in productivity losses and poor health outcomes if the vehicle is directly involved in health care delivery. If the vehicle is broken down for a long period, this increases the likelihood that the vehicle will no longer be used, even if only a simple repair is necessary, as the engine remains idle and parts may be pilfered for other vehicles. Reactive maintenance also results in expensive repairs that may be unexpected, and unaffordable, making planning difficult.

Rather than repairing vehicles when they break down, Riders' vehicle management systems are built on preventive maintenance. For each vehicle or motorcycle under management, Riders has developed a servicing schedule based on manufacturer recommendations so that parts are replaced before they break. In this system, Riders aims for a "zero-breakdown standard," meaning that if the vehicle is used correctly it should not sustain breakdowns. The technician regularly examines the vehicle and monitors usage through log sheets provided by the vehicle user to inform the maintenance schedule. Preventive maintenance also allows Riders to maintain an appropriate supply chain of replacement parts for each vehicle according to the maintenance schedule. Whenever possible, Riders procures these parts directly from the supplier to guarantee the maintenance schedule is adhered to rather than relying on local parts with questionable quality. While this procurement process may take several months, a preventive maintenance system with regular monitoring of kilometres travelled allows Riders to create a reliable supply chain of high-quality parts. Preventive maintenance is most critical in rural areas of Africa where skilled technicians are rare.

2.3 Training of vehicle users in defensive driving and daily preventive maintenance

Riders' operational experience shows that the vehicle user is the single most important factor affecting how the vehicle performs over time. However, Riders encounters vehicle users across Africa with varying skill levels in operating vehicles, especially when they are health workers using a vehicle to carry out their responsibilities rather than a professional driver. Some vehicle users are not licensed and may be illegally operating the vehicle. Others may have had little training in basic driving or defensive driving to anticipate events on the road, and very few have been trained in basic maintenance to understand the vehicle's operation. These low skill levels may result in high accident rates, most importantly jeopardising the safety of the vehicle users but also the vehicle itself.

Riders believes that training vehicle users in defensive driving and daily preventive maintenance will keep the user safe and prolong the life of the vehicle. In a high-accident rate environment with difficult terrain such as in many African countries, defensive driving is critical to ensure vehicle users are acutely aware of other vehicles, pedestrians, and obstacles on the road. Moreover, Riders instructs vehicle users in the mechanics of how an engine works and basic maintenance techniques. During this training, Riders teaches vehicle users simple checklists for daily maintenance so that they can determine potential problems quickly and communicate these to Riders' team. These checklists are especially successful when vehicle users are assigned to specific vehicles, and as a result, take pride in maintaining that vehicle or conversely are held accountable. Riders' experience has shown that vehicle pools with unassigned drivers can result in reduced vehicle management quality.

To accomplish training in defensive driving and vehicle maintenance, Riders has opened an International Academy for Vehicle Management (IAVM) in Zimbabwe and Kenya. Thousands of vehicle users have now participated in two-week training courses for motorcycle riders and one-week training courses for vehicle drivers at these academies and also in field-based courses across Africa hosted by IAVM staff. Moreover, Riders' contracted vehicle management programmes include annual refresher training for each vehicle user to ensure skills continue to be developed. Riders believes that these courses have made the vehicle users better prepared to operate vehicles in hostile environments.

2.4 Outreach maintenance from vehicle maintenance units

In rural areas of Africa, skilled technicians and workshops may be rare or non-existent, and vehicles and motorcycles may have to travel long distances to reach dealerships or other workshops in urban areas for servicing. These long distances generate high costs in parts and fuel and significant downtime for the vehicle whereby the vehicle user is not able to deliver health care during those times. If travelling long distances is too costly, organisations may sacrifice quality by going to a local mechanic who may not be skilled or may not have genuine parts. The result is additional vehicle breakdowns, perpetuating a cycle of potentially high repair costs.

Recognising the costs and time required to call vehicles into a workshop, Riders has developed a hub-and-spoke model for outreach maintenance. In rural environments where it is difficult for vehicles to reach a central workshop, Riders' technicians meet the motorcycles or four-wheeled vehicles, when possible, to maintain them in the field where they are based. This addresses the challenges of reaching a central point, which can be time-intensive and cost-prohibitive. Therefore, according to a timetable determined by the number of kilometres travelled per vehicle or motorcycle, Riders' technician schedules a servicing at a pre-determined location. In some cases, this may be where the vehicle is based, or in other cases this is a central hub for all vehicles to meet from their separate routes, or spokes, but in all cases this is a more convenient location than an urban centre. The technician carries all tools and parts necessary for the servicing and completes the maintenance on-site. In some cases for vehicles, servicing may require bringing the vehicle to a workshop, such as for tyre rotation, but Riders tries to minimise these instances.

In a vehicle management programme that relies on preventive maintenance and outreach maintenance, significant workshop infrastructure is not required. Therefore, in each region where Riders operates, the team manages a vehicle maintenance unit (VMU) that serves as a base for programme operations. Each VMU has equipment necessary for the servicing schedule, but expensive infrastructure is usually not necessary unless there is a large fleet of motor vehicles. In cases where there might be an accident or large servicing is required, Riders has contracted with local workshops that may be able to provide more intensive servicing. As a result, operating an outreach maintenance schedule and VMUs keeps costs low and reduces time diverted from health care delivery.

2.5 Predictable budget planning tools

For health-focused organisations who have limited resources, accurate budgeting is important for long-term sustainability. Unexpected repairs may divert funding from fuel, decreasing availability of the vehicle, or from health care service delivery activities. In addition, organisations may not budget sufficiently for all aspects of transport, such as insurance, fuel, or vehicle replacement. Also, conventional transport budgets may provide an incentive for vehicle users to take unnecessary trips to use available budget allocations, generating additional costs and wear-and-tear on the vehicle. Finally, after many years of operation, vehicles can become more expensive to run than to dispose of the asset and procure a new vehicle. However, disposal is often considered as a last resort when replacement is not planned in advance.

Riders believes that good management of finance corresponds to good vehicle management. To address many common transport budget challenges, Riders developed a finance system called cost-per-kilometre (CPK) budgeting to assist partners. To compute the CPK, Riders calculates all costs over the lifetime of the vehicle, usually a contract period of three to five years, and divides that by the estimated number of kilometres travelled. The CPK incorporates all parts replacement and repairs, potential risk of accidents or breakdowns, and all other costs, producing a predictable budgeting tool. Each month when Riders' technician services the vehicle, an odometer reading is taken to inform the monthly invoice based on actual kilometres travelled. Multiplying the number of kilometres driven each month by the CPK, which includes all fixed and variable costs, produces a predictable vehicle management budget. In this model, Riders assumes the risks associated with a vehicle breakdown and thus the potential cost because in a preventive maintenance system the vehicle should not break down. Moreover, the CPK system provides an incentive for both Riders and the partner organisation to closely monitor the kilometres travelled each month. The partner wants to reduce all unnecessary vehicle usage, such as personal trips, which in turn reduces the overall cost, and Riders wants to make sure the kilometres travelled are precise for accurate payment. Finally, Riders can advise the partner on how to budget and plan for transport needs, enabling timely scheduled disposal of underperforming and expensive vehicles at the appropriate time.

Based on partner needs, Riders can incorporate options such as a vehicle replacement fund in the CPK, which divides the price of a new vehicle over the number of kilometres estimated in the contract, to contribute a small fraction to a replacement fund each time the vehicle travels. When the vehicle is nearing the end of its useful life, the organisation will have a fund available for vehicle replacement. Partners have reported that this tool has helped to overcome the challenge of needing a large capital allocation every few years and assisted with programme sustainability and planning.

Riders' predictable budgeting tools also provide a steady revenue stream to support programme operations. Similar to any service delivery organisation, Riders' contract costs can be separated into variable (e.g. fuel, replacement parts, some maintenance costs) and fixed (e.g. staffing and management, equipment and infrastructure) costs. Each earned contract covers all variable, per-vehicle costs and contributes an allocation to fixed costs. In each country programme, Riders calculates capacity of the staff and equipment to manage a certain number of vehicles and allocates a percentage of each contract to cover these fixed costs. In large-scale operations, it can be more challenging to maintain quality and will require closer monitoring of the programme to ensure adherence to Riders' model, but in small-scale operations it can also be difficult to cover all fixed costs. If programmes have not reached capacity, Riders may also offer vehicle maintenance services to non-contracted customers who in rare cases are not involved in health care delivery. If there is still a gap between costs and revenues, Riders' fundraising team may help meet the difference through donations or grant funding from private foundations such as the Bill and Melinda Gates Foundation or Skoll Foundation, especially in new countries where start-up capital may be required. However, the long-term goal for each country programme is that revenues generated from vehicle management contracts cover all costs of the programme and provide a contribution to the UK support centre as well.

3. IMPACT OF RIDERS' TRANSPORT MANAGEMENT INNOVATIONS

These five core principles form the foundation of Riders' programmes across seven African countries. Riders now manages over 1,300 four-wheeled vehicles and motorcycles in The Gambia, Kenya, Lesotho, Malawi, Nigeria, Zambia, and Zimbabwe. In these countries, Riders works with diverse stakeholders to provide an outsourcing solution for transport so that health-related organisations can focus on health care delivery rather than transport or logistics management. However, transport can play a critical role in facilitating health care delivery.

To measure the impact of transport on health care delivery, in 2009, Riders established a monitoring and evaluation (M&E) team for programme monitoring and to collect evidence showing efficiency increases. This paper examines two case studies demonstrating the impact of Riders' programmes and an external evaluation conducted by OC&C Strategy Consultants.

3.1 Case Study 1: Emergency referrals via ambulance in The Gambia

In 2009, Riders and the Gambian MoH entered into a fleet leasing agreement whereby Riders owns a fleet of vehicles that is leased to the MoH for health care delivery. Riders manages this fleet at a not-for-profit rate, resulting in a fully sustainable model that covers all in-country costs. Prior to this arrangement, the MoH stationed one ambulance at each health centre throughout the country that was used for emergency referrals and outreach clinics. Each ambulance had a limited monthly fuel allocation and was repaired by Riders on a reactive basis. In 2009, Riders entered into an agreement to lease a fleet of new vehicles to the MoH, whereby the MoH would pay for all costs, including bank finance charges, drivers' salaries, fuel, and all preventive maintenance, on a CPK basis. Under this agreement, Riders now manages 36 ambulances used by the Gambian MoH for emergency referrals and also outreach clinics.

Riders' M&E team conducted interviews with health centre staff following programme implementation and examined MoH data to determine impact of the programme. During this programme, no outreach clinics have been cancelled due to transport/fuel constraints. However, in 2008 prior to the agreement, 32% of outreach clinics were cancelled for this reason. Moreover, in one region of the country, the proportion of patient referrals via ambulance increased from 58.5% of total referrals in 2008 to 88.3% in 2011. Lack of fuel, patient inability to pay for fuel, and vehicle breakdown were reported as constraints of ambulance referrals in 2008 but not under the new programme.

3.2 Case Study 2: Mobilisation of outreach health workers on motorcycles in Lesotho

In 2008, Riders began a programme in Lesotho with support from the Elton John AIDS Foundation (EJAF) whereby Riders manages 90 motorcycles used by the Ministry of Health and Social Welfare (MoHSW) for outreach health care. Riders mobilised the MoHSW's outreach health workers on motorcycles to deliver health care to rural communities. Activities include health education, counselling and testing for HIV/AIDS and Tuberculosis, defaulter tracing and patient care. Riders was awarded grants from the Elton John AIDS Foundation for the initial motorcycle procurement and running costs and other donors for additional running costs, but the Lesotho MoHSW has since assumed all running costs of the programme.

Riders' M&E team conducted interviews with mobilised outreach health workers and collected weekly log sheets to determine impact of the mobilisation on their productivity. Outreach health workers can conduct over three times more health education meetings each week after being mobilised on Riders-managed motorcycles. Health workers are also able to do follow up visits to patients more frequently. Before Riders, only 18% of health workers reported being able to do fortnightly follow ups with patients, compared to 47% after Riders.

3.3 External evaluations of Riders' programmes

External evaluations of Riders' programmes are highly valued to ensure validation of the Riders model. In 2005, OC&C Strategy Consultants conducted an independent analysis of programme costs as they relate to productivity increases. These data show that health care delivery costs have decreased under Riders' managed-transport programmes. First, Zimbabwe has seen a 62% reduction in the annual costs for motorcycle fleet maintenance, relative to people reached with health care services. Similarly in The Gambia, there has been a 24% reduction in annual vehicle maintenance cost, relative to patients treated.

Furthermore, Riders is now collaborating with Stanford University on a large-scale study in Southern Province, Zambia to review the impact of Riders' programmes on transport management of the MoH fleet, cost-effectiveness, and health outcomes. Riders also continues to explore other partnerships with research institutions to validate and inform the Riders model.

4. FUTURE INNOVATIONS

While the innovations described in this paper form the core competencies of Riders' transport management programmes, the organisation continues to improve its vehicle management platform through various innovations. For example, Riders' team is currently testing the use of Global Positioning System (GPS) devices to assist with operational data collection in a number of countries. Riders is now reviewing how these data will be used by the operations and M&E teams to monitor the programme and will compare the cost of GPS monitoring compared with programme improvements. In addition, as transport infrastructure often requires significant upfront investment, Riders is examining creative financing arrangements with potential partners. For example, in The Gambia, Riders' agreement with the MoH is in partnership with the Skoll Foundation and the Guarantee Trust Bank, which enabled Riders to purchase a new fleet of vehicles and lease them back to the MoH using a non-profit service fee. Riders is now exploring additional loan arrangements to increase the size of the fleet in The Gambia. Finally, Riders continues to discuss with health-focused partners on transport needs and has developed new transport solutions to address rural access challenges. For example, Riders created a sample transport (ST) programme in Lesotho in 2009 in response to low access to laboratory-based services in rural areas. Previously, nurses or patients transported the samples themselves over long distances. Today, Riders' ST motorcycle couriers transport samples from rural health centres to laboratories for disease diagnosis and monitoring and return results to the health centres every week, resulting in increased number of patients receiving laboratory-based test results. Riders is also considering offering other services in conjunction with ST, such as “last mile” distribution of supplies to rural health facilities.

5. CONCLUSION

Riders believes that the future of rural transport in Africa should be based on evidence collected through experience. As described in this paper, Riders’ innovative solutions to common transport challenges are based on over 20 years of experience in operating and managing vehicles and motorcycles for health care delivery. While the five principles presented in this paper can be applied outside of the health sector, Riders focuses on the health sector because it is unique: in no other sector do vehicle breakdowns threaten people’s lives. In conjunction with infrastructure improvements, these tested vehicle management platforms will improve rural mobility and access for those most in need of health care.

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KEY WORDS

Transport management, rural transport, outreach, health care access, health systems

ACKNOWLEDGEMENTS

We would like to acknowledge Victoria Blundy, Emma Howard, and Astrid Jenkinson, all from Riders for Health, for their support in reviewing this paper and providing valuable comments.

2nd AFCAP PRACTITIONERS CONFERENCE 3rd to 5th July 2012

LEAPFROGGING FROM RURAL HUBS TO NEW MARKETS

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Abstract

Growth in demand for food globally is creating new markets for small scale farmers to sell high value agricultural products. However, Inefficiencies dominate the traditional rural freight transport operations in Sub-Saharan Africa (SSAfrica) thus inhibiting farmer's access to these markets. Using a case study approach, an in-depth analysis of six agriculture logistics chains in Kenya has been carried out. The objective is to examine how rural transport services are organised and how they can be improved. Results show that emerging markets create diversified opportunities for small scale farmers. In marketing of these products supply chains that cover both upstream processes and downstream transport logistics are necessary. In conclusion, for smallholder farmers to improve access to emerging agricultural markets, appropriate rural transport logistic structures are necessary.

ACKNOWLEDGEMENTS

Special thanks to AFCAP for funding this research. The authors acknowledge the role of KENDAT for their immense support and facilitation in conducting this research. We also appreciate IFRTD-ESA and TCP International key persons for their contributions. We appreciate greatly Sunripe, HCDA, Meru Greens and Mt. Kenya Gardens companies for allowing us to study their logistics chains that gave us great insights on high value agricultural value chains and transport logistics. Lastly we thank the rural small scale farmers in the study areas for their time and information.

1 INTRODUCTION

This paper is based on an ongoing AFCAP funded project known as "Rural Logistics for Smallholder Farmers to Meet New Agricultural Market Demands". This is a 16.5 month project being implemented in Kenya from February 2012 to May 2013. The project is currently in its 4th month of implementation. Progress to date includes extensive stakeholder consultations, review of literature relevant to agricultural value chains in Kenya, identification of the value chains to be studied and initial field visits and discussions with key informants involved in the selected value chains. The issues and perspectives presented in this paper are therefore work in progress, based on background work done to date, including the key ideas underpinning the project. Detailed field surveys are currently underway. We expect that detailed case studies, underpinned by quantitative and qualitative data will begin to take shape in the first quarter of 2013

2.0 CONTEXT OF THE PROJECT

According to the World Development Report [2008], new markets for high value agricultural produce – driven by urbanisation, rising incomes, liberalised trade, advanced logistics systems and use of Information communication technologies (ICTs) - have proliferated in many Developing Countries. These represent a considerable share of marketed value. In Kenya, the rapid urbanisation creates an increased demand for fresh, high quality, agricultural products. Additionally, increased access to international markets has opened new income opportunities for farmers, rural food processing industries and transport companies.

These new markets represent a good opportunity for rural smallholders to increase incomes from agricultural production and thus escape the poverty trap. For example in Kenya, three quarters of the fruit and vegetable export production is coming from smallholders.. Participation in modern supply chains can increase farmer income by 10% to 100% as examples from Guatemala, Indonesia and Kenya show (WDR 2008, p.127).

The smallholder farmer is, however, increasingly being asked to compete in markets that demand much more in terms of quality and food safety which have significant cost implications. As small farms attempt to diversify into higher-value products, they must increasingly meet the requirements of these demanding markets, both at home and overseas. Rural transport logistics provide a major challenge for small scale farmers to deliver produce to the market efficiently, cost effectively, while maintaining quality and standards. To optimise benefits from these emerging markets, there is need to improve the structure, and organisation of rural transport services, with a focus on optimal multi-modal solutions at every stage of the transport/marketing chain.

Currently, the spatial dispersal of small scale rural farms and the accompanying poor transport access is a major barrier to the efficient integration of rural farmers into the emerging value chains. A precondition for marketing of high-value products is transport efficiency and proper management of various activities within the supply chains. This includes local transport services for load consolidation, handling, packaging and outward transport to final markets. The new markets demand high quality, timely deliveries and innovative upstream and downstream practices.

This paper focuses on logistic chains for high value products in Kenya with the main goal being to improve marketing access and incomes of smallholder farmers. The paper first gives an overview of state of the art marketing of high value agricultural produce and agricultural value chains in SSAfrica. It then describes the methodological approach applied to study rural logistics chains in the selected study chains in Central Kenya. The results describe typical logistics chains observed, their production and marketing conditions, the prospects and constraints of high value products in Kenya. The paper concludes by giving recommendations on possible ways to improve rural transport logistics for smallholder farmers.

2 Agricultural Transport in SSAfrica

The spatial dispersal of small scale rural farms and the accompanying poor transport access is a major barrier to the efficient integration of rural farmers into the emerging value chains. Rural roads may generate strong impacts on agricultural production and marketing and thus contribute to poverty alleviation.

Early research by Barwell (1996) and Sieber (1996) revealed that rural households in SSAfrica transport between 6.6 and 12 tonne-kilometres (tkm) to evacuate and market their crops. This is mostly done by headloading, which implies enormous time requirements especially during harvesting seasons, where household labour is in short supply. A study that was carried out by Sieber (2009) revealed that transporting one tkm by headloading in SSAfrica, approximately 100km have to be walked that can consume about four days labour.

In SSAfrica, transport services are generally provided by individuals operating within the informal sector and the operations appear to have a low profitability. Surveys conducted by Starkey et al (2007) did not identify any transport entrepreneurs who were investing significantly to build up large fleets of transport vehicles operating in rural areas.

Even though the rural transport market is rather unregulated and market access is mostly virtually free (Londoño-Kent 2007, p14), the frequencies of the services in rural areas are rather low and service quality is often unsatisfactory. Where roads are in a bad condition and population densities low, the market generates too little returns to give incentives for the transport industry. As a consequence, all inputs of the vehicle owners are kept to a minimum, including fuel, repairs and replacements and most operators feel they have to cover their costs on each and every journey. This need to cover all costs prevents operators from keeping to fixed timetables and exacerbates the vicious circle of low transport demand and unreliable transport market (Starkey 2007 p.100ff). The poor condition of rural transport infrastructure hampers all year access to markets and causes excessive vehicle operation costs.

3 New opportunities for smallholder farmers in SSAfrica

In the past decade new markets for high value produce have proliferated in many Developing Countries, which are changing the demand for agricultural produce and thus transport. High value products are demanded by exporters and increasingly by domestic supermarkets in developing cities. This is stimulated by an increasing demand for high-value primary and processed products, driven by rising incomes, faster urbanization, liberalized trade, foreign investment, and advancing technology. Flowers from Kenya, cherry tomatoes from Senegal, green beans from Niger, organic cucumbers from China are offered more and more in supermarkets of industrialised countries.

However, smallholders' farmers are disadvantaged, since they typically face high transaction costs and low bargaining power in factor and product markets. Vorley (2001) describes the proliferation of buyer driven Supply Chains as detrimental to smallholder farmers. Reardon

(2007, p. 2846) argues that in the processing sector, supermarkets tend to source as much as possible from medium and larger growers. Thus, it is not the poorest or smallest farmers that produce fruits and vegetables for supermarkets, rather it tends to be the social upper tier. However, governments can improve smallholders' access to modern Supply Chains through the strengthening of producers'-, marketing-, and traders' associations and cooperatives.

4 Requirements for modern logistics chain in emerging market

The emerging agricultural markets for high value products impose requirements on marketing, procurement processes, quality control, warehousing, packaging, Logistic Chains as well a number of other requirements such as transport through modern logistic chains and compliance with international food standards. For these products modern Supply Chains are necessary to cover upstream processes, such as the provision of inputs, as well as downstream transport logistics from the producer to the final consumer. Thus, they call for high quality transport services that require major investments in facilities, transport equipment and management capacities. Consequently, the new markets require a number of innovations with respect to marketing organisation and infrastructures, which have their specific demands for logistic transport services.

A precondition for marketing of high-value products is transport efficiency and proper management of various activities within the supply chains. This includes local transport services for load consolidation, handling, packaging and outward transport to final markets. The new markets demand high quality, timely deliveries and innovative upstream and downstream practices. Stakeholders in rural transport services have responded to the new demand in different ways, often led by brokers chasing quick money to serve dispersed markets under logistical operations that break-up quickly, leaving produce going to waste, and farmers disappointed.

In order to satisfy the demand from customers and adhere to the high Quality Standards demanded by emerging markets, the produce have to undergo a number of processes, such as pre-cooling, pack line operations, ripening, de-greening or labelling. A well-equipped and hygienically maintained infrastructural base is a pivotal support element of the chain. The technological level must be appropriate to the needs of the target market and the length and complexity of the chain. For simple chains, such as where the producer is within hours of the market, a simple infrastructural base consisting of packing and well ventilated transportation facilities is adequate. For longer, more complex chains, packing houses, cooling systems and logistics infrastructure, such as refrigerated transportation, storage/warehousing and containerisation, supported by appropriate logistical operations are required. A large number of detailed and practical instructions on Supply Chain Management for horticultural production are given in Korsten (2008).

5 Transport requirements of modern Logistic Chains

Modern Supply Chain transport requirements are much higher than those presently provided by exisitng rural transport services. The main requirement for transport is to complement an almost frictionless logistical interface between the producer, the processing unit, the warehouse and the market. This requires high reliability of transport services providing an on-time delivery.

Distance and time to market are critical considerations in Supply Chain management, given that fresh produce progressively deteriorates with increasing time between harvest and consumption. Fresh produce must be properly protected during transportation in order to minimise mechanical damage, temperature abuse, taint and contamination by food-borne pathogens. It is the responsibility of the transport provider to ensure that the transport vehicle is well maintained and is in a hygienic condition (Korsten 2008, p. 153).

The high requirements on transport logistics call for professional management with experience and know-how. Thus, in modern Supply Chains, a tendency of outsourcing to specialised transport firms can be observed. Pedersen (2001, p. 97) observes in Africa “a new integration between the logistic and production chains, based on strategic alliances and long run contracts instead of ownership”. This is accompanied by outsourcing transport to professional logistics companies and an increasing vertical integration between the modes in the logistic chain.

Modern transport services require an integrated regional planning approach (Rwelamira 2003), which encompasses disciplines such as agriculture, logistics, manufacturing, transport, business development and ICT applications. At the regional level, conventional and modern transport chains may be planned using the approach of basic access provided by multimodal transport, embedded in the concept of central locations and combined with modern communication infrastructures (Sieber 2009).

Central locations may form a system of rural development nodes that serve as hubs for trans-shipment. For the first mile, goods can be transported by IMT using low cost tracks and roads. At rural hubs, cargoes can be trans-shipped onto motorized goods vehicles, from where they can use well maintained rural roads. The rural hubs are placed in central locations that function as buying points or local markets and provide communication and agricultural extension services for rural producers. In these rural hubs, facilities for modern supply chains may be provided, such as cooling, refrigeration, processing, and packaging and ICT solutions for management of the logistics chains. Superior centres may provide additional transport hiring or brokering services. For regional planning an interdisciplinary approach and the involvement of stakeholders, especially the private sector is required.

6 METHODOLOGY

A case study method is being employed to study logistics chains in Kenya. Six regions have been chosen for in-depth analysis. Prior to field work, secondary source of data has been analysed to document data on value chains which has formed a key resource into the preliminary study outputs.

