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There is much evidence of roads in Africa having been poorly maintained for some decades now which will require billions of US dollars to restore them to a serviceable state. In addition, the limited application of comprehensive integrated road management systems hampers a rational approach to address these shortfalls and effective network planning for road construction and improvement schemes.

TITLE: IMPROVED RURAL ROAD NETWORK ASSET MANAGEMENT THROUGH APPROPRIATE TECHNOLOGY

ABSTRACT

Many Sub-Saharan African road networks are still substantially only constructed to earth or gravel standard (more than 80% and equivalent to approximately 2 million km). In recent decades, maintenance techniques for these roads have normally been based on the use of motor graders. Due to a range of factors these approaches are very expensive and suffer from serious funding and operational constraints. Consequently, rural road networks often remain in generally poor condition, with a deteriorating cycle of poor condition and reluctance to fund works. The consequence for the agricultural sector and rural communities is poor accessibility and high transport costs. Crop losses are often high and producer prices poor. This all contributes to a universal constraining cycle of impediments to rural development and poverty alleviation. There is now the prospect to address all of these issues by utilizing proven tractor technology for road rehabilitation and maintenance techniques at a much lower cost than traditional heavy equipment approaches. Thus, rural tractor utilization can be raised benefiting both road and agri- sectors with lower unit costs. Consequently, road maintenance will become cheaper and more sustainable, and agricultural production and transport costs will be reduced. The tractor attachments; such as towed graders, trailers and bowsers can be manufactured locally contributing to the support of the local commercial economy. The capital investment requirements for tractor equipment are also a fraction of those required for heavy civil engineering plant, and are thus more affordable for Micro, Small and Medium Enterprises (MSMEs) in an environment where credit/capital is scarce and expensive.

AUTHORS: Robert Petts & Kingstone Gongera, Intech Associates.

Address for communication: rob@intech-consult.demon.co.uk

1. THE IMPORTANCE OF AFRICA'S RURAL ROADS

1.1 Introduction

This paper has been prepared drawing on research and operational experience of the authors, and transport sector and poverty reduction programmes supported under various AfCAP, ReCAP, DFID initiatives[1]. Rural transport plays an indispensable role in achieving more than half of the UN endorsed Sustainable Development Goals (SDGs) and fulfilling the promise of the 2030 Agenda for Sustainable Development to 'leave no one behind'. The provision of safe, reliable, and affordable transport infrastructure and services to and from rural communities is essential to facilitate access to markets and services such as education and health facilities, enterprise and employment opportunities, increase agricultural production, develop modern supply chains for crop delivery, prevent food loss, and hence achieving zero hunger and alleviating poverty (Cook et al, 2017).

Rural access is primarily defined as the distance to all-season roads and transport services (SuM4All, 2017), and additionally includes the distance to market and basic services, as well as first/last-mile connectivity with appropriate infrastructure and services. The provision of affordable, reliable, and inclusive rural transport infrastructure and services is at the heart of rural access.

Box 1

Challenges of The First/Last Mile

The First/Last Mile is the segment of transport that links the farmers and communities to the nearest all-season motorable rural road or a produce collection point. Its infrastructure may consist of the local village or farms paths and tracks that are often inaccessible to conventional transport vehicles. The distance of the first mile, in actual terms can range from 0.25km to 5km. Means of transport typically used in this segment are human porterage, animal carts, bicycles, animal carts, motorcycles and in some cases, tractors and pick-up trucks.

Head loading which is commonly used in the first mile is the most expensive method of transport. This is on account of the low individual volumes transported, the poor condition of the first mile road infrastructure, and limited options in the means of transport available. Head loading can be over 20 times as expensive (on a per ton/km basis) than transport by truck. Even if distances of the first mile are short (0.25km – 5km) compared to the full journey to final markets, the transport costs can make up to 20% of the overall transport costs of a value chain.

Source: Muhi & Ngenga, 2016

Rural communities in developing countries are often completely disconnected from the major roads, rail lines, and public transport services that enable access to the economic and social activities and opportunities in cities (HLAGST, 2016). Rural access is thus a main driver in solving the first/last mile problem and enabling the rural poor to emerge from poverty and overcome social exclusion by

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[1] AfCAP: Africa Community Access Partnership, ReCAP: Research for Community Access Partnership, DFID: The Department for International Development programme of UKAid. http://www.research4cap.org

connecting their goods to markets and linking rural areas to market towns, large cities, and the global marketplace.

