DESIGN AND CONSTRUCTION OF LOW VOLUME RURAL ROADS IN TANZANIA

Application of the Environmentally-Optimised Design (EOD)

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November, 2013

Presentation Outline

- Background
- The Challenge
- The Proposed Solution: EOD approach
- Design and Construction of Two Demonstration Low Volume Roads using EOD approach
- Costing: Construction and Whole-Life Costs
- Performance Monitoring: Methodology
- Performance Monitoring: Outcomes
- Conclusions
- Recommendations

Background: Tanzania Road Network

Road class	Paved (km)	Unpaved (km)	Total (km)
Trunk	5,150	7,636	12,786
Regional	722	19,504	20,226
District	0	29,337	29,337
Feeder	0	22,703	22,703
Urban	790	5,207	5,997
Total	6,662	84,387	91,049

The Challenge

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- Earth and gravel roads are economically and practically unsustainable
- Impose huge maintenance burdens on poorly-resourced Road Authorities and Governments
- Good gravel is becoming increasingly scarce or available at long haul distances, further increasing the cost of gravelling and re-gravelling
- Even with increased maintenance budget from Road Funds, there still remains a serious lack of maintenance due to increasing demand
- The Tanzania Development Vision 2025 recognises that more durable and cost-effective pavement and surfacing design standards are required on the vulnerable sections of the District road network
- Most African Governments cannot afford to upgrade the rural road network using traditional equipment-based contractors and to seal entire lengths of road to reduce maintenance demand

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The Challenge (Cont...)

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Year	2004/05	2005/06	2006/07	2007/08	2008/09
Maintenance needs (T.Shs billions)	186.6	208.0	210.0	226.4	291.5
Maintenance budget (T.Shs billions)	65.4	71.5	76.2	195.0	195.0
Percentage covered (%)	35	34	36	86	67

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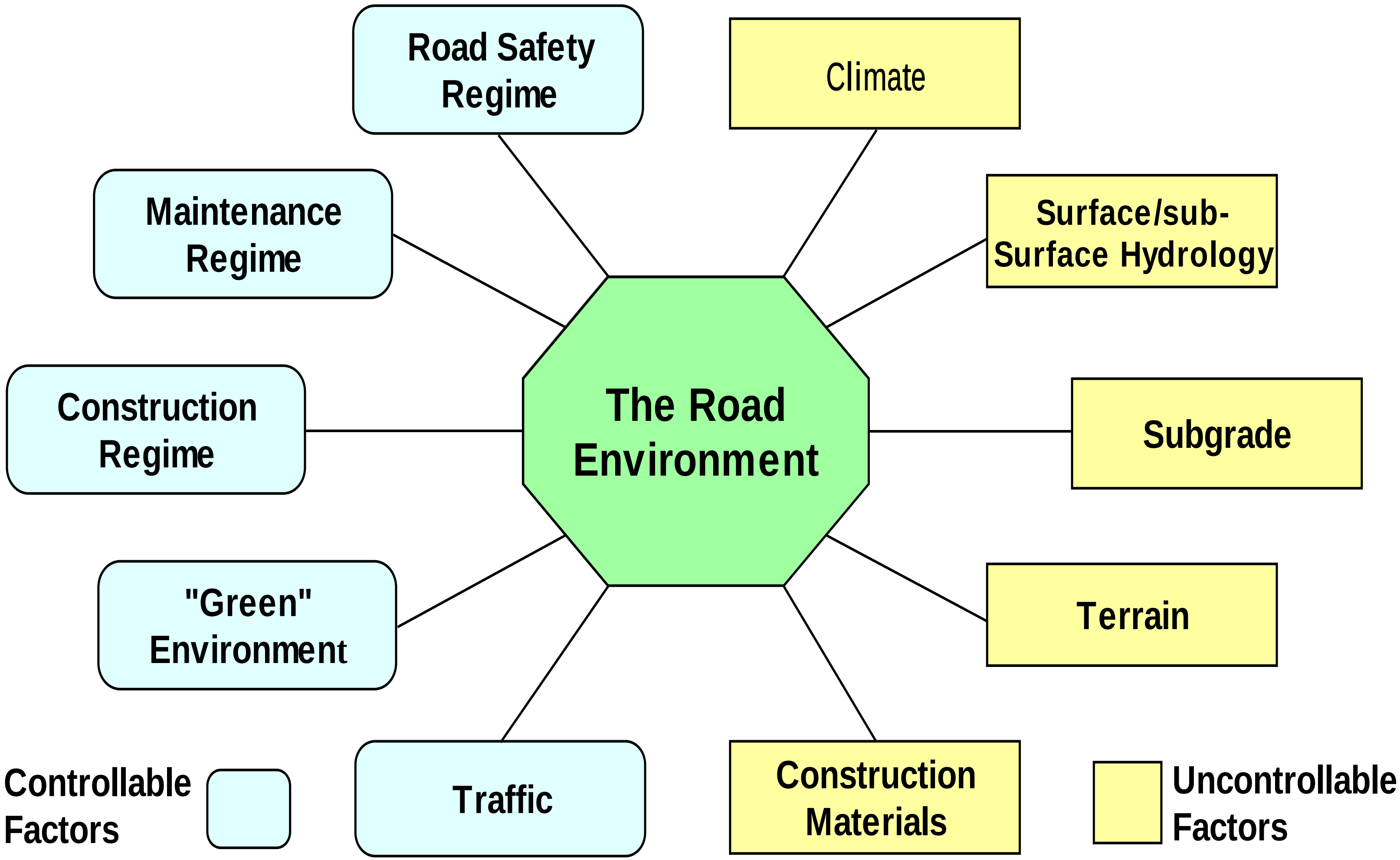
The Proposed Solution: EOD Approach