Primary data is being collected through structured and unstructured interviews and field visits interviews from both small scale/large scale farmers. Three different types of field surveys are being conducted; "*Farm surveys"* which will target 10% of the farmers in each chain. Within this, farmers' selection will be based on clustered sampling to ensure representative geographical distribution of farms per value chain. Secondly "*Collection Point /Processing Point Survey'*; interviews will be conducted in all the product's collection points, cool houses and packaging units that serve the chains. Finally, *transport Survey;* a survey of transport costs will be conducted on the farmers (if they are the ones transporting their own produce), the marketers who have their own transport and transport service providers. In addition, key Informants interviews will be conducted for major players in the horticultural industry to get and in-depth insight. In addition a kick off workshop conducted yielded extremely useful information for this study.

6.1 Creating a Geo-Marketing database for rural logistics value chains

Geographic Information System (GIS) will be used in spatial mapping and geo-visualization of various components of the logistics chains during fieldwork. Individual farms, collection sheds and collection points (CP) will first be geo-coded and mapped as point data using GPS. In addition, road networks from farm through collection points to the destination markets will be mapped as line data. Existing paper maps will be digitized and integrated with the collected data. ArcGIS software will then be used to create a geo- referenced digital database where spatial analysis and visualization of logistics chains will be carried out. This database can be used to develop a pilot rural "geo-marketing tool" that integrate GIS and Mobile phone's Short Messaging Service (SMS) that can improve rural transport logistics planning and management but also link farmers in real-time directly to the world markets.

7 DISCUSION OF THE RESULTS

7.1 Main types of Logistic Chains in Kenya

This study has identified five generic logistics systems that exist in Kenya. By logistics systems, we refer mainly to mechanisms for produce consolidation, transportation and systems for ensuring retention of quality during transportation. Figure 1 shows the general concept of logistic chains observed in Kenya. Starting point is the farm, either small or large scale. The farmer may sell some of the low quality products locally or feed them to his animals. The better quality is delivered to the local collection point. If the farmer transports his products on his own, usually non-motorized means of transport are used. Another option is the transport by a trader, who collects the harvests by small truck or pickup. At the collection point the products are graded and either sold locally or transported to a processing plant, where they are graded, packed, labeled, etc. This part of the chain is usually by light goods vehicles or larger trucks with a cooling device. From this last point, the products are either sold on the national market to be delivered to the supermarket or exported by airplane.

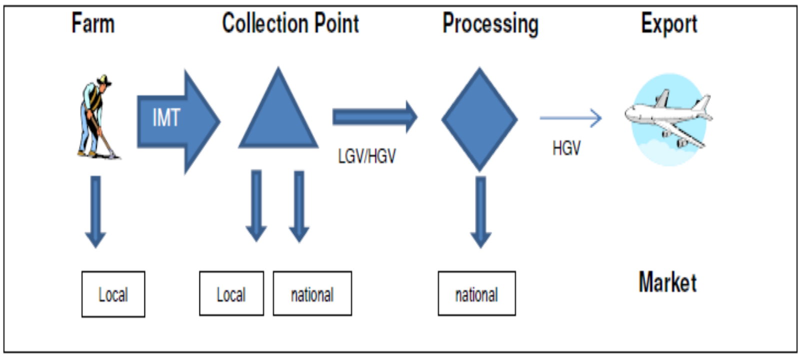

Figure 1: General concept of logistic chains

7.1.1 Four-stage logistics system.

This chain consists of Small Farms [SF] which are linked or contracted by a specific marketer. Products are sold on the national (Super) market or exported as illustrated in Figure 2. This system was observed for the marketing of French Beans by Meru Greens. The farmers transport products from their farms to a primary collection shed. Typically, this 1st mile transport uses Intermediate Means of Transport [IMTs] on a short distance. From the primary shed the marketer uses Light Goods Vehicles [LGV] to transport produce to an intermediate cooling house [typically owned by them] before transporting the produce to larger cooler houses in Nairobi for local or export markets. The latter stage of transport uses Heavy Good Vehicles [HGV] that typically have cooling facilities.

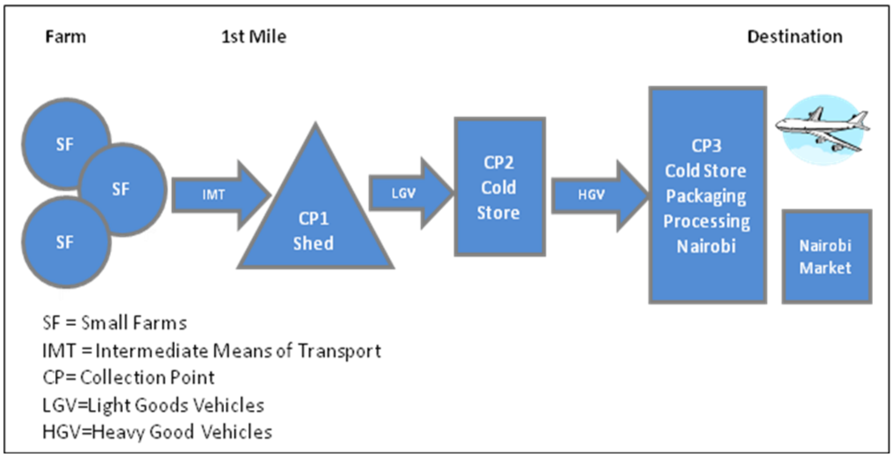

Figure 2: Four stage transport chain [e.g. French Beans]

7.1.2 Three stage logistics chain.

This is a slight variation of the four-stage logistics chain. It has only one collection point before the produce is taken to final markets. A typical example for this study has been identified as Mt. Kenya Gardens. The company specializes in pawpaw, banana, mango and citrus fruits. The fruits are picked by LGVs traveling from one Small Farmer to another and assembled at a ripening/de-greening at the company's central collection point before delivery to Nairobi for processing/canning either for local niche or export markets. An example of above logistic system is illustrated in the Figure 3 and with key logistical and transport issues within the chain described in details in section 5 of this paper.

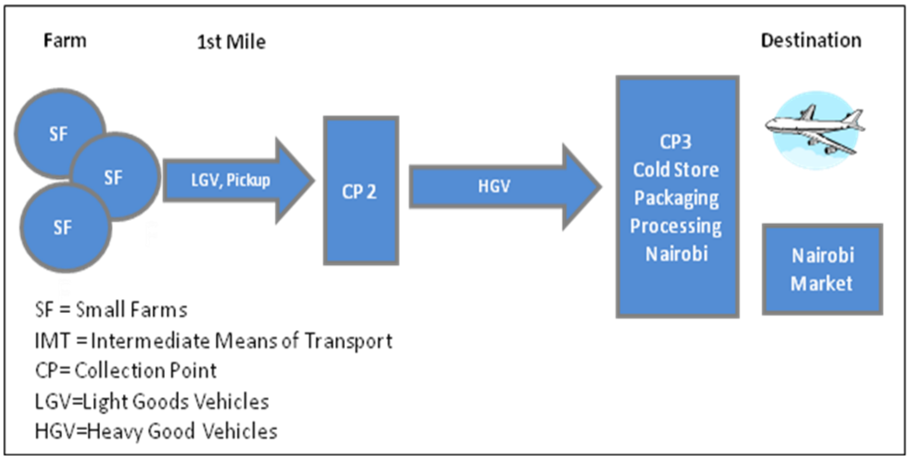

Figure 3: Three-stage transport chain

7.1.3 Capital intensive, large scale integrated production and logistics chain

This chain consists of a centrally owned, large scale production and logistics chain (Figure 4). Production, storage and transport are capital intensive, centrally owned and managed. Several chains of this nature exist in Kenya, some foreign owned, some owned by Kenyans. A good number of them are concentrated in the Rift Valley and Central Highlands of Kenya. A typical example selected for this study is SUNRIPE Company that specializes in a variety of high value horticultural products. They own large farms from which they transport using their own refrigerated Heavy Goods Vehicles to centralized cold rooms in Nairobi for export markets.

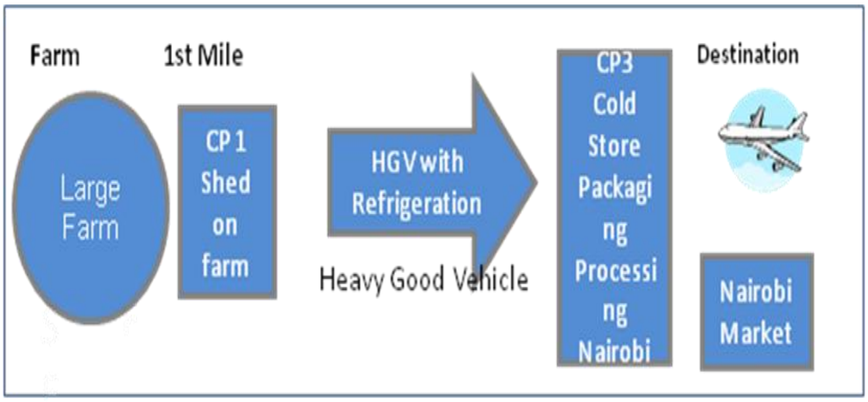

Figure 4: Large farm owned by SUNRIPE, refrigerated logistic chain

SUNRIPE is a large farm located about 15 kilometers from Naivasha area on the Nakuru-Nairobi highway. The farm owns a number of refrigerated trucks of various capacities that transport the produce daily to Nairobi. Transport trucks are organized and managed centrally from the Nairobi office. The vehicles are refrigerated with a capacity of 6 tones.

The company owns 300 ha of land in Naivasha where a wide variety of horticultural crops and products are grown. These include Snow Peas and Sugar Snaps (20%), French Beans (20%), Runner Beans (15%), Baby Corn (10%), Garden Peas (15%) and Tender-Stem Broccoli (15%). While these products are mainly for export to Europe, Asia, Middle East and South Africa, they also serve local markets. The access to the SUNRIPE farms is generally good because they are located close to a tarmac major highway. The compound comprises grading and packaging facilities on the farm where casual workers harvest various products on the farm, sort them and package them on trucks which offer same day delivery. The company experiences some problem with regards to fuel prices, access to cooling facilities, and general planning under unpredictable conditions etc.

7.1.4 Small to medium scale logistics chains for small exporter

In Kenya, new marketers are presently trying to gain a share of the export market. There are numerous small and medium scale logistics chains that are presently emerging, geared to entering the export market. Their modest levels of capitalisation mean that they rely on Small Farmers as the source of their produce. Typically, they do not have contracts with Small Farmers, relying mainly on use of mobile phones to organise IMT based produce consolidation at various points. Their main investment is in semi cooled or cooled Heavy Goods Vehicles. They rely on shared cold rooms – typically provided by Horticultural Crops Development Authority (HCDA) – at central locations in production zones and also at the airports (Figure 5). More detailed information will be gathered during this study.

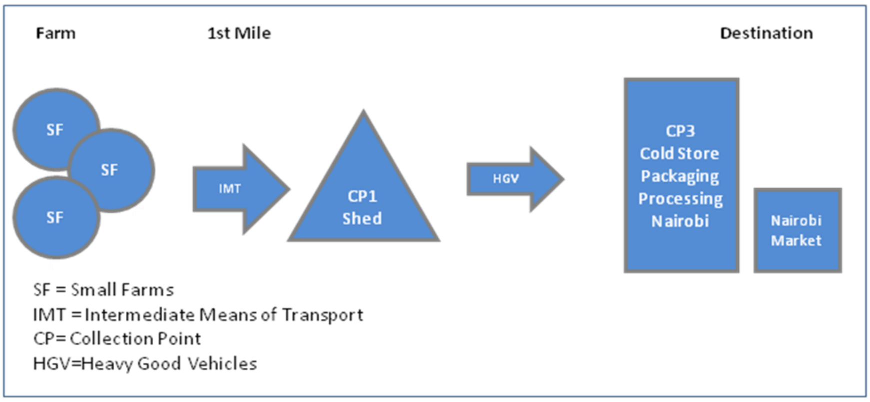

Figure 5: Assumed features of Logistics Chains for upcoming exporters

7.1.5 Collective marketing by small holders for local markets

There is increasing demand for key food products across the country. The government and development agencies are providing resources to facilitate commercialization of smallholder agriculture across traditional and nontraditional food crops. Apart from injecting a commercial culture into traditional farming, other challenges that need to be addressed are ensuring fragmented small holders achieve collective production volumes that would enable transport and marketing efficiency.

An example of this approach is being implemented by FARMCONCERN, an international NGO that has a programme for supporting development of Commercial Village Models [CVM] in Kenya. This model aims to ensure that villages graduate from a preoccupation with food security and into value addition hubs. Their approach is to organize small holders in a village into a confederation of producers, who work towards consolidation of their produce in order to achieve joint economies of scale for marketing. In a typical model, individual farmers use IMTs to bulk their produce at the village collection center. From a transport point of view, it then becomes easier for buyers to collect the produce from a central location. Mobile phones are an important tool for organizing this system. Figure 6 below illustrates the logistics systems for a typical product – potatoes – under the system.

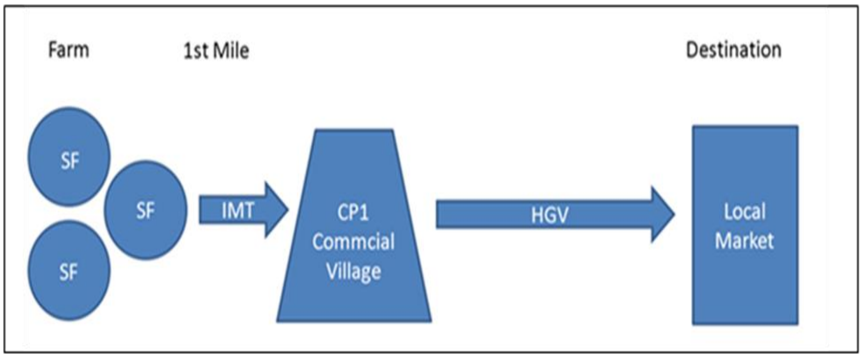

Figure 6: Logistic Chain of a Cooperative (FARMCONCERN)

7.2 a case example of Meru Greens and Mt. Kenya Gardens companies' logistics chains in Meru, Kenya

As described and illustrated above, this study identified Meru Greens company (Figure 2) that provides a good example of "four-stage logistics systems" and Mt. Kenya Gardens company (Figure 3) that offers a good case example of a "Three stage logistics chain". Both companies organize growth of produce among small holder farmers. Mount Kenya Gardens handles fruits while Meru greens handle French beans. They both market for local processing and canning for export but they also have local niche market targets at super-market level where they sell fruit (pawpaw, banana, mango, citrus and others).

For the "first mile" all modes of IMT are used to transport the product from the farm to the collection points. The commonly used means of transport are one tonne or three tonne trucks that collect the produce from the farms. Fruits are collected by trucks traveling from one farm to another and assembled at the first collection point before delivery to Nairobi.

Value addition is a key component which these companies capitalize on in order for their products to meet the standards set for high value export products. This is carried out in all the stages of the value chain starting from farm harvesting to final packaging. Pre-processing through sorting and preliminary grading is done while harvesting. To improve assurance of product's quality throughout the entire value chain, farmers are mandated and trained on how to carry out preliminary grading and sorting at the farms. At the collection points sorting is further carried out to eliminate defects and those spoiled during transport within the first mile. Further processing and packaging is done at Nairobi before the products are sold to national markets and exported. Some of the waste products at this stage are sold to farmers as animal feeds at the Nairobi hub

To ensure high quality standards, minimize the postharvest period and ensure longevity of those fruits that have very short lifespan, both Meru Greens and Mt. Kenya Gardens own and operate a ripening/de-greening plant at the intermediate collection points. They use appropriate technology consisting of improvised charcoal coolers that use cold charcoal pallets which have rechargeable coolers. They have a storage capacity of around one tonne of products. By using alternative energy instead of expensive power sources, the charcoal coolers help the company to save considerable refrigeration costs. Another innovative mode observed is to the products from the collection points at night when the temperatures are very lower hence reducing the cost of using refrigerated vehicle.

A major challenge these companies face within the first mile are the poor state of rural roads especially during the rainy season. It not only becomes very expensive to transport the produce on such roads but also increases vehicle operation and maintenance costs. The company use small capacity 4-wheel drive pickups during the rainy seasons which have to make additional farm trips thereby increasing costs. They also contract the services of brokers to transport produce to the collection point and paid commissions per kg delivered multiplied by the number of trips made to the collection points.

8 CONCLUSION

We expect the results of this study to be available for wide dissemination in the 1st quarter of 2013. However, the scope and scale of this study is small and exploratory. We foresee this study as providing an important platform for further detailed studies on the development of agricultural value chains as one of the major channels through which poverty reduction is happening. We would like to underscore the need for support to build on this initial work in order to develop our understanding of the interaction between road infrastructure, availability of appropriate transport services, spatial planning, and use of emerging information technologies as management tools for a rural logistics system.

Additionally, initial findings of this research open up an interesting research area in geo-marketing that if support is provided can be explored. Geo-Marketing is a new discipline within Marketing-Analysis that can be explored. Using Information communication technology (ICT) and GIS database that will be created; It is possible to develop a *“geo-marketing tool”* that can be used in rural logistic planning and marketing. The tool integrates GIS’ geo-positioning technology and Mobile phone’s Short Messaging Services (SMS) where farmers can send a coded SMS to the buyers and transporters. The SMS code contain the type of produce, quantity farmer has harvested, spatial location of farm and the condition of the route to that farm. The buyers/transporter will then be able to know in advance the quantity of produce to collect in the farms, the shortest route to follow and the capacity of vehicle to use. Future scenario is to map/visualize these SMS codes in the Google earth web page in real time to link farmers directly to the world markets.

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10 KEY WORDS

LOGISTICS VALUE CHAIN; RURAL TRANSPORT; SMALLHOLDER FARMERS; GEO-MARKETING, GEOGRAPHIC INFORMATION SYSTEMS

BICYCLES: AN ANSWER TO MOBILITY NEEDS OF RURAL CHILDREN?

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Abstract

Many Sub Saharan African countries still have dire transport needs. Children in particular are faced with mobility constraints in their quest to access, education, health and recreation. This study investigated the ownership and use of bicycles among children in Rural Ghana. The study was conducted in six rural communities within two ecological zones (forest and coastal). Both qualitative and quantitative data collections were employed within the context of a cross-sectional study design. A sample size of 454 was chosen among children aged between 8 and 18. Individual and households were used as unit of analysis where appropriate. Results from this study revealed that 36.4% of the households owned bicycles whilst usage was significantly higher at 63.9%.

1. Introduction

Severe mobility constraints still persist in many Sub Saharan African countries, especially in remote rural areas. Continuous neglect of rural transportation by successive governments and local authorities has led to serious transportation deficiencies in rural communities. Mobility of the rural dweller is constrained by poor roads, inadequate transport services and poverty. The situation is even worse for women and children who are often obliged by culture and society to perform duties that are transport related.

Access to education and educational resources is imperative for all children regardless of location. However children living in rural areas where schools and educational resources are few and sparsely distributed are faced with the challenge of access to education. Studies in some Sub Saharan African countries have shown that children walk long distances to attend school (Amoako-Sakyi and Owusu, 2011, Porter et al, 2010 and Starkey 2007). For instance 98% of children in some rural Ghanaian villages walk between 0.2 to 8 km to attend school as similarly reported by Starkey (2007), children in Boucle du Mohan, a rural settlement in Burkina Faso walk to primary schools and even though they preferred the use of bicycles they were generally not affordable for use by children. In spite of its potential, bicycles have not been exploited to address the problem of access to education and educational resources in rural communities.

Bulterys (2007) suggests that African nations have failed to accept bicycles as an effective mode of transport, a stance he believes could be blamed on development planners and policy makers' narrow-minded development approach. In Ghana, most children use bicycles mainly for recreational activities and sometimes for running errands for parents (Amoako-Sakyi and Owusu, 2011). This notion reiterates Work and Malone (1983) assertion of a bicycle prejudice in Africa which has inadvertently led to the notion that bicycles are mere toys or recreational device

Several factors may influence the utilitarian use of bicycles in rural communities. However, the issue of access to education in these communities is better understood in the context of child mobility, bicycle usage and cycling behaviour. This study therefore sort to investigate bicycle use and cycling behaviour among children in six rural communities in Ghana.

The paper draws data from a larger project on child mobility designed and led by Durham University in collaboration with the University of Cape Coast, Malawi and the CSIR, South Africa (Amoako-Sakyi and Owusu, 2011). It used both quantitative and qualitative data collection and analysis within the context of a mixed-method study design.

This study involved the administration of questionnaires to 458 children aged between 8 and 18 with 51.1% of them females and 48.9% males from six rural communities. These communities were Ebukrom, Antem, Baamu, Teinso, Kudjo Krobo and Kweku Mensah. Additionally 64 In-Dept Interviews (IDIs) and 4 Focus Group Discussions (FGDs) were conducted in each of the communities except Kudjo Krobo and Kweku Mensah which were considered only for the quantitative surveys. Table 1 shows the breakdown of the IDIs in the various study communities. The FGD's were conducted among children and the groupings were based on the sex and school enrolment status of the children.

Table 1: In-Dept Interview in various communities

Community	Children		Parents	Drivers	Teachers	Health personnel	Opinion leaders	Total
	In-school	Out of school						
Ebukrom	16	16	16	4	4	4	4	64
Antem	16	16	16	4	4	4	4	64
Baamu	16	16	16	4	4	4	4	64
Teinso	16	16	16	4	4	4	4	64
Total	64	64	64	16	16	16	16	256

Source: Child mobility data (2007)

Quantitative data was analysed with Statistical Package for Social Sciences (SPSS) and is presented in tables, graphs and charts while narratives from participants in FGDs and IDIs are directly quoted to supplement the quantitative analysis.

2.0 Results

The paper will present and discuss some of the results of this study. The authors will then share some perspectives on the possibility of harnessing the potential of bicycles in addressing the problem of accessibility to education and educational resources.

2.1 General characteristics of study participants

Of the 458 children who participated in the quantitative survey, 51.1% were females whilst 48.9% were males. 88.4% were in school and 11.6 % out of school. Distribution of the survey population across the 6 rural settlements was as follows: Ebukrom (28.6%), Antem (19.4%), Kujo Krobo (1.5%), Kweku Mensah (5.2%), Tainso (27.3%) and Baamu (17.9%). The distribution of the qualitative interview schedules is presented in Table 1.

2.2 Bicycle ownership and usage.

Results from the study showed that 27.6 % of households owned bicycles in good order, 9% owned bicycles which were not in working order and 63.4 % of households did not own any bicycles. Although consistent with studies that have shown low bicycle ownership in Africa, our finding that functional bicycle ownership is less than 30% in communities with severe transport deficiencies is worrying. This study neither captures the number of bicycles per household nor ownership at the individual level. Thus, we consider the bicycle ownership statistic presented in this paper as very conservative estimate. Ownership among various study communities is presented in figure 1.

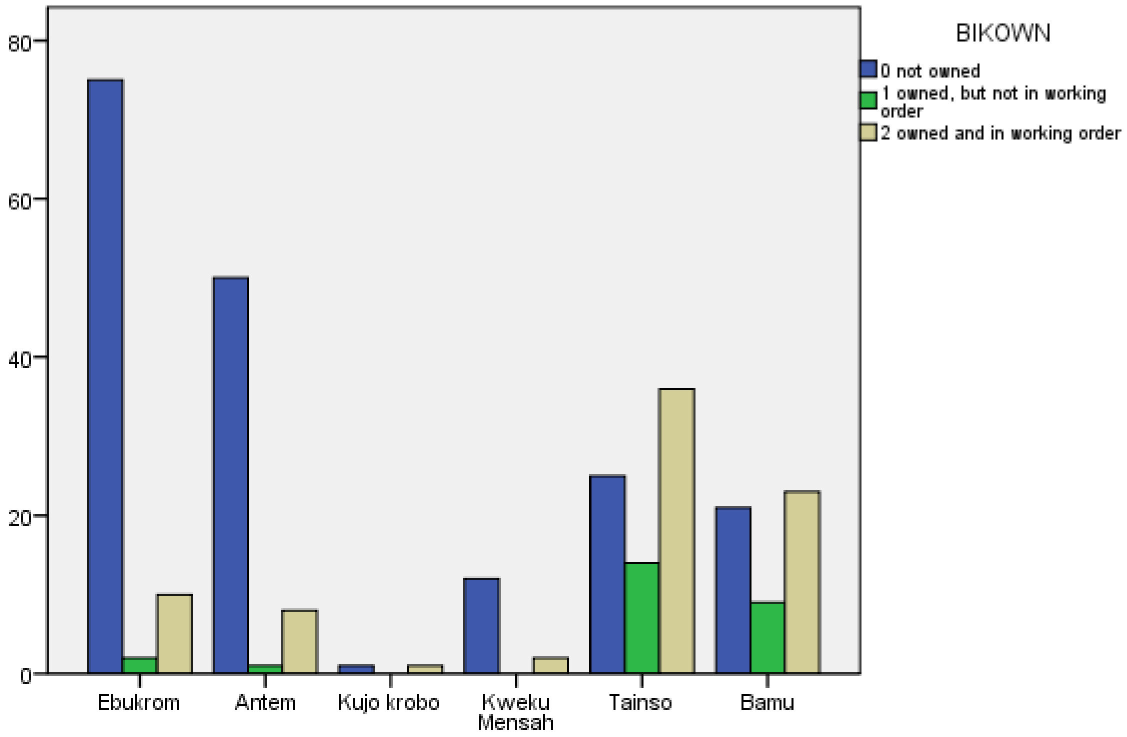

Figure 1: Bicycle ownership among households in study communities

Source: Child mobility data (2007)

Interpreting bicycle ownership data alongside bicycle usage gives a truer picture than looking at them individually. Thus, we compare bicycle usage data with bicycle ownership and found usage to be higher than ownership. Generally 63.9% of all children use bicycles periodically. Periodic use ranged from everyday- use to less than once a week. The usage – ownership deficit is partly explained by the presence of bicycle hiring services. Another explanation to this is the culture of bicycle sharing among family and friends.