1.2 The Sub-Saharan Africa Situation

Many Sub-Saharan African road networks are still substantially only constructed to earth or gravel standard (more than 80% and equivalent to approximately 2 million km) (World Bank, 2017). Traditional maintenance techniques for these roads have normally been based on the use of motor graders. Due to a range of factors, these approaches are very expensive (basically unaffordable) and suffer from serious funding and operational constraints (Petts et al, 2017). Consequently, rural road networks often remain in generally poor condition, with a deteriorating cycle of poor condition and reluctance to fund works.

The consequence for the agricultural sector and rural communities is poor accessibility and high transport costs. Crop losses are often high and producer prices poor. This all contributes to a universal constraining cycle of impediments to rural development.

1.3 The Solution

Fortunately, there is now the prospect to address all of these issues by utilizing **proven** tractor technology for road rehabilitation and maintenance techniques at a much lower cost than traditional heavy equipment approaches.

There are a number of ways this solution may be achieved. Firstly, in many agricultural regions the existing utilisation of agricultural tractors can be low and uneconomic (Hancox and Petts, 1999). Agri-sector tractor utilisation tends to be low during the rains, with tractor activity highest before and after this season. Where appropriate, arrangements can be made to use the tractors for the beneficial light grading of roads be carried out during the rains thus avoiding the need and additional cost of watering and compaction (Gongera and Petts, 2003). Thus, rural tractor utilization could be raised benefiting both road and agriculture sectors with lower unit costs. Consequently, road maintenance will become cheaper and more sustainable, and agricultural production and transport costs will be reduced.

Where under-utilised tractors are not available, then either local authorities or MSMEs can be equipped with new tractors and the necessary attachments for roadworks at a fraction of the cost of heavy equipment alternatives.

A further option for MSMEs is the purchase of reconditioned popular brand tractors, and the necessary new attachments. The technology is simple, investment are costs low, spares for popular models are cheap and easily available for many years after production ceases. This is an option for MSMEs entering the market with access to good basic rural mechanical services.

The tractor attachments; such as towed graders, trailers and bowsers can be manufactured locally contributing to the support of the local commercial economy. The capital investment requirements for tractor equipment are also a fraction of those required for heavy civil engineering plant, and are thus more affordable for Micro, Small and Medium Enterprises (MSMEs) in an environment where credit/capital is scarce and expensive.

There is considerable potential to introduce proven, low cost, agricultural tractor technology methods for rehabilitating and maintaining the unpaved classified road network in the African context. Cost savings over heavy equipment based technology will be of the order of 50% or more (Petts et al, 2017).

There is also potential to use proven agricultural tractor technology for recycling, rehabilitation of deteriorated bitumen paved roads.

In summary; all of these tractor technology, low-capital-investment techniques are ideally suited to adoption by local authorities and local Micro Small and Medium Enterprises (MSMEs).

2. THE CHALLENGES – ISSUES TO BE ADDRESSED

2.1 Building Blocks for Asset Management Capacity

The ReCAP Economic Growth through Effective Road Asset Management (GEM) project initial investigations in a number of SSA countries researched the challenges of the rural road sector (Geddes et al, 2017).

