



AfCAP

Africa Community Access Partnership



Establishment of Tractor-based road works Demonstration-Training Unit in Zambia.

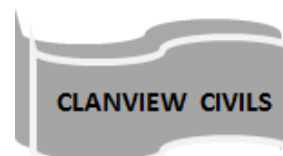
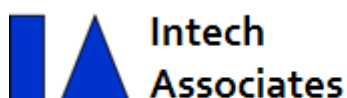
Equipment Evaluation Report



Authors: Robert Petts, Kingstone Gongera and Ian Petts

Equipment Evaluation Report, Rev 1. May 2018

AFCAP Project Reference Number: ZAM2059B



ESTABLISHMENT OF PILOT TRACTOR TECHNOLOGY DEMONSTRATION-TRAINING UNIT (DTU) TO IMPLEMENT TRACTOR-BASED ROAD MAINTENANCE APPROACHES IN ZAMBIA

Project Reference: ZAM2059B

The views in this document are those of the authors and they do not necessarily reflect the views of the Research for Community Access Partnership (ReCAP), the Africa regional component (AfCAP), DFID or Cardno Emerging Markets (UK) Ltd for whom the document was prepared.

<i>Quality assurance and review table</i>			
Version	Author(s)	Reviewer(s)	Date
Draft 1	Robert Petts, Kingstone Gongera & Ian Petts	Thomson Banda; Senior Manager - Research and Development, RDA. Presley Chilonda; Principal Engineer, RDA. Nkululeko Leta; Deputy Team Leader – Infrastructure Henry Nkwanga; AfCAP Regional Technical Manager, East and Southern Africa.	September 2017
Final	Robert Petts, Kingstone Gongera & Ian Petts		October 2017
Rev.1	Robert Petts, Kingstone Gongera & Ian Petts		May 2018

ACKNOWLEDGEMENTS

The authors would like to express appreciation to Eng. Thomson Banda, Presley Chilonda, Victor Miti and the RDA team, Eng. Musonda Mulenga of NCC, Eng. Peter Banda of Chongwe MC, Rob Geddes and Charles Bopoto (GEM team) for liaison on current ReCAP project and the DTU Coordination Committee who facilitated the activities of the assignment and introductions to the stakeholders. The various stakeholders continue to contribute their time and knowledge through the Coordination Committee to support the successful implementation of piloting, training, demonstration and uptake of tractor technology road works applications.

Cover Photo: Kingstone Gongera

Other images: Intech Associates

The Africa Community Access Programme (AfCAP) is a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID). AfCAP is promoting safe and sustainable rural access in Africa through research and knowledge sharing between participating countries and the wider community.

ReCAP Project Management Unit
Cardno Emerging Market (UK) Ltd
Oxford House, Oxford Road
Thame
OX9 2AH
United Kingdom



©Intech Associates

CONTENTS

ACKNOWLEDGEMENTS.....	1
CONTENTS.....	2
ABBREVIATIONS AND ACRONYMS.....	3
EXECUTIVE SUMMARY.....	4
1. BACKGROUND.....	5
1.1 Overview.....	5
1.2 Project Context.....	5
1.3 Related Projects.....	5
1.4 Project Partners.....	6
2. PROJECT OBJECTIVE.....	6
3. THIS REPORT.....	6
4. EXISTING EQUIPMENT RESOURCES.....	7
4.1 National Fleet.....	7
4.2 Chongwe Council.....	7
4.3 Private Sector Resources.....	9
4.4 NCC Equipment Resources.....	10
5. DTU EQUIPMENT INVENTORY NEEDS.....	11
6. GRADING EQUIPMENT AVAILABILITY & ASSESSMENT.....	12
6.1 Routine Light Grading.....	12
6.2 Heavy Grading.....	13
7. ECONOMIC CONSIDERATIONS OF TRACTOR TECHNOLOGY ROAD WORKS.....	15
7.1 Economic Environment.....	15
7.2 Assessment of Equipment Costs.....	15
7.3 Current Maintenance Funding Situation.....	20
7.4 Implications for Future Road Maintenance Budgeting and Costs.....	21
8. SPECIFICATIONS FOR DTU EQUIPMENT PROCUREMENT.....	22
9. BUDGET COSTS FOR DTU EQUIPMENT PROCUREMENT.....	22
10. VIABILITY OF PLANT HIRE POOLS.....	23
11. CONCLUSIONS AND RECOMMENDATIONS.....	24
REFERENCES.....	25
ANNEX 1 ROAD MAINTENANCE EQUIPMENT OPTIONS FINANCIAL COST ANALYSIS.....	27
ANNEX 2 ECONOMIC COST COMPARISON BETWEEN MOTOR GRADER & TRACTOR TOWED GRADER LIGHT GRADING.....	32
ANNEX 3 EQUIPMENT SPECIFICATIONS.....	37
ANNEX 4 – ANCILLIARY TRACTOR ATTACHMENTS.....	58

ABBREVIATIONS AND ACRONYMS

AfCAP	Africa Community Access Partnership
CEO	Chief Executive Officer
CIA	Central Intelligence Agency
CMC	Chongwe Municipal (formerly District) Council
CRN	Core Road Network
DCF	Discounted Cash Flow
DFID	Department for International Development
hp	horse power
IRI	International Roughness Index
km	kilometre
kW	KiloWatt
LRA	Local Road Authority
LVR	Low (traffic) Volume Road
MoA	Ministry of Agriculture
MoLG	Ministry of Local Government
MSMEs	Micro Small and Medium Enterprises
NAMSSC	National Association of Medium and Small Scale Contractors
NCC	National Council of Construction
NRFA	National Road Fund Agency
OPRC	Output and Performance-Based Road Contract
RDA	Road Development Agency
ReCAP	Research for Community Access Partnership
RMS	Road Maintenance Strategy
ROPS	Roll Over Protection Structure
SSA	Sub Saharan Africa
TDU	Training and Demonstration Unit
TEVETA	Technical Education, Vocational and Entrepreneurship Training Authority
ToT	Training of Trainers
TT	Tractor Technology
USA	United States of America
US\$	United States Dollar
VAT	Value Added Tax
ZAWIC	Zambian Association of Women in Construction
ZMK	Zambian Kwacha
ZNFU	Zambia National Farmers Union
ZNS	Zambia National Service

EXECUTIVE SUMMARY

Chongwe District has been selected as the location for a Tractor Technology Demonstration and Training Unit (DTU).

This report describes the initial project activities with regard to reviewing the Intermediate Technology Equipment needs of the Tractor Technology Demonstration Training Unit. This involved assessment of the existing national, NCC and Chongwe Municipal Council equipment resources, a visit to the manufacturer of a heavy towed grader in RSA, consideration of the economics of the tractor technology approach and preparation of specifications for procurement of equipment for the DTU.

A preliminary cost comparison has been made between routine maintenance grading by motor grader and tractor technology. The analysis indicates cost savings of the order of 50% or more using the proven agricultural tractor technology.

The project follows completion of a scoping study in 2016. That study was commissioned by AfCAP at the request of the Road Development Agency (RDA). It investigated the potential and rationale for Tractor Based maintenance of rural roads in Zambia and was aimed at investigating the location, institutional and management arrangements, organisation requirements and costs of setting up a Tractor Technology demonstration-training unit (DTU) for rural roads in Zambia. Stakeholders from the principal beneficiary and contributory sectors have endorsed the recommendations for establishment of the Unit and are actively involved in this implementation phase.

Under the current assignment, also commissioned by AfCAP for RDA, visits were made by the Consultant's team members Robert Petts and Kingstone Gongera to Zambia and RSA.

The purpose of this project is to embark on implementation of the recommendations of the scoping study in a phased manner, focusing mainly on setting up and conducting DTU activities in a selected District as a pilot project; namely Chongwe Municipal Council.

This is a capacity building project that seeks to introduce a cost-effective and sustainable approach to rural road maintenance by using tractor-based technologies already successfully applied in a number of countries in the region (including Zimbabwe and Mozambique). This project complements the Economic Growth through Effective Road Asset Management (GEM), Satellite Imagery and Climate Change projects, also funded under AfCAP and being implemented in Chongwe District (now designated a Municipal Council). Training of a whole range of personnel from the District, contractors' and engineering firms as well as staff from the Road Development Agency (RDA) of Zambia and local authorities will be a key element of the project.

Key Words: Tractor, Equipment, Road, Maintenance, Zambia, Demonstration, Training Cost-effective, Sustainable.

1. BACKGROUND

1.1 Overview

The Africa Community Access Partnership (AfCAP) is a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID). AfCAP is promoting safe and sustainable rural access in Africa through research and knowledge sharing between participating countries and the wider community. The first phase of AfCAP commenced in June 2008 and ended in July 2014. The second phase, which will also run for 6 years, commenced on the 1st August 2014. The management of AfCAP2 is contracted by DFID to Cardno UK. The aim of the new AfCAP initiative, under the overall Research for Community Access Partnership (ReCAP) umbrella, is to build on the programme of high quality research established under AfCAP phase 1 and take this forward to a sustainable future in which the results of the research are adopted in practice and influence future policy.

1.2 Project Context

All-season road-based transport is a vital enabler for rural development, social and economic activities and community wellbeing, particularly for vulnerable groups (e.g. women, children, elderly, disabled) (Cook et al, 2017). Serviceable rural roads reduce crop waste, improve market prices for produce transported, improve the flow of information to rural communities and are an important catalyst and enabler to other government and development initiatives in rural areas. Currently, the majority of the rural road networks in Zambia are unpaved (earth and gravel standard) and as such require regular maintenance input to retain acceptable levels of access. However, unpaved road network maintenance is generally substantially underfunded in the Sub-Saharan Africa region (SSA) and Zambia is no exception. There is a clear demand, therefore, for innovative, cost-saving approaches to maintenance activities. Currently routine maintenance of unsealed roads is usually based around the use of imported motorised graders which are expensive to buy and operate in the prevailing high-finance-cost environment. They are also over-powered for the routine maintenance task.

Within appropriate road environments agricultural tractor-based technology is a lower-cost, easier to maintain, more flexible, multi role, proven alternative to the use of high cost specialist plant for low volume unsealed road maintenance. There is no established unit in Zambia to demonstrate and train for this more affordable and more sustainable tractor-based technology.

Following completion of the scoping study which was aimed at investigating the location, institutional and management arrangements, organisation requirements and costs of setting up a Tractor Technology demonstration-training unit (DTU) for rural roads in Zambia, the stakeholders have endorsed the recommendations for establishment of the Unit. The outcomes of the study and recommendations thereof are contained in the Scoping Study Final Report (Petts & Gongera, AfCAP ZAM2059A, Scoping Study Final Report, April 2016).

1.3 Related Projects

Related projects include previous and on-going experience with tractor-based technology in the region, for example in Zimbabwe and Mozambique. Not only are towed graders manufactured in the region (e.g. in Zimbabwe and South Africa), there is a wide range of other road construction and maintenance activities that the agricultural tractor can do to offer a total road rehabilitation and maintenance package based on the use of tractors.

Synergies with other programmes in Zambia have already been explored and details are contained in the Scoping Study Final Report mentioned in Section 1.2 above.

Other related AfCAP projects are:

GEN2018A "Economic Growth through Effective Road Asset Management – GEM".

GEN2070A “The use of appropriate high-tech solutions for Road network and condition analysis, with a focus on satellite imagery”.

GEN2014A Climate Adaptation: Research on Risk Management and Resilience Optimisation for Vulnerable Road Access.

1.4 Project Partners

Project partners have been established through AfCAP and the DTU Coordination Committee:

- Regional partner countries, with particular reference to Zimbabwe, Mozambique and South Africa.
- Roads Development Agency (RDA)
- National Council of Construction of Zambia (NCC)
- Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA)
- Ministry of Local Government (MoLG)
- National Road Fund Agency (NRFA)
- Ministry of Agriculture (MoA)
- Zambia National Service (ZNS)
- Chongwe Municipal (formerly District) Council (CMC)
- Zambia National Farmers Union (ZNFU)

2. PROJECT OBJECTIVE

The purpose of this project is to embark on implementation of the recommendations of the scoping study in a phased manner, focusing mainly on setting up and conducting DTU activities in a selected District as a pilot project; namely Chongwe Municipal Council.

This is a capacity building project that seeks to introduce a cost-effective and sustainable approach to rural road maintenance by using tractor-based technologies already successfully applied in a number of countries in the region (including Zimbabwe and Mozambique). Training of a whole range of personnel from the District, contractors’ and engineering firms, and students of sustainable rural development and engineering, as well as staff from the Road Development Agency (RDA) of Zambia and local authorities will be a key element of the project.

3. THIS REPORT

This report describes the initial project activities with regard to reviewing the Intermediate Technology Equipment needs of the Tractor Technology Demonstration Training Unit. This involved assessment of the existing national, NCC and Chongwe equipment resources, a visit to the manufacturer of a heavy towed grader in RSA, consideration of the economics of the tractor technology approach and preparation of specifications for procurement of equipment for the DTU.

Previous project reports have included an Inception Report and an Asset Inventory Report for the target Chongwe District.

The rationale and compelling case for adoption of agricultural tractor technology for the maintenance of rural roads in Zambia is set out in detail in the Scoping Study Report (Petts & Gongera, 2016), and it is not necessary to replicate the discussion in this report.