We do not have one but we are one and united here so if anybody needs a bicycle to travel on long distances, you can easily get one by requesting from a neighbour who has one.-(Nantilla, FGD- out of school, Tainso)

This study evidently shows that children actually did not own bicycle themselves. Thus, they often used oversized bicycles belonging to older people. This obviously affected the user experience and also limited the utilitarian use of bicycles by children. Imperatively, some children had not learned to ride because available bicycles oversized them.

2.2.1 Age, sex and bicycle use

The study revealed that age was associated with bicycle use. Older children were more likely to have used a bicycle at least once a week than their younger counterparts. Only 10.5% of daily users of bicycles were between 8 and 11 years. The low usage of bicycle within this age bracket can be attributed to the non availability of bicycles suitable for use by younger children. The study also revealed that children learned to ride under various conditions and circumstances including threats, coercion and often under the tutelage of abusive instructors.

Table 2: Sex of selected child on ownership of bicycles in household

Ownership of bicycle by household	Sex of selected child		Total
	Male	Female	
Not owned	115	69	184
Owned but not in good working order	19	6	25
Owned in good working order	42	38	80
Total	176	113	289

Source: Child mobility data (2007)

Tables 2 and 3 shows that sex of children was not a significant determinant of bicycle ownership among households. On the other hand gender was important in shaping bicycle use among children: while 81% of boys used bicycles (7.2% on a daily basis), only 48.3 % of girls used bicycles (1.3% on a daily basis).

Table 3: Distribution of sex of children among households with bicycles in working order

Number of children in the household (excluding sampled child)	0		1		2		3		4		5	
Sex	M	F	M	F	M	F	M	F	M	F	M	F
Number of households who own bicycles	17	15	28	38	22	16	8	8	5	2	0	1

Source: Child mobility data (2007)

Although parents generally approved of their children's use of bicycles, most were sceptical of the effects of bicycle use on their female wards. The perceived physical vulnerability of girls, particularly in relation to reproductive health, often underpinned disapproval of girls riding bicycles. Gender and bicycle use is very complex and intricate. Although authors of this paper are cognisant of its importance it is not the focus of this paper.

3.0 Present but not available?

Daily use of bicycles was low in all communities studied. The highest daily use (4.8%) was recorded in Baamu. No child used a bicycle on a daily basis in Kujo Krobo and Kweku Mensah. Averagely, only 4.2% of children get to ride bicycles on daily basis in the whole study area. Even among households that owned bicycles, the bicycles were not always available for use by children. This is because most parents use it to transport themselves to farms while their children are left to trek long distances to school. This perhaps explains the low utilitarian use of bicycles in the study community. As reiterated by 17 year old Yaa, children in Tainso usually have access to free bicycles on Wednesdays and Sundays. Yaa tells the story of how she gets access to free bicycles especially on Wednesdays:

> *"....usually I get to ride bicycles on Wednesdays and Sundays. On Sundays people do not take their bikes to the farm so it is easy to get some to ride usually on Wednesdays which are market days people come to park their bikes in my house and go to sell their things at Sunyani. So when they come to park their bikes I ride some" - Yaa, 17 year old Tainso.*

To contextualise Yaa's narrative, Sunyani, which is the regional capital, has Wednesday as its market days and Tainso which is a relatively large community becomes the conduit for farmers to transport their wares to Sunyani. Usually these farmers from neighbouring villages come on their bicycles but park them in order to board vehicles travelling from Tainso to Sunyani. This becomes an opportunity for young people such as Yaa whose family do not own a bicycle to use bicycles whilst their owners are away to sell off their farm produce.

Available data from the study also suggests that majority of the bicycles are big and only suited for adults use. Adults within the communities typically purchase bicycles to address the mobility need of commuting to their farms and back. Another respondent in an FGD organised for out of school girls Linda, reiterates this point

> *My brother has one but it is not always available for use because my brother uses it when he is going to the farm. However, my uncle also has one and I use it. – FGD participant, Tainso.*

This invariable determines the age at which a child can begin to learn to ride bicycles. Thus, the 11.1% of children who could not ride attributed their inability to ride on the unavailability of suitably bicycles. Plate 1 shows a picture of a child and bicycle available in her household.

Plate 1: Adult sized bicycle in an African country (Courtesy Daniel Amoako-Sakyi)

4.0 Parental concerns

Parental approval or disapproval goes a long way in influencing bicycle behaviour as the study revealed that most parents supported their children's quest to learn to and subsequently ride. The motivation for parents who encouraged their children to ride comes partly from the fact the ability of the child to ride helps the child to overcome obvious mobility challenges faced in rural areas. Children who know how to ride are able run errands for their parents faster and cheaper, as illustrated by Ernest a 32 year old father of two:

> *None of my children know how to ride the bicycle. I have however decided that since I have a bicycle I will start teaching them to learn to ride whenever I get the time. Because this is a village and the transport here is not regular. On market days one can get a car more easily as compared to the other days because more cars come here to load foodstuffs as compared to days that are not market days when the cars are few here. If they know how to ride and they need to move they will not need to go and look for transport before they can move. Also since the communities here are not very far from each other, if they know how to ride I can send them with the bike to go and run errands for me and it is faster than when they walk and also cheaper than when they pick cars- Ernest, Ebukrom.*

Though supportive of their children's quest to ride, most parents expressed major concerns over their safety mainly because they share roads with motorised vehicles. Drivers of motorised vehicles in Ghana sometimes consider child bicyclist as intruders in their private space.

The study asked child respondent to do a self assessment of their own risk of being hit by a car while riding on the road. This assessment revealed that 1.8% of children thought that they were very likely to be hit by a motorised vehicle while riding. Similarly, 22.1%, 52.3% and 23.7% respectively affirmed that they were fairly likely, unlikely and very unlikely to be hit by car whilst riding. However out of 130 children who said they had been involved in Road Traffic Crashes (RTCs) in the recent past in these communities, 90.8 % were hit whilst riding bicycles along roads 6.2% were hit whilst walking along the road. The remaining were knocked down whilst road peddling, crossing the road or riding as passengers on motorbikes.

Rates of RTCs involving bicyclist is generally high in Ghana, especially in communities that lie along major roads and those linking farming communities. Percentages of study participants who had been involved in RTC at the various sites are shown in figure 2. These figures seems very high compared to national average of bicyclist injured through RTCs in 2009 (1.6 %) and 2010 (1.4%) (National Road Safety Commission, 2011) This interpretation is however done with care since our study looked at a restricted age bracket. It is also important to note that the national average maybe an underestimate since not all RTCs are reported to the police. Simply put, our figures are generated from an active case search whilst the national average is from a passive case detection.

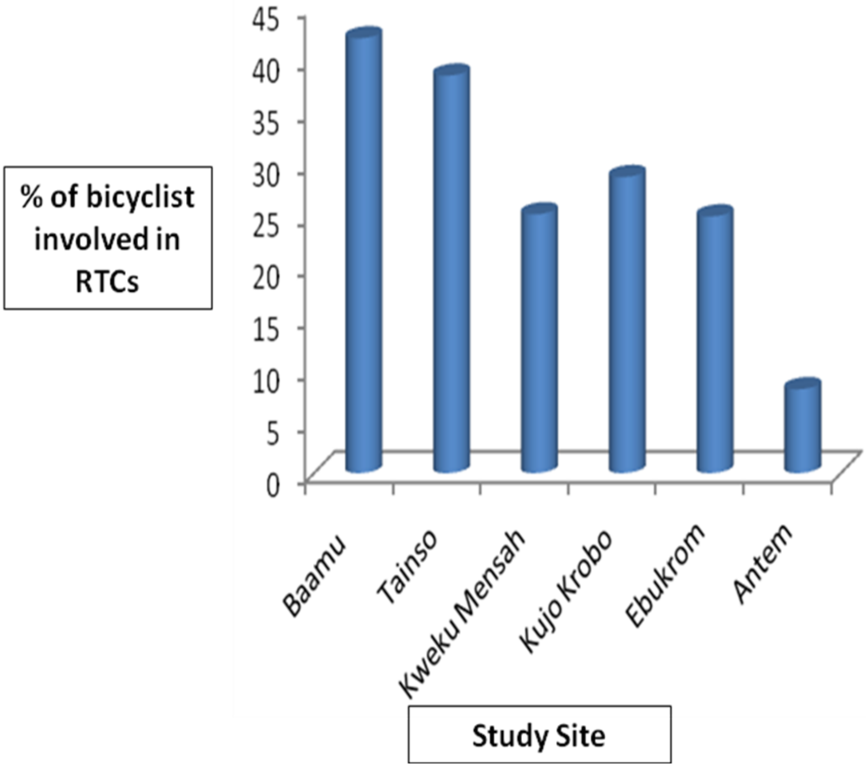

Figure 2: Distribution of RTCs involving child cyclist in various study sites

Source: Child mobility data (2007)

Children between the ages of 12-15 years are most at risk of being hit by a motorised vehicle whilst riding a bicycle. This age category accounted for 57.6 % of all bicycle related accidents and was followed by children aged between 16-18 years (22%) whilst 20.3% were between the ages of 8 and 12.

It is therefore not surprising that 17% of rural children who did not know how to ride attributed their inability to learn to ride to parental/guardian disapproval whilst 3.9% mentioned they were frightened to ride because of injuries that could be sustained as a result. Even among parents whose children were allowed to learn to ride, they were in fear of the inevitable happening to the children and always cautioned them to be careful especially when riding along the roads.

4.0 Overcoming distance to school

Children from the various study areas travelled to school over distances which ranged from 200 metres to over 8 km. Of these, 98.5% of children walked while only 0.2% used bicycles. Another 0.2 % used motor taxis to commute to school. Figure 3 shows the average time taken by children in rural areas to get to school each day.

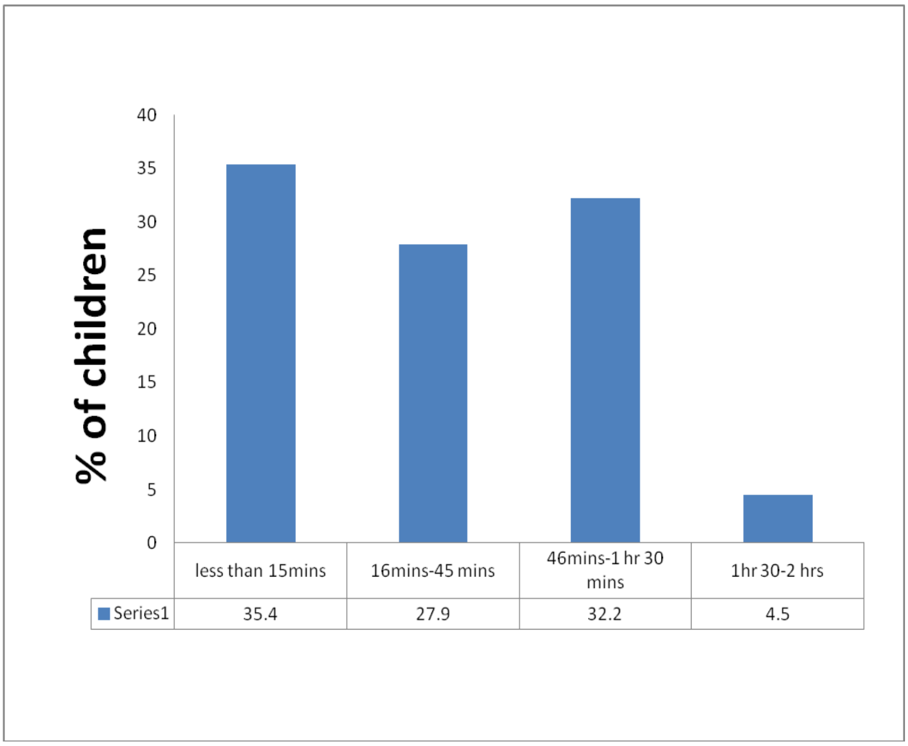

Figure 3: Average time taken to commute from home to school

Source: Field work (2006)

Figure 3 shows that only 35.4% of Children spend less than 15 minutes commuting from the house to school daily with another 27.9% of school children using an average of 16-45 minutes. The graph further shows that 32.2% spend between 46 minutes and 1½ hours whilst 4.5% spend between 1½ and 2 hours. Distance to school is a worry not only for the children involved but parents as well, especially with younger children. The following edits from the IDIs with both parents and Children help explain this:

> *"Usually I walk to school because there are no vehicles and even when we get some plying this route we cannot bear the cost of transport to school every day. I had a problem with walking to school. This is because I experienced some pains in my chest and my parents took me to the hospital. I was told to reduce my level of walking but if I do that it means I will have to quit school because there is no other school close by I can attend. I don't enjoy the journey to school at all. This is because mostly I walk alone to school. Even though my siblings also attend this school my mother makes them stay at home and brings them personally to school on her way to the farm and this makes me very unhappy because I have no one to walk with. If I decide to wait for my mother and siblings, I will report late for school and will be caned for that".- Vida, 11 year old primary 4 pupil (Antem)*

"There are so many developmental challenges that confront us in this village. Let me start with our children. Some of the children walk for about 8 km in and out every day to Besease to attend school because we do not have a school here. Those who are below 6 years are denied kindergarten education because they cannot walk that long distance. The associated problems, I guess, you can count. Those who walk to the school have to endure all manner of hazards including meeting dangerous animals like snakes on the road. They sometimes meet strange people who make them afraid of using the road. Some of them especially the weaker ones become tired of walking and so had to absent themselves from school during some of the days. Besides, the scorching sun they walk through is another source of concern for us. They arrive in school late and come back home tired". –Joe, 50 year old opinion leader, Antem

"The only thing I feel is a problem is the distance. Because of that she (10 year old daughter) sometimes breaks school for a day in order to rest. She leaves the house at 6:30am and gets to school at about 7:45am. When she started schooling, we had to work hard to keep her going to school because of the distance. However, now she is more used to the distance and attends school more regularly. However, on some days, she absents herself when she feels she is too tired to go to school. Because of the distance, she is not punished at school when she reports late but when she fails to report for school she is either caned or left off the hook. She could board a vehicle to school but the cost of transportation is too high. It cost as much as 30 or 40 pesewas and I cannot afford to allow her board a vehicle to school always. I will prefer she stays at home rather than pay such high transport fares. Elizabeth (6 year old daughter) will start schooling next year in the same school. She would also have to walk like her sister. I believe she will become used to it with time. If she gets tired she will also rest for about 2-3 days and then go back".- Egya Kobina 48 year old father.

The above narrations raise a myriad of issues that distance to school brings upon the community. As reported by Porter et al (2010) and Amoako-Sakyi and Owusu (2011), distance to school greatly influences school going age, absenteeism and early drop out. Among out-of-school children sampled for this study, 14.5% named long distances they had to travel to school as the main reason for dropping out.

Even though walking may represent an inexpensive means to getting to school, the afore mentioned repercussions make it unattractive. The ability of bicycles to mitigate such challenges children face in their quest to acquire an education cannot be underestimated considering the fact that they are generally socially accepted right from the North where there is high ridership down to the South where its usage is gradually picking up (KPMG, 2008 World Bank, n.d). Bicycles are said to be highly cost effective means of transporting both people and goods in a flexible independent way (Gautheir and Hook, 2005) and maintenance is relatively easy. Results from the qualitative study indicated that at least 1 out of every 6 children who used bicycles had some basic repair skills. This runs from simple fixing of the chain when it comes off through repair of a punctured tyre to more complex activities such as the repair of the spokes, hub, fixing of the gears and the steering when it loosens or breaks. Even in situations where bicycles are taken to repairers, Yaw, an 18 year old part-time bicycle repairer who learnt the trade from his brother, said he had many customers who flock to him for services and charges only 30 pesewas if the repair works involve the fixing of a punctured tyre and 1cedi (100 pesewas) when he has to grease the bike emphasizing its relatively low cost maintenance advantage.

5.0 Conclusion

One of the greatest and most controversial debates in transport and development is on the potential role of non-motorised transport (NMT) in addressing the transportation deficiencies in rural and urban Africa (Bulterys and Hunt, 2007). Although bicycling has proven to be a cost effective means of transport in rural areas it is yet to be exploited to meet the mobility constraints in those areas.

Children in particular can benefit from using bicycles in accessing educational resource but up till now Ghanaian children mostly ride for fun and running errands for parents. We still do not know why bicycles have not been used to address the mobility constrains of children in Africa.

Perhaps the first step towards answering this question is to understand bicycle behaviour among children in these areas and that is what this study sort to do. This study revealed that although some households own bicycles, they are purposely suited for use by adults and not children.

The study also revealed that parents are less enthusiastic in encouraging bicycle use by children because of the risk of RTCs in those communities. Other socio-cultural factors and believes such as labelling child bicyclist as truants and the fear that female bicyclist may become barren have militated against the utilitarian use of bicycles.

A government led initiative to incorporate bicycle infrastructure into current and future development will be crucial in promoting bicycling. For instance the construction of dedicated bicycle lanes to protect child cyclist who hitherto shared road space with motorised vehicles from RTCs would be a good point to start from. Advocacy and civic education on the benefits of bicycling to school must also be considered. Community and opinion leaders may also have to come up with novel and ingenious ways of glamorising bicycle use such as making frantic efforts in educating local folks in a bid to dispel misconceptions about the use of bicycles especially among girls.

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THE N14 AND N10 CORRIDORS ALONG THE ORANGE RIVER IN SIYANDA DISTRICT MUNICIPALITIES - NORTHERN CAPE

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Abstract

Rural mobility and access may be taken as a major contribution for poverty alleviation in Africa. Sustainable development starts at the community level where agricultural products are grown to provide food for the community followed by provincial capitals and also later to major cities. Road infrastructure provision becomes essential to enable the movement of goods and people.

This paper looks at the development of National Roads N14 and N10 along the Orange River in the Siyanda District Municipality where employment opportunities are seasonal and low education levels imply a low skill base. The main focus of the regional plan is the provision of infrastructure, namely access roads, bicycle and foot paths, low level bridge crossing facilities and upgrading intersections.

A case study highlighting project achievements is included.

1. INTRODUCTION

The South African National Roads Agency SOC Limited (SANRAL) in addition to its responsibility of managing the national roads has looked to the concept "rural mobility corridor development" aimed to assist communities living along the Orange River in the Northern Cape Province.

This road integrated strategy is aimed at promoting rural mobility and access. The Western Region's Regional Development Plan (WR-RDP) outlines the processes of identifying a development corridor, project implementation strategies, monitoring and evaluation and exit strategies for the identified Community Development Projects in the region. SANRAL's Western Region is responsible for both the Western Cape and the Northern Cape provinces.

The involvement of a variety of stake holders, namely communities, district and provincial authorities as well as Municipalities at the project conceptual design phase was viewed as critical for project's success. For this reason, all projects were implemented in close partnership with the local municipalities at the district or local level using the Empowerment Impact Assessment (EmpIA) approach for the identification of local resources.

EmpIA is a participatory process which involves a number of stakeholders depending on the type of project that is implemented. The EmpIA process is aimed to achieve the following objectives:

- Provide the local people an opportunity to influence development in their local area,
- Identify job creation opportunities and improve skills and employment levels in the local area,
- Provide opportunities to stimulate economic growth in the area and directly impact on the poverty levels,
- Facilitate the upgrade of the local infrastructure and social development, and,
- Allow for growth in size and capacity of participating contractors and subcontractors, especially those from previously disadvantaged background.

The EmpIA Implementation Process

Four phases are identifies in the process, namely:
Empowerment information gathering – collection of information on beneficiary community and the infrastructure needs in that community;

Empowerment impact analysis – analyzing the collected information to determine labour: enhancing implementation methods, local labour and resources and need of vulnerable groups;

Developing Empowerment Impact Targets – setting of targets in order to be able to measure the impact of the process;

Developing empowerment implementation strategies **–** identification of most suitable implementation methods including project planning, design and construction methods as well as skills development needs.

2. PROJECT RATIONALE & CRITERIA FOR SELECTION

The development of agriculture was the main driver for the selection of the project.

2.1 Selection Criteria Strategy

The following criteria were used as part of the selection strategy:

i. communities' proximity to the national road network,
ii. their latent and real economic potential,
iii. social transport needs
iv. pedestrian safety needs and
v. contribution to the development of the province.

In order to maximize the desirable outcomes all projects were to be implemented in close partnership with the local municipalities at the district or local level using the EmpIA approach for the identification of local resources, identification of training needs and skills transfer and monitoring and evaluation of projects.

2.2 Projects Identified

Identified projects included the following scope of works:

- The upgrading of access roads (including storm water control).
- Safety improvement of intersections.
- Construction of public transport facilities (collector routes, taxi/bus embayment & shelter, trading area facilities).
- Construction of low level bridges.
- Construction of pedestrian/bicycle paths.

2.3 Prioritization of Project

A number of consultative processes were undertaken between SANRAL and the identified stakeholders. The main objective of the consultation was to ensure that the WR-RDP is aligned to the needs of both the province and the local and district municipalities. These consultations took place as one-on-one meetings, interviews, focus group discussions and site visits to the proposed areas.

Further consultation with the municipalities resulted in the identification of potential opportunities which existed within civil engineering projects for the local beneficiary communities in four specific categories, namely:

- Opportunities for local labour – both skilled and unskilled;
- Opportunities for Small Medium and Micro Enterprises (SMME) and Black Enterprise (BE) suppliers and service providers;
- Opportunities for local contractors and subcontractors;
- Opportunities for local skills development agencies;

The approach was aimed to measure both delivery of services and the impact of delivered services in the improvement of the quality of life of the targeted communities. In order to ensure cost effective implementation of the projects the proximity of high priority projects was also taken into account.

The following phased implementation of project sets as, shown in Fig 1, were agreed upon for the N10/N14 Development Corridor.

Project set 1 (P004-038-2006/1)
- Wegdraai
- Topline
- Grootdrink

Project set 2 (P004-037-2006/1 & P004-040-2009/1)
- Rooikopeiland
- Currieskamp
- Soverby

Project set 3
- Leerkrans
- Karos
- Ntsikelelo

Project set 4
- Louisvale
- Raaswater

Project set 5
- Cillie
- Mc Taggetscamp
- Loxtonville

Project set 6: Ad-hoc: (P004-039-2006/1)
- Kuyasa
- Lowreyville

These roads were design in accordance to SANRAL Design Standards and the Highway Capacity Manual. An example of the Project Scope of the Works for Wegdraai Community is provided as annexure 1 to this Report.

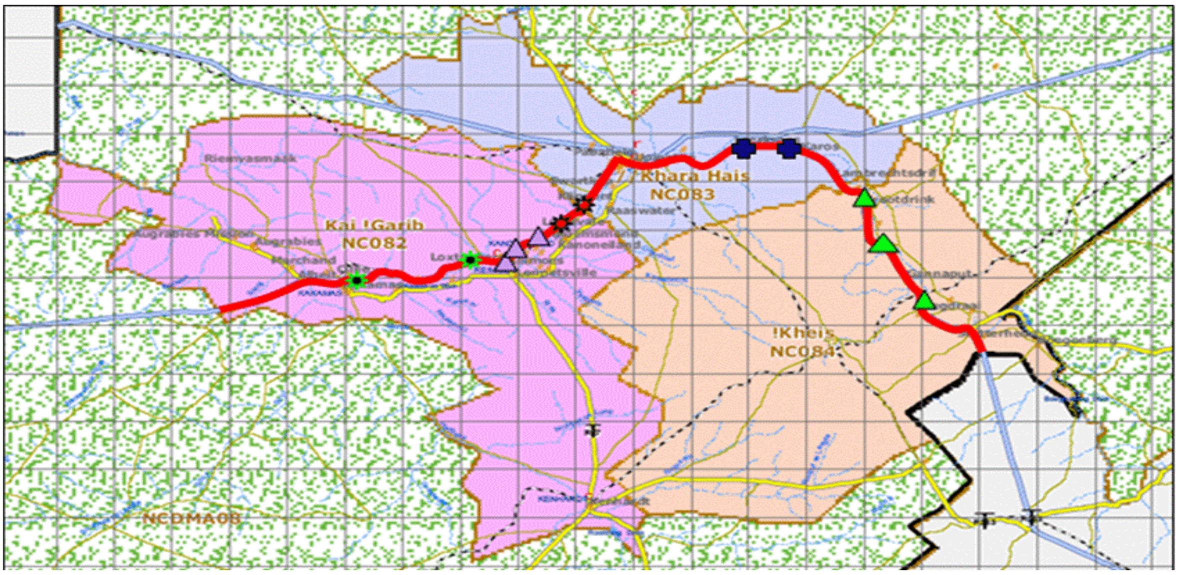
3. PROJECT IMPLEMENTATION STRATEGIES

Socio-Economic Development

South African people, with their aspirations and collective skills, are an important resource. The creation of employment opportunities, the generation of income and the promotion of SMMEs are, amongst others, key elements in a socio-economic development environment.

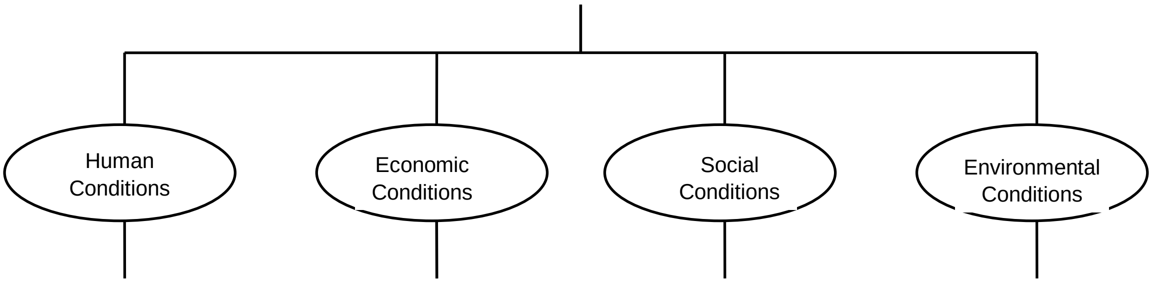
This development environment includes prevailing conditions in the spheres of Human, Economic, Social and the Environmental conditions as indicated in Figure 2, and offers numerous opportunities for activities in support of each.

