WHAT DOES THE FUTURE HOLD FOR LOW VOLUME RURAL ROADS IN DEVELOPING COUNTRIES SUCH AS SOUTH AFRICA?

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1. Abstract

It is estimated that 80% of the developing world's poor live in rural areas. Low volume rural roads account for 80 to 90% of the road infrastructure in most developing countries and are critical to the access and mobility of rural communities. Despite their importance to economic growth and sustainability of rural communities these roads are often neglected and marginalised in terms of funding and appropriate management. This paper will look at the current situation related to South Africa, outline a desired future for these roads and looks at possible solutions and interventions to take rural access and mobility from the current, generally unacceptable situation and condition to an improved all-season access in the next 10-15 years. Current initiatives related to rural access, Sustainable Mobility for All (SUM4All) and the relevance to the overall Sustainable Development Goals (SDGs) will be discussed along with the introduction of innovative, alternative, cost-effective technological solutions for LVRs (e.g. nano- and bio technologies) and the need for a relative quick evaluation of the suitability of these designs and products for specific circumstances.

Keywords: Low Volume Rural Roads; Rural Access; Mobility; Rural Development; Sustainable Development Goals.

2. Introduction

According to a United Nations, Department of Economic and Social Affairs (UN-DESA) Policy Brief, (Lee and Kind, 2021) reducing poverty and inequality in rural areas is the key to inclusive development. The article states that an estimated 80% of people in poverty (defined as living below the $1.90/day international income poverty line) live in rural areas and the situation is worst in Sub-Saharan Africa where more than 50% of the total rural population live in extreme poverty. The situation is exacerbated by inadequate access to public services, infrastructure and social protection, which in recent years, has been compounded by the Covid-19 pandemic by reducing incomes, limiting mobility and undermining food security.

Rural development strategies are generally designed to promote growth and reduce poverty yet few aim at explicitly reducing the inequality between rural and urban development (Ravallion, 2016b). As will be seen in this paper, equitable and inclusive rural development does not occur in isolation and is impacted on by wider national trends and requires specific attention in promoting all-weather access to education, health, markets and other services. It also requires building resilience to climatic events and addressing the depletion and degradation of natural resources. The optimum mix of economic and social policies, both rural and national, can accelerate economic development while reducing poverty and inequalities in rural areas.

The UN-DESA identifies five broad lessons from countries that have succeeded in reducing rural poverty and inequalities:

- Invest in infrastructure and public services. Sustained investment in roads, electrification, sanitation, safe drinking water, education, health care and the bridging of the digital divide in rural areas is required. Such investment should also address inequalities in access to public infrastructure and service in rural areas.

- Promote agricultural development. This includes ensuring suitable access from farm to market.
- Ensure fair distribution of and secure access to land and its natural resources. As part of this, it is important that women in rural areas have equal access to land and natural resources and address discriminatory laws and practices that impede women's rights.
- Improve social protection coverage in rural areas by modifying legal, financial and administrative barriers in rural areas.
- End all forms of discrimination as this remains a persistent driver of inequality.

This paper looks at the South African roads sector and how it can contribute to improved rural development and ultimately assist in reducing poverty in rural areas through improved access and mobility over the next 15 years.

3. Overview of the SA Road Transport Sector

Similar to most countries, the South African road transport sector is an integral part of the broader transport sector, it is essential for socio-economic development and is a major driver of economic growth. According to Ittmann (2018) the logistics performance of the transport sector is still performing at reasonable levels although the Logistics Performance Indicator (LPI) has decreased from 3,67 (world ranking 23 out of 167) in 2012 to 3,38 (world ranking 33). A World Bank survey ranked South African Transport infrastructure 38th in the world compared with a ranking of 19th in 2012 indicating a marked decrease in quality (Ittmann, 2018).

In terms of the road infrastructure, South Africa has about 750,000 kilometres of roads that include 131,919 kilometres of unproclaimed roads (Sabita, 2018) almost exclusively providing access in rural areas. Roads are managed at three levels (SAICE, 2017):

- National, primary intercity roads (economic roads) managed by SANRAL on behalf of the Department of Transport (DOT);
- The secondary and tertiary intercity network, primary access and mobility roads managed by the provinces, and
- Urban and rural municipal roads managed by local authorities.

Table 1 shows a breakdown of the South African road network (Sabita, 2018).