4. EXISTING EQUIPMENT RESOURCES

4.1 National Fleet

The Consultants made investigations regarding the availability of tractor based road works equipment in Zambia.

Regarding the motive power of agricultural tractors, there are no national statistics available regarding numbers of tractors imported, the current national fleet or conditions. The relevant officials at the Ministry of Agriculture had no data, but estimated that the national fleet could be more than 4,000 units. The local tractor agents keep records of individual clients' usage and servicing. However, this is commercially confidential information and not accessible to the consultants.

The website Nationmaster ¹ estimated the Zambia national tractor fleet to be 6,000 units for 2003.

The World Bank (2012) advised *"There is no reliable figure for the total number of working tractors in Zambia, but it is estimated at around 6,000 tractors"*, based on data available up to 2011. Tractor imports according FAOSTAT were about 570 units per year between 2003 and 2007. It can therefore be estimated that the current national tractor fleet should be in the region of 10,000 units. However, the serviceability situation is unknown.

The Consultants findings regarding agricultural tractors can be summarised as:

- The current in-country stock is more recently estimated at 10,000 tractor units.
- It is estimated that the in-country stock has increased by about 6000 tractor units over the last 10 years.
- It is not clear how many units are in serviceable order. No national database exists.
- The Bulk of tractor units apparently reside with commercial farmers.
- A few are owned by individuals who are not farmers.
- Some operational units were procured under development partner projects such as Musika

Regarding the tractor attachments of light and heavy towed graders, trailers, bowsers and rollers, local agents can supply imported models. Although, there is potential to manufacture these items locally in Zambia.

4.2 Chongwe Council

Chongwe Municipal Council (CMC) owns a number of equipment items to be operated under their own force account road work operations.

The list of CMC equipment and vehicles available fully or partially for road works and their age and current condition are shown below.

TABLE 4.1 – CHONGWE MUNICIPAL COUNCIL EXISTING EQUIPMENT FLEET

¹ <http://www.nationmaster.com/country-info/profiles/Zambia/Agriculture/Agricultural-machinery>

ITEM	DESCRIPTION /NAME	OWNED PARTIALLY FOR ROAD WORKS	OWNED FULLY FOR ROADWORKS	AGE (YEARS)	CONDITION
1	Grader CAT 140K		✓	6	Good
2	Tractor with Tipping Trailer	✓		7	Fair
3	Nissan Patrol utility Vehicle	✓		6	Fair

The motorgrader, with only just over 3,000 hours of metered use, has already had the transmission replaced at a cost of US\$33,000; which is incidentally the approximate cost of a new agricultural tractor.

FIGURE 4.1 – THE CHONGWE MOTORGRADER



The relevant specifications of the motor grader are:

- Rated Power: 128kW (174hp)
- Typical Operating Weight: 15,000 kg
- Moldboard length: 3.7 metres
- Cutting edges reversible: No
- Turning circle radius: 7.5 metres
- Fuel Capacity: 305 litres

- Blade operation: Hydraulic.

The current replacement cost of the CAT 140K motorgrader is US\$ 296,000 plus VAT (@16%) = US\$ 343,360.

Although the local market for such equipment is limited, from international market prices the current value of the Chongwe six year old CAT120k would be about US\$120,000.

Other issues relevant to the assessment of the motorgrader for the maintenance of rural roads are:

- The motorgrader is a single function machine and can only be used for grading;
- Because of the long and rigid frame, the motor grader can only turn at junctions. A minimum of 4 passes are required to light grade a section of rural road. Therefore, long sections of road are required for operational works with logistical and road safety consequences;
- The annual utilisation of about 500 hours per year is low, causing overall unit operating costs to be high;
- The Council has no watering or compaction equipment. This means that heavy grading tasks are not possible to execute effectively without the hiring in of such equipment. Furthermore, any grading in the dry season, with low moisture in the surface material leads to accelerated material loss from the road surface as traffic or the grader cannot consolidate the loosened, reshaped dry material;
- With a core feeder road network, the one piece of grading equipment is not sufficient to meet even the basic routine grading needs of the 320 km network (Figure 4.2); without consideration of the extensive rehabilitation grading demands due to the current road network conditions (See Separate Chongwe Road Inventory Report – Intech-Clanview 2017).
- From experience, the power requirements for light (routine maintenance) grading at the altitudes for Chongwe operations are 70hp (52kW) and for heavy grading are 100hp (75kW). The 174hp CAT140K is therefore overpowered for the maintenance requirements. It is notable that until 1955, the largest Caterpillar motorgrader was 100hp (Ref: Caterpillar Handbooks).

The council currently does not have sufficient equipment for the transport of materials and labour for maintenance works.

4.3 Private Sector Resources

Chongwe Municipal Council are able to hire in heavy road equipment from a locally based contractor to supplement their small equipment fleet.

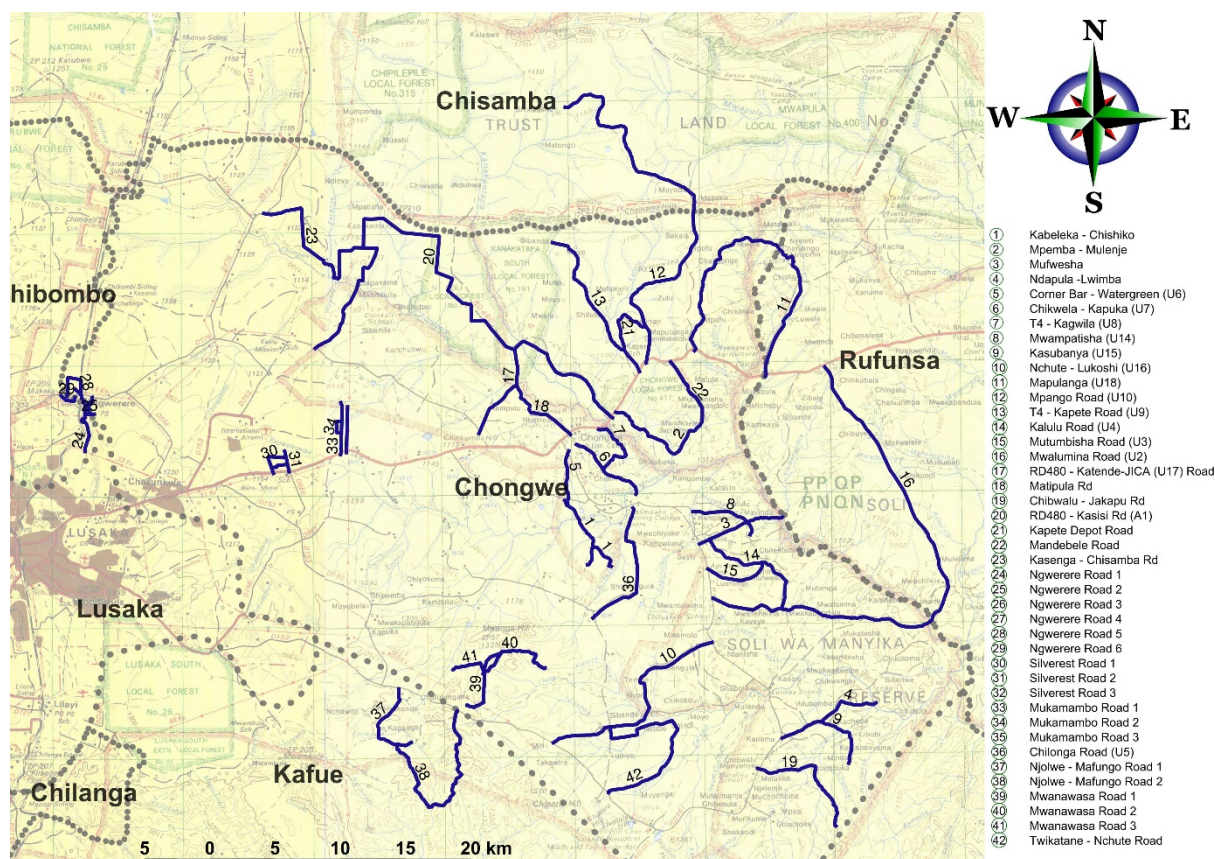
The hire rates of currently available items of equipment are shown in Table 4.2. The rates include operator but exclude fuel.

Table 4.2 – CURRENT COMMERCIAL EQUIPMENT HIRE RATES - CHONGWE

Item	Equipment Name	Rate/8 hour Day (ZMW)	Rate/8 hour day (US\$ equivalent)	Remarks
1	Excavator	7,200	800	
2	Drum Roller	4,000	444	
3	Bulldozer D6	5,600	622	
4	Water tank	3,600	400	
5	Tipper	2,800	311	
6	Low bed	240	27	PER KM
7	Front End Loader	4,800	533	

Source: Chongwe Council

FIGURE 4.2 – (PRIMARY FEEDER) CORE ROAD NETWORK



4.4 NCC Equipment Resources

In the Scoping Study Report (Petts & Gongera, 2016) it was reported that the NCC training centre has seven MF tractors that would require minor refurbishment to make serviceable. It was considered that some of these tractors could be rehabilitated for use in the DTU. However, the funding, expertise and supervision resources required for such an option are

not currently readily available and adopting this option would risk compromising the project programme. Furthermore, it would be more motivational, relevant and influential if the DTU operations train and demonstrate using currently marketed tractor models.

However, the NCC tractors could be used for the hands-on training of the field mechanics as the basic preventive maintenance procedures will be the same on both the older and current tractor models.

Consideration was also given to the possibility of hiring in the equipment for training purposes. However, there are no established tractor roadworks attachment hire organisations available locally. The team was not able to identify sources for long term lease/hire of tractors in Zambia.

5. DTU EQUIPMENT INVENTORY NEEDS

The procurement requirements were outlined in the Scoping Study Report to be provided by the Zambian Government.

The tractor based technology equipment will be required to satisfy trials, field training and demonstration in both the pilot district and for mechanical workshop training purposes for both force account and private sector. It must be possible to train and demonstrate for all unpaved Feeder Road Maintenance activities. The requirements have been refined slightly from the current Phase 1 implementation investigations to minimise procurement requirements.

Routine Maintenance

- 2 No. 70hp 2WD agricultural tractors
- 1 No. 2 tonne towed grader (From J Mann, Zimbabwe mechanical – proven performance)
- 1 No. 5 tonne 2 axle general purpose heavy duty trailer
- 1 No. 2,500 litre water bowser units for use on the trailers
- 10 No. tyre drags – locally fabricated

Periodic Maintenance and Rehabilitation

- 2 No. 100hp 4WD agricultural tractors
- 1 No. 5 tonne towed grader (CMC, Kenya) – proven performance
- 1 No. 5 tonne towed grader (Rogue, RSA) – these have been reviewed and deemed suitable for the project
- 1 No. 5 tonne towed Pneumatic Tyred Rollers (PTR)
- 1 No. 5 tonne steel towed roller
- 1 No. 5 tonne 2 axle general purpose heavy duty trailers
- 1 No. 4,500 litre single axle water bowsers

Estimated purchase costs and specifications for the required DTU equipment fleet are discussed in other sections of this report. From preliminary investigations, the currently allocated procurement funds will require to be supplemented.

In consideration of training and demonstration activities being programmed from February 2018, it is desirable that the key items of equipment are procured beforehand; namely one of each of the agricultural tractors and towed graders.

It is understood that the equipment procurement will be exempt from VAT.

Ownership and responsibility for operator provision, fuelling, servicing and repair of the DTU equipment needs to be agreed between the project partners; RDA, NCC, MoLG and Chongwe Council.

6. GRADING EQUIPMENT AVAILABILITY & ASSESSMENT

The key element of technology being introduced by the project is that of towed grading. The technique is proven elsewhere, but this approach is a fundamental component of the demonstration and training objective of the project.

There are two towed grading equipment requirements:

- Routine, or light towed grading, and
- Rehabilitation, or heavy towed grading.

The authors have extensive experience with tractor towed grading equipment and have also carried out an extensive web search and evaluation of equipment available on the international market. This has enabled the towed grading equipment possibilities to be narrowed down to just three manufacturers in the region that are able to supply and support suitable equipment for the planned DTU road maintenance operations. Specific details are provided in the following sub-sections.

6.1 Routine Light Grading

For Routine Maintenance grading a 70hp tractor and 2-3 tonne towed grader is usually required. This is a 'little and often' work approach for roads still retaining some camber as an integral part of preventive maintenance of unpaved surfaces. Effectively moving a few centimetres thickness of material back to the 'crown of the road'.

The activity is best done in the rainy season when the moisture present allows the loose graded material to 'bed down' under traffic without the need for (expensive) watering and compaction.

A 2 tonne light towed grader has been manufactured in Zimbabwe for over 20 years and has been used extensively in Zimbabwe and other countries (Gongera & Petts, 2003).

This equipment is proven but not widely adopted by local authorities or contractors in the private sector.

FIGURE 6.1 – ZIMBABWE MANUFACTURED LIGHT TOWED GRADER

6.2 Heavy Grading

For Heavy or Rehabilitation grading to restore camber, a 100hp 4WD tractor and 5 tonne towed grader is required. It should be supported by watering and compaction equipment to ensure a more durable running surface. The task can be carried out at any time of the year.