Fig 1: N10/N14 Development Corridor



Legend: Project set 1: ▲
Project set 2: ▲
Project set 3: ✚
Project set 4: ✲
Project set 5: ✷

Fig2: Elements of Socio-economic Development



- Human Resource Development
- Mentoring

- Creation of Employment Opportunities
- Small, Medium and Micro Enterprise Development
- Promotion of Growth and Economic Activity in the Secondary Business Sector
- Participation of women and rural people

- Participation
- Empowerment
- Human resource development
- Attending to basic needs

- Sustainable
- Restoration of environmental damage

The N14 and N10 Corridors would be used to contribute towards meeting some of the following socio-economic development objectives:

a) Creating sustainable employment
b) Development of the social and physical environment
c) Enabling and empowering people, communities and businesses, through human resource development and by exploiting opportunities arising from the Project
d) Establishing a quality and productive workforce
e) Stimulating economic growth and reducing imbalances in access to opportunities
f) Poverty relief
g) Correcting historically distorted social and economic patterns
h) Promoting sustainable integrated development
i) Promoting sustainable environmental management actions

3.1 SANRAL's Strategy Towards Socio-Economic Development And Training

The SANRAL's strategy towards Socio-Economic Development and Training establishes that Tenderers are evaluated in accordance with their commitment to achieve and preferably surpass targets set for Socio-Economic Development and Training. The criteria for consideration in the evaluation of the Tender submission relate to:

(a) The Contract Participation Goals (CPG),
(b) Training and skills transfer for staff members under the Project; and
(c) Socio-Economic Development;

3.1.1 Contract Participation Goals (CPG)

Contract Participation is a process by which any employer, such as SANRAL implements Government's policies on maximizing labour and small and medium contractor development. Targets are set for equipment/system installations and operations by specified entities, the Rand value for which is based on the goods, services and work undertaken by the specified entities and measured as a percentage of the Contractors spend (excluding VAT). The Contractor is obliged to commit, as a minimum, to the targets set by SANRAL. Tenderers who are bona fide empowered companies do not qualify for relief from the obligations created by the requirement to set a CPG for SMME utilization.

Two examples of CPG targets defined by SANRAL vs. Compliance by Tenderers were:

A) P004-039-2006/1: CPG Achievements

	Targeted Labour	Targeted Procurement
Specified target	20%	30%
Tendered target	20%	30%
Achieved target	35%	47%

B) P004-040-2009/1: CPG Achievements

	Labour content	Employment of SMMEs/BEs
Specified target	20%	30%
Tendered target	21.2%	30.1%
Actual percentage in relation to scheduled items	35.9%	49.5%

The Contractor's performance including that of its sub-contractors were measured monthly in order to monitor the extent to which it is was striving to reach the required Contract Participation Goals.

To this end, contractors produced monthly reporting forms, which would form part of his own record keeping and reporting.

3.1.2 Technical Skills Training Strategy

SMMEs workforce and the Contractor's own targeted labour groupings that show initiative shall be offered accredited structured training that shall improve on-task skills necessary for the execution and successful completion of the Project.

The training programme undertaken by both the contractor and Accredited Training Providers offered complete courses comprising some or all of the following modules:

a) Use and maintenance of hand tools

b) Operation of small plant

c) Manufacture and installation of minor precast concrete units

d) Erect, dismantle and maintain formwork

e) Basic concrete and carpentry skills

f) Excavation, backfill and compaction

g) Bricklaying

The municipalities worked closely with other departments to improve the skills base of the local people. A number of local Small Micro and Medium Enterprises were set up through the Expanded Public Works Programme. These units were actively involved in the implementation of the projects.

The WR-RDP was also a process of identifying gaps in the labour force and the skill level. A training programme was developed, implemented and monitored to assess its effectiveness. Demographics indicate that a number of households were headed by women. Therefore, there was a need, to effectively increase the participation level of females to improve the quality of life in the affected households. However, the long term economic growth programmes need to be gender sensitive to ensure that both men and women take ownership of their growth and development processes.

3.1.3 Generic Skills Training

Generic skills were taught where the need for these has been identified as being necessary.

The training programme offered complete courses comprising but shall not be limited to some or all of the following modules:

a) Basic hygiene and HIV/AIDS awareness;
b) Road safety; and
c) Basic management of the environment.

Course certificates were issued by the Service provider at end of each individual module.

3.1.4 Socio- Economic Development

Community participation,

The communities influenced by these Corridors should be involved in decision-making where the Project will, or could potentially affect their lives whether positively, or negatively.

The level of interaction, decision-making and responsibility sharing between the affected communities and the Contractor depends to a large extent on the groups and issues involved and the influence of these issues on the groups, and involves consultation, joint problem resolution and agreement. The issues may include the identification of labour and SMME opportunities, and the promotion of, inter alia, environmental, economic and tourism programmes.

The Contractor was required to establish community participation structures and to meet regularly with communities in order to deal with any issues raised over which the Contractor may have influence and is able to assist in addressing them, including, but not limited to employment opportunities, environmental disturbances arising out of the Works and so on.

The purpose of community participation is to create awareness between any contractor and communities through which the Project passes. If there is no need on a particular contract to create a project liaison committee (PLC), it is usually advisable that a community relations officer be appointed from the contractor's ranks, for the specific purpose of acting as liaison between management and the various communities in the zone of influence of the Project.

3.2 Monitoring and Evaluation

Monitoring and evaluation played a crucial role in the implementation of the WR-RDP. It was important that that information collected for the EmpIA was valid and reliable in order to be able to draw a sensible conclusion on the effectiveness of these projects. Some of the issues being monitored included the following:

- The empowerment targets that were set
- Level of job creation
- Availability and use of local resources
- Participation of stakeholders and their contribution in the programme
- Set targets for skills development
- Participation of vulnerable groups including women and people with disabilities
- Improvement of social environment, including issues such as mobility, safety, security, etc.

Results of the monitoring process and project outputs are discussed in Chapter 4.

4. PROJECT OUTCOMES

4.1 Job Creation

A total of labour hours was created of which 725 850 for men and 184 435 for women. This translates to:

- 90 743.75 men labourers/40 hours per week,
- 23054.4 women labourers, or more specifically,
- 2269 men weeks, and,
- 570 women weeks respectively
- Effective women participation, thus contribution to cash injection into the families

4.2 SMME

A total of 18 contracts were awarded to SMME. These included:

- Drainage contracts
- Ancillary Contracts,
- Road works

4.3 Training

Training activities were undertaken in areas of:

- Safety on construction site.
- General construction life skills
- Construction of paving blocks,
- Installation of concrete culverts;
- Aids awareness campaigns

4.4 Access Roads

The following infrastructure was constructed under the project:

- Approximately 26 km of access roads,
- Foot paths,
- A pedestrian bridge,
- Substantial amount of drainage structures and culverts,
- Accessibility for the local communities was largely improved.

4.5 SUMMARY

Table 1: Summary of project outcomes – Job Creation, SMME and Projects Expenditure

Project	Job Creation Labour Hours • Men • Women	Total Expenditure in Rand	Training in Rand	SMME in Rand
P004-039-2006/1	210 805 41 364	10 731 073	87 554	5 853 282
P004-040-2009/1	261 250 68 588	9 471 184	138 670	9 392 842
P004-037-2006/1	297 672 85 567	10 318 345	108 535	7 024 191
P004-038-2006/1	273 736 67 507	5 878 712	668 150	3 014 730
Total	**1 043 463** **263 026**	**36 399 314**	**1 002 909**	**25 285 045**

Table 2: Summary of project outcomes – Roads and footpaths

Project	Access Roads (meters)	Footpaths (Meters)	Sidewalks (Meters)
P004-039-2006/1	1929	1085	1000
P004-040-2009/1	11970	NA	NA
P004-037-2006/1	6695	NA	NA
P004-038-2006/1	5500	NA	NA
Total	**26094**	**1085**	**1000**

5. PROJECT COSTS

Table 3: Summary of Project Costs

CONTRACTS	AMOUNTS (in RAND)
Project set 1: P004-038-2006/1 Contract commenced: July 2008 with a 18 month contract period.	31,785,111.00
Project set 2: P004-037-2006/1 Contract commenced: September 2009 with a 12 month contract period.	31,761,927.49
P004-040-2009/1 Contract commenced: September 2009 with a 14 month contract period.	30,439,323.94
Project set 6: P004-039-2006/1 Contract commenced: April 2009 with a 12 month contract period.	14,957,398.50
TOTAL	**108,943,760.93**

6. CASE STUDY

6.1 The Project

The project comprises the upgrading of access roads, footpaths and sidewalks in the Kuyasa and Lowriville communities in Colesberg.

6.2 Project Location

The Project is located in Colesberg, in the Northern Cape, approximately 250 km South west of Bloemfontein.

6.3 Rationale for choice

- Need to reduce the number of pedestrian crossings over the N1
- The need to provide some upgraded footpaths
- The need to attract traffic to some priority roads
- The provision of street lights to enhance communities' safety

6.4 Contract Details

Contract Prices (including VAT)

Tender Amount	:	R14 957 398.50
Original Contract Period	:	12 months
Final Approved Contract Period	:	12 months
Actual Contract Period	:	17½ months
Final Project cost	:	R10 731 078.00

6.5 Scope of Works

6.5.1 Road Works

The project includes the following activities:

- Upgrading of existing gravel access roads to surfaced roads.
- Providing sidewalks and crossing facilities for pedestrians.
- Construction of pedestrian walkways on critical routes.
- Installation of street lighting on pedestrian walkways.
- Drainage and stormwater improvements.
- Construction of traffic calming measures.
- Signage.
- Road marking.

Table 3: Summary of the Scope of works:

Section	From (m)	To (m)	Action
Lowryville Access Road	0.0	792.0	Upgrade gravel to surfaced
Kuyasa Street	0.0	1137.8	Upgrade gravel to surfaced
Lowryville Footpath 1	0.0	250.0	New construction
Lowryville Footpath 2	0.0	490.8	New construction
Lowryville Footpath 3	0.0	153.1	New construction
Lowryville Footpath 4	0.0	190.8	New construction
R58 Sidewalk	0.0	1000.0	Upgrade gravel to surfaced

6.5.2 Pavement design for access roads

The following pavement design methodology outlined shown in Table 4 below applies to Kuyasa Street and Lowriville Access roads.

Table 4: Design standards for access roads

Layer	Thickness	Description
Surfacing	Nominal	Medium grade slurry
Base	125 mm	Slurry bound macadam
Sub-base	200 mm	C3 stabilized gravel compacted to 97% MOD AASHTO
Selected	150 mm	G7 gravel compacted to 93% MOD AASHTO

Reason for this Specific Design:

- High volumes of Public Transport
- Commercial activities in the area

6.5.3 Pedestrian sidewalks and footpaths

The pavement design outlined in Table 5 below applies to pedestrian sidewalks and footpaths in Lowryville.

Table 5: Pavement Design standards for pedestrian side walks and footpaths

Layer	Thickness	Description
Surfacing	60mm	Class 60 A-S 25 MPa concrete block paving
	20mm	Bedding sand
Sub-base	150mm	C4 stabilized gravel compacted to 95% MOD AASHTO
Selected	Varies	G7 gravel compacted to 93% MOD AASHTO

6.6 Contract Participation Goals and achievements

Table 6 below shows the contract participation goals achieved on this project.

Table 6: Project Contract Participation Goals

	Labour content	Employment of SMMEs/BEs	BP Supervisory Staff
Specified target	20%	30%	20%
Tendered target	21.2%	30.1%	33%
Tendered value	R2 755 275.00	R4 113 900.00	-
Achieved value	R3 742 036.00	R5 853 286.46	86%
Actual percentage in relation to scheduled items	36.0%	56.21%	-

6.7 Project Benefits & Outcomes

6.7.1 Job Creation

- A total of 210 805 labour hours for men was achieved;
- A total of 41 364 labour hours for women was also achieved;
- 18 months of full employment,
- 88 maximum number of males employed at any given time,
- 30 maximum number of females employed at any given time.

6.7.2 SMME

A total of 9 contracts were awarded to SMME. These included:

- Drainage contracts
- Ancillary Contracts,
- Road works
- Electrical works (footpath lighting)

6.7.3 Training

Training activities were undertaken in areas:

For Owners of SMME's

a) Estimating and Tendering processes,

b) Preliminary and budgeting

c) Employment of Labour,

d) Basic man management,

For Labourers

- Safety in construction site,
- life skills, budgeting, ATM, etc
- Construction of paving blocks,
- Installation of concrete culverts;
- Laying of precast kerbs,
- Installation of gabions and reno mattresses
- Aids awareness campaigns

6.7.4 Access Roads

- A total of 1000 m of side walks were built;
- A total of 1085 m of footpaths were built;
- total of 1138 m of surfaced road were built;
- total of 792 m of access road was built;
- Pedestrian bridge;
- Substantial amount of drainage structures and culverts were build,
- Accessibility for the local communities was largely improved;

6.7.5 Impact on the use of pedestrian footpaths

Table 7 below shows footpaths 1 & 2 as well as the pedestrian's utilization.

Table 7: Assessment of pedestrian utilization

		14-Sep			15-Sep		
		FP1	FP2	Total	FP1	FP2	Total
06:30	08:30	87	105	**192**	66	89	**155**
08:30	10:30	89	29	**118**	63	59	**122**
10:30	12:30	111	32	**143**	39	67	**106**
12:30	14:30	105	92	**197**	105	77	**182**
14:30	16:30	51	81	**132**	119	126	**245**
16:30	18:30	29	61	**90**	58	82	**140**
Total for day				**872**			**950**

6.8 Challenges to the Project

a) **Excessive floods during the project implementation;**

These were addressed in accordance to the existing FIDIC conditions of contract.

b) **Change of the design which had impact on overall project labour targets,**

Contractors were in some cases allowed to change their original technical solution in order to maximize the use of labour intensive methods. This brought a positive impact on the overall project financial structure.

c) **Overall management of key stakeholders particularly the role of local authorities;**

Strong and focused management style was required from SANRAL Project Managers in order to minimize claims and to ensure that projects were delivered successfully;

d) **Handling of Municipal Services,**

Proactive interface was required between SANRAL and Municipality in order to minimize claims or delays on the project implementation process.

e) **Proposed Technical Solution (Slurry bound macadam vs. extreme cold temperatures)**

Contractor was required to perform at very high standards of quality control to ensure that the overall end product would not be compromised.

7. CONCLUSIONS

Projects of this nature have been shown to be effective and valuable to communities as they contribute towards job creation, training opportunities, improving road access to markets and can also the maximize economic opportunities for Small Micro and Medium Enterprises (SMME).

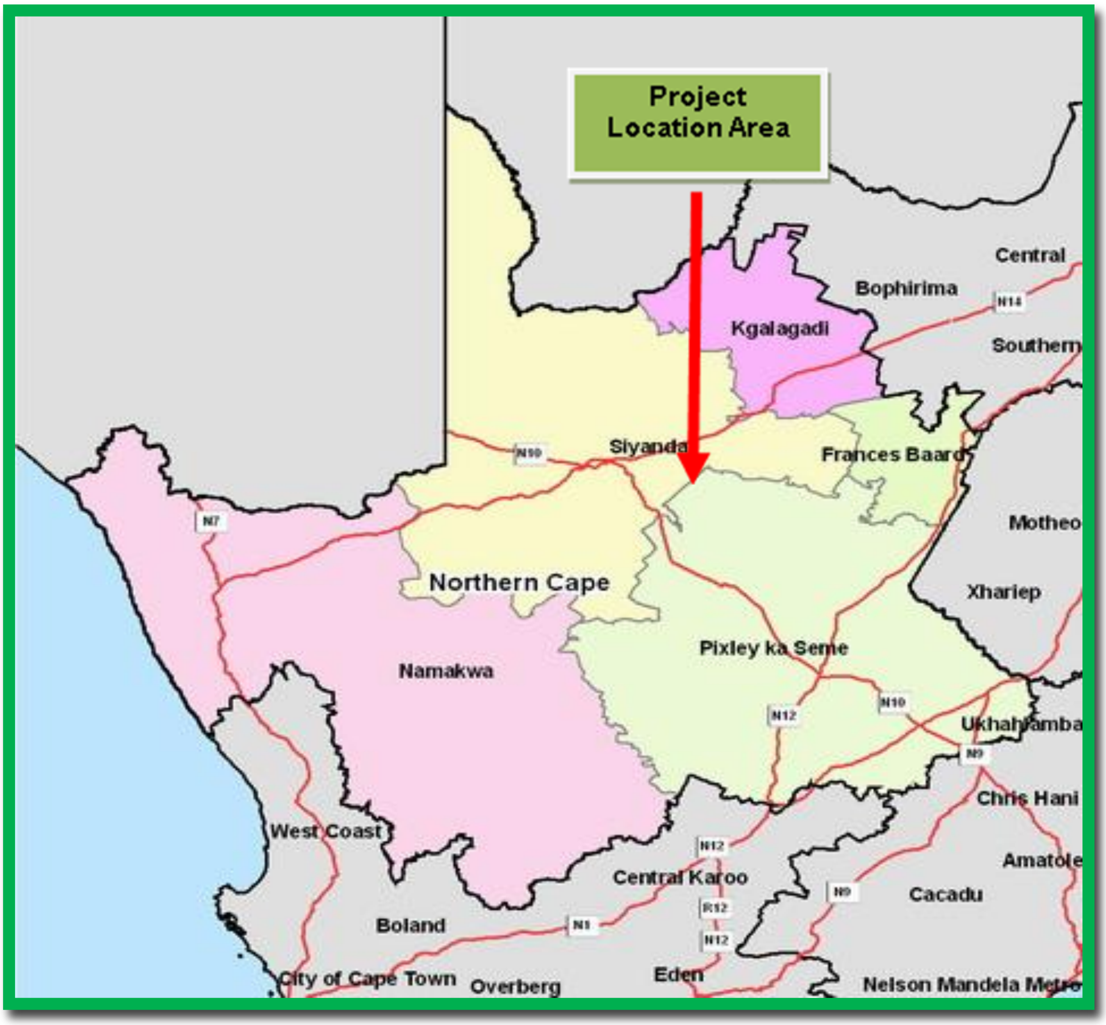
The following achievements were recorded from the N10 and N14 Corridor development:

- More than 26 Km of rural roads were built,
- Contract P004-040-2009/1 covered more roads with a total of 11,97 km;
- Contract P004-039-2006/1 extended the concept of access roads to 1085 m of footpaths and 1000 m of sidewalks;
- The use of labour intensive methods was maximized in all contracts. This has contributed to job creation and empowerment of local communities;
- RDP requirements for these projects was that 60% of the Tender Price was to be spent on the BEE subcontractors; on all projects the SMMEs were local. The Main Contractor did not have a problem in achieving the RDP requirements

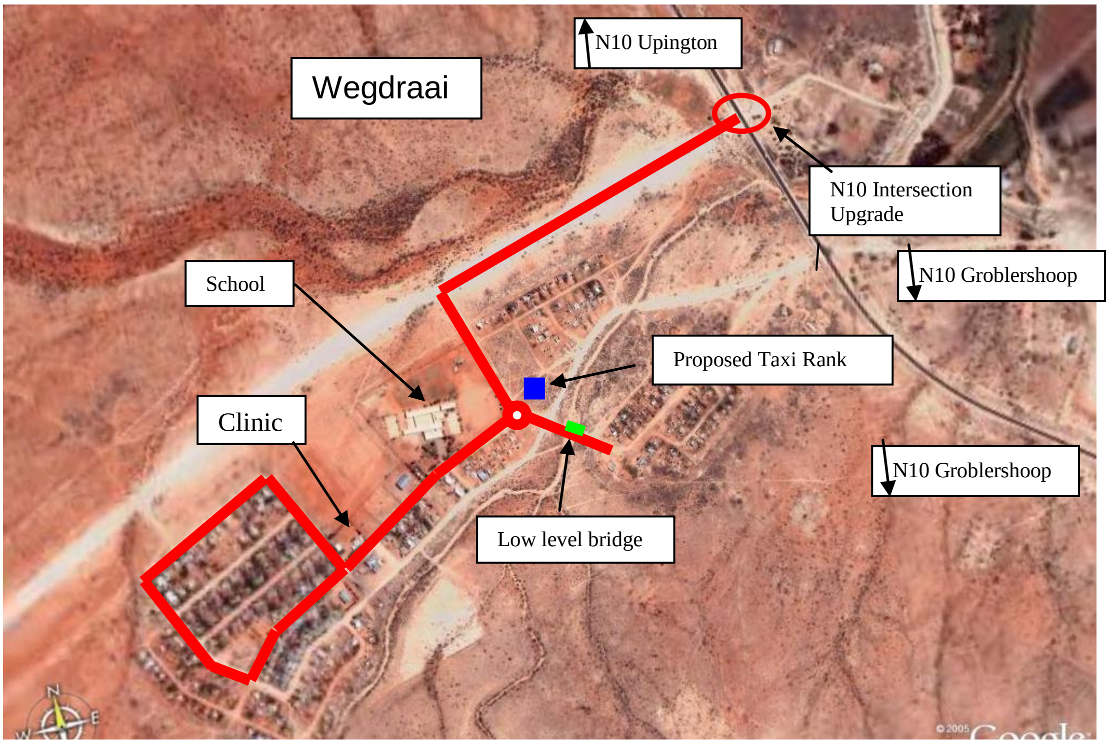
Projects like this should be used to promote sustainable development in rural communities.

Annexure 1: Example of Design Details for Wegdraai Community

PROJECT LOCATION



Wegdraai



Photos of access road to Wegdraai

Proposed Scope of Works for Wegdraai

• Road Layout	
○ Access Road	Surface of access road
○ Ring road	Facilitate internal mobility (motorized and non-motorized modes), promote public transport.
○ Major intersections /accesses	Upgrade of N2/Wegdraai Intersection: Introduce right turning lanes and deceleration and acceleration turning lanes
• Total length of Road	2,0 km
• Typical Cross-Section	2 x 3,3 m lanes + 1 x 2 m raised sidewalks
• Proposed Surfacing Type	All weather surface, to be determined
• Stormwater control	Channels / drains on proposed road Low level bridge crossing
• Non-motorized transport needs	
○ Sidewalks	Raised sidewalks
○ Crossing facilities	Raised Intersections and raised pedestrian crossings at school, clinic and community hall
• Traffic Calming	
○ Speed Bumps	Strategically located speed bumps, on similar locations to those already created by the community
○ Other	To be investigated
• Public Transport Needs	
○ Bus Shelters	At location of school
○ Bus / Taxi Embayment	Upgrade of main taxi rank area close to main N10 intersection. Taxi lay byes along ring road
• Transport Needs of the elderly, disabled	To be determined Special traffic calming measures in vicinity of clinic and school
• Signage	Typical regularity and warning signage to compliment infrastructure

2ND AFCAP PRACTIONERS CONFERENCE 3rd to 5th July 2012

OVERVIEW OF LOW COST SEALING TRAINING ON LOW VOLUME DISTRICT ROADS IN UGANGA.

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Abstract

Sealing of Low Volume Roads in Africa is taking a centre stage as a means of attaining sustainable road infrastructure. Uganda in particular has embarked on with the training of technical staff at Mount Elgon Labour-based Training Centre (MELTC) Mbale; who thereafter trained district Local Government technical teams and Labour-based Contractor's staff on design and construction of sealed low volume roads.

The training involved class theoretical aspects followed by field demonstrations of the different sealing options. Experience from the field work, construction, costs associated with different seals and design consideration have also been included in this paper.

This paper should contribute to the on-going initiatives on sealing LVR in Sub-Saharan Africa and the further promotion of the technology in other countries in Africa.

2ND AFCAP PRACTIONERS CONFERENCE 3rd to 5th July 2012

1. INTRODUCTION

Themes of this conference “Innovations for Rural Mobility and Access” and “Research and Future of Rural Transport in Africa” is most relevant for Uganda as a developing country in Africa. Labour Intensive Approaches is one of the strategies in the country’s plan to attain its developmental goals.

Government of Uganda, through its National Development Plan (NDP), envisages rehabilitating up to 11,067 km of district roads of which 10,095 km are expected to be sealed using Low Cost Sealing (LCS) technology. The policy for the Development and Strengthening of the National Construction Industry advocates for up to 50% of District and Urban road works to be executed using Labour-Based Technology (LBT). In this respect MELTC is expected to play a key role in ensuring that both the Private and Public sector possess the necessary skills and capacities in executing such works hence achieving the targets of the NDP.

Government of Uganda, with Danish assistance under the U-Growth programme, is providing support to Rural Transport Infrastructure (RTI) development. Under this initiative it is envisaged that MELTC trains 212 district staff and 100 contractors’ staff in the techniques and skills of sealing Low Volume Rural Roads as part of the preparation for the target of sealing 300 km of district roads.

The purpose of this paper is to share with other AFCAP member countries the progress so far made in Uganda towards sealing of district roads using labour based methods and this would contribute to the ongoing initiatives of sealing of LVR in sub-Saharan Africa and that experiences from Uganda would contribute to the further promotion of the technology.

2. BACKGROUND

Basic information on Uganda:

Location: In the Eastern part of Africa; straddling the equator between latitudes 1˚ 29’S and 4˚ 12’N and longitudes 29˚ 34’E and 35˚0’’E.

Area: 241,550.7km² of which 41,743 km² is water and wetlands.

Population:

- 24.1m (2002 census) and currently at 34million (Uganda Bureau of Statistics).
- It has registered an average growth rate of 3.5%. Out of this 56% are children under the age of 18 which makes it the youngest and most dependable in the world.
- The Total Fertility Rate (TFR) is 6.7 children per woman, also the highest in the world.
- Additionally 80% of this population live in the rural areas and are engaged in agriculture. Agriculture alone accounts for 24% of Gross Domestic Product (GDP) while the construction industry has over the last 10 years been growing at an average rate of 11% per annum. It now accounts for 12% of the country’s GDP.
- Wages of casual labourers have also shoot up to not less than UShs. 6000/= (close to US $ 2.5) per day. This is turning to be a big threat to the agriculture sector which is being depleted of the youth’s labour as it migrates to urban centres in search for better pay.