- A more innovative and cost-effective approach is required to provide year-round access along most of the road network
- Environmentally Optimized Design and Construction (EOD&C) methodology is a design approach that considers the variation of the different road environment conditions along the length of the road.
- Typical environmental conditions include steep gradients, soft wet areas, black cotton soils, areas prone to severe erosion, deep sand, human habitation, as well as passage over easy terrain.
- A pavement structure and surfacing type is chosen to suit the actual environmental conditions of a given section of the road to ensure that specifications and designs support the functions of different road sections.
- EOD assesses whether the standard design is sufficient for problematic areas and whether it is necessary for the good areas.
- An under-design of poor sections can lead to premature failure and an over-design will often be a waste of resources which would be better applied on the problematic sections.

The Road Environment



Some typical environmental conditions

Some typical environmental conditions (cont'd)

Double Surface Dressing

Concrete Strips

Design of Low Volume Roads (LVR)

The Traditional Design and Construction of LVR in Tanzania

- Existing pavement and materials design manuals (Pavement and Materials Design Manual, 1999) and specifications (Standard Specifications for Road Works, 2000) are focused on the relatively heavily trafficked roads and restrictive materials requirements, hence limited applicability to LVR

- The current practice of design and construction of Low Volume Roads in Tanzania depends much on experience of Engineers and surrounding environment of selected route.