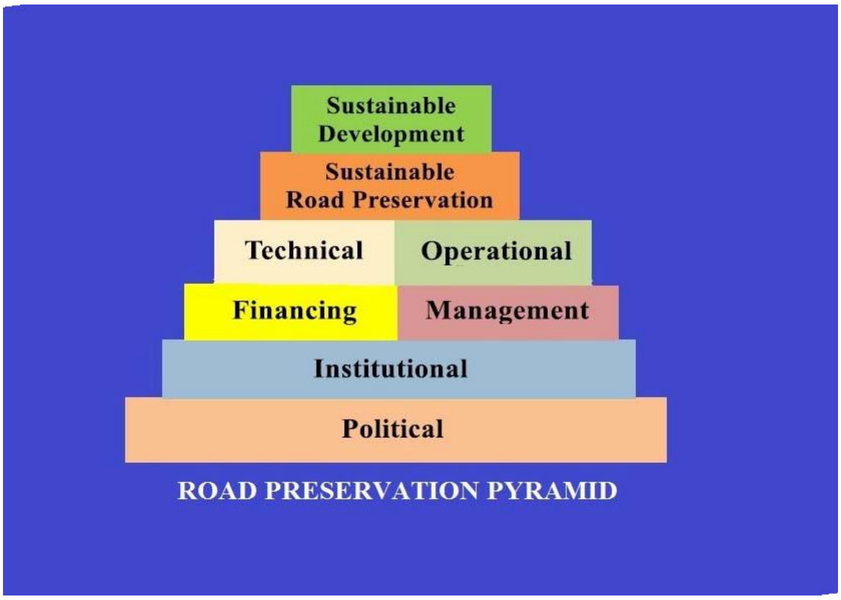
It is evident from that project literature review, discussions with stakeholders and feedback from key informants that there are very few examples of sustainable rural road asset management currently operational in sub-Sahara Africa (SSA). Rural road maintenance tends to be characterized by a poor maintenance culture, inadequate human resources and funding, reliance on inappropriate technologies, poor quality control, mismanagement and corruption. Where examples of good practice exist, they tend to be on donor-funded programmes with high levels of technical assistance, but these initiatives tend to flounder when the donor support is withdrawn.

As a result of the low existing capacity in rural roads agencies, a highly innovative approach is required to achieve meaningful results. It is necessary to build an asset maintenance culture in the participating countries and organisations. This will be achieved through the GEM implementation phase though an evidence-based approach to changing the mind set of policy makers and practitioners, and targeted technical assistance and training at the implementation level. It is necessary to develop a strategy to improve performance in road asset management and, ultimately, to achieve home-grown and sustainable improvements to the management of rural roads.

Accordingly, a self-assessment framework has been developed which seeks to assess the performance of a rural road agency in six key areas, or building blocks, which are considered necessary for effective road asset management (Pinard et al, 2016). These are:

- Political
- Institutional
- Financing
- Management
- Technical
- Operational.

This is illustrated in the following diagram:



This paper focusses on the application of appropriate, affordable and sustainable **technology** for solving the rural road asset management challenge. However, it will be essential that all of the other building blocks of the Road Preservation Pyramid are also actively addressed. A brief discussion on financing is appropriate at this point.

2.2 Financing Road Asset Preservation

How much funding is required to maintain the existing Sub-Saharan African rural road networks? This is very difficult to assess due to a generally poor record keeping and costing culture prevalent in the sector, and indeed the rarity of application of good asset management practice. The cost of road maintenance actually depends on a wide range of factors, standards adopted, methodology and efficiency of implementation (Petts, 2002). It is very location and operational environment specific. Estimates have been made by various parties. However, these tend to be based on project experiences and usually do not reflect stable 'steady state' network management conditions. For example, the assessments rarely include realistic financing and depreciation costs for equipment and facilities. These are particularly influential in the high-finance-cost environment experienced in SSA where real market finance costs may be in the range 25-40% per annum. Agency or donor subsidised finance also distorts the real costs in terms of sustainability perspectives.

Research by the Africa Infrastructure Diagnostic (Gwilliam et al, 2008) for actual maintenance funding of the rural road network, assessed the range of actual funding extended from barely US$20 per kilometre per year in Chad to more than US$3,000 per kilometre per year in Lesotho. On average, countries were assessed to be spending US$1,100 per kilometre of the rural network in the 2008 report.

With current total real costs of motorgrader ownership and operation in the region of US$1,000-2,000 per day in a high-finance-cost environment (Petts et al, 2017), and re-gravelling costs under aided project conditions typically ranging from US$25,000-40,000/km in 2008 (Africon, 2008), the realistic current cost of maintaining earth and gravel rural roads using heavy equipment technology will generally be considerably more than US$2,000/km/year in most African situations.

There is clearly a total disconnect between the maintenance needs of the SSA rural road network on the one hand, and the financial resources deployed and the costs of traditional heavy equipment based maintenance on the other. The heavy equipment approach is thus neither affordable, nor sustainable, thus road maintenance has and will continue to struggle to gain political support under the current regime with so many other demands on public finances.

