Agricultural Tractor Based Solutions for Rural Access and Development

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Abstract. From the agricultural sector perspective in developing countries, agricultural tractors are desirable to increase productivity and reduce the work burden, particularly for the poor and women. Wider rural community benefits are also possible through tractor use for transport, water provision, irrigation, power generation, crop processing. However, these often cannot be achieved due to the relatively high capital costs (compared to labour approaches) for the usual agricultural-sector-only orientated tractor application. Generally low annual productive utilization and lack of local knowledge regarding good resource management and cost-effective applications often mean poor returns on the capital investment in the tractor equipment in a high-cost-of-capital environment. This severely hampers efforts to improve the efficiency of rural activities. From the road sector perspective, many rural road networks are still substantially only constructed to earth or gravel standard. Traditional maintenance techniques for these roads have normally been based on the use of motor graders for maintenance. Due to a range of factors these approaches are usually expensive and suffer from serious funding and operational constraints. Consequently, rural road networks often remain in generally poor condition. The unfortunate consequence for the agricultural sector is poor accessibility and high transport costs. Crop losses are often high and producer prices poor. This all contributes to a constraining cycle of impediments to rural development There is now the prospect to address all of these issues by utilizing proven tractor technology for road rehabilitation, spot improvement and maintenance techniques at a lower cost than traditional heavy equipment approaches. Thus, rural tractor utilization will be raised benefiting both 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 Small and Medium Enterprises (SMEs). The paper reviews the positive experiences with tractor based road rehabilitation and maintenance in various developing countries and presents a justification for a commercial approach to providing a range of affordable rural services based on the use of tractor technology. The adoption of these techniques will have a beneficial impact on efforts to achieve the Sustainable Development Goals (SDGs). The paper also introduces the Handbook of Intermediate Equipment for Road Works in Emerging Economies.

Keywords: Road Maintenance, Agricultural Tractor, Rural Road, Intermediate Equipment, Developing Regions, Low Cost, Local-Resource-Based, Cross Sector, Rural Services, Sustainable.

1 Introduction

There are considerable challenges facing rural communities in developing regions, not the least of which is the lack of reliable road transport access throughout the year. With typically less than 20% (World Bank, 2008) of the classified road networks constructed to paved standards and with generally sub-optimal maintenance regimes, many communities suffer poor or severed unpaved access for long periods. This is a substantial constraint to social and economic development of rural communities. Considering that this is the situation after at least a century of the era of motor transport, the rural road networks in many countries are expected to continue to be mostly unpaved for the foreseeable future. The sector must recognize this situation and develop appropriate and affordable strategies for maintaining and enhancing the vital networks of earth and gravel roads that serve rural communities.

Road maintenance approaches in economically Emerging and Developing Countries (EDCs) have generally been derived from practices in developed countries. In the post 2nd World War period this has been based on the use of heavy equipment, with motor graders at the forefront of camber and drainage system maintenance of unpaved roads.

These methods suffer from a number of technical and operational problems in developing and emerging economies (Petts, 2012) and are high-capital, import-intensive and expensive. They are generally inappropriate for a resource-constrained, high-cost (and scarce) finance and low-labour-wage environment. Small and Medium Enterprises (SMEs) face major challenges to enter and survive in the equipment intensive road sector market due to the high cost of credit or its unavailability to contracting enterprises (Larcher, 1999). Although the obvious solution appears to be adoption of labour-based methods, there are significant management, institutional and safety issues with such an alternative (O'Neill et al, 2010).

We need to find an intermediate approach, and the use of intermediate equipment such as the agricultural tractor, offers a solution to the current challenges faced as a result of the use of imported heavy and expensive equipment. In developing countries, agricultural tractors are desirable to increase productivity and reduce the farm work burden, particularly for the poor. Wider rural community benefits are also possible through tractor use for transport, water provision (including earth dam construction), irrigation, power generation, crop processing however, these often cannot be achieved due to the relatively high capital costs (compared to labour approaches) for the usual agricultural-sector-only orientated application. Generally low annual productive utilization and lack of local knowledge regarding good resource management and cost-effective applications often mean poor returns on the capital investment in the tractor equipment in a high-cost-of-capital environment (Hancox and Petts, 1999). This severely hampers efforts to improve the efficiency of rural activities.