Based on assumptions from Table 1, it is estimated that approximately 630,000 kilometres (84%) are rural low volume roads which, for the purpose of this paper, are defined as roads carrying less than 500 vehicles per day or less than 1 million E80s over a 20-year design period. Ittmann et al (2016) stated that in general the national roads under SANRAL are in a good condition but the state of provincial and local roads vary greatly and in many small towns and rural areas, the roads are in an atrocious condition.

Therefore, as a critical factor to rural development and economic growth in rural areas with improved access and mobility, the road infrastructure in these areas needs serious and sustained attention to have lasting impact on overall Social Development Goals (SDGs) for the country. Currently, the National Development Plan (NDP) has a 74% convergence with the SDGs and prioritises the elimination of poverty, job creation, the reduction of inequality and growing an inclusive economy as requiring urgent attention (Stats SA, 2019, SA country report for SDGs, DPME, 2019). All of these factors are critical to economic growth in rural areas.

Authority	Paved	Gravel	Total
National	22,197		22,197
Provincial	48,945	173,732	222,677
Metro	51,682	14,461	66,143
Municipalities	40,648	266,416	307,064
Total proclaimed	163,472	454,609	618,081
Unproclaimed		131,919	131,919
TOTAL	163,472	586,518	750,000

Table 1: Breakdown of the South African Road network

4. Roads and Transport related SDGs

As indicated, sustainable transport drives poverty eradication and sustainable development. There are a number of SDG targets directly linked to transport, including SDG 3 on health (increased road safety), SDG 7 on energy, SDG 8 on decent work and economic growth, SDG 9 on resilient infrastructure, SDG 11 on sustainable cities (access to transport and expanded public transport), SDG 12 on sustainable consumption and production (ending fossil fuel subsidies) and SDG 14 on oceans, seas and marine resources. In addition, sustainable transport will enable the implementation of nearly all the SDGs through inter-linkage impacts, especially SDG 1 on no poverty and SDG 2 related to zero hunger and food security. Access to sustainable transport for all should be at the forefront, including for vulnerable groups such as. Women, children, persons with disabilities and the elderly.

SDG 9: Industry Innovation and Infrastructure and SDG 11: Sustainable Cities and Communities contain specific indicators for the roads and transport sector. These are:

- SDG 9.1: Develop quality reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access to all.
    - SDG 9.1.1: Rural Access Index (RAI) which is a measure of the proportion of the rural population who live within 2 km of an all-season road as a percentage of the total population (Bradbury 2019).
    - SDG 9.1.2: Passenger and freight volumes by modes of transport.
- SDG 11.2: By 2030 provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to those in vulnerable situations, women, children, persons with disabilities and older persons.

5. Rural Access

Rural accessibility is primarily defined as the distance to an all-season road and transport service and includes the distance to basic service as well as the critical initial link from agricultural production areas (termed the “first mile”). The provision of affordable, reliable and

inclusive rural transport infrastructure and service is at the heart of rural access (Cook et al 2017). Hence, rural access is a key enabler in achieving a number of SDGs of the 2030 Agenda.

To underscore the critical role of rural transport in achieving the SDGs a set of key messages were developed (SLoCaT, 2017):

- Improved rural development drives sustainable rural development and natural growth. Good rural road infrastructure and services promote connectivity and social cohesion, drive commercial activities, as well as accessibility to social and economic facilities necessary to counteract poverty, isolation and social exclusion.
- Better rural transport is key to food security and zero hunger. Improving rural access can lead to lower costs for farm inputs and lower transport costs for marketed outputs, thus increasing agricultural production to enhance food security.
- Poor rural transport condemns the poor to stay disconnected and poor. Access to markets and employment opportunities through better rural transport infrastructure and services is an essential pre-condition to generating rural income and reducing poverty.
- Additional money and commitment are needed to build and maintain rural road networks and develop sustainable rural transport services. Existing funding sources need to be expanded and new funding sources need to be developed, piloted and implemented, not only for building, but also for managing and maintaining the asset.
- Better rural transport calls for local solutions for local challenges. Rural access challenges require local resource-based solutions that are compatible with the local road environment conditions.

The key messages will drive short-term advocacy for the need to allocate more financial and human resources to improve rural transport infrastructure and services. They can also form the basis of a longer-term research agenda to build further evidence on ways to increase rural access and to create lasting institutional change through the uptake and embedment of the evidence. (Cook et al, 2017)

6. Sustainable Mobility for All (SuM4All)

Sustainable Mobility for All (SuM4All) was established in 2017 with an agreement that transport was a key component of economic development and central to peoples' quality of life. It brings together 55 public and private organisations and companies with a shared ambition to transform the future of mobility. The Global Mobility Report of 2017 benchmarked countries' performances on mobility relative to four policy goals and based on the report, no country, developed or developing, has achieved sustainable development.