One proven viable option to reduce this enormous delivery deficiency is by improving the routine maintenance performance using much cheaper, proven, agricultural tractor technology methods and by giving routine maintenance the highest priority for budget allocations (over periodic maintenance, rehabilitation and new construction/upgrading). This would substantially improve network conditions and community access, extend re-gravelling time cycles and reduce earth road rehabilitation needs.

Experience of proven tractor technology maintenance methods shows that routine maintenance can be achieved for annual costs in the region of US$1,000/km/year (Petts & Gongera, 2003 and Petts et al, 2017).

3. ROLE OF ROAD MAINTENANCE

The Engineer or Network Manager's main function is the safe custody of the road infrastructure asset through good planning, management and technical practices. The aim should be to preserve, and where possible enhance, the condition, value and serviceability of the network. The objective is to ensure that all roads under his/her charge are properly maintained and trafficable throughout the year, and that they are safe to use.

3.1 What is road maintenance?

It is work done on a road to keep the road in good condition or it is a set of resources and actions (technical, administrative, managerial and economical) required for retaining or restoring a road as close as possible to its original as-constructed state. The rural road network is usually the largest and most extensive public investment in any local authority area. Road maintenance is required to prevent the deterioration, wasting and loss of value and serviceability of this vital asset. The condition of the road network will have a direct impact on the social and economic wellbeing and development of the local community.

For any maintenance to be effective the work must be clearly defined.

There are three types of road maintenance (PIARC, 1994):

3.2 Routine maintenance activities are relatively minor activities to be carried out each year on a road. However, they are critical to ensure that the road serves the intended purpose. They focus on the road drainage system, running surface and vegetation control. As the name suggests; these activities should be part of a 'routine' regime. They do not require significant technical inputs and are essentially a logistical challenge within the budget allocation and should be the first priority for available funds and resources. They are the most cost-effective use of available resources.

3.3 Periodic maintenance activities are only required occasionally and require substantial resources and funds to be mobilized. These are activities such as re-gravelling, camber or structures rehabilitation. They usually require a higher level of technical input.

The Routine and Periodic maintenance activities need to be planned and implemented as part of the asset management regime.

3.4 Urgent or Emergency Maintenance activities are required from time to time. This includes storm washouts or repair of vehicle accident damage to the road infrastructure. Although these activities cannot be planned in advance, they need to be budgeted for, based on previous network experience of incidence and resourcing.

The foregoing definitions refer strictly to maintenance of the existing assets and do not relate to the increasingly practiced approach of 'enhanced maintenance' or 'spot improvements' to modestly upgrade the infrastructure according to good asset management practices, and within resource constraints.

3.5 Management Issues

It is necessary to keep appropriate records of works carried out on each part of the network and the resources used, to assess the costs and efficiency of the maintenance carried out and to help plan and budget for future works.

A pre-condition for successful road maintenance is that the road must be in a maintainable condition. Routine maintenance is the best use of available resources. If scarce resources are deployed to rehabilitate limited sections of network, then the rest of the network if unattended will be allowed to deteriorate; increasing the future workload.

To be in a maintainable condition, the road will have been constructed to set standards and to specified quality. This refers to the road profile, drainage, surface type, structures and all required protection works. An essential feature for the road to be 'maintainable' is that there is a functioning drainage system.

3.6 In Summary

The purpose of road maintenance is:

- ✓ To provide a comfortable riding surface to traffic using the road
- ✓ To minimize the vehicle operating costs and freight costs for road users
- ✓ To enhance road safety for road users
- ✓ To preserve capital investment in the road infrastructure as good asset management practice.

This is done to reduce the rate of deterioration of a road and keep it as close as practicable to its designed and as-constructed condition, and to preserve its considerable infrastructure investment.

4. TECHNOLOGY OPTIONS

There are a number of Technology options open to contractors and road authorities for road works. The technologies can be broadly grouped into heavy equipment, intermediate equipment and labour (using hand tools). Many operations involve combinations of technology, however it is not widely appreciated that there is a range of technology options for nearly every road sector construction or maintenance activity. There are various definitions and interpretations of terminology used in the appropriate technology road works sector. The following definitions are recommended (Petts, 2012):-

LOCAL RESOURCES

These can include human resources, local government, private, NGO and community institutions, local entrepreneurs such as contractors, consultants, industrialists and artisans, local skills, locally made or intermediate equipment, local materials such as timber, stone, bricks, and marginal materials, locally raised finance or provision of materials or services in kind.