Watering and compaction work can also be tractor powered, allowing spares rationalization of power units.

A 5 tonne towed grader manufactured in Kenya was used on road rehabilitation and maintenance projects there (Petts, 1992) and in Tanzania and South Sudan. The performance is proven and the model is available ex-works from Kenya.

FIGURE 6.2 KENYA MANUFACTURED HEAVY TOWED GRADER

The web searches identified another suitable heavy towed grader currently manufactured in RSA. Under Phase 1 of this project, a study tour visit was made to the manufacturer in Pietermaritzburg, RSA (Rogue Engineering), that produces the heavy towed grader; suitable for both camber rehabilitation and routine maintenance of unpaved roads. Discussions were held with the management regarding this and other road maintenance equipment that they are able to supply. The manufacturing facilities were visited and a site visit was arranged to

observe the heavy towed grader in operation. The team verified its quality and suitability for the project purposes. This is in terms of appropriate design, dimensions, proportions and weight, quality of construction, ease of application and performance.

FIGURE 6.3 – RSA MANUFACTURED HEAVY TOWED GRADER



FIGURE 6.4 – RSA MANUFACTURED TOWED GRADER WITH SCARIFIER ATTACHMENT



Images of the general purpose tractor attachments are shown in Annex 4.

7. ECONOMIC CONSIDERATIONS OF TRACTOR TECHNOLOGY ROAD WORKS

7.1 Economic Environment

The Bank of Zambia recently lowered the policy interest rate to 11%. It had been at 14% in May 2017. Interbank overnight interest rates have been in the range 12 - 13% during the same period (Bank of Zambia August 2017 Report).

Through discussions with a number of banks and finance companies, the minimum interest rate for commercial loans currently starts at about 35% per annum. With arrangement fees and insurances, etc., the cost of commercial credit is extremely high, and this issue is seen to be a serious problem for local Micro, Small and Medium Enterprises (MSMEs). Many finance houses and even asset based lenders are reluctant to lend for vehicles or mobile equipment due to the risk of mobile assets moving beyond the reach of the lender and invalidating collateral assurance.

7.2 Assessment of Equipment Costs

There is very little reliable data available on the costing of equipment and operations for road maintenance in Sub-Saharan Africa. Most data sources are out of date, incomplete or project based and therefore distorted. The road maintenance contracting market in Zambia is very small and does not operate efficiently. It is suspected that there is cross-subsidisation from the relatively large scale construction activities to the costs of the small quantity of occasional maintenance contract work. Furthermore, World Bank review of Sub-Saharan contracts showed evidence of sector inefficiencies and irregularities (Queiroz, 2012). These include:

- Long periods between bid opening and contract signing
- Significant cost increases during implementation
- Time overrun of the originally contracted period
- Contract value is much more than the Engineer's Estimate
- Half or more firms buying bidding documents do not bid
- Significant number of pre-qualified firms do not bid
- Difference between winning bid and next lowest bid is minimal
- Winning bid is not the lowest bid accepted for detailed examination
- Only one or two bidders
- Cost per km for similar works and unit road works costs are higher than norms.

Road Maintenance costs rarely include all components that are necessary to represent and convey the overall costs of owning and operating equipment in a limited resources environment. Benchmark costing systems are rare in Africa. This is in stark contrast to developed economies where detailed equipment and task costing data is readily available and regularly updated for clients and contractors to access and refer to. In consequence, African road authorities and contractors are generally both oblivious to the overall real costs and this factor contributes to poor long-term planning and bidding.

To carry out a preliminary assessment of real costs of owning and operating road works equipment for the purposes of this project, key parameters to be considered are cost of

finance or opportunity costs, and annual utilisation. These will be particularly influential in assessing technology and capital investment options appropriate for rural road works.

In countries such as Germany, for economic evaluation a typical discount rate of 3% is applied to transport projects due to the low finance rate and a desire to encourage infrastructure projects. Other European countries such as Denmark use 6%, UK 8% and USA 8%. For developing countries discount rates of 10 – 20% are typically used to reflect the added risk and higher cost of capital, with the World bank using between 10 – 14% worldwide for transport projects. In contrast, a private investor in a toll road may require a return in excess of 30%.

Typically, infrastructure projects and investment decisions are valued using a combination of Internal Rate of Return, Net present Value and payback period.

In a constrained resource environment such as Zambia, the finance/opportunity cost of capital is a particularly influential factor. The high rates of interest suggest a capital minimisation strategy should be most appropriate.

To model real costs a comprehensive financial analysis has been carried out from first principles using three indicative rates of interest for equipment technology comparison:

- 5% p.a. to indicate a benchmark comparison with developed economies
- 15% p.a. to represent Zambia government opportunity costs of capital
- 25% p.a.
- 35% p.a. to represent the commercial finance rate for the private sector.

The financial analysis results are contained in Annex 1 and summarised hereafter.

The annual utilisation of a piece of equipment has the most direct influence on investment payback period, unit costs of ownership and operation, and indeed viability of ownership. In a low-cost finance environment such as the UK, it is suggested that utilisation rates for construction sector equipment well in excess of 1,000 hours per year are required for efficient ownership (Petts, 2010).

For the preliminary assessment of equipment costs, the following rates of key equipment utilisation have been investigated for the Zambian situation:

- 500 hours per year
- 1,000 hours per year

The typical Lusaka price of diesel has recently dropped in August from 10.7 Kwacha/litre to 9.9 Kwacha/litre. This latter price has been used in the analysis.

Since 1 March 2017 the Zambian Kwacha has appreciated against the US\$ from 9.5 to 9.0 Kwacha/US\$ (exchange-rates.org). This latest rate has been used in the analysis. Inflation in Zambia according to the government is 6.3%

VAT is Zero rated on selected agricultural equipment and accessories, e.g. small/medium sized two-wheel tractor and accessories. Government agencies are anyway understood to

be exempted from VAT; which is normally levied at 16% on construction equipment and large agricultural tractors (90hp or more). The preliminary analysis therefore excludes VAT. However, it must be born in mind that the local private sector will not have the benefit of this exemption.

The results of this preliminary financial analysis are shown in Table 7.1. Phase 2 of the project will allow, this assessment to be refined, and for benchmark costs, for grading works, to be established.

TABLE 7.1 – ROAD MAINTENANCE EQUIPMENT COSTS RELATING TO UTILISATION AND FINANCE COST

Equipment & Annual Utilisation (hours)	Ownership & Operating Cost per Day (excluding VAT on procurement)		
	Opportunity/Finance Costs 15% P. A.	Opportunity/Finance Costs 25% P. A.	Opportunity/Finance Costs 35% P. A.
140hp Motorgrader 1,000hours/year	US\$1,007	US\$1,092	US\$1,178
140hp Motorgrader 500hours/year	US\$1,481	US\$1,650	US\$1,819
100hp Tractor+Heavy Grader 1,000hours/year	US\$552	US\$576	US\$601
100hp Tractor+Heavy Grader 500hours/year	US\$774	US\$818	US\$863
70hp Tractor+Light Grader 1,000hours/year	US\$478	US\$495	US\$511
70hp Tractor+Light Grader 500hours/year	US\$635	US\$661	US\$686

Note that the High Utilisation figures are to the left of the columns and the Low Utilisation figures are to the right to ease comparisons.

The detailed cost calculations and assumptions are provided in Annex 1.

It is clear that at all rates of interest and utilisation the tractor technology options are about 50% or less in cost than the heavy equipment option. Higher finance costs also have a proportionately higher negative effect on ownership of capital intensive heavy equipment. Furthermore, for the local private sector the necessity to pay VAT (at 16%) on construction plant and large agricultural tractors (90hp+) mean that the actual real costs of ownership are even higher.

An interesting observation from this financial analysis is that all three equipment options are proven to be capable of light grading up to 10 route-km per day (4 passes) under efficient operational and logistical situations (Petts, 1992, and Gongera & Petts, 2003). Applying this potential output to the Table 7.1 analysis figures indicates the feasibility of achieving routine maintenance light grading for between about US\$50 to US\$180/km for each light grading operation, with the tractor options being substantially cheaper than using a motor grader.

This analysis provides results comparable with reliable data from the Western Cape in South Africa and Namibia. That data indicates light grading operations for a whole year are

assessed to be in the range US\$290 to US\$720/km/year, where a variable number of individual gradings would be required to achieve to achieve satisfactory routine maintenance.

For economic assessment purposes, a discounted comparison of whole life costs between motor grader and tractor equipment has been made specifically for routine maintenance light grading operations. The time value of money and the more onerous investment, operating and maintenance costs of a motor grader, favours the lower capital cost of the tractor. To demonstrate 10%, 20%, and 30% discount rates have been used in the Discounted Cash Flow (DCF) lifecycle costing.

In practice a motor grader would be intended to be used for both light and heavy grading in an annual cycle. The tractor would also be used for a range of productive activities throughout the year. The analysis focusses on the periods of feasible efficient routine light grading and makes a range of assumptions to pro-rata performance and costs to a one year analysis basis. The economic analysis assumptions for the various Discounted Cash Flow (DCF) and results are contained in Annex 2 and summarised hereafter. Two main scenarios are analysed; that of high utilisation (1,000 hours per year) and low utilisation (500 hours per year). The low utilisation is the order of current usage of the Chongwe motorgrader and typical road maintenance motorgrader utilisation experience elsewhere (Petts & Jones, 1991). Results in parenthesis are uneconomic.

TABLE 7.2
Summary findings for light grading (maintenance) comparison
Motorgrader V's Tractor Towed Grader - HIGH UTILISATION

Net Present Value of Investment	DCF 10%	DCF 20%	DCF 30%
Motor Grader	\$ 166,234.77	\$ 17,273.67	\$ (53,242.39)
Tractor & Towed Grader	\$ 683,177.62	\$ 463,290.01	\$ 347,784.25

Internal Rate of Return	DCF 10%	DCF 20%	DCF 30%
Motor Grader	22%	22%	Uneconomic
Tractor & Towed Grader	1000%	1000%	1000%

Payback Years	DCF 10%	DCF 20%	DCF 30%
Motor Grader	7	12	Never
Tractor & Towed Grader	1	1	1

TABLE 7.3
Summary findings for light grading (maintenance) comparison
Motorgrader V's Tractor Towed Grader - LOW UTILISATION

Net Present Value of Investment	DCF 10%	DCF 20%	DCF 30%
Motor Grader	\$ (2,348.00)	\$ (93,902.03)	\$ (136,851.53)
Tractor & Towed Grader	\$ 340,212.81	\$ 224,547.55	\$ 163,862.01

Internal Rate of Return	DCF 10%	DCF 20%	DCF 30%
Motor Grader	Uneconomic	Uneconomic	Uneconomic
Tractor & Towed Grader	1000%	1000%	1000%

Payback Years	DCF 10%	DCF 20%	DCF 30%
Motor Grader	Never	Never	Never
Tractor & Towed Grader	1	1	1

From the outline economic analysis, the following conclusions are drawn:

- Net Present Value of the Tractor and Towed grader is always positive and repays even with 30% discount rate within a year, even at low utilisation.
- The Motor Grader will only pay itself back at low discount rates and high utilisation. At low utilisation rates, the Motor Grader is uneconomic.
- The Motor Grader breaks even at discount rates of 22%, so it is not worth investing unless cheap finance is available and high utilisation can be assured.
- The difference in Net Present Value of the investments for high utilisation scenarios, even at African discount rates, is over US\$400,000.
- The potential attraction of the tractor technology to the MSME sector is clear if contractors are allowed and encouraged to be involved in rural road maintenance, as the capital investments are substantially lower, payback period is short and there is potential for cross sector earnings, compared to heavy equipment approaches.

The economic analysis compares the two technologies at equivalent utilisation and discount rates for a specific activity. In reality, the potential economic advantages of the tractor technology approach are substantially greater for the following reasons:

- The flexibility of the agricultural tractor as the low cost mobile power source with many rural activity applications and opportunities for other economic development in the roads, agriculture, water and other rural sectors are additional economic benefits to be added to the return on investment for the Tractor.
- For any level of funding in a resource constrained environment, more tractor based operational units can be procured than heavy equipment based.
- The multi-tasking potential of the tractor technology, synergies with the agricultural sector and private sector involvement potential will mean that in the future higher actual tractor utilisation and much lower unit costs will create greater economic returns on tractor investments than heavy equipment options. Dialogue is proposed with the Zambia National Farmers Union (ZNFU) to explore this potential in detail.

- The potential for the tractor attachments to be made in Zambia and feasible tractor assembly in Zambia would enhance the economic benefits of the tractor technology approach.
- The feasibility of delivering more road maintenance at lower unit costs using the tractor technology should realise further socio-economic benefits as a result of improved all-season rural access, lowering of user transport costs and stimulation of other investments in the rural areas.

7.3 Current Maintenance Funding Situation

Available Funding

The following data was provided by Chongwe Council regarding funding for road maintenance operations in the current year.