However, bringing agricultural tractor technology to the rural road sector will increase annual equipment utilization, reduce unit costs to more affordable levels and accelerate 'payback' of the capital investment for owners; a truly 'win-win' situation for all stakeholders.

2 Heavy Equipment Issues

Sophisticated heavy civil engineering equipment is typically designed for, and generally manufactured in, high-wage, low-investment-charge economies. Whereas USA plant operator wages are in the order of US$22/hour (USA Bureau of Labor Statistics, 2013) and finance is currently relatively easily available at annual interest rates of about 5%, wage rates in developing countries are a fraction of US rates and commercial credit, where available, often costs more than 20% per annum. Heavy plant is expected to operate with close support and high annual utilisation; usually designed for a specific single function or task with high efficiency operation.

Many problems encountered in the road sector in emerging and developing countries with heavy equipment can be attributed to the application of inappropriate technology when constructing and maintaining rural roads with low or marginal economic returns (see Box 1).

Box 1

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!

 # Breakdowns are usually power unit or transmission related. By comparison, tractor power units can be reassigned between tasks if a breakdown occurs.

Source: Intech Associates (2012)

A further deficiency in the current rural road 'maintenance' regime in many countries is that in the dry season the motor graders are usually deployed without the support of watering and compaction equipment. In dry conditions, this operation disturbs the compacted soil/gravel road surface, fails to re-consolidate it after grading and simply creates a loose, dusty surface even more susceptible to erosion by traffic. It is no surprise that large sections of unpaved road have become 'sunken' or 'canal' profiles which can become impassable in wet weather. People and vehicles using the road after dry weather grading are coated with dust, as are any adjacent properties and crops. Grading without watering and compaction should normally be confined to the 'wet' season so that traffic consolidation occurs at no cost to the road authority.

From the foregoing, it is therefore evident that a low capital, flexible and local-resource-based approach would be more appropriate for developing countries for many road sector operations where there is a clear choice of technology (TRB 1981). Tractor technology offers the flexibility of different task applications according to season and multi-sector applications potential.

3 Agricultural Tractor Benefits

Agricultural Tractors are the simplest and cheapest mobile power source available in developing countries (Petts, 1997). 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 and the contracting sector to achieve substantial reduction in capital costs and reduced unit costs for a range of work items.

All of this would be achieved with the essential outcome of the same, or improved, quality and durability of work for national, regional and local road authorities.

The potential benefits (Petts, 2012) for the various stakeholders can be summarised as:

Road works – lower unit works costs, greater logistical flexibility, lower capital and operating costs,
Market – provides complementary market opportunities between heavy equipment and labour technologies for improved market flexibility and efficiency. Opportunities for local SMEs to enter market and provide sub-contracting and multi-sector services at low capital outlay,
Rural Communities – improved accessibility, lower transport costs, employment opportunities, better prices for crops, less crop wastage,
National Economy – more serviceable roads at lower cost, SME development, local equipment manufacturing capacity development and export potential, imported equipment substitution, reduced importation of fuel and spares, rural and urban employment increases in related works and industry, increased tax base,
Agricultural sector – improved roads, lower input and output costs, development of rural sector agricultural services based on tractor technology for increased tractor utilisation, farm income diversification, and lower cultivation processing and transport costs,
Environmental – Lower carbon footprint of tractor technology.

Although wheeled tractors have been developed and designed for the agricultural sector, there is a large range of **proven** applications in the road and other rural sectors as indicated in Table 1 (Petts, 2012).