Road Network: The categorizations of roads in Uganda are based on their proposed functions and the level of service that they provide. They are divided into the following functional classes:

- **National (Trunk /classified Roads);**
  Responsibility of Ministry of Works and Transport. Since July 2008, Uganda National Roads Authority took up the mandate of developing and maintaining all national roads totalling *19,500km* with only 16% paved, the rest unpaved with gravel or earth surface.
- **District roads:**
  Directly the responsibility of district local governments as far as planning, maintenance and rehabilitation is concerned. Total up to 18,500 Km, of which 30% are gravel and the rest earth. It is part of this length that needs to be sealed.
- **Urban roads**
  Directly the responsibility of and within the boundaries of Urban Authorities as defined by the Urbanised Area Map Gazette, total up to 3,500 km.
- **Community Access Roads:**
  Under the administration of Sub-County (LC-3) administrations, over 30,000 Km all earth roads.

3. OVERVIEW OF START UP ACTIVITIES

With funding secured from both governments of Uganda and Denmark; it was time to draw a roadmap of how to incorporate Low Cost Sealing Technology into the MELTC curriculum. MELTC is the only training centre directly under the Ministry of Works and Transport (MoW&T) charged with the responsibility of developing capacity of the private and public sector in the planning and implementation of road rehabilitation and maintenance using labour based methods in a manner responsive to environmental, gender and social aspects. The MoW&T "Strategy for Sustainable Maintenance of District, Urban and Community Access Roads" emphasises the use of local level planning and labour Intensive methods of road construction and maintenance to address unemployment in the country currently at 16%.

With the target of sealing 300 Km of district roads under the RTI sub component in the U – Growth program document, the government procured the services of Transport Research Laboratory (**M/S TRL LTD - UK**) in Association with Prome Consultants Limited – Uganda to *" Develop Training Modules, Conduct Training and Establish Demonstration Sites for Low Cost Sealing of Roads,".* With the experience and research knowledge in Sealing of Low Volume Rural Roads from a number of countries in Africa, TRL LTD. embarked on the following: -

- Production of the Inception report detailing the chronology of the activities and required resources from both the client and the consultant.
- Demonstration site establishment and execution of the different sealing options.
- Production of training materials and updating of the training curriculum in modular form to incorporate low cost sealing of low volume roads using labour based methods.
- Production of Technical and Works approval manuals for labour based Low cost sealing road works to include appropriate designs and standard specifications.
- Production of guidelines on use of locally available materials for Low cost Sealing works
- Production of Tender documents for sourcing of labour based works for Low cost surfacing.
- Preparation of a report on the entire training process highlighting experiences and lessons learnt.

3.1 Classroom Training

All MELTC technical staff underwent training in the theoretical aspects of Low Cost Sealing and field based practical training to develop skills. The training modules covered during the classroom training involved:

Module 1: *Road Evaluation: -* This module focuses on evaluating the condition of the existing road to determine if it is suitable to receive surfacing. It also includes data collection that can be used for decision making and design.

Module 2: *Road Improvement:* Focuses on determining which elements of the road need improvement before surfacing e.g. the drainage system, the geometrical alignment etc.

Module 3: *Designs of Surfacing: -* Covers design of low cost surfacing; the participants should be able to design the different sealing options from first principles using the design charts and traffic count data.

Module 4: *Occupational Health, Safety and Environmental Issues: -* Exposes the engineer to issues related to Health Safety and Environment (HSE). The key issues to be considered before work starts and how to cater for HSE on site.

Module 5: *Preparation for surfacing works:* Describes the planning aspects before surfacing operations can be carried out. The necessary requirements in terms of organisation for a successful and safe surfacing operation.

Module 6: *Surfacing Operations: -* Demonstrates how to construct each type of surfacing.

Module 7: *Maintenance of Surfacing;* A discussion on the causes of defects common on sealed roads and how to rectify and maintain a sealed low volume road.

3.1.1 Training of District Local Government Technical Team

The target group trained under the district technical team included: District engineers, Supervisors of Works (S.o.W) and Road Inspectors. This group was taken through all training modules that the training centre technical staffs were trained on by TRL LTD. This involved two weeks of classroom training and one week of field practical training. A lot more emphasis was given to design aspects, data collection and analysis including materials prospecting and testing.

3.1.2 Training of Contractor staff

The contractor staff trained included; one (1) Forepersons, two (2) Assistant Foreperson and the Managing Director of the company. Their training took a period of four weeks comprising of two weeks of classroom theory training and two weeks of field practicals. The areas of coverage included: Materials identification and testing, sealing operations, Quality control of works, Cost estimates and Pricing, Tools and Equipment, Occupational, Health and Safety and Preparation of Surfacing works.

3.2 Field Practical Training

The field practical training took place immediately after the classroom training on Busamaga – Magada – Bumulya (BABA) road which was previously rehabilitated using labour based methods under the supervision of the training centre. It is located 20 Km away from the training centre within the outskirts of Mbale town. A length of 600 metres was used to demonstrate the six different low cost sealing options each covering a stretch of 100 metres namely: *Penetration Macadam*, *Single Surface dressing with either sand or quarry dust capping, Sand seal, Otta seal, Single Surface Dressing (SSD) and Cold Pre-mix.*

Prior to the construction of the sealing options the existing road surface (to become the sub-base layer, see section 4) was scarified using a towed grader and then compacted. This ensured bondage to the base course and when tested it registered a CBR of 30%. The consolidation from previous traffic usage of this road greatly contributed to the reduction of the base course thickness.

3.2.1 Base Construction

The practicals involved construction of a base layer of 120 mm compacted gravel thickness placed in two different leaves of 75mm loose thickness. The gravel used was obtained from two different sources namely Kachumbala – Komuge borrow pit (25 Km away); which indicated the following properties; Plasticity Index (PI) of 14% and a CBR of 57%. This Laterite gravel was used on 350 metres portion without any modification to these properties. The remaining 250 metres composed of limed stabilised gravel from a quarry within the vicinity of the training road which had a PI of 22% and a CBR of 27%. This was stabilised with a 4% hydrated lime which lowered the PI to 14.5% and CBR increased to 52% at 98% of Maximum Dry Density (MDD).

Figure-1; Base construction at Busamaga – Magada (Mbale-Uganda) with lime stabilised gravel.

The base course was constructed with a 3% cross fall and was finished smooth with a towed grader. Compaction was tested using the sand replacement method which registered values in the range of 1,795 -1,830 kg/m³; and comparing with the MDD of 1932 kg/m³, it showed that compaction was attained up to 92.9 % - 95% of MDD.

The procurement of specialised equipment such as a bitumen distributor tank, pneumatic roller, and concrete mixer etc, ensured quality of works are attained. However it was not possible to procure all equipment in time, particularly the pneumatic roller which up to date has been a challenge for the training centre.

Following base course construction the surface was primed with MC-30 that cures within a period of 3 – 5 days. The base course (also referred to as the road base) is the main layer in terms of providing additional strength and load bearing capacity to the road and was given due attention to ensure that the materials used had the required specification limits such as Plasticity Index (PI) not exceeding 15% and 4 day soaked California Bearing Ratio (CBR) minimum of 45%.

Figure-2: Busamaga – Magada final smooth cut to 3% camber using a towed grader.

3.2.2 Sourcing of local materials

Materials for use on low volume roads have a big contribution towards cost reduction if they are located within the vicinity of the construction works of the project. The haulage costs when tagged into the rates significantly increase costs. Sourcing of suitable local materials are usually a challenging activity for engineers and yet the sustainability of low cost surfacing depends largely on innovative surfacing options which take into account the use of locally available materials with or without modifications. Material prospecting and testing involved a range of materials which included: natural gravel, aggregates, sand and quarry dust. Laterite gravel (a precipitate of aluminium and ferrous oxides) where obtainable within the project road area although on further tests such as: - gradation, Atterberg limits and CBR from the laboratory indicated values that fell in the lower limits of the grading envelops.

Fig-3: Sampling of gravel at BABA borrow pit **Fig-4:** Sampling of Hand crushed aggregates.

Surfacing aggregates obtained where both hand crushed and machine crushed all from the same parent rock; that is granite. The available aggregate sizes were, <5mm, 6-10mm, 10-14mm, 14 - 19mm up to about 40mm. The hand crushed sizes can loosely be regarded as being 20-40mm, <13mm, <5mm and 5-13mm. It should be noted that the hand crushers/sellers refer to them by different sizes, usually very different from what they truly are. A summary of the aggregates properties is as shown **Table-1** below.

To use these aggregates for surfacing works they have to be screened to the desired sizes. The tested hand crushed aggregates are of flakiness indices between 14.2 and 17.3; the Aggregate Crushing Valve (ACV) is consistent with granite at between 21 and 29%.

Table-1 A summary of the properties of hand crushed aggregates**.**

Sample Test Identification	Sieve Analysis % passing given sieve							Average Flakiness Index (%)	Bulk Density (g/cm^3)	Aggregate Crushing Value (%)	Aggregate Impact Value (AIV)	10% Fines Value (kN)	LAA	Bitumen Affinity (%)
	50.0 mm	37.5 mm	20.0 mm	14 mm	10.0 mm	5.0 mm	2.36 mm							
Mudonga Quarry (Hand crushed aggregates)	100.0	100.0	71.3	31.3	14.2	3.6	1.9	16.0	1.41	22	19.1	214	30.8	>95
Akimu Quarry (Hand crushed aggregates)	100.0	91.1	10.6	2.9	1.1	0.8	0.8	17.3	1.35					
Mudonga Quarry (Hand crushed aggregates)	100.0	100.0	84.0	49.1	29.1	9.9	5.0	16.6	1.36					
Baba IB (Hand Crushed aggregates)	100.0	100.0	92.1	52.6	29.1	10.6	5.0	14.2	1.34	29.7	29.3	120	46.8	>95 (Better)
Blue stone Quarry (Machine crushed aggregates)	100.0	100.0	99.0	83.4	28.4	1.0	0.6	36.1	1.31	21.7	20.1	187	27.8	>95 (Best)

4. OVERVIEW OF DESIGN CONSIDERATIONS AND EXPERIENCES FROM THE SEALING OPERTIONS ON THE TRAINING ROAD.

The success of a surface treatment is dependent on the soundness of the base on which it is built. If planned carefully, designed and constructed well on a good base, low volume sealed roads can be very economical and give very good engineering performance.

4.1 Pavement design Considerations.

In order to assess the adequacy of the existing pavement, and then design the pavement layers; it is important to obtain the following results since they are guides and parameters that are required as inputs in the design namely:-

- Sub grade CBR
- Cumulative equivalent standard axle loads (CESALS),
- Weinert Value and
- Base course CBR value.

4.1.1 Sub grade CBR.

The In-situ CBR of the sub grade being one of the primary in-put parameters in the empirical designs of Low cost sealed roads, are obtained using non destructive testing techniques namely the Dynamic Cone Penetrometer (DCP). It is a labour intensive testing instrument that rapidly measures in-situ strength of existing flexible pavements constructed with unbound materials. The results obtained by this instrument are analysed using a software package called “UK DCP data analysis”. The average value adopted for design was a CBR of 17% derived from the average of the field values obtained after analysising them using the UK DCP analysis software. A more conservative approach is to use the lower 10th percentile value of the measured Subgrade CBR, the final choice lies with the designer.

4.1.2 Cumulative Equivalent Standard Axle loads

To design the structural pavement, only medium and heavy vehicles categories need to be considered. This result is generated from the 7 days classified traffic count survey which enables the calculation of the Average Daily Traffic (ADT) from which the daily equivalent axle loads (ESA) are determined. To calculate the Cumulative Equivalent Standard Axle Loads (CESALS), the daily ESA for each vehicle type are multiplied by the number of vehicles per day and the valve obtained is used to forecast the ESA over the design life.

Therefore the design CESALS can be computed using the equation below:

$$\mathrm{CESAL} = \left[\frac{A\ X\ 365\ X\ 100}{R}\right] X \left[\left(1+\frac{R}{100}\right)^{x+y} - \left(1+\frac{R}{100}\right)^{y}\right] \text{ (Eq. 1)}$$

Where A = Total ESA/day

R = Predicted annual traffic growth rate.

X = Design life in years

y = Number of years before start of design life

Some typical values of ESAs by vehicle type found on Ugandan rural roads are presented below:

Table – 2 Typical ESA values on Uganda rural roads

Vehicle Type	ESA/vehicle
Light Truck (2 – axles, single rear tyres)	0.01
Medium Buses (Costa)	0.16
Medium Trucks (2, 3 axles)	2.20

Figure-5: Busamaga – Magada In-situ Strength determination using the Dynamic Cone Penetrometer.

4.1.3 Weinert Value

The Weinert values obtained from the **table-3** below relate to the ratio of evaporation in the hottest month of the year to the annual mean rainfall. It helps in choosing the right design charts (attached as an appendix) depending on climatic conditions where the paved road is to be constructed. The North-Eastern part of Uganda where sealing of low volume roads is being tried has value greater than 4. The Weinert Value (N) is calculated from equation 2 below:

$$N = 12\,X\,\frac{E_y}{P_a} \text{ [Eq. 2]}$$

Where E_y = is the evaporation in the hottest month of the year; in mm and

$P_{a\,=}$ is the annual precipitation in mm.

Table -3 Indicative Weinert N Values

Description	Weinert N Value	Thornthwaite Moisture Index, I_m	Typical Mean Annual Rainfall (mm)
Arid	5+	<-40	<250
Semi-arid	4 to 5	-20 to -40	250-500
Semi-arid to Sub-tropical	2 to 4	-20 to +20	500-1000
Humid Tropical	<2	+20 to +100	>1000

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4.1.4 Base Course CBR value

With all the necessary in-puts in place such as the CESALS, sub grade CBR value and the Weinert value; the right pavement thicknesses can be obtainable from design charts. The sub-base and base layers have min CBR values that are to be met by the constructed base course layers. Therefore from the material laboratory tests the 4 days soaked CBR and the values are compared against the designed requirements.

4.2 Experience of sealing operations for the different seals

Thin bituminous surfacing can be an ideal solution for low-volume roads. These surfacing are low cost and can last a long time when traffic volumes are low. The various options tried in Uganda by the training centre to date include the following:

- Penetration Macadam,
- Single Surface Dressing with Capping of sand or quarry sand,
- Sand seal,
- Surface dressing,
- Otta seal,
- Cold Premix.

4.2.1 Penetration Macadam

Penetration Macadam (Pen Mac) consists of a compacted layer of coarse stone aggregates into which has been introduced a binder which is allowed to penetrate into the layer & bind the stone aggregate. Angular stones as opposed to rounded stone were preferable as this provides better interlock and a denser structure. It is laid as a waterproof surface on a previously prepared road base primed with MC–30. It consists of two layers of stone applications with the first layer 20/40 mm size (hand crushed) laid at a rate of 22 l/m^2 after a tack spray of 0.8l/m^2 is applied using *K1-60/K2-60* Emulsion bitumen. This is then rolled without vibration using a 1.7 tonne sit–on roller. A penetration spray of emulsion bitumen at a rate of 2.9 l/m^2 is then followed, on which smaller size aggregate chippings 5/13mm (second layer) is laid at a rate of 12 l/m² or as per design followed by 3-4 passes of steel roller/pneumatic roller. The final surface is applied with 1.0lt/m² of fog spray generating a matrix of keyed stones grouted and sealed with bitumen to a depth of about 50–60mm. Applications of bitumen are high with this option in the range of 4.5 –7 l/m².

Fig-6: Spotting of 20/40mmstone

Fig-7: Laying 20/40stone on tack coat

Fig-8: Applying the 2.9 l/m² as 1st penetration

Fig-9: Rolling over 20/40 stone with 1.7 t roller

4.2.2 Single Surface Dressing with Capping of Natural sand or quarry sand.

This seal type is obtained by constructing a single surface dressing followed by an application of a sand seal. The sand is applied on the single surface dressing immediately after spraying a penetration coat of bitumen and definitely before trafficking. The construction process involves brooming thoroughly the primed base layer to remove debris and dust, marking out the section to be surfaced, then applying tack coat using emulsion bitumen at rate of 0.8l/m². 10/14mm machine crushed aggregate chippings is then applied and rolled with 1.7 tonnes sit–on rollers without vibration as mentioned before under the Pen Mac option. The 10/14mm surface is immediately sprayed with 1.0lts/m² of the binder to receive the sand. The sand is applied at a rate of 7.0l/m² and rolled over 2 days at 6 – 8 passes per day (ppd).


Fig-10: Applying 1.0l/m² on 10/14mmstone

Fig-11: Rolling sand with 1.7 t sit-on rollers

4.2.3 Sand seal

Purpose is to have sand glued to the surface and preferable for bitumen to rise slightly in the interstices and harden immediately. Hard grade bitumen such as 80/100 pen grade can be used although emulsions are still preferred for labour based methods. The construction involves use of graded river sand with maximum size of 5mm. In the construction process tack coat is applied at a rate of 1.5l/m² on a well compacted and primed base course layer; immediately sand is applied at rate of 7.0l/m². This is followed by 15 passes of rolling for the first day and 6 - 8 passes for the next 3 days while allowing traffic at controlled speed of 20 Kph.


Fig-12: Quarry sand seal applied on tack coat

Fig-13: Completed sand seal section

4.2.4 Single Surface Dressing (SSD)

Single Surface dressing is the most common option for sealing roads in Sub-Saharan Africa. It is cheap, durable and appropriate for most of the road networks where traffic is relatively low and is often also appropriate for trunk roads. Surface dressing is a non-structural thin seal of a bitumen bound layer of single sized stones/aggregate (10–14 mm) machine crushed chippings laid on a primed road base. In its construction "spotting" of aggregates ready to be spread on to the tack coat is done per work cell (see calculation below). Prior to stopping, the cured primed surface is thoroughly swept of dust and animal droppings.

The length of each work cell is computed from the equation below:

$L = \frac{2\,XV}{WXR}$ [Eq. 3]

Where L = Length of work cell

V = Volume of Half drum equivalent to 110 litres.

W = Carriage way width

R = Design application rate of chippings.

Based on the design application rate of the chippings, mark out sections on the carriageway that are to receive surfacing. Determination of the time required to spray bitumen on each sections at the specified rates is carried out by calibration using a half drum with marked out point at 10 l, 20 l, 30 l and 40 l respectively and then timing using stop clocks to obtain the time (in seconds) required to attain those litres . This is beneficial in that it helps in the computation of bitumen application time per work cell.

After the tack coat is applied at a rate of 1.0 l/m², 10/14mm chippings are then gently spread at a designed rate of 13 l/m² and rolled using 1.7 t Sit–on rollers without vibration (pneumatic rollers are preferred if available). Lastly a fog spray at rate of 0.7 l/m² is applied and allowed to set for 24 hours before rolling for extra 2 days.

Fig-14: Single Surfaced Dressed section prior to application of fog spray

4.2.5 Otta Seal

Otta Seals are a 16 to 32 mm thick bituminous surfacing constituted of an admixture of graded aggregates ranging from natural gravel to crushed rock in combination with relatively soft (low viscosity) binders. Graded aggregate is placed on a relatively thick film of comparatively soft binder which, on rolling and trafficking, can work its way upwards through the aggregate interstices resulting in a dense durable matrix that relies on both mechanical interlocking and bitumen binding for its strength - a bit like a bituminous premix. Extensive daily rolling is required for up to 1-3 weeks on low-volume roads to allow bitumen to rise through the interstices.

The bitumen material should consist of cut-back bitumen binder free from water and showing no separation prior to use and conforming to all the requirements for Grade MC-3000 medium-curing cutback bitumen.

Aggregates used in this case were screened natural crushed rock, of uniform quality; hard, durable, and rounded or cubical in shape. The amount of fines passing the 0.075mm sieve did not exceed 10%.

The bitumen binder was first heated in drums up to a temperature of approximately 45ºc and then transferred into the bitumen tank distributor and then further heated to 145ºc. It was then applied at rate of 1.6 l/m^2.

The quality of the seal is dependent very much on the grading of the aggregates. A dense grading, i.e. well graded, will stand up to an Annual Average Daily Traffic (AADT) well over 1000 Vehicles Per day (vpd) while medium and open grading, containing less fines, should only be allowed for limited traffic volumes. Equally the grading determines the exact binder spray rates, ranging from 1.5 to 2.0 l/m^2, with the dense grading demanding slightly higher rate.

4.2.6 Cold Premix (Cold Asphalt)

This was made by mixing hand crushed aggregates of size < 13mm with bitumen emulsion in a concrete mixer or in a mixing pan. The experience on site was that hand mixing was more effective than the concrete mixer because when using the mixer the material was breaking and setting at the bottom of the mixing drum. Therefore we decided to go for hand mixing although that has to be done in small quantities; we mixed 144 litres of aggregates to 23 litres of K1-60 emulsion bitumen.

The mixed pre-mix is then carried and transported in wheel barrows and laid between guide rails that have been fixed on the primed road base surface and levelled off with a screed bar. The laying is done before the emulsion breaks and this is within 25 minutes, from the time of mixing of the emulsion with the < 13mm hand crushed aggregates.

After levelling off and after the emulsion has broken to the full depth of the mix it is then rolled with a steel drum roller, but at the same time allowing water to drip on the surface of the drums and wet it so that coated aggregates don't stick to the surface of the steel drums. In the mix design; the residual bitumen is to be between (6 – 8) percent of aggregate by unit weight. And this was generating a proportion of 22 litres of K1-60 to 144 litres of < 13mm hand crushed aggregates.

Table – 4 Bitumen and aggregate application rates for the different seals**.**

S/No.	Sealing options	Bitumen Type/Rate (l/m^2)			Aggregate type/rate		Source
		Tack	Penetration 1	Penetration 2	Layer 1	Layer 2	
1.	Penetration Macadam	K1-60/0.8	K1-60/2.9	K1-60/1.0	20-37.5mm/22	5-13mm/11	Hand Crushers
2.	SSD Capped with Quarry Sand	K1-60/0.8	K1-60/1.3		10-14mm/10	<5mm/7	Blue Stone/ Hand crushers
3.	River Sand Seal	K1-60/1.5			<5mm/9		Malaba
4.	SSD (Control)	K1-60/0.7	K1-60/1.0		10-14mm/10		Bluestone
5.	Otta Seal	MC-3000/1.6			<13mm/16		Hand Crushers
6.	Premix	K1-60/2.0			5 – 13mm		Hand Crushers

5. COST ESTIMATES DEVELOPED

Cost estimates for the different sealing options have been compiled and summarised in a tabular form. However there is need to note the following regarding costs:

- To talk of Low cost sealing, we need to focus to both the initial capital costs of constructing the roads and as well as the life cycle costs of maintenance and programmed future rehabilitation costs. It is vital to look at both costs rather than focussing on the initial construction costs only.
- It is important to note that bitumen (binder) alone, contributes to approximately 72% of the total sealing costs. Therefore, in order to reduce sealing costs it is paramount that the bitumen costs are minimised.
- Low Cost sealing Technology (LCST) enables the use of locally available marginal materials as long as "WE DESIGN FOR AVAILABLE MATERIALS rather than Procuring MATERIALS FOR THE DESIGN"; and this is the way to go for Africa.
- By sealing district and rural roads we shall be preserving gravel placed on the road, thereby saving the environment (dust free and reduced additional extraction of the gravel) and hence sustainable rural road infrastructure.

Table - 4 Estimated Cost components for the different Sealing options per square metres

S/No.	Works	Bitumen Cost (UGX/m²)	Aggregate Cost /Gravel (UGX/m²)	Labour (UGX/m²)	Equipment (UGX/m²)	Total Cost (UGX/m²)
1.	Base Improvement Stabilised Gravel (120mm)		2,243 (0.92 $/m²)	1,467 (0.60$/m²)	1,910 (0.78$/m²)	**5,620 (2.30$/m²)**
2.	Penetration Macadam	15,980 (6.52 $/m²)	3,006 (1.23 $/m²)	1,018 (0.42 $/m²)	3,139 (1.28 $/m²)	**23,143 (9.45 $/m²)**
3.	Single Surface Dressing capped with River Sand	7,140 (2.92 $/m²)	1,296 (0.53 $/m²)	486 (0.20 $/m²)	2,242 (0.92 $/m²)	**11,164 (4.56 $/m²)**
4.	Quarry Sand Seal	5,100 (2.08 $/m²)	677 (0.28 $/m²)	319 (0.13 $m²)	1,568 (0.64 $/m²)	**7,664 (3.13 $/m²)**
5.	Single Surface Dressing	6,800 (2.78 $/m²)	1,030 (0.42 $/m²)	354 (0.14 $/m²)	1,879 (0.77 $/m²)	**10,063 (4.11 $/m²)**
6.	River Sand Seal	5,100 (2.08 $/m²)	270 (0.11 $/m²)	319 (0.13 $/m²)	1,568 (0.64 $/m²)	**7,257 (2.96 $/m²)**
7.	Otta Seal	6,400 (2.61 $/m²)	2,171 (0.89 $/m²)	385 (0.16 $/m²)	3,140 (1.28 $/m²)	**12,096 (4.94 $/m²)**
8.	Cold Mix (Premix) 25mm thick	14,960 (6.11 $/m²)	1,647 (0.67 $/m²)	394 (0.16 $/m²)	2,325 (0.95 $/m²)	**19,326 (7.89 $/m²)**

Table – 5 Percentage Contribution of materials, labour and Equipment to the Total cos**ts**

Item	Works	Bitumen Cost (%)	Aggregate Cost /Gravel (%)	Labour (%)	Equipment (%)	Total Cost (%)
1.	Base Improvement Stabilised Gravel (120mm)		40	26	34	100
2.	Penetration Macadam	70	13	4.5	12.5	100
3.	Single Surface Dressing capped with River Sand	64	12	4	20	100
4.	Quarry Sand Seal	67	9	4	20	100
5.	Single Surface Dressing	68	10	4	18	100
6.	River Sand Seal	70	4	5	21	100
7.	Otta Seal	53	18	3	26	100
8.	Cold Mix (Pre-mix) 25mm thick	77	8	3	12	100

5.1 Basic Cost data

The above derived costs were developed based on the following basic cost data being used at the training road and these include;

5.1.1 Materials employed in the sealing works:

- MC – 30 (200 litres) capacity drum: US$: 310.20 (UGX: 760,000/=)
- MC – 3000 (200 litres) capacity drums: US$ 327 (UGX: 800,000/=)
- Emulsion (K1-60), 200 l drum: US$ 278 (UGX: 680,000/=)
- Hand crushed aggregates 20/40mm US$ 108 (UGX: 265,000/=) inclusive of transport and loading costs for a 3.0m³ capacity Isuzu Forward tipper truck.
- Machined crushed 10/14mm US$ 163 (UGX: 400,000/=) inclusive of transportation and loading costs.
- Hand crushed aggregates 5/13 and < 13mm US$ 169 (UGX: 415,000/=) inclusive of transport and loading costs for a 3.0m³ capacity Isuzu Forward tipper truck.
- Natural sand from Malaba (60 Km away) US $ 200 (UGX; 490,000/=) purchased and transported using a 15 tonnes tipper truck (9.5m³)

5.1.2 Labour Costs:

- Unskilled labour working for 8 hours — US$ 3.15 (UGX: 7,700/=) inclusive of lunch.
- Skilled labour working for 8 hours — US$ 4.57 (UGX: 11,200/=) inclusive of lunch.
- Bitumen tank operator working for 8 hours — US$ 6.60 (UGX: 16,200/=) inclusive of lunch.