TABLE 7.4 – CHONGWE FUNDING FOR ROAD MAINTENANCE

CHONGWE MUNICIPAL COUNCIL		
2017 -ROADS BUDGETARY ALLOCATION		
SN	Budget Activity	Allocation (ZMW)
1	Servicing of Community Roads in the District	101,980.00
2	Servicing of roads, bush clearing, grading, and spot gravelling	29,150.00
3	Servicing of roads-Grading, provision of drainage system and spot gravelling of Township Roads	227,500.00
4	Spot Gravelling and Grading of roads in Kwamwena, Ndeke, Silverest and other areas	285,940.14
5	Procurement of a Tipper Truck	500,000.00
	Total Allocation	1,144,570.14

Setting aside the planned procurement of the Tipper Truck, the remainder of the budget (ZMW 644,570) equates to approximately US\$72,000 at current exchange rates. If spent entirely on the Core Feeder Road Network of 320km, this would represent a total maintenance allocation of **US\$225/km/year**.

Funding Needs

The Draft Road Maintenance Strategy (2015-2024) states that experience with OPRC on unpaved Main and District Roads estimates that costs are US\$2,240 per km per year for maintenance. The report also stated that "It was considered that the average estimated maintenance cost of **US\$2,400 per km per year** was unsustainable.". Although, no justification for this statement was made.

Costs provided to us by RDA from their 2016 cost database indicate the following:

TABLE 7.5 - AVERAGE RATES FROM RDA COST DATA BASE 2016

Item	Activity Description	Unit	Rate ZMW	Rate \$
1	Road Gravelling (New Road)	Km	780,000.00	78,000.00
2	Heavy Grading	Km	23,000.00	2,300.00
3	Minor Grading	Km	15,000.00	1,500.00

Notes:

- Item No. 1 include grubbing, formation, heavy grading and gravelling. Gravelling only ZMW 468,000.00/Km (\$46,800/km)
- Carriageway width is 6.1m and 1m shoulder
- Two gravel layers 200mm bottom and 150mm upper layer

Returning to the Draft Road Maintenance Strategy (2015-2024) document, Tables 7.6 and 7.7 show a requirement for US\$202,974,120 for the maintenance of 6,629km of Primary Feeder Roads in 2017. That is US\$30,000/km; which must assume that most of the costs are periodic maintenance regravelling.

If we focus on Routine Maintenance, from the foregoing analyses, it seems that the present heavy equipment methods demand in the order of **US\$2,000/km/year** or more.

From the Zimbabwe DDF experience, and inflating to current costs, it is likely that Routine Maintenance using tractor technology approaches could achieve costs of below **US\$1,000/km/year** (Gongera & Petts, 2003).

However, this is still well above the current maintenance funding allocation.

It will be necessary to bid for a substantial increase in budget allocations for Chongwe Council for the years 2018 and 2019 to be able to adequately support the DTU project activities.

7.4 Implications for Future Road Maintenance Budgeting and Costs

For a broad indicative cost comparison between heavy equipment and tractor technology options for routine maintenance of unpaved feeder roads, an outline assessment of equipment capital cost requirements has been made for a typical road network of 150km.

The capital requirements for both technology options are assumed as:

TABLE 7.6 - COMPARISON OF ROUTINE MAINTENANCE TECHNOLOGY CAPITAL INVESTMENT COSTS

ITEM	Cost New (US\$)	Total Cost (US\$)
1. Heavy Equipment Unit Option		
1 No CAT 120K motor grader	264,000	264,000
1 No Tipper truck	50,000	50,000
	Total (US\$)	314,000

2. Tractor Unit Option		
1 No 70 hp tractor	24,000	24,000
1 No light towed grader	15,000	15,000
1 No Trailer	10,000	10,000
10 No tyre drags	200	2,000
	Total (US\$)	51,000

Note: Excludes VAT

Setting aside the dry weather constraints on the use of the motorgrader without watering and compaction support, it is clear that the tractor technology option capital requirements are about one sixth of that of the heavy equipment option.

Grossing this up to the Zambia national Core Feeder Road network of approximately 15,000km, and assuming an equipment replacement cycle of 10 years, then the tractor technology option would achieve national equipment capital investment savings of the order of US\$2.6million per year.

According to CIA data, the Sub-Saharan Africa unpaved classified road network extends to more than 2 million km. If the potential tractor technology routine maintenance cost savings indicated by the Zambia situation (i.e. over US\$1,000/km/year) were to be introduced to just 10% of this network, then US\$200million/year of direct financial benefits could be realised. Tractor technology would also offer substantial savings in the rehabilitation of the road networks to bring them to a maintainable condition. The performance and data collection components of this project will allow the wider 'roll-out' benefits assessment to be refined.

8. SPECIFICATIONS FOR DTU EQUIPMENT PROCUREMENT

Specifications have been prepared for procurement of the key items of DTU equipment by RDA principally through an open tender arrangement.

Although many of the equipment items can be procured from a number of manufacturers, there are key equipment items that are unique and proven specifically for the purposes of the rural road maintenance. This will necessitate that these items can only be procured either directly from the manufacturer, or from their agent.

The specifications have been produced from unique experience of tractor technology roadworks in a number of countries. They set out the specification requirements, but allow tenderers to submit alternatives for consideration. It is strongly recommended that any deviation from the recommended specifications be very carefully considered and discussed with the project consultants before actual procurement.

The recommended procurement specifications are contained in Annex 3, along with the details of the manufacturers of the small number of key sole source items of equipment.

9. BUDGET COSTS FOR DTU EQUIPMENT PROCUREMENT

Procurement budgets have been prepared for the DTU equipment requirements. These are based on consultations with suppliers on their list pricing and ex-VAT costs of items

delivered to Lusaka and recognising the programme requirements and existing budget constraints for the current financial year.

The suppliers of the specialist towed grading equipment are all based outside of Zambia and may not have local agents. Contact details are provided in Annex 3.

Table 9.1 details the equipment procurement requirements for the demonstration and training activities of the DTU.

TABLE 9.1 – TRACTOR TECHNOLOGY DTU EQUIPMENT PROCUREMENT REQUIREMENTS AND COSTS

Equipment Item	DTU No. Required	Target Procurement Cost/Item (US\$)	2017 Procurement (US\$)	2018 Procurement (US\$)
Routine Maintenance				
70hp 2WD agricultural tractor	2	24,000	24,000	24,000
2 tonne towed grader (Mann Zimbabwe)	1	15,000	15,000	0
5 tonne 2 axle general purpose heavy duty trailer	1	10,000	10,000	0
2,500 litre water bowser units for use on the trailer	1	2,000	0	2,000
Tyre drags – locally fabricated	10	250	0	2,500
TOTALS (US\$)			49,000	28,500
Periodic Maintenance and Rehabilitation				
100hp 4WD agricultural tractor	2	47,000	47,000	47,000
5 tonne towed grader (Rogue, RSA)	1	22,000	22,000	0
5 tonne towed grader (CMC, Kenya)	1	28,000	0	28,000
5 tonne towed Pneumatic Tyred Roller (PTR)	1	15,000	0	15,000
5 tonne steel towed roller	1	10,000	0	10,000
5 tonne 2 axle general purpose heavy duty trailer	1	10,000	0	10,000
4,500 litre single axle water bowsers	2	10,000	0	20,000
TOTALS (US\$)			69,000	130,000
Add 5% for tools, manuals, FMS & supplier training			5,900	7,925
2017 Procurement			US\$ 123,900	
2018 Procurement			US\$ 166,425	

NOTE: FMS = Initial Fast Moving Spares

10. VIABILITY OF PLANT HIRE POOLS

The Terms of Reference requested exploration of the commercial viability of establishment of equipment hire and maintenance pools.

There is currently not an active plant hire market for the road sector in Zambia. There is little evidence of an effective plant hire pool sector outside of RSA in Sub Saharan Africa.

The Zambian road construction market is dominated by foreign contractors that generally bring their own equipment into Zambia for their contract works.

The Consultants believe that the current environment in Zambia is not conducive to the introduction of conventional plant hire businesses for intermediate equipment relevant to the road maintenance sector for the following reasons:

- There is currently not an active and viable market for road maintenance works and equipment hire for rural roads in Zambia,
- There is no benchmark costing system for clients and contractors to assess the true costs of owning and operating equipment economically or profitably in the Zambian environment,
- There is currently no proven performance data available for the operation of tractor technology on road maintenance operations in Zambia,
- Local authority budgets for road maintenance are substantially sub-optimal and prevent efficient sector operation,
- There is not an appropriate or efficient contracting framework to hire in agricultural equipment to the rural road sector as required.

Importantly, the DTU project itself will address some of these issues and make data available to justify adoption of tractor technology and increased road maintenance budget allocations. It could be that in future the operating environment will improve to allow intermediate equipment plant hire businesses to be commercially viable.

However, there are many underutilised agricultural tractors in the Zambia agricultural sector national fleet. There is great potential for authorities to hire these in for road maintenance works. The necessary realistic costing systems and contracting framework are required to meet the awareness creation and expectations of clients and suppliers. Again, this project aims to support this objective. Once the performance and cost data are available from the Phase 2 activities, this can be discussed with the stakeholders and ways to develop sustainably the cross-sector hire environment and realise the substantial potential, create awareness and mainstream the concept.

11. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The team has reviewed internationally available towed grading equipment as a viable and sustainable option to motor grading for unpaved road maintenance purposes and identified three regional suppliers that can supply proven equipment suitable for the Zambia Demonstration Training Unit (DTU) and eventual national application.

There is a severe shortage of credible data on the costs of routine maintenance of unpaved roads in Zambia, and indeed for nearly the whole of Sub-Saharan Africa. There are no credible benchmark equipment and road maintenance costing systems available to road planners, financiers and practitioners or the client's or contractor's bodies. With Over 2 million km of unpaved classified roads in the region with a probable asset value well in excess of US\$50 billion, this is an alarming and indefensible situation; preventing any rational costing and meaningful asset management strategies.

In the circumstances, preliminary financial and economic costings have been prepared by the team from first principles for the unpaved road primary routine maintenance task of

routine maintenance grading using heavy equipment and the proven tractor based alternative. The costings have considered a range of equipment utilisation and finance/opportunity costs. The evidence presented in this report demonstrates that the tractor alternative offers unit cost savings of about 50% or more in all practical scenarios. Furthermore, investment requirements for tractor technology for routine maintenance of unpaved roads are about one sixth of that for heavy equipment technology. The adverse costs of operating motor graders for LVR maintenance are clearly demonstrated. This has major implications for potentially improving the performance and cost-effectiveness of the sector, and reducing investment funding requirements.

Recommendations

Detailed recommendations have been made for the equipment to be procured for the training centre (NCC) and field demonstration and training operations for the tractor technology DTU initiative.

It is proposed that the recommended procurement is actioned without delay to avoid compromising the project programme.

It is recommended that urgent consideration is given to developing a benchmark costing system for unpaved road maintenance that includes the principle factors of finance/opportunity cost of capital, equipment utilisation and other key influential variables.

An appropriate and simple intermediate equipment hire and MSME contracting framework is also required to be developed for cost-effective and sustainable maintenance of rural roads in Zambia.

REFERENCES

- Archondo-Callao Rodrigo S. (1999), Unpaved Roads Roughness Estimation by Subjective Evaluation. World Bank Infrastructure Note RT2.
- Burrow M, Petts R, Snaith M, Ghataora G, & Evdorides M. (2015). What is the evidence supporting the technology selection for low-volume, rural roads in low-income countries and what evidence is there to support the sustainability of different rural road technologies? A Systematic Review, for EPI and DFID.
- Paul Collier, Martina Kirchberger, Måns Söderbom (2015), The Cost of Road Infrastructure in Low and Middle Income Countries, World Bank Group.
- Cook J, Petts, R. C. & Rolt J. (2013). Low Volume Rural Road Surfacing and Pavements, A Guide to Good Practice, AFCAP and DFID, 134 pages.
- Cook J, Petts R C, Visser C, & Yiu A. (2017), The Contribution of Rural Transport to Achieve the Sustainable Development Goals.
- Gongera K. and Petts R. C. (2003). A tractor and labour based routine maintenance system for rural roads, Institution of Agricultural Engineers, LCS Working Paper No 5, DFID, Landwards, 2000 & IRF 2001.
- Gongera K. (2012). Road Maintenance Management in Inhambane Province Mozambique, AFCAP Practitioners Conference.
- Gongera K. and Petts R. C. (2015). Agricultural Tractor Based Solutions for Rural Access and Development, T2 Conference, Bulawayo, May 2015.
- Hancox W and Petts R. C. (1999), Guidelines for the development of Small Scale Tractor-based Enterprises in the Rural and Transport Sectors.
- Intech Associates (1990), Minor Road Programme Master Plan, for MOPW, Kenya.
- Intech Associates (1991), Preliminary 10 Year Plan for labour based maintenance of the Classified Road Network, for MOPW, Kenya.