Location of Bago-Talawanda Road, Bagamoyo District

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Bago – Talawanda Road

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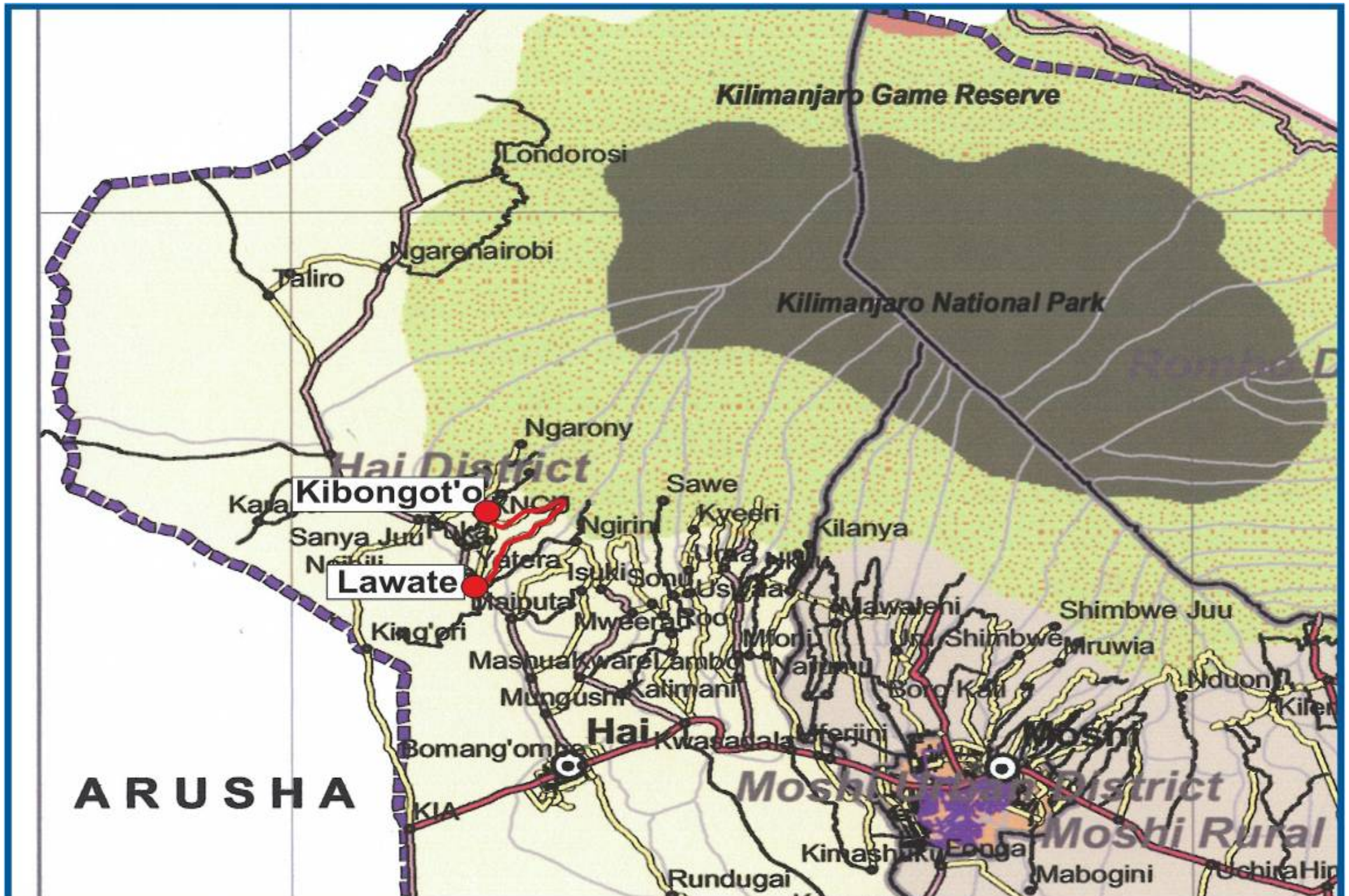
Location of Lawate – Kibong'oto, Siha District

Lawate – Kibong'oto Road



Design Of LVR

Pavement Design Under EOD (Environmental Optimized Design)

- Traffic levels were calculated based on data from the respective District Engineers
- Axle loading had to be assumed due to lack of an axle load survey.
- The subgrade strength was assessed by means DCP tests.

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DCP Pavement design profile for different LVR categories

Pavement Class E80 X 10^6	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
150 mm Base ≥98% BSH	DN ≤ 8	DN ≤ 5	DN ≤ 4	DN ≤ 3.2	DN ≤ 2.5
150 mm Sub base ≥95% BSH	DN ≤ 19	DN ≤ 14	DN ≤ 9	DN ≤ 6	DN ≤ 3.5
150 mm Sub grade ≥93% BSH	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 12	DN ≤ 6

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Lengths of Different Gradient Categories

Length and percentage	Flat (0 – 3%)	Slight (3 – 5%)	Moderate (5 – 10%)	Steep (10 – 15%)	Very steep (>15%)
Bagamoyo					
km	14.24	3.53	2.58	0.12	0.01
%	69.53	17.24	12.60	0.59	005

Length and percentage	Flat (0 – 3%)	Slight (3 – 5%)	Moderate (5 – 10%)	Steep (10 – 15%)	Very steep (>15%)
Siha					
km	2.98	2.69	4.15	2.62	1.04
%	22.11	19.96	30.79	19.44	7.72