LABOUR-BASED ROADWORKS
Operations carried out principally by manual methods, using hand tools. They may be supported by intermediate or sophisticated equipment for activities not ideally suited to labour methods, e.g. medium-long distance haulage, heavy compaction. Labourers usually walk or cycle to work each day from their homes.

LABOUR-INTENSIVE ROADWORKS
The use of large numbers of labourers for work on roads with no equipment support and with the prime objective of creating temporary employment. The experience has been that this is often arranged with limited, or without the necessary, technical inputs to ensure durable outputs to accepted specifications and standards. This approach has unfortunately usually resulted in unsustainable outputs.

INTERMEDIATE EQUIPMENT
Simple or intermediate equipment is designed for low initial and operating costs, durability and ease of maintenance and repair in the conditions typical of a limited-resource environment, rather than for high theoretical efficiency. It is preferable if the equipment can also be manufactured or fabricated locally. Modern wheeled agricultural tractors are a low cost mobile power source and with various attachments can be used to substitute for heavy equipment for a proven range of tasks in the road sector.

HEAVY PLANT
Sophisticated civil engineering equipment is typically designed for, and manufactured in, high-wage, low-investment-charge economies. It is expected to operate with close support and high annual utilisation; usually designed for a specific single function or task with high efficiency operation.

The choice of technology has important cost implications for the owner and operator of any equipment. These technology options should each be properly costed to ensure that the most technically compliant and cost-effective application of available resources is used.

Many problems encountered in the road sector in emerging and developing countries can be attributed to the application of inappropriate technology (see Box 2).

Box 2

PROBLEMS OFTEN ASSOCIATED WITH SOPHISTICATED IMPORTED HEAVY EQUIPMENT FOR ROADWORKS IN DEVELOPING COUNTRIES

Operational:

- Dedicated function (can only be used for one operation)
- Inter-dependence (e.g. dozer, loader, trucks, motorgrader, bowser, roller all required for gravelling – fleet idle when ONE link in the chain breaks down #)
- Lack of continuity of workload for plant items of dedicated function
- Usually based at locations remote from worksites – plant transporters required and long mobilization/demobilization distances involved

Technical:

- High pressure hydraulic systems
- Sophisticated mechanisms and hydraulics
- Disposable components; difficult to repair or refurbish

Local Support and Equipment Maintenance:

- Limited local market for equipment sales of each model
- Specialist repair and maintenance skills, tools and facilities required (often only available in the capital city or regional centre)
- Few dealers able to provide the necessary close support
- Long spares supply lines and delivery times
- Frequent model 'improvements' causing spares stocking and procurement problems and 'planned' obsolescence

Cost:

- All equipment and spares imported – consuming scarce foreign exchange
- High capital and finance costs
- High costs of stocking and provision of spares

RESULT - low availability & high overall costs!

Source: Handbook of Intermediate Equipment, for Road Works in Emerging Economies, Petts, 2012.

Preliminary investigations in many countries have identified the potential for considerable construction and maintenance works cost savings and beneficial flexibility from the introduction of wheeled tractor based technologies and Intermediate Equipment approaches. These approaches could be adopted by both own-force (force account) and the contracting sector to achieve the following key benefits:

- Substantially reduced capital investment and importation requirements
- Substantially reduced unit costs for a range of works items.