SECTOR	OPERATIONS
AGRICULTURE	Ploughing, Harrowing, Rotavating, 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 tyre/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-PROCESSORS	Threshing, Hulling, Milling, Haulage
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

Table1 Agricultural Wheeled Tractor Applications in the Rural Sectors (Petts, 2012)

4 Experiences in Zimbabwe

A Tractor Based Road Maintenance System was developed in Zimbabwe from 1985 to 1998 to look after roads that had been constructed under the Germany - Zimbabwe cooperation agreement. The programme involved construction of 25,000km of roads and development of an institution to maintain the considerable investments.

The maintenance concept which was applied uses fixed maintenance areas; each one covering between 150 - 200km of road network. Through practice, this length of road was established to be the optimum length a single unit can effectively maintain. A single operational unit comprises an agricultural tractor, a towed grader, tractor drawn trailer and a tractor drawn water bowser. Tyre drags are deployed at one every approximately 10km.

Working on fixed maintenance areas makes it easier to define road maintenance tasks to be carried out on sections of the roads. This is so because the roads supervisor will be familiar with common defects occurring during the wet and dry season. Appropriate remedial actions can therefore be predicted, planned and budgeted for. The frequency of road maintenance cycles varies according to traffic, terrain and climate. The Zimbabwe experience is based on a system operated under force account arrangements. A total of 180 maintenance areas were defined, each equipped with a maintenance unit, a supervisor and a dedicated maintenance budget allocated per kilometre of road under maintenance.

A basic requirement for the success of the system is that the roads to be included on the maintenance programme need to be fully constructed or rehabilitated before they qualify for inclusion on maintenance programmes. Roads to be included should not have missing camber, drainage structures or sections requiring graveling. The roads have to be technically complete before inclusion on the road maintenance list. The underlying rationale is that road maintenance is a response to preserve capital investment. In the absence of capital investment, routine maintenance is not a substitute for road improvement, construction or rehabilitation. Roads cannot be upgraded cost-effectively through maintenance, initial capital outlay is necessary before maintenance work can be effective. Therefore road maintenance aims to preserve the road as much as possible to its original state after improvement or construction.

4.1 Suitable roads

Roads that are suitable for this type of maintenance as experienced in the Zimbabwean maintenance programme are those with low traffic volume; typically between 5- 50 vehicles per day, because the damage on the road as a result of traffic is relatively low. As the traffic volume increases, so does the required frequency of road maintenance of gravel and earth roads.

4.2 Service levels

Service levels that can be achieved by using the tractor based road maintenance system aim to keep the road in its original state after improvement and minimise deterioration.

4.3 Work cycles

The work cycles can be split into two; labour and equipment activities. Equipment based activities comprise cycles of towed grading using the tractor drawn grader. This is a wet season activity as the road surface materials will be moist, allowing the grader to re-shape and restore camber on the road. The towed grader is light enough to scrape only 20 – 30 mm of gravel or soil on the surface during re-shaping. This process does not damage the consolidated and established camber with good structural integrity. Similarly tyre drags are drawn during the dry season to minimise setting in of ruts and corrugations and to re-distribute loose gravel on the surface. These equipment based activities are programmed according to terrain, climate and traffic on each road by the unit teams themselves.

ACTIVITY	**High ≥ 30vpd**	**Medium ≥10 -30**	**Low ≤ 10vpd**
Towed grading (rainy season)	1 cycle /month	1 cycle / 2 months	1 cycle per year
Tyre Dragging (dry season)	1 cycle /week	1 cycle / 2 weeks	1 cycle / month

Table 2 Equipment Based Road Cycles Based on a rainy season November to March

Labour cycles are not dependent on traffic but more responsive to terrain and climate. The more hilly terrain and high rainfall, the more the road will require higher level of labour input, especially for drain clearing and vegetation encroaching on to the road and around curves.

ACTIVITY	**No of Cycles per year**
Verge clearing	2
Cleaning Culverts	2
Cleaning drains and repairing erosion damages	2
Patch graveling	2
Road furniture maintenance	1

Table 3 Labour Based Road Cycles

The tractor and trailer are used to transport the labour gang to and from their work location each day.