5.1.3 Equipment costs

- Bitumen Distributor (BD) tank of 1000 litres capacity, which was procured from India cost: US $ 12,500 (UGX: 31.0 million).
- Roller hire rates per day — US$ 82 (UGX: 200,000/=)
- Tractor/Trailer hire rate per day — US$ 102 (UGX: 250,000/=)
- Water Bowser hire rate per day — US$ 75 (UGX; 180,000/=)
- Water pump hire rate per day — US$ 12.25 (UGX: 30,000/=).

6. CHALLENGES

The challenges faced in carrying out the training of both the trainers at METLC, and the district technical team together with the contractors included;

- The high costs of bitumen compared to our counter parts in the neighbouring Kenya coupled with the long procurement process generally delayed the timely executions of field training activities.
- The fluctuating fuel prices significantly altered cost of transporting materials, especially gravel from Komuge borrow pit located 25 Km away from the training road.
- Impatience by "hand crushers" – they tended to sell to the first available buyer and could not stockpile for an order that has been made. This changed the planning where certain sealing options had to be postponed.
- The changing weather pattern. This affected mostly the sealing works. Most of the activities had to be done in the afternoon after a morning down pour.
- The availability of pneumatic rollers for hire within the country and importation of the same has similarly been challenging and this has affected to some extent the quality of the seals done.
- The bitumen distributor tank was frequently broken down despite it being new and the availability for hire to trained contractors during the time of implementation of the trial.

7. CONCLUSIONS

For sustainable district and rural roads, we need to embrace Low Cost Sealing technology, by training all the technical staff in both the private and public sector so that innovative knowledge is acquired by way of designing for locally available materials and applying correct construction procedures in line with specifications. This will boost road infrastructure and hence speed economic growth in developing African countries.

Generally the cost of the different seals varied with penetration macadam option being the most expensive at US $ 9.45/m², trickling down to cold pre – mix at US $ 7.89/m², Otta seal at US $ 4.95/m² and with sand seal being the cheapest at US $ 2.96/m². These cost variations are in line with both stability and durability of the options, hence an influence to design life of the seal. Therefore penetration macadam option appears to be the most durable with design life of 15 years as long as maintenance is kept at the required intervals while sand seal being the cheapest could last for approximately 5 years.

Cold pre – mix sealing option is most appropriate on steep slopes than any other options because of the advantage of mixing the binder with the aggregate chippings before placing and hence eliminating the need of the bitumen distributor tank, therefore avoiding the flow of bitumen down the slope.

On steep slopes of 6% and above we opted to reduce the tack coat sprays to 0.6 l/m² from 0.8 l/m² and increase on the penetration and fog sprays, more especially for the penetration macadam and Single Surface Dressing with capping sealing option. This was because of the risk associated with the rapid flow of K1 – 60 Emulsion binders on steep slopes.

Follow up on monitoring and evaluation of these different sealing options is being planned for under the department of construction standards and quality management. They are expected to evaluate the performance of these seals visa-vie annual traffic growth and development of distresses on the pavement surface.

Finally there is urgent need for adequate funding toward research so that home grown specifications are developed for attaining quality and correct construction methodologies for the different sealing options.

ACKNOWLEDGEMENTS

I would like to send my sincere gratitude to: **Kenneth Mukura** and **Andrew Otto** all of Transport Research Laboratory Limited **(TRL LTD) – UK**; for their tireless efforts in rolling out Low Cost Sealing Technology to the Technical staff of MELTC. My the Almighty God reward you abundantly.

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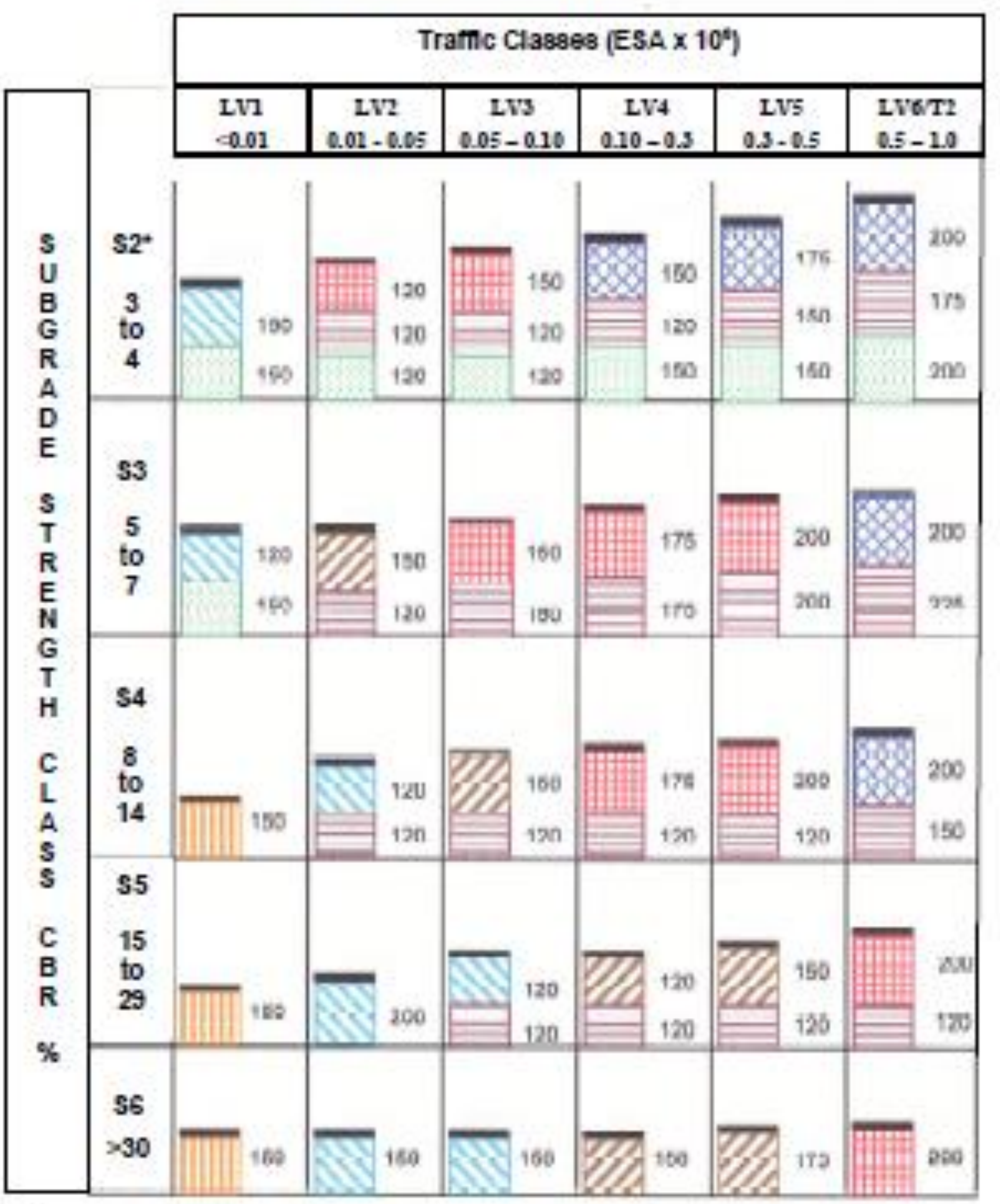
Adopted from; cost effective design of low volume roads.

Table 3.3-1: Pavement Catalogue (N < 4)



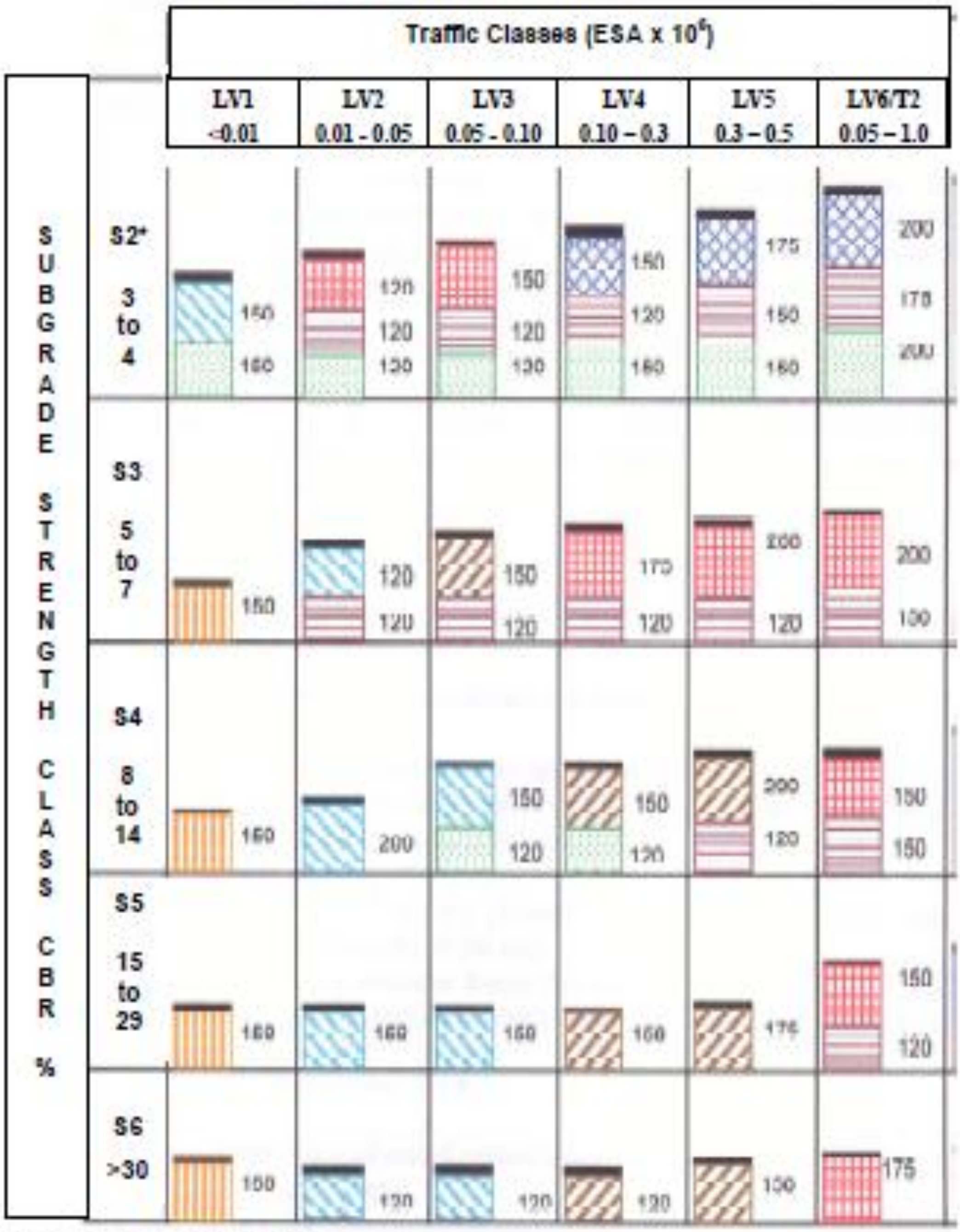
Note: * Non-expansive subgrade

Adopted from; cost effective design of low volume roads


Bituminous surfacing
Base, CBR 80
Base, CBR 65
Base, CBR 55
Base, CBR 45
Gravel wearing course quality
Sub-base, CBR 30
Selected subgrade fill, CBR 15

Adopted from; cost effective design of low volume roads

Table 3.3-2: Pavement Catalogue (N > 4)



Note: * Non-expansive subgrade

TRAINING PROGRAMME FOR IMPROVED PERFORMANCE OF SURFACE TREATMENTS IN ETHIOPIA

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Abstract

This paper explains the background and the implementation of the training courses in thin bituminous surfacings, in February 2012 near Addis Ababa, Ethiopia. These courses are aimed at improving the skills of practitioners in order to revive the practice in Ethiopia, particularly on rural roads where they are preferable to the more expensive asphalt concrete form of construction. The training courses have been delivered using classroom, laboratory and field demonstration methods. Evaluation questionnaires filled by the participants showed that they felt they had gained from the courses and it is recommended that the training courses are implemented again so that they can be further developed. They will eventually be carried out independently by the Alemgena Training and Testing Centre.

1 INTRODUCTION

Thin bituminous surfacings are a family of thin surfacings including surface dressings, Otta seals, cape seals and slurry seals, and are used throughout the world for surfacing newly built roads with light to medium traffic. They can also be used as a maintenance treatment for roads with heavy traffic. The chief purpose of thin bituminous surfacings is to give a waterproofing layer to the road surface and prevent the ingress of harmful moisture; they can also be used to seal hairline cracks. Thin bituminous surfacings can also provide a durable, skid-resistant and dust-free wearing surface to the road.

The use of thin bituminous surfacings is declining in Ethiopia due to a lack of industry confidence in their performance. Confidence has been reduced by factors such as inappropriate project specifications, bidding issues and inadequate quality control (AFCAP, 2010). Therefore, expensive asphalt concrete (AC) is often in use on rural roads where the relatively inexpensive thin bituminous surfacing could perform very well.

As part of the AFCAP activities of the Ethiopian Road Authority (ERA), training courses in thin bituminous surfacings were implemented in February 2012 at the Alemgena Training and Testing Centre (ATTC) near Addis Ababa, Ethiopia, in order to improve the skills of practitioners and to revive the use of thin bituminous surfacings. The training was delivered as three separate one week courses for each of the three training groups; Operators and Foremen; Technicians and Engineers. As part of this project, a Best Practice Manual on Thin Bituminous Surfacings was produced.

1.1 Purpose and Scope

The purpose of this paper is to explain the various aspects of the training programmes carried out at the ATTC and to describe observations made during implementation of the courses. The paper will also illustrate the successes of the training programmes as well as discussing aspects of the courses that can be improved.

The scope of this paper is to:

- Outline the course material on thin bituminous surfacings used in this project.
- Explain the training schedules for each of the three participant groups, as well as the various training methods used.
- Give an overview of the training participants who attended the courses, including their specific job roles, level of experience and previous education.
- Describe the participants' own evaluation of the courses.
- Describe the facilities available at the ATTC and their suitability for delivery of the courses.
- Outline the Best Practice Manual produced during this project.
- Give conclusions and recommendations for improvement of future training courses.

In order to address the above points this paper is divided into the following sections:

1. Introduction
2. Training Programmes
3. Training Participants
4. Alemgena Training and Testing Centre
5. Best Practice Manual for Thin Bituminous Surfacings
6. Conclusions

2 TRAINING PROGRAMMES

2.1 Course Material

There are three training courses

- Operators and Foremen
- Technicians and
- Engineers

Each is modular in format and contains a different set of modules. Table 1 shows the modules that are included in each of the three courses. Sections 2.1.1 to 2.1.13 give more detail on the content of each module.

Table 1 Modules included in each course

Module	TOPIC/CONTENT	Engineers	Technicians	Operators and Foremen
1	Registration of Participants	✓	✓	✓
2	Introduction to Thin Bituminous Surfacings	✓	✓	✓
3	Safety and First Aid	✓	✓	✓
4	Design of Thin Bituminous Surfacings	✓		
5	Materials	✓	✓	✓
6	Equipment	✓	✓	✓
7	Construction of Thin Bituminous Surfacings	✓	✓	✓
8	Quality Control and Supervision	✓	✓	
9	Laboratory Demonstration		✓	
10	On-site Practical Surface Dressing Demonstration	✓	✓	✓
11	In-yard Demonstration Operation and Maintenance of Equipment			✓
12	Fault Avoidance and Corrective Procedures			✓
13	Evaluation and Closing	✓	✓	✓

2.1.1 Module 1: Registration of Participants

Module 1 is an introduction to the course, Roughton International and the trainers. During this module, participants fill in a registration questionnaire giving their name in English and Amharic, registration number, registration date, job title, employers name, type of employer, language ability in English and Amharic, number of years experience in roadworks and number of years experience working for their current organization. This information is then used to form a clear picture of the participants, as shown further in Section 3.1. During the module, participants introduce themselves to the group and indicate their experience.

2.1.2 Module 2: Introduction to Thin Bituminous Surfacings

Module 2 provides an overview of the different types of thin bituminous surfacing that are covered in the course, their characteristics and appropriate uses including: surface dressing; Otta seals; Sand Seals; Slurry seals; and Cape Seals. The module is intended to illustrate how each type of surfacing is prepared and the different layers of binder and aggregate required for each. Videos are used in this module to illustrate the surface dressing operation, as this is the most common type of thin bituminous surfacing in Ethiopia.

2.1.3 Module 3: Safety and First Aid

When thin bituminous surfacings are being constructed with heated bitumens safety and first aid are particularly important. Module 3 covers safety and first aid with particular attention being given to the hazards of working with heated bitumen. Information is given on treatment of bitumen burns, and the method of extinguishing a bitumen fire. The correct use of Personal Protective Equipment (PPE) is highlighted as well as the importance of applying correct traffic safety measures. Videos produced by the Southern Africa Bitumen Association (Sabita) are used as training media in this module. Sabita videos on working safely with bitumen, the treatment of bitumen burns and fighting bitumen fires are used as aids in this module (Sabita).

2.1.4 Module 4: Design of Thin Bituminous Surfacings

Module 4 is only included on the Engineers course. It provides details of the design parameters and procedures required for designing surface treatments using Overseas Road Note (ORN) 3 (Transport Research Laboratory, 2000). ORN 3 gives comprehensive guidance on the design of surface dressings. Slurry seals, sands seals, Otta seals and enrichment sprays are introduced in ORN 3 but are not covered in great depth; these seals are covered in greater depth during the course than in ORN 3. Additional information has been obtained from TRH 3 produced by the CSIR in South Africa and Publication 93 of the Norwegian Road Research Laboratory which provides information on the development and design of Otta seals. Areas covered in Module 4 include: survey and data collection; traffic surveys; the preparation of the road surface before a surfacing is applied; the selection of suitable aggregate and chippings with appropriate properties; the selection of the material application rates; and the use of additives and modifiers.

2.1.5 Module 5: Materials

The different types of bituminous binder, aggregate and other materials used in thin bituminous surfacings are described in Module 5. The properties that bituminous binders must have in order to meet the specification for each type of binder are defined, including properties such as viscosity, ductility, penetration and flash point. Properties that aggregates must have, such as Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), Los Angeles Abrasion value (LAA), Polished Stone Value (PSV), soundness and affinity to bitumen, are also defined. The materials appropriate for use in different applications, including prime coats, surface dressing, slurry seals, cape seals, Otta seals, sand seals, fog sprays and enrichment sprays, are listed.

2.1.6 Module 6: Equipment

Module 6 describes the mechanical equipment used in thin bituminous surfacings, and includes bitumen distributors, chipping spreaders, rollers, bitumen heaters and brooms. The different types of distributor are described and discussed together with the different nozzles that are available for the spray bars. Calibration procedures for the distributor are included. The components of the various types of chipping spreader are described and their advantages and disadvantages discussed. Reasons are given for the preferred use of the Pneumatic Tyre Roller (PTR) over the steel wheeled roller, and the advantages of mechanical brooming techniques over manual methods.

2.1.7 Module 7: Construction of Thin Bituminous surfacings

The construction procedures and techniques used to construct the different thin bituminous surfacings are detailed in Module 7. In addition, a section on cold mix asphalt is also included. Procedures necessary for correcting pavement defects before a surfacing can be applied are covered as are the correct storage and spraying temperatures of bitumen and the correct method of heating them. Procedures for the application of aggregate are also provided.

2.1.8 Module 8: Quality Control and Supervision

Module 8 describes the specifications that materials must meet and the laboratory tests used to control their quality. Laboratory tests for aggregate include testing Flakiness Index, Average Least Dimension (ALD), LAA, PSV, adhesion to bitumen, strength, soundness and grading methods. Laboratory tests for bitumen include testing for viscosity of cut backs, emulsions and penetration values for penetration grade bitumens. A Sabita video on bitumen testing is also shown in this module (Sabita).

2.1.9 Module 9: Laboratory Session

This module, included on the Technicians course only, is carried out in the laboratory and involves practical demonstration of a number of tests mentioned in Module 5 and 8. Bitumen testing was carried out at the ATTC with demonstrations that included: flash point test; ring and ball test; penetration; and ductility tests. Testing for aggregate was carried out at the ATTC and included the LAA test, grading, AIV and ACV tests and the PSV test.

2.1.10 Module 10: On-site Practical Demonstration

The on-site practical demonstration is carried out at a location outside the ATTC, and involves practical demonstration of the construction of a surface dressing. It is a good opportunity to demonstrate the preparation required, the procedure used in the construction, the problems that can occur and methods for correcting these problems.

2.1.11 Module 11: In-yard Practical Demonstration

A further day of practical training for the Operators and Foremen group is carried out in the Alemgena yard. It involves demonstration of how to operate, maintain and calibrate the mechanical equipment, particularly the asphalt distributor and chipping spreader. The transverse and longitudinal distribution of the binder spray is checked in the ATTC yard, as well as the evenness of the chipping distribution. The equipment provided for the practical demonstrations is supplied by both the ATTC and a unit of the Ethiopian Road Construction Corporation (ERCC), located adjacent to the ATTC.

2.1.12 Module 12: Fault Avoidance and Corrective Procedures

The Operators and Foremen group meet in this module to discuss how to avoid and correct faults in a thin bituminous surfacing. Common faults include bleeding, stripping and uneven distribution of aggregate. Participants have the opportunity to discuss questions that are frequently asked and to discuss problems that they may have on their current projects.

2.1.13 Module 13: Course Evaluation

This is an overview and revision session. The trainees also complete a questionnaire that captures their views on the course and their suggestions for its improvement. These suggestions may include comments on the practical relevance to their occupation, the various training methods used, the training modules, facilities, administration and any other matter. Most training participants in February 2012 stated that they are pleased with the courses, and suggested that they should be longer and should involve more practical work.

2.2 Training Schedules

Table 2, Table 3 and Table 4 show the planned timetables for each training course in February 2012. Some adjustments were necessary when difficulties were encountered, particularly the preparations for the on site demonstration. For example, due to problems with the bitumen distributor on Wednesday 15 February, the Operators and Foremen completed worksheets instead of taking part in the planned practical demonstration within the ATTC. These worksheets are described in Section 2.3.6. The practical demonstration was then delivered on Friday 17 February, when the problems with the distributor had been corrected.

Table 2 Training programme for Operators and Foremen Course

Start Times	**Monday 13.02.12**	**Tuesday 14.02.12**	**Wednesday In Yard 15.02.12**	**Thursday On Site 16.02.12**	**Friday 17.02.12**
09.00	Module 1	Module 5	Module 11	Module 10	Worksheet 2
10.30	Break	Break	Break	Break	Break
11.00	Module 2	Module 6	Module 11	Module 10	Worksheet 3
12.30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
13.30	Module 3	Module 7	Module 11	Module 10	Module 13
15.00	Break	Break	Break	Break	Break
15.30	Worksheet 1	Preparation for Site Visit	Module 12	Module 10	Closing

Table 3 Training Programme for Technicians

Start Times	**Monday 20.02.12**	**Tuesday 21.02.12**	**Wednesday Laboratory 22.02.12**	**Thursday Site Visit 23.02.12**	**Friday 24.02.12**
09.00	Module 1	Module 5	Module 9	Module 10	Worksheet 2
10.30	Break	Break	Break	Break	Break
11.00	Module 2	Module 6	Module 9	Module 10	Worksheet 3
12.30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
13.30	Module 3	Module 7	Module 9	Module 10	Module 13
15.00	Break	Break	Break	Break	Break
15.30	Worksheet 1	Module 8	Module 9	Module 10	Closing

Table 4 Training programme for Engineers

Start Times	**Monday 27.02.12**	**Tuesday 28.02.12**	**Wednesday 29.03.12**	**Thursday Site Visit 01.03.12**	**Friday 02.03.12**
09.00	Module 1	Module 4	Module 5	Module 10	Worksheet 2
10.30	Break	Break	Break	Break	Break
11.00	Module 2	Module 4	Module 6	Module 10	Worksheet 3
12.30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
13.30	Module 3	Module 4	Module 7	Module 10	Module 13
15.00	Break	Break	Break	Break	Break
15.30	Worksheet 1	Module 4	Module 8	Module 10	Closing

2.3 Training Methods

2.3.1 General

A combination of theoretical classroom training and practical instruction in the field is believed to be the most effective method of transferring skills. Theoretical training is particularly important for Engineers, while Operators and Foremen obtain more benefit from practical work.