5. TECHNOLOGY & IMPLEMENTATION CHOICES & TRACTOR TECHNOLOGY EXPERIENCES

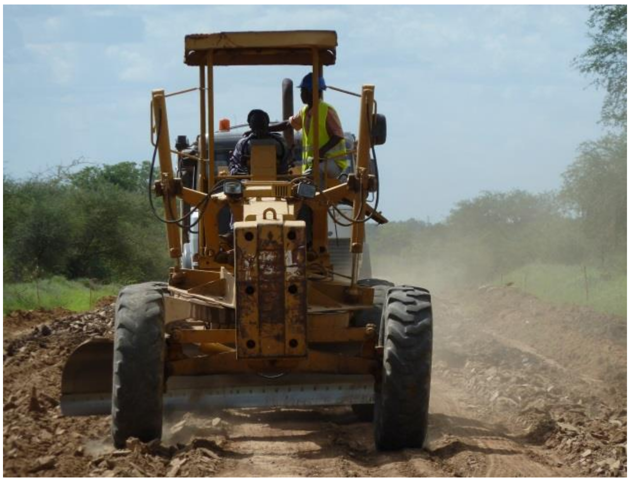


***Figure 5.1** – Motor grader used for maintenance of unpaved rural roads, (Image: Intech Associates)*

The SSA rural road network is substantially only constructed to earth or gravel standard. Traditional maintenance techniques for these roads have normally been based on the use of heavy equipment; particularly motor graders (Figure 5.1), for the essential maintenance of the camber and side drainage system. Due to a range of factors previously discussed these approaches are expensive and suffer from serious funding and operational constraints. Consequently, the rural road networks remain in generally poor condition. The unfortunate consequence for the rural communities and agricultural sector is high risk of deprived accessibility, poor services and excessive transport costs. Other risks are crop losses and poor producer prices. This all contributes to a constraining cycle of impediments to rural development and poverty reduction.

Heavy equipment-based methods are anyway not suited to most rural roads, which are relatively narrow, compared to main roads. However, the principal disadvantage is the enormous capital investment costs of heavy equipment operations. They also involve very high equipment finance (bank loan or opportunity), operating, maintenance and mobilization costs; usually necessitating the use of low-bed transporters to move them between work sites. They also require specialist operational and support skills and resources. With relatively low fleet numbers in the country there are serious support and spares issues. With most unpaved road maintenance and rehabilitation equipment tasks fundamentally requiring no more than 100hp, the use of heavy equipment is an extremely expensive, inflexible and avoidable luxury in the SSA context. Market rates for credit/finance are in the range 25 – 40% per annum. Therefore, the opportunity cost of capital is very high. This suggests that an alternative low-capital approach is required.

Fortunately, there are **proven** alternative, low-capital solutions available, which vitally, do not suffer from the issues highlighted in Box 2. Currently a range of low cost but powerful, premium brand tractors (e.g. Figure 5.2) are now more widely available to the agricultural sector in SSA countries. The brands are established and have good backup support with future spares availability for the national fleets assured. It is estimated that there are many underutilised tractors in many SSA countries; mostly deployed to the agricultural sector for commercial and small-scale crop farming.

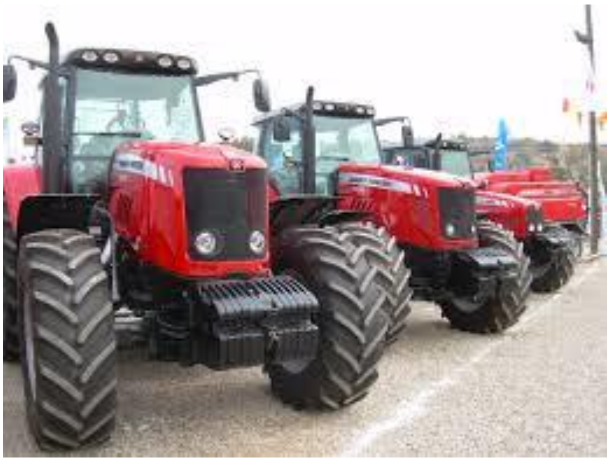


Figure 5.2 – 100hp, 4WD Agricultural Tractors now available in the rural areas. (Image: Commons).