- Intech Associates (1993), Roads 2000, A programme for labour and tractor based maintenance of the Classified Road network, Pilot Project, Final Report, for MPWH, Kenya.
- Larcher P. (1999), A Model for a Contractor Support Agency, MART WP14.
- O'Neill P, Petts R. C. & Beusch A. (2010), Improved Asset Management – Climbing out of the Road Sector Pothole!
- Petts R. C. & Jones T. E. (1991). Towed Graders and Tractor based Maintenance of Low Volume Roads, Fifth International Conference on Low Volume Roads, USA.
- Petts R. C. (1992). Roads 2000, a programme for labour and tractor based maintenance of the classified road network, paper for the RMI road maintenance policy seminar, Nairobi 2 - 5 June 1992.
- Petts R. C. (1994). International Road Maintenance Handbooks (4 Volumes), For TRL, ODA and PIARC World Road Association.
- Petts R. C. (1995-1997) Agricultural Tractors in Roadworks”, and other MART Working Papers.
- Petts R. C. (1998). Seminars Report on Tractor Based Enterprises for the Roads and Other Sectors in Ghana, for RIO.
- Petts R. C. & Cutler M. (2006). Tractor solutions for Rural Roads & Agriculture, PIARC – CIGR International Seminar on Maintenance of Rural Roads, Rabat, Morocco.
- Petts R. C. (2010). Handbook of Intermediate Technology Roadworks Equipment.
- Petts R. C. & Gongera K. (2016), Scoping Study for Establishment of Pilot Project to implement tractor-based road maintenance approaches in Zambia, for AfCAP.
- Petts, Gongera and Goma (2017), Introduction of tractor based rural road maintenance approaches in Zambia.
- RDA (2014), Road Maintenance Strategy 2015 -2024 (draft).
- Cesar Queiroz (2012), Monitoring Road Works Contracts and Unit Costs in Sub-Saharan Africa for Enhanced Governance.
- World Bank (2012), Agribusiness Indicators: Zambia.

ANNEX 1 ROAD MAINTENANCE EQUIPMENT OPTIONS FINANCIAL COST ANALYSIS

To model real costs a comprehensive financial analysis has been carried out from first principles using three indicative rates of interest for equipment technology comparison:

- 5% p.a. to indicate a benchmark comparison with developed economies
- 15% p.a. to represent Zambia government opportunity costs of capital
- 25% p.a.
- 35% p.a. to represent the commercial finance rate for the private sector.

ANNEX 1 : EQUIPMENT COST ANALYSIS - ZAMBIA September 2017 (Assumes rural road maintenance application)

TABLE 1A - Finance/Opportunity Cost Interest Rate 5% per annum

	1	2	3	4	5	6	7	8	9	10
Equipment Type	140hp Motorgrader	140hp Motorgrader	100hp 4wd Tractor	5ton Towed Grader	100hp 4wd Tractor	5ton Towed Grader	70hp Tractor	2ton Towed Grader	70hp Tractor	2ton Towed Grader
Ownership	High utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation
Max Life (hours)	12,000	12,000	10,000	10,000	10,000	10,000	8,000	8,000	8,000	8,000
Max Life (years)	15	15	15	15	15	15	12	12	12	12
Cost New (US\$) delivered ****	264,000	264,000	47,000	22,000	47,000	22,000	24,000	15,000	24,000	15,000
US\$1 = Zambian Kwacha	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Cost New (Zambian Kwacha) ****	2,376,000	2,376,000	423,000	198,000	423,000	198,000	216,000	135,000	216,000	135,000
Residual Value %	10	10	10	10	10	10	10	10	10	10
Annual Utilisation (hours)	1,000	500	1,000	800	500	500	1,000	600	500	500
Finance/Opportunity Cost % P.A. ***	5	5	5	5	5	5	5	5	5	5
Spares, Repairs, Consumables (% of cost new per 500 hours)	4.5	5.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fuel Consumption L/hour (incl. 15% lubs + losses)	16	16	12	0	12	0	8	0	8	0
Fuel Price Kwacha/litre *	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Operator cost US\$/operating hour	12.0	24.0	8.0	10.0	16.0	16.0	8.0	13.3	16.0	16.0
Overhead and Profit (% on depn, spares, fuel, operators)	100	100	100	100	100	100	100	100	100	100

COST COMPONENTS : KWACHA / HOUR

1. Depreciation	178	285	38	18	51	24	24	17	32	20
2. Finance/Opportunity Cost	64	127	12	7	23	11	6	6	12	7
3. Spares, repairs, consumables	214	261	34	16	34	16	17	11	17	11
4. Fuel & Lubricants	158	158	119	0	119	0	79	0	79	0
5. Operator	108	216	72	90	144	144	72	120	144	144
6. Overheads & Profit	658	921	263	124	347	184	193	148	273	175

Total Dry Hire (No fuel) / hour	1,223	1,810	418	254	599	378	312	301	478	357
Total Wet Hire (inc fuel) / hour	1,381	1,968	537	254	717	378	392	301	557	357

COST : KWACHA / DAY

	#	#	#	#	#	#	#	#	#	#
Total Dry Hire (No fuel) / 6 hour-day	7,337	10,860	2,510	1,524	3,591	2,267	1,875	1,809	2,870	2,144
Total Wet Hire (inc fuel) / 6 hour-day	8,287	11,811	3,222	1,524	4,304	2,267	2,350	1,809	3,345	2,144

COST : US\$ / DAY

	#	#	#	#	#	#	#	#	#	#
Total Dry Hire (No fuel) / 6 hour-day	815	1,207	279	169	399	252	208	201	319	238
Total Wet Hire (inc fuel) / 6 hour-day	921	1,312	358	169	478	252	261	201	372	238
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
			527		730		462		610	

Note that the 100 hp tractor + heavy towed grader costs substantially less than a motorgrader for the same work

* Typical retail pump price, rural areas

** Operator Cost based on salary 9000ZKW/month for plant operator and 6000ZKW/month for tractor and TG operators

*** Finance/Opportunity cost of Zambian Bank assumed Loan Rate of 5% p.a..

**** Equipment Purchase Costs are VAT free.

US\$1 = 9.0 ZKW

Zambia DTU Equipment Review

Intech-Clanview

ANNEX 1 : EQUIPMENT COST ANALYSIS - ZAMBIA September 2017 (Assumes rural road maintenance application)

TABLE 1B - Finance/Opportunity Cost Interest Rate 15% per annum

	1	2	3	4	5	6	7	8	9	10
Equipment Type	140hp Motorgrader	140hp Motorgrader	100hp 4wd Tractor	5ton Towed Grader	100hp 4wd Tractor	5ton Towed Grader	70hp Tractor	2ton Towed Grader	70hp Tractor	2ton Towed Grader
Ownership	High utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation
Max Life (hours)	12,000	12,000	10,000	10,000	10,000	10,000	8,000	8,000	8,000	8,000
Max Life (years)	15	15	15	15	15	15	12	12	12	12
Cost New (US\$) delivered ****	264,000	264,000	47,000	22,000	47,000	22,000	24,000	15,000	24,000	15,000
US\$1 = Zambian Kwacha	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Cost New (Zambian Kwacha) ****	2,376,000	2,376,000	423,000	198,000	423,000	198,000	216,000	135,000	216,000	135,000
Residual Value %	10	10	10	10	10	10	10	10	10	10
Annual Utilisation (hours)	1,000	500	1,000	800	500	500	1,000	600	500	500
Finance/Opportunity Cost % P.A. ***	15	15	15	15	15	15	15	15	15	15
Spares, Repairs, Consumables										
(% of cost new per 500 hours)	4.5	5.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fuel Consumption L/hour										
(incl. 15% lubs + losses)	16	16	12	0	12	0	8	0	8	0
Fuel Price Kwacha/litre *	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Operator cost US\$/operating hour	12.0	24.0	8.0	10.0	16.0	16.0	8.0	13.3	16.0	16.0
Overhead and Profit										
(% on depn, spares, fuel, operators)	100	100	100	100	100	100	100	100	100	100
COST COMPONENTS : KWACHA / HOUR										
1. Depreciation	178	285	38	18	51	24	24	17	32	20
2. Finance/Opportunity Cost	193	380	35	20	68	32	18	18	35	22
3. Spares, repairs, consumables	214	261	34	16	34	16	17	11	17	11
4. Fuel & Lubricants	158	158	119	0	119	0	79	0	79	0
5. Operator	108	216	72	90	144	144	72	120	144	144
6. Overheads & Profit	658	921	263	124	347	184	193	148	273	175
Total Dry Hire (No fuel) / hour	1,352	2,064	442	267	644	399	325	314	502	372
Total Wet Hire (inc fuel) / hour	1,510	2,222	560	267	762	399	404	314	581	372
COST : KWACHA / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	8,109	12,381	2,649	1,604	3,862	2,393	1,948	1,882	3,010	2,232
Total Wet Hire (inc fuel) / 6 hour-day	9,060	13,332	3,362	1,604	4,575	2,393	2,423	1,882	3,485	2,232
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
COST : US\$ / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	901	1,376	294	178	429	266	216	209	334	248
Total Wet Hire (inc fuel) / 6 hour-day	1,007	1,481	374	178	508	266	269	209	387	248
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
			552		774		478		635	

Note that the 100 hp tractor + heavy towed grader costs substantially less than a motorgrader for the same work

* Typical retail pump price, rural areas

** Operator Cost based on salary 9000ZKW/month for plant operator and 6000ZKW/month for tractor and TG operators

*** Finance/Opportunity cost of Zambian Bank assumed Loan Rate of 15% p.a..

**** Equipment Purchase Costs are VAT free.

US\$1 = 9.0 ZKW

Zambia DTU Equipment Review

Intech-Clanview

ANNEX 1 : EQUIPMENT COST ANALYSIS - ZAMBIA September 2017 (Assumes rural road maintenance application)

TABLE 1C - Finance/Opportunity Cost Interest Rate 25% per annum

	1	2	3	4	5	6	7	8	9	10
Equipment Type	140hp Motorgrader	140hp Motorgrader	100hp 4wd Tractor	5ton Towed Grader	100hp 4wd Tractor	5ton Towed Grader	70hp Tractor	2ton Towed Grader	70hp Tractor	2ton Towed Grader
Ownership	High utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation
Max Life (hours)	12,000	12,000	10,000	10,000	10,000	10,000	8,000	8,000	8,000	8,000
Max Life (years)	15	15	15	15	15	15	12	12	12	12
Cost New (US\$) delivered ****	264,000	264,000	47,000	22,000	47,000	22,000	24,000	15,000	24,000	15,000
US\$1 = Zambian Kwacha	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Cost New (Zambian Kwacha) ****	2,376,000	2,376,000	423,000	198,000	423,000	198,000	216,000	135,000	216,000	135,000
Residual Value %	10	10	10	10	10	10	10	10	10	10
Annual Utilisation (hours)	1,000	500	1,000	800	500	500	1,000	600	500	500
Finance/Opportunity Cost % P.A. ***	25	25	25	25	25	25	25	25	25	25
Spares, Repairs, Consumables										
(% of cost new per 500 hours)	4.5	5.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fuel Consumption L/hour										
(incl. 15% lubs + losses)	16	16	12	0	12	0	8	0	8	0
Fuel Price Kwacha/litre *	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Operator cost US\$/operating hour	12.0	24.0	8.0	10.0	16.0	16.0	8.0	13.3	16.0	16.0
Overhead and Profit										
(% on depn, spares, fuel, operators)	100	100	100	100	100	100	100	100	100	100
COST COMPONENTS : KWACHA / HOUR										
1. Depreciation	178	285	38	18	51	24	24	17	32	20
2. Finance/Opportunity Cost	322	634	58	33	113	53	30	30	59	37
3. Spares, repairs, consumables	214	261	34	16	34	16	17	11	17	11
4. Fuel & Lubricants	158	158	119	0	119	0	79	0	79	0
5. Operator	108	216	72	90	144	144	72	120	144	144
6. Overheads & Profit	658	921	263	124	347	184	193	148	273	175
Total Dry Hire (No fuel) / hour	1,480	2,317	465	281	689	420	337	326	525	387
Total Wet Hire (inc fuel) / hour	1,639	2,475	584	281	808	420	416	326	604	387
COST : KWACHA / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	8,881	13,902	2,789	1,684	4,133	2,520	2,020	1,955	3,150	2,320
Total Wet Hire (inc fuel) / 6 hour-day	9,832	14,852	3,501	1,684	4,846	2,520	2,496	1,955	3,626	2,320
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
COST : US\$ / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	987	1,545	310	187	459	280	224	217	350	258
Total Wet Hire (inc fuel) / 6 hour-day	1,092	1,650	389	187	538	280	277	217	403	258
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
			576		818		495		661	

Note that the 100 hp tractor + heavy towed grader costs substantially less than a motorgrader for the same work

* Typical retail pump price, rural areas

** Operator Cost based on salary 9000ZKW/month for plant operator and 6000ZKW/month for tractor and TG operators

*** Finance/Opportunity cost of Zambian Bank assumed Loan Rate of 25% p.a..

**** Equipment Purchase Costs are VAT free.

US\$1 = 9.0 ZKW

Zambia DTU Equipment Review

Intech-Clanview

ANNEX 1 : EQUIPMENT COST ANALYSIS - ZAMBIA September 2017 (Assumes rural road maintenance application)