2.3.2 Classroom Training

Modules 1, 2, 3, 4, 5, 6, 7, 8 and 13 are designed to be delivered in the classroom. Trainers deliver PowerPoint presentations to the participants, who are provided with handout booklets containing the slides. The booklets are organised with space next to the slides in which the participants can make notes as they follow the presentations. Participants are also given additional smaller booklets containing general information on the courses, as well as a CD containing soft copies of all handouts and additional resources such as videos, manuals, specifications and papers. Participants are encouraged to ask questions throughout the classroom sessions, and many became actively involved.

2.3.3 Laboratory Training

The laboratory demonstrations carried out in Module 9 are particularly useful for the Technicians whose day to day job largely involves such testing. These demonstrations are far more effective if the participants are allowed to carry out the testing themselves under guidance, but this is only possible with small numbers of participants. Some of the participants in the Technicians' group in February 2012 have considerable experience in laboratory testing and were able to assist the instructors. The two figures below show the laboratory training carried out in February 2012.

Figure 1 Bitumen penetration test

Figure 2 Aggregate strength tests

2.3.4 On-site Training

The on-site demonstrations are vital for all three participant groups. The Operators and Foremen have practical occupations and Engineers are responsible for supervising practical operations. Technicians can also be involved in the site testing, to control construction. However, the practical demonstrations are not as effective with large numbers of participants, unless more equipment and trainers can be made available. Other problems encountered in the practical demonstrations included the bitumen pump malfunctioning on the new distributor, problems with the quality of the materials and problems with the strength of the roadbase. Demonstrating these problems and how to solve them proved to be useful to the participants, as they are common problems which all participants must recognise in their occupations. The two figures below show the Technicians practical demonstration in February 2012.

Figure 3 Bitumen spraying

Figure 4 Chipping spreading

2.3.5 Videos

Videos proved to be a highly effective learning medium and were a preferred training method for the participants. Many requested copies of the videos for internal training uses within their organizations.

2.3.6 Worksheets

Three worksheets were completed in order to allow the participants to test what they have learnt in the modules, and to reinforce their learning. The contents of the worksheets are as follows:

- Worksheet 1 Introduction to Thin Bituminous Surfacings.

  This worksheet is based on the content of Module 2 and requests participants to produce labelled diagrams showing the layers in different types of thin bituminous surfacing. Participants are also requested to answer basic questions on the purposes of thin bituminous surfacings and their advantages.

- Worksheet 2 Materials and Equipment.

  This worksheet requires participants to answer questions on the appropriate choice of materials and specifications that they must meet. Participants are also asked questions on different types of equipment and their appropriate use.

- Worksheet 3 Construction of Thin Bituminous Surfacings.

  In this worksheet participants are asked questions on possible pavement defects that must be corrected before applying a surfacing. Participants then answer questions on bitumen spraying temperatures, the procedure of applying a prime coat and the procedures involved in constructing a double surface dressing, slurry seal and Otta seal.

These worksheets were particularly successful with the Engineers and Technicians. Some of the Operators and Foremen struggled due to language difficulties; around half of the group did not speak English. However verbal translation into Amharic was provided by the local support engineer working with the team, following which the participants performed well.

2.4 Training Personnel

The training staff consisted of the project director, two key experts and two support staff. The first key expert, Dr Harold Bofinger, has over forty years experience in international road projects and is a specialist in pavement and materials engineering, as well as a specialist on thin bituminous surfacings. He has contributed to the TRL Overseas Road Notes, the South African Pavement

Design Manual and has produced numerous papers. He also has had experience as a lecturer at the University of Queensland in Australia.
The second key expert, Jon Hongve, is also a specialist in thin bituminous surfacings, particularly Otta seals. He is also a specialist in low cost sealed roads. His extensive experience includes field operations, project management, training contractors, consultants and government staff.

The support staff included a young engineer from the UK as well as a local engineer with knowledge and extensive experience of the Ethiopian roads industry. The local engineer also provided translation into Amharic when it was required by the participants.

3 TRAINING PARTICIPANTS

The participants came from a number of organisations, working on projects across Ethiopia. Their experience varied from junior level to some with thirty to forty years experience. There was also a wide variation in the specific job roles of the participants in the Technicians and Engineers groups (Roughton International, 2012).

3.1 Registration Questionnaires

The participants completed a questionnaire on registration in order to give the training staff a detailed picture of job roles, experience levels and language ability.

3.1.1 Operators and Foremen

Seventy-four participants attended the Operators and Foremen course. Table 5 to Table 7 detail the registration statistics for the participants. The stated employers included the Ethiopian Road Construction Corporation (ERCC), Sunshine Construction, Sur Construction, Emgoco, Defence Construction Enterprise, SATGON Construction, Gemshu Beyene Construction and Fasil Construction.

Table 5 Participant job titles

Job Title	Proportion of Participants, %
Foreman	34
Operator	61
Foreman and Operator	3
Laboratory Technician	3

Table 6 Participant English language ability

English Language Ability, %					
0	**1**	**2**	**3**	**4**	**5**
26	11	14	24	16	9

Table 7 Experience in roadworks

Years spent working in roadworks, %							
0	**1**	**2**	**3**	**4**	**5**	**6**	**7+**
0	1	7	0	5	8	9	69

3.1.2 Technicians

Forty-eight participants attended the Technicians course. Table 8 to Table 10 detail the registration statistics for the participants in the Technicians group. The stated employers included the Ethiopian Road Construction Corporation (ERCC), ERA, CORE Consulting Engineers, Dana, Defence Construction Enterprise, Gemshu Beyea Construction PLC, Rama Consult PLC, CDSCO, Satcon, Keang Nam, Eng Zewdie Eskinder & Co. PLC, Zewdie Engineering, Gemshu Beyene Construction and Fasil Construction.

Table 8 Participant job titles

Job Title	Proportion of Participants, %
Laboratory Technician	38
Material Inspector	17
Works Inspector	10
Civil Engineer	2
Resident Engineer	2
Associate Engineer	4
Surveyor	21
Foreman	2
Operator	4

Table 9 Participant English language ability

English Language Ability, %					
0	**1**	**2**	**3**	**4**	**5**
8	0	4	19	42	27

Table 10 Experience in roadworks

Years spent working in roadworks, %							
0	**1**	**2**	**3**	**4**	**5**	**6**	**7+**
0	4	2	8	10	6	6	63

3.1.3 Engineers

Ninety-eight participants attended the Engineers course. Table 11 to Table 13 detail the registration statistics for the participants in the Engineers group. Their employers included the Ethiopian Road Construction Corporation (ERCC), ERA, Eng Zewdie Eskinder & Co PLC, ID CON Consulting Engineers, SABA Engineering PLC, Sur Construction PLC, Yencomad Construction PLC, China Highway Group, Defence Construction Enterprise, ELDA Engineering Consultants, Sunshine Construction, CORE Consulting Engineers, Net Consult Consulting Engineers and Architects, CDSCO, Alemgena Training Centre, Gemshu Beyene Construction, BRD Construction PLC, Godwana Engineering, BS Consulting Engineers and Architects and RAMA Consult PLC.

Table 11 Participant job titles

Job Title	Proportion of Participants, %
Junior Engineer	18
Project Engineer	13
Material Engineer	11
Site Engineer	9
Resident Engineer	7
Office Engineer	5
Civil Engineer	5
Construction Engineer	4
Designer	4
Surveyor	4
Trainer	4
Pavement Engineer	3
Planning Engineer	3
General Manager	3
Cost Engineer	1
Senior Engineer	1
Supervisor	1
Foreman	1
Researcher	1
Material Inspector	1
Works Inspector	1
Trainer	1

Table 12 Participant English language ability

English Language Ability, %					
0	**1**	**2**	**3**	**4**	**5**
0	0	0	4	50	46

Table 13 Experience in roadworks

Years spent working in roadworks, %							
0	**1**	**2**	**3**	**4**	**5**	**6**	**7+**
13	16	27	11	1	4	8	20

3.2 Evaluation Questionnaires

Evaluation questionnaires were filled by the participants at the end of each course, so that they could rate the different aspects and give their opinions. The feedback given by the participants was positive and they generally stated that they feel the courses should be implemented again and should be extended with more practical work involved.

3.2.1 Operators and Foremen

Table 14 and Table 15 detail how the participants in the Operators and Foremen group rated the course with 5 being the highest score and 1 the lowest.

Table 14 Participant rating of the quality of each training module

Module	Rating from 1 to 5, %					
	1	**2**	**3**	**4**	**5**	**No Response**
1 Registration	0	6	9	17	67	1
2 Introduction	1	0	6	31	59	3
3 Safety & First Aid	1	0	3	17	77	1
5 Materials	0	1	13	24	59	3
6 Equipment	0	3	13	26	54	4
7 Construction	1	1	14	20	56	7
10 Surface Dressing Demonstration	0	1	9	23	37	30
11 Equipment Operation and Maintenance	3	1	7	19	40	30
12 Fault Avoidance	1	4	11	29	33	21

Table 15 Facilities and Administration

Module	Rating from 1 to 5, %					
	1	**2**	**3**	**4**	**5**	**No Response**
Training Rooms	0	4	11	20	60	4
Catering	0	0	10	14	70	6
Accommodation	4	4	19	36	33	4
Other (cleaning)	3	0	13	23	23	40
Joining Instructions	0	6	7	24	61	1
Timeliness	0	6	9	27	59	0
Adequacy	0	3	20	19	56	3
Helpfulness of Staff	0	4	14	19	61	1

3.2.2 Technicians

Table 16 and Table 17 detail how the participants in the Technicians group rated the course, with 5 being the highest score and 1 the lowest.

Table 16 Participant rating of the quality of each training module

Module	Rating from 1 to 5, %					
	1	2	3	4	5	No Response
1 Registration	0	0	11	14	64	11
2 Introduction	0	0	5	23	66	7
3 Safety & First Aid	2	2	23	25	41	7
5 Materials	0	2	9	25	57	7
6 Equipment	0	0	16	25	50	9
7 Construction	0	5	16	34	36	9
8 Supervision and Quality Control	0	0	14	41	34	11
9 Laboratory Session	0	2	11	34	39	13
10 Surface Dressing Demonstration	0	0	7	30	55	9

Table 17 Facilities and Administration

Module	Rating from 1 to 5, %					
	1	2	3	4	5	No Response
Training Rooms	0	0	7	26	60	7
Catering	0	0	12	28	49	12
Accommodation	5	2	14	44	28	7
Other (transport)	2	0	7	12	12	67
Joining Instructions	5	0	16	30	47	2
Timeliness	2	0	5	53	40	0
Adequacy	0	5	14	37	42	2
Helpfulness of Staff	2	2	2	30	63	0

3.2.3 Engineers

Table 18 and Table 19 detail how the participants in the Engineers group rated the course, with 5 being the highest score and 1 the lowest.

Table 18 Participant rating of the quality of each training module

Module	Rating from 1 to 5, %					
	1	2	3	4	5	No Response
1 Registration	0	2	14	22	57	6
2 Introduction	0	0	6	27	63	4
3 Safety & First Aid	0	0	2	25	65	8
4 Design	0	0	6	24	67	4
5 Materials	0	0	2	25	69	4
6 Equipment	2	0	6	27	61	4
7 Construction	0	2	12	25	55	6
8 Supervision and Quality Control	0	0	12	41	39	8
10 Surface Dressing Demonstration	8	6	20	25	22	20

Table 19 Facilities and Administration

Module	Rating from 1 to 5, %					
	1	2	3	4	5	No Response / not used
Training Rooms	2	6	18	31	37	6
Catering	0	2	16	37	31	14
Accommodation	2	14	12	18	24	30
Other	2	0	2	6	4	86
Joining Instructions	0	0	6	57	31	6
Timeliness	0	0	4	43	47	6
Adequacy	0	0	14	47	35	4
Helpfulness of Staff	0	2	4	35	53	6

4 ALEMGENA TRAINING AND TESTING CENTRE

4.1 Facilities

A lecture theatre is provided at the ATTC with a capacity of approximately 100 participants. It is equipped with audio and visual equipment. There are also other smaller classrooms with a capacity of approximately 40. The laboratories at the ATTC are in good condition and are well equipped for carrying out various tests with bitumen and aggregates.

The accommodation available at the ATTC is generally found to be satisfactory by training participants, although with a capacity of approximately 200 there is not always sufficient space for all trainees to be accommodated. The quality of the catering provided at the ATTC is very good, with lunch, morning refreshments and afternoon refreshments provided daily.

4.2 Equipment

In February 2012, the two bitumen distributors available at the ATTC were in disrepair and non-functional. The bitumen distributor used in the demonstrations was borrowed from the ERA Emergency Unit. It had not been used prior to the training project and operators from the ATTC and adjacent Ethiopian Roads Construction Corporation (ERCC) were being trained to use it. During the implementation of the training, the operation and maintenance of the distributor were demonstrated to both ATTC operators and those from the ERCC, who was the contractor appointed to carry out the practical demonstration work.

The ATTC is equipped with a good quality self-propelled chipping spreader, manufactured by Phoenix Engineering in the UK. Additional good quality equipment at the Centre includes water bowsers, front end loaders, trucks, pneumatic tyred rollers (PTRs) and air compressors, which are in good working order. Much of the available equipment has been donated to ERA by the Japan International Co-operation Agency (JICA).

4.3 Staff

The ATTC is staffed with trainers, engineers, laboratory technicians, management, administrative assistants and other support staff. Whilst carrying out the training during February 2012, these staff assisted with the logistical aspects of the training. Laboratory technicians from the Centre delivered testing demonstrations during the Technicians course. Some ATTC staff attended the Engineers course as participants.

5 BEST PRACTICE MANUAL FOR THIN BITUMINOUS SURFACINGS

This Best Practice Manual is primarily based on Overseas Road Note 3, the South African TRH 3 and the Norwegian Road Research Laboratory Publication 93, and draws on the experience of the key experts assigned to the project. It is important that the Manual complies with the current Ethiopian specification. The purpose of the Manual is to provide guidance to practitioners on design, quality control and workmanship. The areas included are:

1. Introduction to the practice of thin bituminous surfacings.
2. Selection of an appropriate thin bituminous surfacing.
3. Field Investigations and methods of gathering design data.
4. Design of thin bituminous surfacings.
5. Pricing, including construction costs and other long term costs that should be considered.
6. Construction of thin bituminous surfacings, including procedures and safety measures.
7. Quality control during construction. Information on laboratory tests included as appendix.
8. Maintenance, including repair of structural defects.

As of May 2012, the Best Practice Manual is under review.

6 CONCLUSIONS

6.1 Successes

The ratings given by the participants, summarised in Section 3.2, illustrate that the participants generally were happy with the course and felt that they learnt from it. Particularly in the Operators and Foremen and Technicians courses, participants interacted well with the trainers, and many engaged enthusiastically in group discussions. The CDs and handout booklets were welcomed by the participants, in order to follow the classroom sessions and to take notes.

The long term success of the courses should be measured by monitoring future projects across Ethiopia. If thin bituminous surfacings begin to be used instead of asphalt concrete on roads where they can give good service, the long term objective of the courses will be achieved. The success of the courses will also be shown through the quality of thin bituminous surfacings on future projects.

6.2 Areas for Improvement

Improvements are required in the practical on-site demonstrations. There were technical difficulties with the preparation of the base, which were worsened by abnormal rainfall for the season. These problems can be avoided if the practical demonstrations are carried out on a road with no existing structural defects that require repair before a surfacing can be applied. There were also difficulties with the bitumen pump on the distributor. More time should be spent preparing for the training to avoid such incidents.

The effectiveness of the practical demonstrations would be greatly increased if the number of participants is reduced to approximately twenty. Not all participants can actively take part if the numbers are approaching one hundred.

6.3 Implementation of Future Courses

It is recommended that future courses for Operators and Foremen allocate more time for practical demonstrations. Operators in particular should work with the equipment, in order to reinforce their understanding of good practice. The Operators and Foremen course should run for two weeks, with three days of classroom training followed by seven days of practical training using the equipment.

Technicians' courses in the future should be longer and contain more laboratory work, with participants carrying out the tests themselves. This recommendation is based on observations, as well as the evaluation forms completed by participants. Due to the variation in the experience of the Technicians, a future course should ideally incorporate a balance of classroom, laboratory and practical training.

It would be beneficial for the Engineers course to also be extended, including theoretical training in the classroom with lectures, worksheets, design examples and videos, followed by practical training with the equipment so that the participants are better placed to supervise operators, foremen and other personnel on site. The course should also include a session carrying out laboratory testing so that awareness of quality control is enhanced.

It is recommended that specialist safety training is integrated into the training programmes at the ATTC. This should involve site safety, traffic control, site barriers and road signs. The safety training should include the correct use of PPE, working safely with bitumen and the treatment of bitumen burns. There is a medical clinic at the ATTC with staff who can assist with first aid demonstrations.

Once future implementations of the course have been carried out and the course has been fully integrated into existing training programmes at the ATTC, monitoring of the quality of thin bituminous surfacings on subsequent projects should be carried out. This can be implemented in the form of site visits to projects on which the training participants are working, or the projects on which their organizations are working. This will give some indication of the success of the courses, and will inform further training needs.

6.4 Accreditation of the Courses

The future intention is that the courses will be adopted by the ATTC, and subsequently accredited under the TVET system. The system of accreditation operated by TVET is based on quality indicators defined by physical assets and human resources. There are also new quality indicators that focus on internal quality management processes within institutions. These include the capacity for labour market analysis, curriculum development, personnel management, human resource development strategies and financial management (Ministry of Education, 2008).

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KEY WORDS

Thin bituminous surfacings, training, design, construction, quality control.

INCREASING RURAL WOMEN'S ACCESS TO MATERNAL CARE THROUGH EMERGENCY TRANSPORT SCHEME IN NORTHERN NIGERIA

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Abstract

The linkage between effective transport system and access to social services such as health care and education in rural Africa is often overlooked. Attention to this linkage becomes necessary if Africa is to meet MDG 4 and 5 of reducing maternal and infant mortality. The aim of this paper is to present the experience of Partnership for Reviving Routine Immunisation in Northern Nigeria and Maternal, Newborn and Child Health (PRRINN-MNCH) in working with a private sector to implement an emergency transport scheme in rural areas, transporting women in labour and with maternal complications to hospital thereby increasing access of women to health care.

1. INTRODUCTION

PRRINN-MNCH is a UKaid and Norwegian government funded programme established in 2006 and MNCH component integrated in 2008 to reduce maternal and child death in Northern Nigeria. In a baseline survey conducted in 2009 physical access in terms of long distance to health facilities and an irregular and unreliable transport system was found to be a key barrier to access maternal and child health (MCH) care. This is because a mobile hospital ambulance service is largely absent in the rural areas. Consequently, in the case of maternal complications, people have to rely exclusively on commercial services for transport to hospitals, often at an exorbitant rate and when it is too late. Unfortunately, in many cases, by the time transport is secured and the money raised to pay the fare, death has occurred (which is referred to as the second level delay). In order to address this type 2 delay, PRRINN-MNCH collaborated with communities, state and local governments and National Union of Road Transport Workers (NURTW) to set up a system called the Emergency Transport Scheme (ETS) to transport maternal and newborn emergencies to health centres. What is the nature of ETS? How is the system managed? How effective is ETS in reducing delay for women to access emergency obstetric care thereby saving women lives? What are the challenges?

The paper is broadly divided into two sections. The first section of the paper provides health and physical background information about the programme areas in order to provide the context within which the programme operates. Thereafter, information on ETS is provided in the second section which is subdivided into three areas; nature of ETS, effectiveness of ETS and the challenges emerging from its implementation. Information used in this paper is drawn from different sources; briefs on community engagement and emergency transport scheme, 2009 baseline barrier assessment, analysis of Community Engagement monitoring system, knowledge, attitude and practice (KAP) surveys and ETS review.

2. BACKGROUND INFORMATION ON PRRINN-MNCH STATES

Maternal health outcomes in Nigeria are among the worst in the world, with Nigeria second only to India in the number of maternal deaths (UNICEF 2008; WHO, 2011). An MDG report in 2006 indicated that the Maternal Mortality Rate (MMR) worsened from 704 to 800/100,000 live births between 1999 and 2004. Similarly, about two million of the 27 million Nigerian women of reproductive age do not survive pregnancy, childbirth or the immediate six weeks after delivery. The situation seems not to have improved as a recent report indicated that a woman in Nigeria has a 1-in-18 risk of dying in childbirth or from pregnancy-related causes, worse than the 1-in-22 risk for women throughout sub-Saharan Africa (Centre for Reproductive Rights and Women Advocates Research and Documentation Centre 2008). The same report indicated that Nigeria has the world's second-highest number of maternal deaths with a ratio of 1,100 per 100,000 live births. The situation is worse for maternal morbidity that indicates for every maternal death, 20 other women suffer serious and often permanent pregnancy-related complications and health problems.

In Northern Nigeria, where the PRRINN-MNCH programme is implemented, the MMR is estimated to be appreciably higher than the national average (Federal Ministry of Health of Nigeria, et al. 2009) with recent estimates for the north being over 1,000, compared to estimates for the southern region below 300 (CRR and WARDC, 2008). In northern Nigeria, high levels of mortality reflect low levels of antenatal care utilization (31% and 43% in the North West and North East regions, respectively) and deliveries with a skilled birth attendant (9% and 13% in the North West and North East regions, respectively). (National Population Commission [Nigeria] and ICF Macro 2009).

In order to improve these statistics PRRINN-MNCH is being implemented in four states; Jigawa, Katsina, Zamfara and Yobe of North east and North west zones of Nigeria, which have the highest burden of maternal mortality. At the inception stage of the programme, studies were conducted to find out why women are not utilising maternal and child care services, particularly, emergency obstetric care. Three broad factors where identified.

(1) lack of adequate knowledge and power to take decision,

(2) financial barriers

(3) physical access barrier.

However, since the concern of this paper is on ETS, the next presentation will focus on physical barriers only.

2.1 Physical Access Barriers to Maternal Health Services

Long distances to health facilities were cited as major barrier to utilisation of both ANC and emergency maternal health services in majority of the communities where the 2009 barrier assessment were conducted. The fact that clients must bypass poorly functioning Primary Health Care (PHC) facilities in favour of secondary health care facilities, or in some cases, tertiary facilities, significantly increases distances travelled. Poor terrain adds to the physical access challenges. Some communities are cut off seasonally when rivers swell after heavy rain, while others are linked to roads that become difficult or impossible to negotiate during the rainy season. This can drastically reduce transport options. Testimonies from community members in 2009 in boxes 1 and 2 below highlight some of the physical access barriers that prevent timely use of maternal health services.

Box 1: Community Concerns About Physical Access Barriers

* "It takes two hours to trek to Musawa General Hospital for ANC. Sometimes the local councillor passes women in his car and picks them up. It is not unusual to see women who are eight months pregnant trekking to the Hospital – two hours there and two hours back."
* "It is a three hour ox and cart ride from this community [Zabakau] to Kaita Comprehensive Health Centre. When you get there you may be referred to the General Hospital. It is not possible to put a woman with a complication on the back of a motorcycle, there is no single private car in the community, and commercial vehicles only come here once a week on market day. This place is hard to reach…. people only come here when necessary."
* "I would like my wife to go for ANC but I cannot afford the N250 that I need to pay for transport for each session. When the local health facility is upgraded and can provide ANC services, all women will go."
* "I suffered from swollen body and fitting. It took about three hours before we decided to go to the health facility. The journey from home to Dan Musa Hospital took us two hours. When we got there we were referred to Dutsin Ma General Hospital. The journey to Dutsin Ma took us another two hours. In total we spent N3,200 on transport."

Box 2: Difficult Terrain Can Cause Significant Delays

"To get to Dutsin Ma General Hospital from this community we need to use a canoe to cross a large dam. We walk to the dam, then pay N100 to cross in a canoe. We then have to take a taxi to the Hospital. This usually costs us N80, but now that it is harvest season the price has gone up to N100. The other option is to go to Musawa General Hospital, in which case it is necessary to follow another road. However, at certain times of the year you have to wait for the river to stop flowing before you can cross. If it is urgent to cross, you have to carry a woman on your shoulders or back. If the river is fast-flowing there are hefty men who help people cross the river. They charge N100-500 depending on the depth of water. We have had three instances in 2007 and 2008 when people were swept away. Once you have crossed the river, you need to hire a car or motorbike. From the river to the main road, you will pay N100-200, depending on the driver. From the main road to the hospital the costs depend on the driver. They may charge N100-200. Some charge from N500-1000."

Ward Head, Raddawa Village, Matazu LGA

"My wife had a terrible experience during delivery. It was during the rainy season at home. She started labour at 11.30am. At 1am the hand of the baby came out. By this time it was raining hard. I was alerted about the situation, but was confused about what to do. I knew very well that the streams in his village could not be crossed, the dirt road was muddy, and there was no single car in the village to take her to the facility. I went to the local councillors house for advice. The councillor was a health worker. When we reached my wife, he gave her some injections, put her on a drip, and repositioned the baby. The baby was born at 5am…. I was very confused because there was no possibility of taking my wife to Musawa Hospital, which is about 50 kms away. The situation reminded me of my late mother who died during labour on the way to the health facility at Dutsin Ma when I was very young.