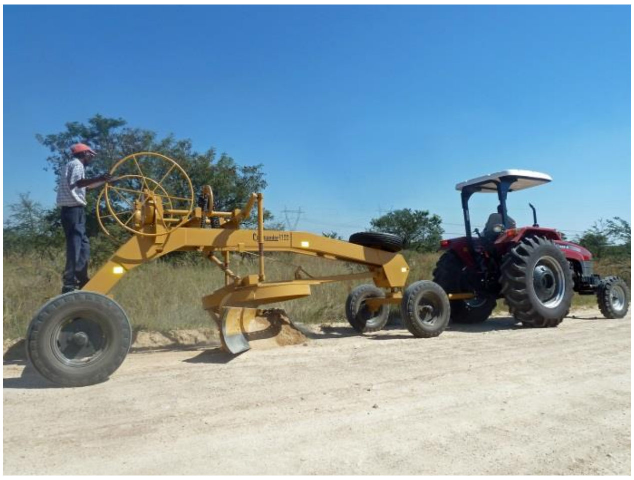


***Figure 5.3** – 2 tonne towed grader manufactured in Zimbabwe for more than 50 years (Image: Intech Associates).*

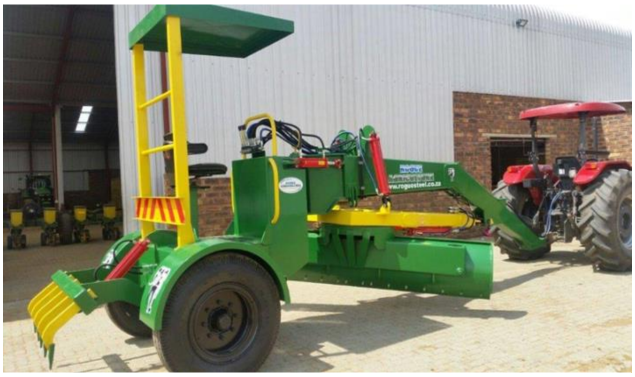


***Figure 5.4** – 5 tonne towed grader manufactured in RSA (Image: Intech Associates).*

There is now the prospect to address many of the road sector maintenance deficiency issues by utilizing proven tractor technology for road rehabilitation, spot improvement and maintenance techniques at a much lower cost than traditional heavy equipment approaches.

For the investment costs of one motorgrader between four and six tractor and towed grader units may be purchased.

Work unit rate costs savings for many tasks are expected to be more than 50%.

The tractors can be used with a range of low cost, simple attachments for the various road construction and maintenance activities (Table 5.1). Thus, rural tractor utilization would be raised, benefiting both road and agricultural sectors with lower unit costs. Consequently, road maintenance will become cheaper, more affordable and more sustainable, and agricultural production and rural transport costs will be reduced.

The tractor attachments; such as towed graders, loaders, trailers and bowsers, could be manufactured locally; potentially contributing to the support of the local commercial economy. Light towed graders have been manufactured for over 50 years in Zimbabwe (Figure 5.3). Heavy towed graders (4-5 tonnes) suitable for heavy, rehabilitation grading are manufactured in Kenya and RSA (Figure 5.4). The capital investment requirements for tractor equipment are also a fraction of those required for heavy civil engineering plant, and are thus more affordable for Micro, and Small and Medium Enterprises (MSMEs) in an environment where credit/capital is scarce and expensive. Table 5.1 illustrates the versatility of the wheeled agricultural tractor to provide low cost services to the various rural sectors.

Regarding the key road maintenance activities of grading, the power requirement for light (Routine) grading is about 70hp (52kW) in conjunction with a 2 tonne towed grader. For heavy (Periodic) grading, which involves recovery of lost camber on earth and gravel roads, or reshaping of the coarse material, stone macadam surfaces, the power requirement is about 100hp (75kW) with a towed grader of 4-5 tonnes weight.

Figure 5.5 *– Pre-World War 2 Caterpillar tractor towed grader with rubber tyre modifications. Still in regular use after 50 years (Image: Intech Associates)*

Motor graders were developed originally just before the Second World War (they took over from the universal use of tractor towed graders - Figure 5.5). By 1955 the largest Caterpillar motor grader was still only 100hp; sufficient for both heavy and light grading. However, since then the size and power of motor graders has been steadily increasing, so that the smallest mainstream model is now rated at about 140hp. Various models up to more than 500hp are now available. This power and size development is likely to have been driven by the developed economy (and particularly USA) wage rates rising from less than US$1 per hour in 1939 to the current US skilled operator basic rate of US$25 per hour[2]. In a developed, low-capital-cost economy it is natural to place as much power as economically appropriate in the hands of the high cost operator. Such a rationale is totally misplaced in SSA countries, where credit/finance costs are extremely high and labour wage rates are substantially lower. The fact remains that modern agricultural tractor technology is flexible and powerful enough for many roadworks tasks, and is proven.