Pavement Design Under EOD along Bago – Talawanda Road

Pavement types		Single Otta + sand seal, 26mm	Double sand Seal, 20mm	Concrete strips unreinf'd, 100mm	Concrete strips reinf'd, 100mm	Geocells, 75mm	Hand packed stone, 150+50mm
Base	Type	Natural gravel CBR ≥ 60%, 150mm	Natural gravel CBR ≥ 60%, 150mm	Natural gravel CBR ≥ 45%, 150mm	Natural gravel CBR ≥ 45%, 150mm	Natural gravel CBR ≥ 45%, 150mm	Natural gravel CBR ≥ 45%, 150mm
Subbase	Type	Natural gravel CBR ≥ 15%, 150mm	Natural gravel CBR ≥ 15%, 150mm	Natural gravel CBR ≥ 15%, 100mm	Natural gravel CBR ≥ 15%, 100mm	Natural gravel CBR ≥ 15%, 100mm	Natural gravel CBR ≥ 15%, 150mm
Improved subgrade	Type				Natural gravel CBR ≥ 7% 150 mm	Natural gravel CBR ≥ 7% 150 mm	Natural gravel CBR ≥ 7% 150 mm

Surfacing Options along Bago – Talawanda Road

Section	Chainage (km)		Length (km)	Width (m)	Surfacing Type
	Start	End			
1	0.030	0.230	0.200	3.00	Single Otta seal with a sand seal (26mm)
2	5.340	5.520	0.180	3.00	Hand packed stone (150 mm
3	5.560	6.080	0.520	3.50	Concrete strips (100 mm- reinforced)
4	6.080	6.740	0.660	3.00	Geocells (75 mm)
5	8.000	8.240	0.240	3.00	Double surface dressing (20 mm)
6	9.980	10.670	0.690	3.50	Concrete strips (100mm- unreinforced)
7	11.200	11.400	0.200	3.00	Double sand seal (20 mm)
8	12.200	12.580	0.380	4.00	Gravel wearing course
9	16.240	17.100	0.860	3.50	Concrete strips (100mm- reinforced)
10	18.480	18.740	0.260	3.50	Concrete strips (100mm- reinforced)
11	19.000	19.200	0.200	4.00	Gravel wearing course
12	20.040	20.260	0.220	3.00	Slurry seal
	Total length		4.610		

Design Of LVR

Pavement Design Under EOD Along Lawate – Kibong’oto Road

Pavement types		Concrete Paving Blocks	Unreinforced Concrete Slab	Double Surface Dressing	Concrete strips reinforced	Geocells	Pen Mac
Surface layer	Thickness	100 mm+50mm	100 mm	20 mm	100 mm	75 mm	60mm
Base	Type	Base Materials, 65mm	Base Materials, 75mm	Natural gravel CBR ≥ 60%, 150mm	Base Materials, 100mm	Base Materials, 75mm	Natural gravel CBR ≥ 60%, 150mm
Subbase	Type	Natural gravel CBR ≥ 30%, 100mm	Natural gravel CBR ≥ 30%, 100mm	Natural gravel CBR ≥ 30%, 100mm	Natural gravel CBR ≥ 30%, 100mm	Natural gravel CBR ≥ 30%, 100mm	Natural gravel CBR ≥ 30%, 100mm

Private and confidential

Surfacing Options along Lawate – Kibong'oto

Section	Chainage (km)		Length (km)	Road Width (m)	Surfacing type
	Start	End			
21	10.680	11.200	0.520	4	Concrete strips
22	11.200	11.620	0.420	4	Gravel wearing course
23	11.620	11.820	0.200	5	Bituminous penetration
24	11.820	12.120	0.300	4	Lightly reinforced concrete Slab (100mm)
25	12.120	12.280	0.160	4	Gravel wearing course
26	12.280	12.560	0.280	4	Lightly reinforced concrete Slab (75mm)
27	12.560	12.640	0.080	4	Gravel wearing course
28	12.640	13.070	0.430	4	Lightly reinforced concrete Slab (100mm)
29	13.070	13.480	0.410	4	Gravel wearing course
	Total length		11.860		

Photos of some completed sections on Bagamoyo

Completed Concrete Geocells

Completed Slurry Seal

Photographs of completed sections Siha

Completed Concrete Strip

Completed Paving Block

Photographs of completed sections Siha

Completed Concrete Slab

Completed Geocells Concrete

Indicative costs for a selection of pavement and surfacing options

Pavement and Surface	Pavement Design	Construction costs, US$/km	Whole Life Costs, $/km	
			NPV 6%	NPV 10%
ENS	TPDM	19,400	25,649	22,892
ENS	DCP Design Method	19,400	27,119	23,943
Gravel Wearing Course	TPDM	23,200	37,395	32,033
Gravel Wearing Course	DCP Design Method	23,200	38,644	32,930
Slurry Seal (8mm)	DCP Design Method	34,200	46,024	40,846
Single Otta with Sand seal (26mm)	DCP Design Method	34,500	35,905	33,661
Double Surface Dressing	TPDM	52,800	53,831	50,715
Unreinforced concrete slab (75mm)	DCP Design Method	55,100	53,241	50,992
Lightly reinforced concrete slab (75mm)	DCP design Method	57,400	54,907	52,722
Concrete strips -100mm	TPDM	59,400	68,130	62,569