TABLE 1D - Finance/Opportunity Cost Interest Rate 35% per annum

	1	2	3	4	5	6	7	8	9	10
Equipment Type	140hp Motorgrader	140hp Motorgrader	100hp 4wd Tractor	5ton Towed Grader	100hp 4wd Tractor	5ton Towed Grader	70hp Tractor	2ton Towed Grader	70hp Tractor	2ton Towed Grader
Ownership	High utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation	High utilisation	High utilisation	low utilisation	low utilisation
Max Life (hours)	12,000	12,000	10,000	10,000	10,000	10,000	8,000	8,000	8,000	8,000
Max Life (years)	15	15	15	15	15	15	12	12	12	12
Cost New (US\$) delivered ****	264,000	264,000	47,000	22,000	47,000	22,000	24,000	15,000	24,000	15,000
US\$1 = Zambian Kwacha	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Cost New (Zambian Kwacha) ****	2,376,000	2,376,000	423,000	198,000	423,000	198,000	216,000	135,000	216,000	135,000
Residual Value %	10	10	10	10	10	10	10	10	10	10
Annual Utilisation (hours)	1,000	500	1,000	800	500	500	1,000	600	500	500
Finance/Opportunity Cost % P.A. ***	35	35	35	35	35	35	35	35	35	35
Spares, Repairs, Consumables (% of cost new per 500 hours)	4.5	5.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fuel Consumption L/hour (incl. 15% lubs + losses)	16	16	12	0	12	0	8	0	8	0
Fuel Price Kwacha/litre *	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Operator cost US\$/operating hour	12.0	24.0	8.0	10.0	16.0	16.0	8.0	13.3	16.0	16.0
Overhead and Profit (% on depn, spares, fuel, operators)	100	100	100	100	100	100	100	100	100	100
COST COMPONENTS : KWACHA / HOUR										
1. Depreciation	178	285	38	18	51	24	24	17	32	20
2. Finance/Opportunity Cost	450	887	81	47	158	74	43	43	82	51
3. Spares, repairs, consumables	214	261	34	16	34	16	17	11	17	11
4. Fuel & Lubricants	158	158	119	0	119	0	79	0	79	0
5. Operator	108	216	72	90	144	144	72	120	144	144
6. Overheads & Profit	658	921	263	124	347	184	193	148	273	175
Total Dry Hire (No fuel) / hour	1,609	2,570	488	294	734	441	349	338	548	401
Total Wet Hire (inc fuel) / hour	1,767	2,729	607	294	853	441	428	338	628	401
COST : KWACHA / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	9,654	15,422	2,928	1,765	4,404	2,647	2,093	2,028	3,291	2,408
Total Wet Hire (inc fuel) / 6 hour-day	10,604	16,373	3,641	1,765	5,116	2,647	2,569	2,028	3,766	2,408
COST : US\$ / DAY #										
Total Dry Hire (No fuel) / 6 hour-day	1,073	1,714	325	196	489	294	233	225	366	268
Total Wet Hire (inc fuel) / 6 hour-day	1,178	1,819	405	196	568	294	285	225	418	268
			Works with 100hp tractor		Works with 100hp tractor		Works with 70hp tractor		Works with 70hp tractor	
			601		863		511		686	

Note that the 100 hp tractor + heavy towed grader costs substantially less than a motorgrader for the same work

* Typical retail pump price, rural areas

** Operator Cost based on salary 9000ZKW/month for plant operator and 6000ZKW/month for tractor and TG operators

*** Finance/Opportunity cost of Zambian Bank assumed Loan Rate of 35% p.a..

**** Equipment Purchase Costs are VAT free.

US\$1 = 9.0 ZKW

ANNEX 2 ECONOMIC COST COMPARISON BETWEEN MOTOR GRADER & TRACTOR TOWED GRADER LIGHT GRADING

Motor Grader – High Utilisation

Comparison of Motorgrader versus Tractor and towed grader at 10% discounted cash flows																	
Ref																	
Motorgrader	[a]	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Value of work carried out																	
Number of km per Year possible per grader	[b]	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Current market price per km to grade a road external contract	[c]	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08
Total value of work		\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354
Initial cost Grader and tipper	[d]	\$ (264,000)															
Residual value																	\$ 26,400
Operating Costs per year for value of work carried out																	
Fuel Grader	[e]	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)	\$ (17,600)
Fuel Tipper	[f]	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Maintenance	[g]	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)	\$ (29,040)
Labour Motorgrader operator	[h]	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)
Labour Tipper operator	[i]	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Overheads		\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)	\$ (23,456)
Total applied cash flows		\$ (214,742)	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 49,258	\$ 75,658
Discount rates		1	0.909090909	0.826446281	0.751314801	0.683013455	0.620921323	0.56447393	0.513158118	0.46650738	0.424097618	0.385543289	0.350493899	0.318630818	0.28966438	0.263331254	0.239392049
Discounted cash flow		\$ (214,742)	\$ 44,780	\$ 40,709	\$ 37,008	\$ 33,644	\$ 30,585	\$ 27,805	\$ 25,277	\$ 22,979	\$ 20,890	\$ 18,991	\$ 17,264	\$ 15,695	\$ 14,268	\$ 12,971	\$ 18,112
Cumulative Payback		\$ (214,742)	\$ (169,963)	\$ (129,254)	\$ (92,246)	\$ (58,602)	\$ (28,017)	\$ (213)	\$ 25,064	\$ 48,043	\$ 68,933	\$ 87,924	\$ 105,189	\$ 120,884	\$ 135,152	\$ 148,123	\$ 166,235
Discount Factor		10%															
NPV	Net present Value	\$ 166,235															
IRR	Internal rate of return	22%															
Payback period		7	Years														

Zambia DTU Equipment Review
Tractor and Towed Grader – High Utilisation

Intech-Clanview

Tractor and Towed Grader		[a]	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
			0	1	2	3	4	5	6	7	8	9	10	11	12
Value of work carried out															
	Number of KM per Year possible		1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
	Current market price per km to grade a road external contractor USD		\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08	\$ 105.08
	Opportunity to use tractor for other operations during 8 months of the year														
	Total value of work		\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354	\$ 131,354
	Initial cost Tractor and Towed Grader	[j]	\$ (39,000)												
	Residual Value														\$ 3,900
Operating Costs per year for value of work carried out															
	Fuel	[k]	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)
	Maintenance	[l]	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)	\$ (3,120)
	Labour Tractor Operator	[m]	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)
	Labour Grader Operator	[n]	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)
	Overheads		\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)	\$ (11,168)
	Total applied cash flows		\$ 53,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 92,266	\$ 96,166
	Discount rates		1	0.909090909	0.826446281	0.751314801	0.683013455	0.620921323	0.56447393	0.513158118	0.46650738	0.424097618	0.385543289	0.350493899	0.318630818
	Discounted cash flow		\$ 53,266	\$ 83,878	\$ 76,253	\$ 69,321	\$ 63,019	\$ 57,290	\$ 52,082	\$ 47,347	\$ 43,043	\$ 39,130	\$ 35,572	\$ 32,339	\$ 30,641
	Cumulative Payback		\$ 53,266	\$ 137,143	\$ 213,396	\$ 282,716	\$ 345,735	\$ 403,025	\$ 455,106	\$ 502,453	\$ 545,496	\$ 584,625	\$ 620,198	\$ 652,536	\$ 683,178
	Discount Factor		10%												
NPV	Net present Value		\$ 683,178												
IRR	Internal rate of return		1000%												
Payback period			1	Years											

Zambia DTU Equipment Review
Motor Grader – Low Utilisation

Intech-Clanview

Comparison of Motorgrader versus Tractor and towed grader at 10% discounted cash flows																	
	Ref																
Motorgrader	[a]	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Value of work carried out																	
Number of km per Year possible per grader	[b]	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625	625
Current market price per km to grade a road external contract	[c]	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59
Total value of work		\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117
Initial cost Grader and tipper	[d]	\$ (264,000)															
Residual value																	\$ 26,400
Operating Costs per year for value of work carried out																	
Fuel Grader	[e]	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)	\$ (8,800)
Fuel Tipper	[f]	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Maintenance	[g]	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)	\$ (14,520)
Labour Motorgrader operator	[h]	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)	\$ (12,000)
Labour Tipper operator	[i]	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Overheads		\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)	\$ (14,128)
Total applied cash flows		\$ (234,331)	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 29,669	\$ 56,069
Discount rates		1	0.909090909	0.826446281	0.751314801	0.683013455	0.620921323	0.56447393	0.513158118	0.46650738	0.424097618	0.385543289	0.350493899	0.318630818	0.28966438	0.263331254	0.239392049
Discounted cash flow		\$ (234,331)	\$ 26,972	\$ 24,520	\$ 22,291	\$ 20,264	\$ 18,422	\$ 16,747	\$ 15,225	\$ 13,841	\$ 12,582	\$ 11,439	\$ 10,399	\$ 9,453	\$ 8,594	\$ 7,813	\$ 13,422
Cumulative Payback		\$ (234,331)	\$ (207,360)	\$ (182,840)	\$ (160,549)	\$ (140,285)	\$ (121,863)	\$ (105,116)	\$ (89,891)	\$ (76,050)	\$ (63,468)	\$ (52,029)	\$ (41,631)	\$ (32,177)	\$ (23,583)	\$ (15,770)	\$ (2,348)
Discount Factor		10%															
NPV	Net present Value	\$ (2,348)															
IRR	Internal rate of return	Uneconomic															
Payback period		Never	Years														

Zambia DTU Equipment Review
Tractor and Towed Grader – Low Utilisation

Intech-Clanview

Tractor and Towed Grader		[a]	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
			0	1	2	3	4	5	6	7	8	9	10	11	12
Value of work carried out															
	Number of KM per Year possible		625	625	625	625	625	625	625	625	625	625	625	625	625
	Current market price per km to grade a road external contractor USD		\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59	\$ 126.59
	Opportunity to use tractor for other operations during 8 months of the year														
	Total value of work		\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117	\$ 79,117
Initial cost Tractor and Towed Grader		[j]	\$ (39,000)												
Residual Value															\$ 3,900
Operating Costs per year for value of work carried out															
	Fuel	[k]	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)	\$ (4,400)
	Maintenance	[l]	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)	\$ (1,560)
	Labour Tractor Operator	[m]	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)
	Labour Grader Operator	[n]	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)	\$ (8,000)
	Overheads		\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)	\$ (8,784)
Total applied cash flows			\$ 9,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 48,373	\$ 52,273
Discount rates			1	0.909090909	0.826446281	0.751314801	0.683013455	0.620921323	0.56447393	0.513158118	0.46650738	0.424097618	0.385543289	0.350493899	0.318630818
Discounted cash flow			\$ 9,373	\$ 43,975	\$ 39,978	\$ 36,343	\$ 33,039	\$ 30,036	\$ 27,305	\$ 24,823	\$ 22,566	\$ 20,515	\$ 18,650	\$ 16,954	\$ 16,656
Cumulative Payback			\$ 9,373	\$ 53,348	\$ 93,326	\$ 129,669	\$ 162,708	\$ 192,744	\$ 220,049	\$ 244,872	\$ 267,438	\$ 287,953	\$ 306,603	\$ 323,557	\$ 340,213
Discount Factor			10%												
NPV	Net present Value		\$ 340,213												
IRR	Internal rate of return		1000%												
Payback period			1	Years											

ANNEX 2 NOTES**ASSUMPTIONS**

- 1 In practice, routine maintenance light grading is only one task in the management of unpaved rural roads. For analysis, it is therefore necessary to separate out this activity to be able to realistically compare technologies.
- 2 Routine maintenance (light) grading can only be effectively carried out during the rains, when there is sufficient moisture in the surface material to facilitate consolidation under traffic.
- 3 It is assumed that whether a motor grader or a tractor towed grader is used, it will be allocated to the light grading for this period each year for maximum efficiency.
- 4 For the motor grader it is assumed that sufficient funds will be available for it to spend the rest of the year on heavy grading work, for which it will be necessary to fund and mobilise watering and compaction equipment.
- 5 For the tractor, it is assumed for the rest of the year it will be deployed on other routine maintenance activities such as materials and labour haulage, or dragging the road surface to remove corrugations.
- 6 Therefore, it is assumed that for both the Motor grader and the Tractor towed grader only 6 months of each year are allocated to routine maintenance light grading.
- 7 TWO SCENARIOS ARE CONSIDERED: a. WHERE THE OVERALL ANNUAL UTILISATION IS 1,000 HOURS PER YEAR (REPRESENTING HIGH EFFICIENCY), AND b) 500 HOURS PER YEAR (REPRESENTING LOW EFFICIENCY). In practice, routine light grading will only consume 500 hours and 250 hours respectively in a period of 6 months each year.

ANNEX 3 EQUIPMENT SPECIFICATIONS

This Annex includes General Procurement Guidelines and detailed Procurement Specifications for the following key items:

Routine Maintenance Operations

1. Small 2WD Agricultural Tractor (The Specification is modelled on the proven and widely available MF375)
2. Light Towed Grader
Manufacturer: J Mann and Company
Douglas Road Workington, Harare, Zimbabwe
Telephone: (04) 759571 / 72 / 73 / 74 / 75 / 76 / 77 / 78

Periodic Maintenance Operations

3. Large 4WD Agricultural Tractor
4. Heavy Towed Grader (RSA)
Manufacturer: Rogue Agriculture
P O Box 11256 Dorpspruit 3206
Doull Road, Pietermaritzburg 3201, RSA
Email: agri@rogesteel.co.za
Web: www.rogesteel.co.za
Skype: Rogue Agriculture
Cell: +27 (0) 71 351 0496
Office: +27 (0) 33 345 0038
5. Heavy Towed Grader (Kenya)
Manufacturer: CMC Motors Group Limited
Alex M. Makaa
Divisional Manager - New Holland
P.O.Box 30135 - 00100; Nairobi, Kenya.
Tel: Main: +254 20 650255; Direct: +254 20 6932364
Mobile: +254 700 876787
Email: amakaa@cmcmotors.com
www.cmcmotors.com

RECOMMENDED PROCUREMENT GENERAL REQUIREMENTS

[The procurer should review/amend text in italics]

Introduction

The following requirements apply to all of the items listed for procurement. The Bidder must verify that the items being offered will comply with the following.