4.4 Lessons learnt

The system has proved to be effective as it has provided regular and timely response to road maintenance needs throughout the year. This was made possible by the size of maintenance areas allocated per tractor together with personnel and a dedicated budget. Frequent in-house training kept skills relevant and the system functional while the responsible institution was well funded and had authority to make management decisions without seeking clearance though a rigorous consultative process. Authority to manage road activities was decentralized to Provincial and district staff. The use of force account ensured continuity of work and better knowledge of the road behaviour; as the same personnel remained in charge of the same sections of road for many years. This knowledge enabled semi-skilled supervisors to be able to know areas prone to damage and plan appropriate reaction. The use of the tractor as the only motorized equipment meant that all activities could be done by changing the accompanying attachment to the tractor. The repair and maintenance of the tractor and attachments is relatively simple and trained artisans responsible for the routine checks on the tractor ensured that it was well kept and serviced. All these arrangements resulted in long equipment life (typically 10,000 hours per tractor) and a reduced cost for road maintenance. Records of expenditure and progress were well documented and quarterly review seminars assisted in planning and managing of the programme. Roads that were incomplete or awaiting for construction were not included on the maintenance programme. This requirement encouraged the Local Authorities to carefully plan the roads and prioritize them for construction in order to secure funding for maintenance.

4.5 Challenges

The whole system relied on funding from central government and as soon as the resources were no longer readily available due to serious national economic conditions, the system suffered. Plans to replace the tractors after their full life were not realised due to financial constraints. The tractors became old and worn out and the system also failed to meet planned targets. The cost of repair and maintenance of tractors increased further; increasing the annual road maintenance costs per kilometre. Failure to fully resource periodic maintenance re-gravelling also led to widespread de facto downgrading of many route sections to earth standard. This is a universal problem. Estimates (Petts, 1992) of classified road re-gravelling in Kenya highlighted the average network cycle to be only once every 70 years. The use of force account does not allow cost systems to reflect the full cost of maintenance; as other expenses such as salaries, unit infrastructure maintenance and initial cost of equipment are paid for by government. All related costs of finance, importation and taxes and other overheads are absorbed by government hence the actual total cost over a period of time is difficult to ascertain; although this can be achieved (Gongera & Petts, 2003).

4.6 Outstanding issues

Gravel and earth roads account for more than 70 percent of rural roads in sub Saharan Africa and this situation is likely to remain for the foreseeable future before adequate funding resources to surface these roads are secured. Gravel is a finite resource and land degradation as a result of road improvement materials extraction is a cause for concern. Alternative methods for provision of affordable and sustainable access need to be explored and alternative techniques for management of these roads are necessary. More research into provision of access is therefore necessary. The need to integrate farming and provision of roads as a way of achieving economic utilization of equipment provides a ‘win-win’ situation where tasks in agriculture are made lighter through the use of tractors during periods when road maintenance is not occupying them. A coordinated programme of works is necessary to achieve this synergy. Sustainable funding arrangements need to be developed to finance road maintenance. The integration of small scale farming with road works offers a possible source of revenue that can be re directed to maintenance of roads. More work needs to be done to explore ways of capitalizing on this and other potential sources of revenue.

5 Experiences in Kenya

Agricultural tractors were successfully used for the haulage of surfacing gravel in the national Rural Access Roads Programme (RARP) and Minor Roads Programme (MRP) in Kenya (Intech, 1990), on rural road networks eventually totalling more than 11,000km over a period of 16 years.

A Kenya Classified Road network maintenance study (Intech, 1991) identified the potential to use agricultural tractors and labour techniques to rehabilitate the wider earth and gravel road networks. The resulting pilot project co-funded by Sida, Danida, KfW and SDC proved the viability. (Intech, 1993).

The Pilot Project used the civil service force account operational structure plus casual labour employment in two districts. Half of the classified road networks in those districts were rehabilitated (700km) and brought under effective maintenance in 18 months. Camber and drainage system were restored, new/upgraded culverts were provided where required, and spot surfacing improvements were made on problem sections. This was achieved without any formal design documentation, merely with good training, operational manuals and good direction and supervision.