Performance Monitoring

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Methodology for Data Collection

Beacons were installed at regular intervals along the implemented pavement options for each of the following methods to be carried out at relevant intervals of time:

- Visual inspection;
- Photographic logging;
- Surface profile measurement between beacons;
- Surface rut measurement using a standard straight edge;
- Surface roughness using a MERLIN apparatus
- Surface texture measurement using sand patch testing;
- Dynamic Cone Penetrometer (DCP) testing;
- Classified traffic counts;
- GPS Monitoring

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Visual Inspection On Slurry Seal

Rut Depth And Sand Patching

Performance Monitoring

Surface roughness using a MERLIN apparatus on Concrete Slab

DCP test on Double Sand Seal

Performance Monitoring

IRI values on the Bago – Talawanda Road

Section	Surface type	IRI (mm/km)			
		Base line	6 month	12 month	18 month
1	Single Otta seal with sand seal	4.24	4.07	4.39	4.83
2	Hand packed stone	9.66	9.84	N/A	13.40
3	Concrete strips	5.51	5.30	5.53	6.06
4	Concrete geocells	7.27	N/A	8.00	7.89
5	Double surface dressing	6.04	6.21	5.99	6.72
6	Concrete strips	5.67	5.72	5.93	6.86
7	Double sand seal	5.16	4.63	5.25	7.14
8	Gravel wearing course	6.59	6.79	7.05	11.85
9	Concrete strips	5.57	5.48	5.95	7.14
10	Concrete strips	6.49	6.49	6.69	6.99
11	Gravel wearing course	5.95	6.25	6.35	6.67
12	Slurry seal	5.63	5.76	5.68	6.86

Performance Monitoring

Average Rut Depth On Bago – Talawanda Road

Surface type	Average rut depth (mm)			
	Baseline	6 months	12 months	18 months
Single otta seal with sand seal	1.48	2.13	1.26	5.61
Double surface dressing	1.80	2.28	1.74	5.96
Double sand seal	2.58	2.88	2.48	7.10
Slurry seal	1.83	2.74	2.74	7.00

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Texture depth results at Bago – Talawanda Road

Section	Surface type	Surface texture depth (mm)		
		Base line	12 month	18 month
1	Single otta seal with sand seal	0.63	0.66	0.22
5	Double surface dressing	2.23	1.96	1.37
8	Double sand seal	0.49	0.62	0.26
12	Slurry seal	0.81	0.89	1.24

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Monitoring Outcomes - Conclusions

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- No predefined answer on which pavement or surface type is suited to a particular application
- EOD philosophy requires that Engineer studies project area and considers the variation in road environment along the road length and then select most appropriate solution
- The demonstration sections now provide all-weather access along the entire road length
- Incorporation of local materials and use of local labour is important in the selection and design of different pavement structures, and should be included where possible

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Monitoring Outcomes

- Concrete strips are likely to provide good and cost-effective solution but thought needs to be given to locations and designs for passing bays to ensure their safe use.

- Concrete block paving, concrete pavements and bituminous bound pavements can be undertaken successfully by small scale contractors using imported and local materials. These initially expensive pavements result in sustainable pavements with reduced maintenance needs.

- Geocell pavements are suited to small contractors as suitable concrete can be mixed in small mixers using local materials.

Monitoring Outcomes

- The cost of the all-weather surface types exceeds the construction cost of the standard gravel road significantly.
- However, potential long term savings and benefits accrue from adopting the EOD approach to rural road design.
- Baseline surveys were carried out on the Lawate – Kibong'otho road in April 2013. First round of monitoring scheduled for April 2014. Current performance satisfactory.

Monitoring Outcomes

Recommendations

- Maintain to an accessible standard, but true deterioration of the road surface should be monitored over a sufficient time period in order to obtain realistic and reliable data on pavement deterioration.

- Monitor all sections at regular intervals for the next 8 years to collect evidence of actual in-service performance

- Axle load control should be a key focus area for future monitoring
- Develop affordable and sustainable standards

Thank you /