G.1 The Bid – The Bidding Document requests submissions for a range of equipment items. The Bidder may submit a bid for any one item, a number of items or all items. The Client reserves the right to accept or reject any bid for any or all of the items.

G.2 General – The equipment offered shall be new, unused and current model production, which is substantially the same as the prototype or other model in successful use for not less than 1 year or 2000 hours.

G.3 Supplier – If the Bidder is not the manufacturer of the item, the Bidder will ensure that the item is manufactured and supplied in accordance with the requirements of the specification.

G.4 Language – All documents, manuals, charts, drawings and manufacturer's specification literature included with the bid shall be in the English language.

G.5 Compliance Certification – All Bidders will provide their Statement of Compliance and Clause by Clause commentary for all parameters and any data by certifying at the right side column of the individual specifications.

G.6 Compliance to Requirements – Bidders are expected to offer equipment that meets or is better than the Specification requirements. Under the SUPPLIER/TENDERER OFFER column the Bidder will either enter 'Complies' or inserts the improvements offered FOR EACH SPECIFICATION REQUIREMENT.

G.7 Service Requirements – The equipment offered to be supplied will be suitable to be used on road construction and maintenance works anywhere in Zambia. The equipment shall accordingly be extra heavy duty for tropical conditions capable of rendering *[10 years or 10000 hours]* of service with scheduled maintenance and without the need for major refurbishment/rehabilitation in adverse conditions that will include possible low grade/contaminated fuels and dusty conditions.

G.8 Manufacturing materials – All materials shall be free from defects, which would adversely affect the performance or maintainability of individual components or the overall assembly.

G.9 Manufacturing construction – The unit and its components and accessories shall be designed and constructed to facilitate field maintenance. All adjustment features, routine maintenance spares and replaceable parts shall be easily accessible.

G.10 Additional features – Additional or better features which are not mentioned in the Specification, but which are a part of the manufacturer's standard product shall be included in the unit being offered.

G.11 On Site Warranty –

- a) The Bidder/Supplier guarantees that all materials, parts, components, accessories and attachments will be manufactured and assembled to high quality and good workmanship. The Bidder/Supplier also guarantees to replace at his own cost (including any freight,

SPECIFICATION 1

taxes, duties and labour) any part or component that may break or fail for reason of inferior or defective design, material or workmanship within the warranty period.

- b) The warranty period shall be 12 months or 2000 hours (whichever is sooner) from the date of formal acceptance.
- c) The Bidder/Supplier shall undertake to rectify each and every fault under warranty upon notification by [*the Customer*] within a maximum of 45 calendar days from the date of notification of such occurrences. Failure to do so will result in remedial action being taken by [*the Customer*] at the risk and expense of the Bidder/Supplier.
- d) [*the Customer*] reserves the right to further claim for consequential down time costs if the faults are not rectified within the time period specified above.

G.12 After Sales Service Facility – A Bidder/Supplier who has an established dealership and after sales service facility in Zambia, or an officially appointed agency providing such equipped and trained personnel facilities will be given preference in bid evaluation to one who has not.

G.13 Pre-delivery service – The Bidder shall arrange for the manufacturer's scheduled and checklist certified pre-delivery inspection and servicing of the unit with the manufacturer's representative or local agent, including removal of transit protection and packaging, washing, greasing, lubrication, adjustment and calibration (if any) at his own cost (including parts, materials and labour etc.) to [*the Customer*]'s satisfaction before formal acceptance of the unit at the final destination.

G.14 Training – Technical training shall be provided at the Lusaka NCC Training Centre at the expense of the Supplier as follows:-

- In operation of the unit to the Training Centre Trainer and at least two operators per unit.
- In repair and maintenance of the unit the Training Centre Trainer and at least two mechanics.

G.15 Documentation – The Bidder/Supplier shall provide the following additional documents with his bid:-

- a) Technical Specifications and manufacturer's brochures describing in detail the unit being offered including all standard and optional equipment.
- b) If the unit includes an engine, the Certified Engine data to ISO or other acceptable standard showing net flywheel power, torque and fuel consumption curves at sea level and at an altitude of 2000 metres above sea level.
- c) Other supporting documentation, certification or validation as appropriate.

G.16 Supply requirements – Each unit shall be supplied with the following:-

- a) Manuals – One copy each of the Operators Manual, Maintenance Manual and Workshop/Repair Manual plus one additional copy of each manual for the total order quantity. Manuals are to cover the units and any attachments or accessories.
- b) Standard Tools – A set of essential tools (to include grease gun, spanners etc.) shall be provided in a lockable toolbox with each unit.
- c) Special Tools – Any tools not expected to be available in a standard workshop toolkit shall be provided at the rate of one set for every unit.
- d) Fire-extinguisher – If the unit includes an engine, a fire extinguisher suitable for fuel and electrical fires shall be provided with each unit.
- e) Optional Equipment – Any items considered by the Bidder/Supplier to be vital for the safe, effective and efficient operation of the equipment and not specified, shall be quoted separately as a supply option.

G.17 Other Information – Data to be provided by the Bidder

- a) Number of units of the offered make and model in service in a) Zambia, and b) East and Southern Africa, and the address of at least two organisations using them.
- b) Approximate number of line items and value of spares stock for the offered units at the local agent/dealership guaranteed to be in place on delivery of the order if awarded.

SPECIFICATION 1

- c) Maximum parts supply time from agent/dealership order to delivery from factory to agent/dealership premises both by air freight and sea freight.
- d) Locations of agencies/dealerships and branches within Zambia/RSA and length of time that these have been established.
- e) Number and level of technical staff employed by the local agents/dealerships for carrying out after sales service and warranty claims.
- f) Manufacturer's recommended lubricants and their renewal intervals (greases, engine transmission drive and hydraulic oils etc.) allowing for a 1% sulphur content in the diesel fuel working under normal conditions and work on dusty unpaved roads.
- g) Manufacturer's recommendations regarding change intervals for any filters (Air Cleaner, fuel, engine oil, hydraulic oil, transmission oil etc.) allowing for a 1% sulphur content in the diesel fuel working under normal conditions and work on dusty unpaved roads.
- h) Work load fuel consumption data
- i) Details of workshop tools, testing facilities and equipment required for all scheduled services.

G.18 Specification Waiver – *[the Customer]* reserves the right to partially or fully waive compliance to any of the requirements or Specifications, and make awards on the basis of serving the best interests of the *[the Customer]* .

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

52kW (70HP) TRACTOR**NO. REQUIRED:**

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
1. General		
2 Wheel drive Wheeled Tractor, Heavy Duty Tropical Specifications, ROPS & sun protection canopy, Heavy Duty belly anchored auto pick-up Hitch, Zambia road legal		
2. Engine		
Diesel fuel, 4 cylinder, naturally aspirated, water cooled		
Max Power (DIN) (SAE net) (ISO-14396) (9768-EC) Max Torque (DIN) Piston Displacement Air Filtration Fuel filtration heavy duty Lubrication system	Min 52 kW/70HP Min 52 kW/70HP Min 55 kW/74HP Min 55 kW/74HP Min 290 Nm 4 litres Heavy Duty suitable for abrasive dusty conditions(e.g. 2 stage dry type fitted with cyclone pre-cleaner and restriction indicator light) With water separator Fully pressurised and filtered	
3. Electrical, 12v	Starter, Charging and lighting	
Alternator	Heavy duty 30 ampere Min	
Battery	80 Ah Min, Holder Lockable	
4. Power Take Off (PTO)		
Independent, single selector lever clutch operation, 540 rpm		
5. Transmission	Manual Type	
Clutch	Heavy Duty, self adjusting, mechanical	
Gear Box	Synchromesh, Min 8 forward & 2 reverse gears	
Drive	4 x 2	
Max Road Speed (kph)	Min 30	
6. Steering	Hydrostatic	

52kW (70HP) TRACTOR (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>7. Wheels & Tyres Wheels Front Rear</p>	<p>Heavy Duty 750 - 16, 8 PR, suitable for Max load of 1000 kg Min 1690 - 30, 12 PR, Traction type Industrial radial tractor, suitable for Max load of 3000 kg</p>	
<p>8. Dimensions Overall Length Overall Width Overall height (bare) Ground clearance under gearbox</p>	<p>Max 3,670 mm Max 1,970 mm Max 1,730 mm(to top of steering wheel) Min 500 mm</p>	
<p>9. Operational weight inc fuel oil water & weights, but excluding ROPS Rear Axle Capacity</p>	<p>Min 2,295 kg Max 4,000 kg Min 3,000 kg</p>	
<p>10. Brakes Service Brake System Parking Brake</p>	<p>Mechanical/Hydraulic on rear wheels, oil bath Independent hand operated on rear wheels</p>	
<p>11. Fuel Tank</p>	<p>Min 108 litre, lockable with filler strainer</p>	
<p>12. Lighting and Reflectors Zambia Road legal. Headlights, Direction indicators, Stop & tail lights, Panel lights, Number plate light, Hazard warning, Park Brake, and working front and rear lights, warning lights for Oil Pressure, Water Temperature, Alternator charge.</p>		
<p>13. Instruments Speedometer metric (km/hr), Service (hour) meter to 9999 hours, Fuel gauge, Alternator charge, Water temperature gauge, Oil pressure gauge.</p>		

52 kW (70HP) TRACTOR (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>14. Hitches</p> <p>Heavy Duty auto pick up hitch with underbelly anchorage secured with at least 8 bolts, to BS 6108/ISO 6489, pin (suitably hardened) and 50 mm eye fitting, for towing up to 8000 kg load. Vertical transfer load up to 3000 kg, Tow height 400 mm</p>		
<p>15. Miscellaneous</p> <p>Full front mounted and rear wheel Ballast weights</p> <p>Tool Kit (Specify)</p> <p>Operation, Workshop and Spare Parts Manuals</p> <p>Spares as per Specification 8.2</p> <p>Steel Roll Over Protection Structure and sun/rain canopy to be fitted</p> <p>Full corrosion protection and finished in paintwork of Purchaser's colour choice</p> <p>Large rear view mirrors to be fitted to provide clear view of towed items</p> <p>Electrical, steering wheel mounted horn operation</p> <p>Fuses, circuit breakers or equal protection against damage of short circuits shall adequately protect all electrical circuits</p>		
<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>		

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

SPARES FOR 52kW (70HP) TRACTOR

<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>	
---	--

Supplier/Tenderer to list recommended initial spares inventory to be supplied with **each** tractor unit sufficient for 2 years or 2,000 hours operation, including consumable and service items.

PART DESCRIPTION	PART NUMBER	NUMBER TO BE SUPPLIED	UNIT PRICE	TOTAL PRICE

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

October 2017

TOWED GRADER (2 TONNE)**NO. REQUIRED:**

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
1. General Two axle, mechanical towed grader for maintenance of camber on earth or gravel roads, construction or maintenance of turn-out (mitre) drains. Complete with scarifier to loosen hard compacted material		
2. Towing Equipment Required (not supplied under this Specification item)	Wheeled agricultural tractor, 2 wheel drive, Min 52kW (70HP) SAE net	
3. Dimensions a) Overall Length b) Overall Width c) Height overall d) Wheelbase	6375 mm 2260 mm (with blade stowed for travel) 2209 mm 4267 mm	
4. Construction Heavy duty, welded steel. Main frame of Rolled Steel Channels. Turntable on "A" frame with manual-mechanically operated height and sideshift control. Greased wear - adjustable ball and socket joint connection of "A" frame apex to main frame. Turntable lockable in range of positions. Rear mounted, manual-mechanically operated scarifier. Operator control platform behind and in full view of blade		
5. Weights a) Gross Weight b) On front axle b) On rear axle	1880 kg 900 kg 980 kg	
6. Axle Front axle (swivel) - single channel section 203x76 mm Rear axle - box section 102x127 mm Heavy duty stub axles.		
7. Wheels Pressed steel rims.		
8. Tyres	750x16x8 PR	
9. Reflectors	Front and rear	
10. Drawbar & Towing Eye Towing drawbar with eye	BS 5891 (1980) or ISO 5692 (1979) Inside hole dia. 50 mm	

TOWED GRADER (2 TONNE) (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
11. Mouldboard length	2743mm (12')	
12. Mouldboard depth	406 mm nominal	
13. Mouldboard thickness	12.7 mm	
14. Mouldboard pitch	3 positions, manual adjustment	
15. Mouldboard positions	Side shift 2 left or right, 152 mm Blade positions 8 left or right Max blade reach outside rear wheel 838 mm Ground clearance stowed 381 mm Max blade inclination 25°	
16. Cutting depth	Max 114 mm	
17. Cutting Edges	Hardened steel and end overlays	
18. Controls on Grader	Left and right blade height adjustment operator wheels	
19. Safety	Heavy duty roll bar and overhead operator sun/rain protection	
20. Jacking Points	Near each end of axle and front of mainframe	
21. Scarifier Width of swath 463mm Ground clearance stowed 220 mm	Rear mounted manually operated with 3 No. replaceable tines and replaceable tips. Max Penetration 127 mm	
22. Hitch Option Towing eye attachment to be supplied for alternative single axle operation by removing the front axle and hitching the grader mainframe directly to the tractor (This significantly increases load transfer to the tractor rear axle and improves performance and versatility). Complete with 50mm internal diameter towing eye to BS5891 1980) or ISO 5692 (1979) or similar swivel barrel seating. Adjustable parking stand to be fitted to the front of the towed grader mainframe for 450mm towing height.		