5.1 Lessons learnt from the Kenya Experience

The pilot project demonstrated that earth and gravel roads could be successfully and inexpensively rehabilitated using agricultural tractor and local labour techniques, and brought under affordable maintenance. It was shown that earth roads on most soils could be shaped into a camber and adequate side and turn out drains provided with cross drainage at required locations. These roads could normally be trafficked by cars and light trucks within hours of rain cessation due to the running surface quickly draining and regaining resilience to wheel damage. The various tractor attachments were successfully designed and manufactured locally. 100hp(75kW) rated 4WD tractors were adequate for all rehabilitation and maintenance operations. The locally made 5 tonne towed grader could achieve heavy regarding, even without a scarifier attachment. Earth and gravel road rehabilitation rates were between 0.6 and 1.13 km/tractor-grader/day. Direct costs (equipment, labour, hand tools, transport and equipment support) of camber, side and turnout drainage was less than US$700/km (1993 prices). Finance, overhead and spot improvement costs were additional (Intech Associates, 1993).

5.2 Outstanding issues

The pilot project successfully tackled the technical, training and operational aspects of tractor and labour based earth and gravel road rehabilitation and maintenance. However, the investigations identified a range of institutional, finance, manpower management and small scale contractor issues to be addressed before successful wider application.

6 Experiences in Mozambique

Soon after the protracted war in Mozambique, rural road access was a priority for the government.

The Mozambique government adopted the Zimbabwe tractor-based road maintenance model and started with a pilot project in Tete and Manica Provinces. ECMEP, a government owned company was charged with the responsibility of carrying out the Emergency Road Opening Programme. The programme was co funded by the Mozambique and German governments. The tractor based road maintenance system was extended to cover Zambezia, Sofala and Inhambane provinces after the pilot. Zambezia province opened up 2,700km, while Inhambane opened 276 km. Unlike the Zimbabwe set up, where implementation was achieved through force account, Mozambique used small and medium enterprise contractors. An initial training programme for the contractors was conducted while a consultant supervised the works. The roads were packaged into lots and a bill of quantities was prepared. Tenders were floated and contractors bid for the works.

The maintenance operations were carried out in the same way as the Zimbabwe setup. The maintenance areas defined were provided with a contractor who had the requisite equipment. Maintenance base camps like the ones in Zimbabwe were constructed for each maintenance unit. Dedicated budgetary provision for these roads was set aside by the Road Fund. Tenders were for periods of two years with provision for extension by one year if the contractor's performance was acceptable. Payment certificates were prepared based on the bill of quantity and work done by the contractor.

6.1 Lessons learnt from the Mozambique experience

The use of private contractors in Mozambique has promoted growth of the private sector and increased employment. However owing to the limited number of participating contractors, the perceived advantage of competing companies is not realized as the same companies compete within each province and little or no effective competition is realized. There is a likelihood that contractors are colluding during the tendering process and avoid competing against each other by putting in rates that favour the selected contractor among themselves.

The new contractors require more frequent training and mentoring until they can manage on their own. The limiting factor is that after the expiry of the initial two years contractors they are not guaranteed more work hence investing in new equipment for road maintenance becomes high risk.

The use of tractors as the only motorized equipment has proved to be effective since the general knowledge to repair an agricultural tractor is available. The delays in releasing funds for a new financial year interfere with the planning for maintenance and results in delayed intervention; the concept of preventive maintenance is therefore defeated In Inhambane where roads have been constructed using marginal materials (calcrete) the system works well and routine activities are effective for both labour and equipment based interventions.

6.2 Outstanding issues

There is need to develop capacity for the mechanical staff to repair and maintain equipment use during maintenance of roads. The private sector also needs support to expand the contractor base and improve on pricing and competitive bidding.

Government needs to improve on the disbursement mechanisms during the period at the beginning of the financial year.