In 2018, SuM4All began the development of a comprehensive policy framework to assist decision makers and practitioners to identify gaps, necessary steps, and appropriate actions to attain the SDGs and improve the sustainability of their transport sector. The Global Roadmap of Action builds on six policy papers which includes the Universal Rural Access paper (published July 2019) that will be discussed further along with the 2022 Mobility performance for South Africa related to rural access and available on the SuM4All website.

The Universal Rural Access paper states that 1 billion people in the world do not have access to transport with the majority living in rural Africa. In terms of the relevant SDGs shown in Section 4, the Rural Access Index (RAI) for different countries ranges from 5% of the rural population who live within 2 kms of an all-season road in some Low-Income Countries (LIC) to 99% of the rural population in High-Income Countries (HIC). Figures from 2016 shown on the South Africa country dashboard of SuM4All show that the RAI for South Africa was 74%.

In other words, 26% of the rural population in South Africa (as a Upper Middle-Income Country) live in excess of 2 kilometres from an all-weather road.

Relevant conclusions from the Universal Rural Access paper are:

- Governments of low-income and medium-income countries (e.g. South Africa), with possible support from development partners, will have to meet all or most of the investment costs, with assurances from the various local governments and communities to commit firmly to contributing to future maintenance. Such costs and assurances relate to procurement, technical support, finance and communications. To finance the investment needed, countries should establish a dedicated source of financing (e.g. fuel tax).
- The policy goal of achieving universal rural access by 2030 is ambitions and challenging but achievable. In many developing countries it will entail providing access for more than half the rural population which may take 10 to 20 years to implement.
- All countries can progress towards universal and inclusive access. Those with lower financial and technical capacity may initially give priority to basic access or motorcycle trails. Those with higher capacity may prioritise lower volume rural roads and higher volume rural roads. When a lower cost access type is provided, initially, it can later be upgraded when justified by traffic growth. Improvements in rural access make it more attractive for transport operators to provide bus and freight services and attract further improvements in service availability and quality.
- Substantial capacity building is needed to provide the skills required to implement the programme and maintain the asset (e.g. technical leadership within central government, programme planning and implementation by local government and skills training for contractors and communities).

The report also highlights pockets of good practice and uses the South African Department of Transport's (DoT) S'Hamba Sonke (Moving Together) Programme in Kwa Zulu Natal as an example of good rural road asset management. The programme introduced in 2011 provides grants for labour-intensive road maintenance of secondary roads and rural roads, while requiring participating provinces and district municipalities to implement and maintain road asset management systems to support decision making on road construction and maintenance.

The following comments are made on the Universal Rural Access paper related to South Africa:

- As an Upper Middle-Income Country, South Africa has pockets of good practice that should be built on to improve rural access to all areas. This is being driven through the DoT but requires sustainable funding, appropriate management systems and increased capacity to be successful.
- While the national roads under SANRAL are generally well maintained and in good condition this does not apply to rest of the network managed and maintained by Provinces and Local Municipalities who have responsibility for the majority of the rural road network. Tolling of the national roads provides dedicated funds for the maintenance of those road and hence their good condition. The Universal Access report suggests a fuel tax as a dedicated source of financing road maintenance and in an ideal world this could be an option. However, South Africa already imposes heavy taxes on fuel that goes into the central fiscus for general government funding and are not dedicated to road maintenance. Without the support and commitment of National Treasury to provide adequate funds for rural development and the required improvements for rural access and mobility, the country with continue to struggle to achieve international SDG goals.

- The 131 919 kilometres (17,6% of the total network) of unproclaimed roads shown in Table 1 provide basic access for rural communities and need to be proclaimed under the responsibility of the relevant provincial and local government structures. It is these roads that service the vast majority of the rural population (26%) who live further than 2 kilometres from an all-season road.
- The capacity and skills both in the public and private sector to manage, construct and maintain the rural infrastructure needs to be increased and improved. Pockets of good practice exist that need to be replicated throughout the country under the leadership of the DoT.
- Climate resilience is particularly relevant to the rural road network and the provision of all-season access. As a matter of course, rural management systems should identify vulnerable areas for spot improvements and climate adaptation measures. In this regard, the work by the CSIR-lead consortium as part of the UK Aid funded Research for Community Access Partnership (ReCAP) in developing a Climate Adaptation Handbook, guidelines and manuals should be built on and implemented in South Africa. (Verhaeghe et al, 2019)
- Ongoing and sustainable national rural access programmes need to be underpinned by appropriate and dedicated research. While international programmes such as ReCAP provide valuable research support on a national and regional level for a period of time, this is not sustainable. Countries have to take responsibility for their own research and development programmes. SANRAL has an active research programme for South African roads and transport, but it mainly focusses on the priorities of SANRAL. To facilitate improvements to the rural road network, there needs to be a parallel research programme, managed through the DoT, to support the rural network which accounts for 84% of South Africa's roads.