TOWED GRADER (2 TONNE) (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>23. Miscellaneous</p> <p>Spare wheel and lockable carrier mounted on body</p> <p>Tool Kit in lockable box (specify)</p> <p>Operation, Workshop and Spare Parts Manuals</p> <p>Spares as per Specification 9.2</p> <p>Full corrosion protection, finish in yellow paintwork</p>		
<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>		

Supplier Company Stamp

Authorizing Signature
 Certifying Compliance

Date

SPARES FOR TOWED GRADER (2 TONNE)

<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>	
---	--

Supplier/Tenderer to list recommended initial spares inventory to be supplied with **each** towed grader unit sufficient for 2 years or 2,000 hours operation, including consumable and service items.

PART DESCRIPTION	PART NUMBER	NUMBER TO BE SUPPLIED	UNIT PRICE	TOTAL PRICE

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

75/90kW (100/120 HP) 4WD TRACTOR**NO. REQUIRED:**

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
1. General		
4 Wheel drive Wheeled Tractor, Heavy Duty Tropical Specifications, ROPS & sun protection canopy, Heavy Duty auto belly anchored Pick up Hitch, Zambia road legal		
2. Engine Diesel fuel, 4 stroke, turbocharged or naturally aspirated, water cooled		
Max Power (DIN) (SAE net) (ISO-14396) (9768-EC) Max Torque (DIN) Piston Displacement Air Filtration Fuel filtration heavy duty Lubrication system	Min 75 kW Min 75 kW Min 79 kW Min 79 kW Min 400Nm Min 4.50 litres Heavy Duty suitable for abrasive dusty conditions(e.g. 2 stage dry type fitted with cyclone pre-cleaner and restriction indicator light) With water separator Fully pressurised and filtered	
3. Electrical, 12 v	Starter, Charging and lighting	
Alternator	Heavy Duty 45 ampere	
Battery	Min 100 Ah Min, Holder Lockable	
4. Power Take Off (PTO)		
Independent, single selector lever clutch operation, 540/1000 rpm options		
5. Transmission	Manual type	
Clutch	Heavy Duty, self adjusting, mechanical	
Gear Box	Synchromesh, Min 10 forward & 2 reverse gears	
Drive	4 x 4	
Max Road Speed (kph)	Min 25	
6. Steering	Hydrostatic and centre mounted	

75/90kW (100/120 HP) 4WD TRACTOR (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>7. Wheels and Tyres</p> <p>Wheels Front</p> <p>Rear</p>	<p>Heavy Duty Min 14.9 - 28, 8 PR, Traction type Industrial radial suitable for Max load of 1800 kg min Min 18.4 - 38, 8 PR, Traction type Industrial radial tractor, suitable for Max load of 4000 kg min</p>	
<p>8. Dimensions</p> <p>Overall Length Overall Width Overall height (bare) Ground clearance under axle housing and hitch</p>	<p>Max 5500 mm Max 2500 mm Max 2500 mm(to top of steering wheel)</p> <p>Min 350 mm</p>	
<p>9. Operational weight</p> <p>Inc. fuel oil water & weights, but excluding ROPS Rear Axle Capacity</p>	<p>Min 4000 kg Max 5500 kg</p> <p>Min 5000 kg</p>	
<p>10. Brakes</p> <p>Service Brake System Parking Brake</p> <p>Brake couplings for towed items Brake Performance</p>	<p>Hydraulic, on all wheels Independent hand operated on rear wheels</p> <p>Yes Capable of controlling and holding the tractor and an 8 tonne towed item on a 20% grade</p>	
<p>11. Fuel Tank</p>	<p>Min 120 litre, lockable with filler strainer</p>	

75/90kW (100/120 HP) 4WD TRACTOR (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>12. Lighting and Reflectors</p> <p>[country] Road legal. Headlights, Direction indicators, Stop & tail lights, Panel lights, Number plate light, Hazard warning, Park Brake, and working front and rear lights, warning lights for Oil Pressure, Water Temperature, Alternator charge.</p>		
<p>13. Instruments</p> <p>Speedometer metric (km/hr), Service (hour) meter to 9999 hours, Fuel gauge, Alternator charge, Water temperature gauge, Oil pressure gauge</p>		
<p>14. Hitches</p> <p>Heavy Duty auto belly anchored pick up Hitch, secured with at least 8 bolts, to BS 6108/ISO 6489, pin (suitably hardened) and 50 mm eye fitting, for towing up to 10000 kg load.</p> <p>Vertical transfer load up to 3000 kg, Tow height 450 mm</p>		
<p>15. Hydraulics (Auxiliary)</p> <p>Hydraulic pump flow rate</p> <p>Operational pressure</p> <p>Valves</p> <p>Couplings</p>	<p>60 litres/minute Min</p> <p>12MPA (1800 psi) Min</p> <p>2 No. Double acting spool valves</p> <p>Flow and return - quick release action couplings for towed items - 13mm ISO</p>	
<p>16. Miscellaneous</p> <p>Full front mounted and rear wheel Ballast weights</p> <p>Tool Kit (Specify)</p> <p>Operation, Workshop and Spare Parts Manuals</p> <p>Spares as per Specification 1.2</p> <p>Steel Roll Over Protection Structure and sun/rain canopy to be fitted</p>		

75/90kW (100/120 HP) 4WD TRACTOR (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>16. Miscellaneous (cont.)</p> <p>Full corrosion protection and finished in paintwork of Purchaser's colour choice</p> <p>Hydraulic connection and control for towed trailer tipping operation</p> <p>7 pin ISO trailer power supply socket</p> <p>Large rear view mirrors to be fitted to provide clear view of towed items</p> <p>Electrical, steering wheel mounted horn operation</p> <p>Fuses, circuit breakers or equal protection against damage of short circuits shall adequately protect all electrical circuits</p>		

<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>	
---	--

Supplier Company Stamp

Authorizing Signature
 Certifying Compliance

Date

SPARES FOR 75/90kW (100/120 HP) 4WD TRACTOR

<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>	
---	--

Supplier/Tenderer to list recommended initial spares inventory to be supplied with **each** tractor unit sufficient for 2 years or 2,000 hours operation, including consumable and service items.

PART DESCRIPTION	PART NUMBER	NUMBER TO BE SUPPLIED	UNIT PRICE	TOTAL PRICE

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

October 2017

HEAVY TOWED GRADER (5 TONNE)

NO. REQUIRED:

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
<p>1. General</p> <p>Heavy duty, single axle or tandem axle pair, towed grader for construction, reconstruction and maintenance of camber on earth or gravel roads, construction or maintenance of side and turn-out (mitre) drains. Complete with heavy duty scarifier to loosen hard compacted material</p>		
<p>2. Towing Equipment Required (not supplied under this Specification item – see separate item)</p>	<p>Wheeled agricultural tractor, 4 wheel drive, Min 75kW (100HP)SAE net</p>	
<p>3. Dimensions</p> <p>a) Max Overall Length</p> <p>b) Max Overall Width</p>		
	<p>6500 mm (ex-scarifier)</p> <p>2500 mm (with blade stowed for travel)</p>	
<p>4. Construction</p> <p>Heavy duty, welded steel. Main frame of Rolled Steel Channels. Turntable on "A" frame with hydraulically operated height and sideshift control. Greased wear - adjustable ball (80 mm Min) and socket joint connection of "A" frame apex to main frame. Turntable lockable in range of positions. Rear mounted, hydraulically operated scarifier. Operator control platform behind and in full view of blade</p>		
<p>5. Weights</p> <p>a) Gross Weight</p> <p>b) At hitch (static)</p>		
	<p>Min 4500 kg Max 6500 kg Min 1500 kg, Max 3000 kg</p>	
<p>6. Axle Heavy duty stub axles each 5,000 kg Min load rating. Stub axles welded in position. 8 No. high tensile steel studs</p>		
<p>7. Wheels</p> <p>8" (200 mm) rims. Rated load Min 5000 kg. Braked</p>		
<p>8. Tyres</p>	<p>1000 - 20, 14 PR, or 1100 - 20, 16 PR</p>	

HEAVY TOWED GRADER (5 TONNE) (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
9. Lights and Reflectors	Tail, brake, reversing and direction lights on rear. Front and rear reflectors. Wiring and 7 pin ISO connection	
10. Towing Eye	Heavy duty swivel hitch with towing eye, welded or bolted to chassis, fitted for 450 mm hitch towing height	BS 5891 (1980) or ISO 5692 (1979) Inside hole dia. 50 mm Swivel barrel 76 mm dia. shaft into bush bearing
11. Parking Stand	Fold back/adjustable heavy duty parking stand for 450 mm height of towing eye	
12. Mouldboard length	3600mm (12') nominal 3000mm (10') option	
13. Mouldboard depth	500 mm nominal	
14. Mouldboard thickness	18 mm Min	
15. Mouldboard pitch	6 positions, manual adjustment	
16. Mouldboard positions	Min 6 left, 6 right, hydraulic locking device. Turntable turning angle from centre position $\pm 55^\circ$ Min	
17. Turntable Diameter	1200 mm approx	
18. Cutting Edges	Standard Caterpillar /Komatsu specifications and end overlays, or reversible supplier manufacture	
19. Hydraulics	Main lift rams (2 No) Stroke 700 mm Bore 80 mm Side shift rams Stroke 700 mm Bore 80 mm Turntable Lock Ram Stroke 100 mm Bore 50 mm Scarifier Ram Stroke 400 mm Bore 100 mm	
20. Working pressure	Minimum 1,500 psi Maximum 2,250 psi	

HEAVY TOWED GRADER (5 TONNE) (CONT)

SPECIFICATION	RECOMMENDED	SUPPLIER/TENDERER OFFER
21. Controls on grader	5 element spool valve	
22. Hydraulic lines to tractor	One delivery One return	
23. Hoses	Quick release couplings 13 mm ISO. Dummy couplings for disengaged situation	
24. Oil Supply assumed	60 litres/min Min	
25. Safety	Heavy duty roll bar & overhead operator sun/rain protection	
26. Jacking Points	At hitch and at each side of the grader close to stub axles	
27. Scarifier	Hydraulically operated with 4/5 replaceable tines and replaceable tips. Penetration 300mm Min	
28. Miscellaneous Brake lines and connection & parking brake Spare wheel-tyre and lockable carrier mounted on body Tool Kit in lockable box (specify) Operation, Workshop and Spare Parts Manuals Spares as per Specification 2.2 Full corrosion protection, finish in yellow paintwork		
SUPPLIER/TENDERER'S SPECIFICATION MAKE: MODEL: COUNTRY OF ORIGIN :		

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

SPARES FOR HEAVY TOWED GRADER (5 TONNE)

<p>SUPPLIER/TENDERER'S SPECIFICATION</p> <p>MAKE:</p> <p>MODEL:</p> <p>COUNTRY OF ORIGIN :</p>	
---	--

Supplier/Tenderer to list recommended initial spares inventory to be supplied with **each** towed grader unit sufficient for 2 years or 2,000 hours operation, including consumable and service items.

<p><i>Recommended Minimum Service & Repair Kit Spares</i></p>	<p><i>4 sets of ram seals, 1 set of hydraulic hoses and couplings, 12 sets of cutting edges, 2 sets of end overlays, 1 set of nuts and bolts for the above</i></p>
--	--

PART DESCRIPTION	PART NUMBER	NUMBER TO BE SUPPLIED	UNIT PRICE	TOTAL PRICE

Supplier Company Stamp

Authorizing Signature
Certifying Compliance

Date

ANNEX 4 Ancilliary Tractor attachments

ANNEX 4 – ANCILLIARY TRACTOR ATTACHMENTS

These items are available from a range of manufacturers and suppliers. The example details shown are from one source. Open invitations will allow the range of available products to be assessed on submission.

5 TONNE, HEAVY DUTY, TWO AXLE, DROP SIDE TRAILER



ANNEX 4 Ancilliary Tractor attachments

TOWED WATER BOWSER



Length:	5400mm
Height:	1760mm
Width:	2500mm
Tyres:	400/60 R15.5
Hitch:	"4" bugle Eye
Axles:	Single Rigid 4 Ton Un-Braked axle
Platform Material:	5mm Checker MSP
Water Tanks:	5mm MSP with 3 x Baffles and inspection compartments. Tanks are bolt on fixtures to chassis.
Pump:	Optional Davey or Normac Twin stage centrifugal pumps powered by either Hydraulic pump or Honda Petrol GX160 Engine.
Hose & Reel:	2 x 30m 25mm hose reels with Forestry nozzle
Power Recommended:	From 50kw >



TOWED PTR



ANNEX 4 Ancilliary Tractor attachments

TOWED STEEL ROLLER



TYRE DRAG