A benchmark works and operations costing system (especially for equipment ownership and operating costs) is required; to be regularly updated. In this way both clients and contractors would have a reference point to bid and judge tenders.

The use of spare capacity from the tractors needs to be incorporated into the farming practice for small holder farmers to benefit from the available resource.

7 Potential Rural Sector Benefits

Table 1 shows the range of rural sector activities that agricultural tractors can be deployed for. As well as the intended agricultural sector tasks, and the proven road sector applications described by this paper, there are many activities that tractor use could lower costs and help economic and social development of the rural areas. Transport of people and goods is already widely practiced. However, activities such as earth dam construction, agro-processing, water sector applications and equipment hire are not widely observed. More research is required to develop these synergies, as well as the obvious agriculture and transport access compatibility.

8 Handbook of Intermediate Equipment

The Handbook of Intermediate Equipment for Road Works in Emerging Economies (Petts, 2012) consolidates research and experience in developing countries over recent decades. It brings together knowledge from the civil and mechanical engineering disciplines, with a focus on the business dimensions of equipment ownership and operation in the challenging environment of developing countries. The document sets out guidelines for the costing and procurement of intermediate equipment. These are two key management functions necessary to achieve successful and affordable road works in the limited resource environment typical of economically emerging and developing countries (EDCs). Some of the intermediate equipment items have useful applications or income earning potential in other sectors such as transport and agriculture.

The Handbook is aimed primarily at Contractors, Contractors Associations, Road Engineers, Planners, Investors, Equipment and other Managers involved with road works in emerging and developing economies. However, it is expected that Trainers and Educational Establishments will be able to incorporate material from the Handbook in their human resource development courses.

9 Conclusions and Recommendations

There are proven low-cost, tractor-based alternatives to rehabilitation and maintenance of earth and gravel rural roads, although there is need for wider appreciation of the costs of ownership and operation of equipment, particularly for intermediate equipment. This is important as it provides basis for calculating costs that will assist clients and contractors during bidding processes. Benchmark works and operations costing systems (especially for equipment ownership and operating costs) are required; to be regularly updated, for clients and contractors. There is also need to develop contract documentation to allow and promote tractor applications in road works.

There is a need to integrate farming and provision of roads as a way of achieving economic utilization of equipment in a range of rural applications.

There is a need for wider dissemination of knowledge regarding tractor-based road works and rural applications regarding the media, academic and professional institutions, the public and national/community leaders. Training is required to be widely available for agricultural tractor based roadworks. This includes mechanical as well as planning and operational skills. There is also a need for practical demonstration units of good practice for these techniques.

Further research and cooperation with the agricultural and water sectors is required to exploit the obvious synergies in tractor applications to realize mutual benefits for the rural communities while providing basic access and further develop the road networks in an affordable way.

Concerted efforts are required to ensure that adequate finances are raised sustainably to fund at least basic access road infrastructure for rural communities to exploit the relatively low cost tractor and supporting labour technology approaches. Efforts are required to ensure timely processing of due contract payments.

References

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.

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.

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). Intermediate Technology Roadworks Equipment, Assignment Reports 1 - 5, for Ethiopian Roads Authority and DFID, 379 pages.
Petts R. C. (2010). The Road Authority Capability Assessment Programme, ROADCAP, A Baseline and Annual Performance Survey Format for Rural Road Management in Emerging Economies, for gTKP, 7 pages.
Petts R. C. (2012). Handbook of Intermediate Equipment for Road Works in Emerging Economies, AFCAP, 135 pages.
Petts R. C. (2012), Low Volume Roads Maintenance Manual, South Sudan Ministry of Roads & Bridges (MRB), Government of South Sudan, UNOPS, AFCAP and DFID, 152 pages, 2012.
Transportation Research Board (1981), Labor-based Construction and Maintenance of Low-Volume Roads, Synthesis 3, Transportation Technology Support for Developing Countries.
World Bank (2008), Safe, Clean and Affordable Transport for Development, The World Bank Group's Transport Business Strategy for 2008-2012.