Table 5.1 *- Potential Agricultural Tractor Applications in the Rural Economy*

SECTOR	OPERATIONS
AGRICULTURE	Ploughing, Harrowing, Rotovating, Sub-soiling, Haulage, Access Road Construction/Maintenance, Land clearance and levelling, Root removal, Planting, Seed Drilling, Fertiliser Application, Pesticide/Herbicide Application, Harvesting, Loading, Pond Construction, Dam Construction, Borehole Construction, Contour drains, Fencing (post hole boring)
FORESTRY	Winching, Loading, Hauling, Poling, Sawing, Access Roads
ROADS (paved and unpaved)	Gravel Haulage, Water Collection Haulage and Distribution, Personnel Transport, Bridge & Culvert Materials Haulage, Fuel Haulage, Plant Haulage (low loader trailer or semi-trailer), Towed Grading (heavy and light), Dragging, Towed Compaction (rubber tyred/steel roller), Earthworks Excavation & Haulage (towed scraper), Excavation (back hoe/ripper /scarifier/compressor & pneumatic tools), Loading (front shovel), Grass & Bush Control, Spreading Materials, Bitumen Sealing (towed bitumen/emulsion heater/sprayer), Stone crushing (towed crusher and screens), Chippings Transport, Recycling pavement (milling attachment), Brushing/Sweeping, Mixing (disc harrow), Slurry Sealing (mixer and spreader), Premix Patching Material Production, Temporary Accommodation (towed caravan/workshop)
AGRO-	Threshing, Hulling, Milling, Haulage

2 US Bureaux of Labor Statistics, 2017.

PROCESSORS	
MUNICIPAL (non-road)	Garbage Skips, Water Haulage, Night Soil Disposal
WATER SECTOR (non-road)	Pipeline Excavation, Pipe Laying, Cranage, Loading, Earth Dam Construction, Irrigation Channel Construction, Water Pumping, Water Haulage, Borehole Drilling
BUILDING CONTRACTORS	Materials Haulage, Excavation (back hoe/ripper/scarifier/compressor & pneumatic tools), Loading (front shovel)
MINING/ QUARRYING	Stone Crushing (from PTO), Loading, Access Roads, Materials Haulage
TRANSPORTERS	Loading, Short Haulage: Goods, Materials & Personnel
PLANT HIRE COMPANIES	Hire to Others for all the applications in this table
RESEARCH/ ACADEMIC/ TECHNICAL INSTITUTIONS	Demonstration Training
NGOs	Any of the above operations

Source: Handbook of Intermediate Equipment, for Road Works in Emerging Economies, Petts, 2012.

All heavy civil engineering equipment is being imported to most SSA countries and at high cost, along with the necessary spares to keep the equipment working. The depreciation of local currencies over recent years means that there is now even more reason to try to introduce lower cost items that can achieve the same results, and to seek local/regional manufacture.

The case for introduction of tractor technology into the SSA rural road sector is powerfully demonstrated.

6 CURRENT INITIATIVES

Agricultural tractor road maintenance initiatives are currently being introduced on rural roads in The Gambia and Zambia, and are expected to be re-established in Zimbabwe.

7. CONCLUSIONS

The generally poor state of Sub-Saharan Africa's rural road networks can be blamed on the low political and operational priority of road maintenance in the asset management practices of the road authorities. The building blocks of good road infrastructure management capacity are also largely deficient or absent. Furthermore, the reliance on heavy civil engineering equipment technology is both unaffordable and unsustainable.

There is now the prospect to address all of these issues by utilizing proven tractor technology for road rehabilitation and maintenance techniques at a much lower cost than traditional heavy equipment approaches. Thus, rural tractor utilization can be raised benefiting both road and agri-sectors with lower unit costs. Consequently, road maintenance will become cheaper and more sustainable, and agricultural production and transport costs will be reduced. The tractor attachments; such as towed graders, trailers and bowsers can be manufactured locally contributing to the support of the local commercial economy. The capital investment requirements for tractor equipment are also a fraction of those required for heavy civil engineering plant, and are thus more affordable for Micro, Small and Medium Enterprises (MSMEs) in an environment where credit/capital is scarce and expensive. A number of countries are taking up these appropriate technology solutions.

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