Male community member, Rinjin Idi, Matazu LGA

Extracted from Report of a Rapid Demand Side Assessment of Barriers to Use of MNCH Services and Care, Katsina State, Cathy Green, Fatima Abdulkadir, and Umar Farouk Wada, January 2009

From the foregoing baseline findings in 2009 it became obvious that *a* transport strategy that addresses the following issues needs to be designed and implemented. Consequently ETS, earlier developed under DFID funded PATHS programme in Jigawa and Kano states, was adapted and is currently implemented in 773 villages: The key concerns identified in the baseline to transport maternal emergencies were:

- Delays associated with flagging down a commercial car driver in some locations
- The reticence of some commercial car drivers to take a woman with a complication to a health facility (concerns about blood, or the woman dying on route etc)
- The high charges levied by some commercial drivers once they recognise that a family has no choice but to use them
- The lack of transport options at night
- Concerns about the lack of security associated with travelling at night

3. EMERGENCY TRANSPORT SCHEME

ETS is a transport arrangement system that provides timely, affordable and safe transport for women during maternal emergencies using locally available modes of transport. It is implemented by the National Union of Road and Transport Workers (NURTW) and the appropriate state government ministry/agency and facilitated by PRRINN-MNCH. Recently, similar ETS have come on board and are implemented by other development partners such as Gates Foundation/Society for Family Health and USAID/Maternal child health integrated programme. PRRINN in collaboration with NURTW are implementing the following forms of ETS:

1. The major form of ETS is integrated into the PRRINN-MNCH community engagement approach. In order to address barriers identified at the inception of MNCH, 'Three Delays' Model, developed by Columbia University School of Public Health, was adopted. The model identifies barriers to timely utilisation of emergency maternal care as follows:

   a. *Delay in deciding to seek care*
   Factors in the household and community that delay the decision to seek care

   b. *Delay in reaching appropriate care*
   The logistical factors that delay a woman in getting to a health facility

   c. *Delay in receiving appropriate care at facility level*
   The promptness with which a woman is seen and treated once she reaches a health facility

ETS as an intervention that addresses the second delay is not a stand-alone intervention; it is part of other interventions such as emergency maternal fund and blood donor groups that address the first delay in deciding to seek care. Other interventions put in place under the Community Engagement (CE) approach are knowledge in maternal danger signs using paperless approach of body as tool and husband standing permission for wives to be transported to hospital. These interventions operate in an organic fashion. For instance, with increased knowledge on maternal danger signs and standing permission from husband, community or a family will call upon an ETS driver to transport a woman to hospital without delay. The delay is further shortened by the existence of emergency maternal fund that is used to pay the driver.

2. Another form of ETS is one not linked to the community system. This involves mobilising and sensitising NURTW drivers in the motor park to provide emergency transport support to any woman in labour or with complication anywhere and not necessarily in the CE sites. PRRINN does not take records of this form of ETS.

3. In addition to transporting women from the community to a nearest health facility, ETS drivers are also involved in transporting women with complication from lower facilities to referral hospitals when the lower facility cannot handle the case.

4. In order to attend to the need of semi-urban areas, rapid awareness raising (RAR) sessions are conducted to raise the awareness of people on safe motherhood. During such sessions, NURTW officer's telephone numbers are provided to the general public to call upon a driver for transport at time of labour. This is essential considering the fact that such towns often lack taxi services to call and the hospital mobile ambulance services are not available. PRRINN does not record this.

3.1 ETS model

The first step in the establishment of an ETS in a community is the selection of the drivers. Drivers must be resident in the community or neighbouring community and must be nominated by the community. Every commercial driver is a member of NURTW and validated by the Union during the selection process. The community nomination and NURTW validation are important process because communities are expected to nominate drivers they trust and have tested. Four drivers serve a community and its settlement. Once selection is confirmed, the drivers are trained by NURTW trainers on the need to reduce delay, recognition of maternal danger signs, how to carry and treat women in labour etc. Thereafter, the ETS drivers are introduced to their communities during a community forum, introduced to catchment health facility staff, security apparatus and the local government authority demand creation team.

Once the process is completed, the ETS driver is given a logbook to record women transported to facilities. Drivers are paid cost of fuel only which in most cases, is drawn from maternal emergency funds. Some husbands are expected to refund the money, however those who cannot afford, as determine by the community, are exempted from payment as was reported by a village head in Yobe state during the ETS review fieldwork:

"The savings were used in all the 10 transfers made. The practice here is every emergency is supported by the savings but the family pays back the money afterwards and for the very poor the community gives it to the family as donation." [*ILELAH COMMUNITY, BURSARI LGA,YOBE STATE, CLUSTER 1, Interview with Traditional Leader].*

The community EMC fund guarantees ETS drivers that their cost of fuel will be paid anytime they take a woman to hospital.

Every driver is expected to fill in his logbook and be countersigned by a hospital maternity staff. It is the countersigned logbook entry that the driver presents in a motor park to allow him to jump queue to the front.

ETS has been operational for almost 3 years, how effective it is in saving women's lives?

3.2 Effectiveness of ETS

The main objective of ETS is to transport women in labour or with complication to hospital without delay in order to save women's lives. Another objective of the ETS is to reduce the cost of transporting women with maternal complications to the minimum. To what extent is ETS effective in meeting these objectives? Findings from Knowledge, Attitude and Practice baseline and midline surveys (2009 and 2011 KAP)[1] indicate that majority (81%) of the respondents are aware of the existence of ETS and other community systems established to tackle MNCH barriers of access and affordability as presented in Figure 1.

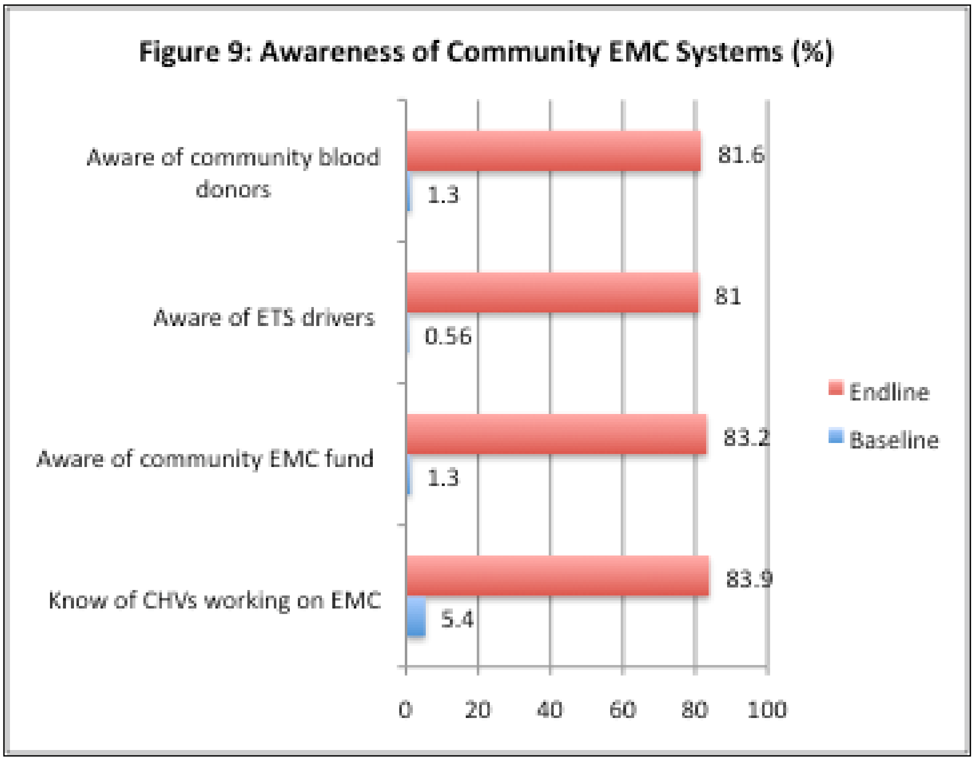


Figure 1: Awareness of Community EMC Systems (%)

Respondents were also asked about whether or not they knew of individuals in the community who had benefited from these systems (Figure 2). 75% of respondents knew of someone in the community who had benefited from the services of an ETS driver.

[1] PRRINN-MNCH, Summary of Results From the Endline MNCH KAP Survey in Katsina, Yobe and Zamfara States, November 2011.

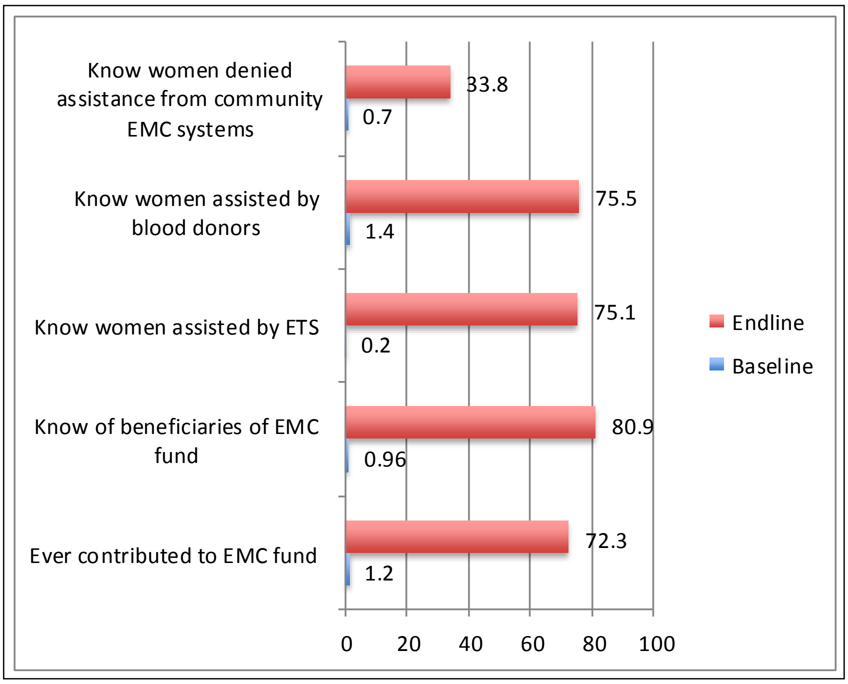


Figure 2: Utilisation of EMC Systems (%)

At baseline, many women who had suffered a complication used public transport to get to a health facility. Some families relied on community members with a car, while others used ox and carts, walked or used other types of transport (e.g. motorcycles). By the time of the endline survey, a significant increase in the use of the ETS (from 19.9% to 77.8%), a 3-fold decrease in use of public transport, and a significant fall in walking and use of other forms of transport had occurred (Figure 3). This demonstrates the growing importance of ETS in the intervention communities. However, the results show that there is room to further improve the functioning of and access to the ETS in the three programme states so that a higher proportion of women with maternal complications benefit from it.

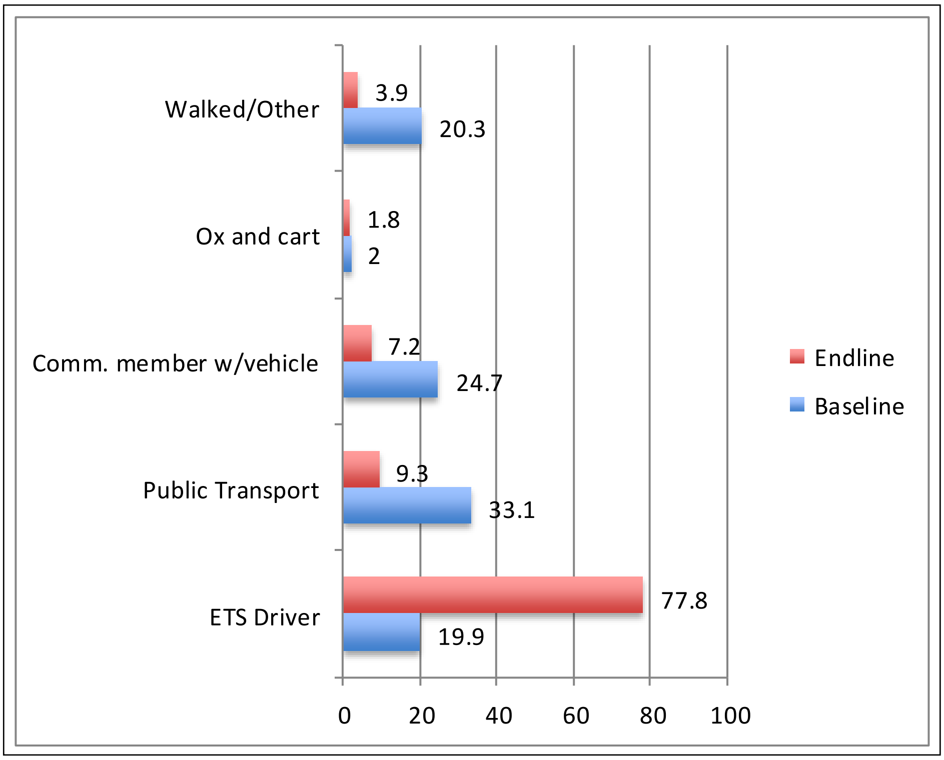


Figure 3: Transport used for maternal emergencies (%)

Another source of information for ETS implementation is the community monitoring system where communities record demographic and health information in a book and LGA collate and collect the data monthly. According to the CMS, about 4733 women have been transported to hospitals using ETS as presented in figure 4. This represents 94% of reported maternal complications in these communities.

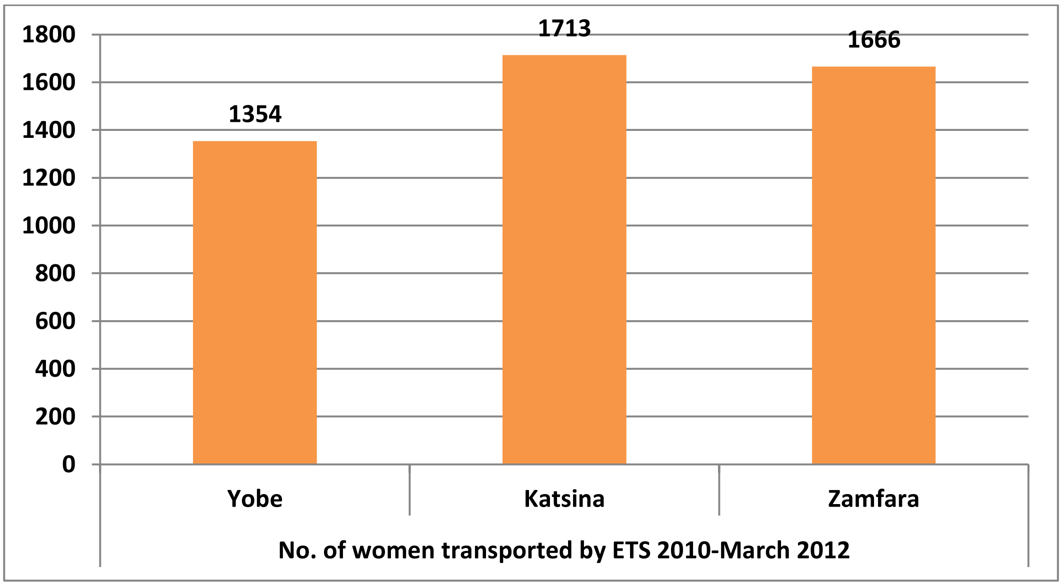


Figure 4: Total number of women transported by ETS 2010-March 2012

Another indicator for assessing the effectiveness of ETS is reduction in delays. All maternal complications require quick attention if the lives of the mother and the baby are to be saved. In the case of haemorrhage, for example, there is usually a period of approximately two hours from onset of symptoms to a woman dying. Lack of affordable transport options combined with challenging terrain and seasonal physical access challenges have a major impact on maternal and newborn health outcomes in all three states. The ETS system introduced by the NURTW with PRRINN-MNCH's support was intended to address the inadequacies of the prevailing weak, costly and inefficient transport system.

Testimonies from just concluded review of ETS (June 2012) indicated some evidence of successes. A husband in Shemori community in Zamfara state narrated his experience with ETS. According to him "....As soon as I got to him I told him my wife was in trouble. He picked up his cap and his shirt immediately and followed me to my house. My wife got into his vehicle immediately and we left for the hospital." [SHEMORI COMMUNITY Gusua LGA, Zamfara State, Cluster 4, Beneficiary]. Another husband also reported that "That very day I had no money. I had to later sell my farm produce out of which I paid the driver. Before the ETS I would have needed to scout for money before getting the driver."

The ETS has evolved over time, the drivers have become advocates for the women they transport especially in negotiating their ways into the hospital system thereby reducing 3rd delay associated with receiving care. An ETS driver in Kurnawa community reported that "Yes, I transported her to the hospital. I collected a card and took her to the labour ward. I claimed to be her husband and I was asked to buy 2 hand gloves….. [KURNAWA COMMUNITY, BURSARI LGA, YOBE STATE, CLUSTER 1]. Officer in charge of the maternity ward of a hospital in Jacusco noted that "Recently, one of the drivers brought a case of retained placenta. We welcomed him; we were already familiar with him" [Jacusco LGA, Yobe State, Cluster 11 Interview with the in charge of the maternity ward]. Another OIC in Kanoma made similar observation that "the ETS drivers are familiar with the hospital and know where to get the staff if they are not found within the hospital premises [MARU LGA, Zamfara State, Interview with OIC, Kanoma Health facility].

The efforts of the ETS drivers are appreciated by not only their Union, but also by community members. In the ETS review, it was reported in the field notes that "the drivers affirmed that they are motivated because they receive thanks and prayers from members of the community"- "they pray for us." [KUNAMAWA COMMUNITY, SAFANA LGA, KATSINA STATE Interviews with 2 ETS Drivers]. In Zamfara similar findings were recorded "the drivers are happy that they are able to render useful services to their communities. No specific reward from the community except that families of the woman assisted and community elders usually visit a driver to formally say thanks [KANOMA BIRNI COMMUNITY, MARU LGA, ZAMFARA STATE, Interview with the Community Members (5men)]. Maigari Danladi Sule, Village Head of Bojo Arewa in Katsina state is full of praise for the ETS. "I'm very happy with the initiative because it is a life-saving scheme. More women are being saved due to the prompt attention they now receive in terms of transportation. There is high acceptability of the programme among my people and many community members come to my house to express their gratitude for having this programme in place".

3.3 Challenges

Despite the successes recorded, many challenges were identified in the recent ETS review. The challenges are:

a. Vehicle maintenance and availability.

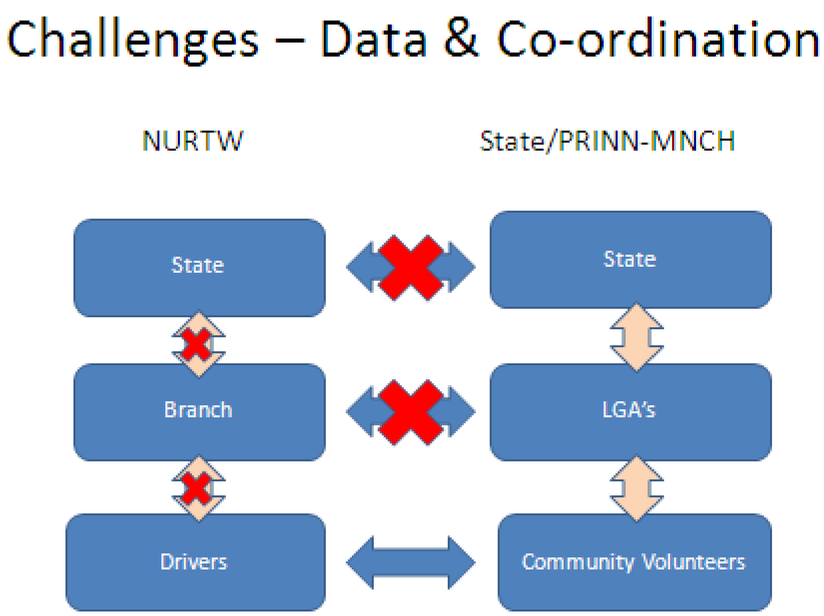
One of the requirements of being an ETS driver is having fuel in the car at all time. This is because an ETS driver can be called upon to transport women in the middle of night. A few cases of delays were experienced by the community where drivers were called but time was lost fueling the vehicle. A community member reported that “It was only by chance that fuel was found in the village –the “black –market” sellers could have run out of fuel” [TURBAN-GIDAN COMMUNITY BURSARI LGA, YOBE STATE /CLUSTER 1 Interviewer note of interview with ETS BENEFICIARY]. Furthermore, over the past two years, some of the trained drivers have lost their vehicle and they have not been replaced. When such driver is called by the community another delay is recorded before another ETS driver could be contacted. An ETS driver in Yobe said “Yes, here in Garin buka, one day a Fulani man came to this community and was looking for vehicle to hire and take a woman to the hospital. I said to him, I am a trained ETS driver with no vehicle now but I called Alhaji Bukar who did the transfer to hospital” [KURNAWA COMMUNITY BURSARI LGA, YOBE STATE CLUSTER, Interview with ETS driver].

b. Data collection:

At the beginning of ETS two parallel channels of reporting were identified; the community monitoring and NURTW channels. Right at the onset of the implementation it became obvious that the ETS drivers are not interested in filing in the logbook. An ETS driver in Yobe noted that “We know we should be writing but we are not writing anything” [TURBAN-GIDAN COMMUNITY, BURSARI LGA, YOBE STATE, Interview with ETS Driver]. Different reasons were identified some of which included- in ability to write, perception that recording in the logbook is needed to claim priority loading or other forms of incentives from NURTW etc. Consequently, data from the outcome of sensitisation and mobilisation of drivers in the motor park are not recorded. Similar thing applied to the ETS services provided through rapid awareness raising sessions.

c. Reaching the hardest to reach areas

Another challenge is putting in place ETS that will serve the need of hard to reach areas. There are many hard to reach communities that are not accessible because they are very remote with weekly access to vehicle or because of bad terrain during the raining season. In such communities the only source of transport is motor cycle. In the event of emergency maternal complications, such women can only be transported by the motor cycle. Yet, the review found little linkage with the motor cycle ETS riders and NURTW ETS drivers.



d. Security

The current insecurity in the north is affecting the implementation of ETS. NURTW and road security agencies have had a good working relationship and ETS drivers have built and benefited from this. In fact, one of the features of PRRINN-NURTW ETS model is the introduction of drivers to the police at the district level. Consequently, when an ETS driver carries a woman in labour or with complication, he jumps the queue to reduce delay. With the current insecurity in the north and the deployment of military personnel to mount security checkpoint, ETS drivers are delayed in the queue. A woman being transported by ETS lost her life in a queue in Yobe state recently for example. This problem is applicable to Yobe state where the leadership of NURTW is considering providing a form of ID card to the drivers and to re-negotiate with the security agencies. DFID may also play a role here, especially with the military.

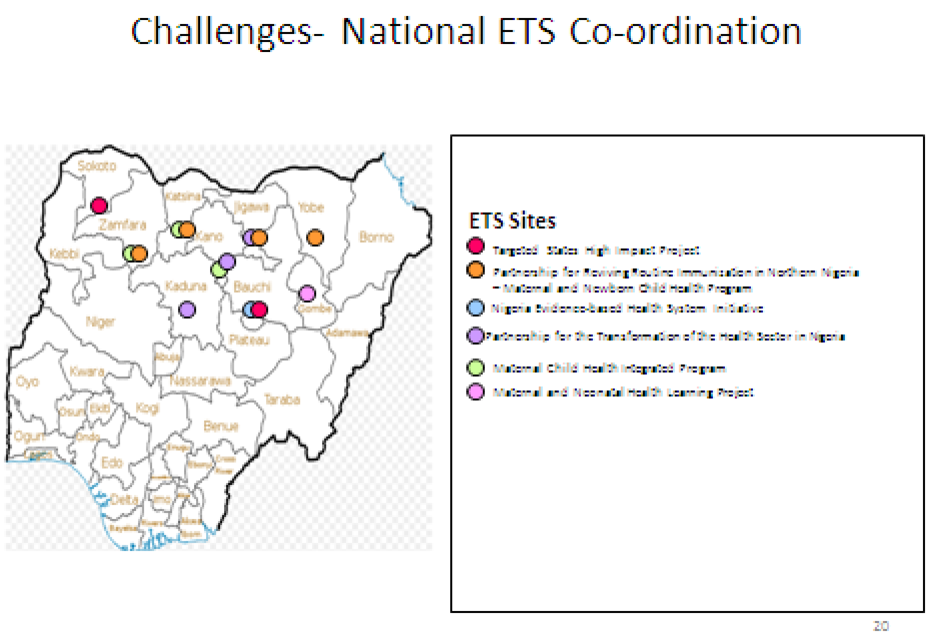
e. Threat of contamination from incentive research

PRRINN-MNCH had secured funding as part of its operational research (OR) to explore different incentive models on ETS to ensure sustainability. This desire to undertake globally-focused research on incentives may jeopardise the locally-based voluntary ethos of ETS. The field work found that in some areas the discussion around providing incentives as part of a MacArthur-funded OR project undertaken by PRINN-MNCH is changing attitudes and there is a serious risk that it may impact negatively on the sense of volunteer spirit intrinsic to the ETS approach. In response to the question, "do you think a lack of support is a problem?" the respondents answered: "There has never been a complaint from the drivers but the recent meeting we went to the drivers said people in Geidam are getting incentives so this is the start." YOBE STATE, BURSARI LGA, NURTW OFFICE with LGA Chairman, Vice Chair, Trustee and Secretary

3.4 Recommendations

a. **Role of ETS in referral:** There is a need to further consider the appropriate role for ETS in referral. This is because ETS drivers are already playing a key role in referral to higher-level facilities. In Katsina state where ambulance services are available, even though very inadequate, linkage between the two needs to be designed and implemented.

b. **National ETS co-ordination**: As reported elsewhere, other development partners are buying into the ETS and setting up their own models. There is the need to coordinate ETS nationally. This is best achieved by NURTW and the federal ministry of health.



c. **Leveraging opportunities to make ETS sustainable**: The signing of MOU between PRRINN-MNCH and NURTW which was attended by the honourable minister of health provided an opportunity to integrate ETS into NURTW policy and structures thereby making it a Nigerian driven scheme rather than donor driven. The signing of the MOU is meant to achieve many things among which is to build the capacity of NURTW at national, state and LGA level to lead on ETS for sustainability. In addition, NURTW is expected to proactively leverage resources on MCH from other sources, especially the one under subsidy reinvestment and empowerment fund (SURE-P) to scale up to more states with high rate of maternal mortality. It is also an opportunity to resuscitate NURTW data collection channel.

d. **Updating training manual and data tool:** ETS has evolved and expanded since the beginning of implementation 3 years ago. However, the manual and tools have not been adapted to meet new experience and needs. This should to be done.

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