7. Technology Interventions

A number of current and future mega-trends and challenges will impact the roads industry (Rust et al., 2021). Those that particularly impact on LVRs include:

- Climate change that will cause increased, rainfall, temperatures and radiation;
- A cyclical economy and associated variable funding for roads;
- The need for capacity building and skills development;
- An ever-changing political landscape that impacts on priorities for road construction and maintenance;
- The need for poverty and hunger eradication;
- The need for sustaining humanity and environmental protection;
- Increasing resource scarcity;
- The need to build a capable state;
- The advent of the 4th industrial revolution that will impact on road building technologies, particularly materials technologies.

The following preliminary technological and management interventions are suggested to "future-proof" LVRs and to address the mega-trends above:

- Appropriate and cost-effective design methods based on locally available materials not necessarily meeting traditional specification should be considered for rural low volume road with spot improvements in vulnerable areas for climate resilience. The Rural Road Note 01: A guide on the Application of Pavement Design Methods for Low Volume Rural Roads (2020) published by the Research for Community Access Partnership (ReCAP) provides good guidance in this regard. However, from a South African

perspective, the DCP/DN design method highlighted as one of the suitable methods in the Road Note is well used and pioneered in South Africa. The DCP-DN design software was updated through ReCAP and is recommended for continued use in designing and upgrading LVRR in the country. The software can be downloaded from the CSIR web site.

- Adaptations for more climate resilient rural roads is becoming critical in providing all-season access. In this regard, the use and implementation of the Climate Adaptation Handbook and the Change Management Guidelines should be implemented in South Africa for rural LVRs. The documents are available on the ReCAP website (research4cap.org). (Verhaeghe et al, 2019)
- Road building materials for LVRs that are based on improving marginal materials to counter the scarcity of good quality crushed aggregates will become increasingly more important in the future. This could include nano-modified emulsions, polymer modification and bio-cementation (Smit et al, 2022);
- Alternative materials for surfacing seals that are resistant to increases in rainfall, temperature and radiation caused by climate change;
- Improved labour-intensive construction technologies for construction and maintenance to assist with job creation;
- Potential treatment for gravel roads to combat increased rainfall such as bio-cementation;
- Improved design of bridges and culverts on LVRs to take account of potential increases in rainfall and to counter flooding;
- Improved safety on rural roads through appropriate geometric designs taking consideration of potential increases in rainfall due to climate change;
- Improved human capital development and training in the maintenance of LVRRs to ensure their longevity;
- Improved road management and funding methods for LVRRs to ensure sustainable funding for construction, upgrading and maintenance;
- Improved condition monitoring techniques for LVRRs using satellite imagery, cellphone technology and Unmanned Aerial Vehicles (UAVs) such as drones.
- Appropriate and cost-effective Accelerated Pavement Testing (APT) techniques to evaluate the suitability of alternative designs and materials for LVRs using a systemic approach that simulates the increasing effect of the environment related to traffic.

Examples of typical intervention are:

Nano-Modified Emulsions (NMEs)

Nano-product improve marginal material at a nanoscale and is an alternative to conventional modification techniques and stabilising agents (Akhalwaya and Rust, 2018). NMEs have improved distribution, coverage and stabilisation characteristics which helps obtain the required design strength criteria at smaller quantities of residual bitumen (Jordaan et al. (2017). They also assist with the waterproofing of marginal materials. Thus, NMEs have the potential to improve long-term performance of LVRRs and reduce the cost of road construction and maintenance by reducing the need to haul good quality material to site. NMEs can be divided into two categories: Nano-polymers and Nano-silanes.

- Nano-polymers are used in nano-emulsions to protect, functionalise and stabilise the polymer particles found within traditional emulsions (Solans et al., 2005).
- Organo-silanes serve as a coupling agent by chemically altering the surface of virtually any silica-based materials and rendering them hydrophobic (Daniels et al., 2009). Jordaan (2017) further mentions that these siloxane bonds are one of the strongest bonds

established in nature and are formed as a direct result of nano-modification at the molecular level of a mineral soil or aggregate.

Polymers

Polymers are large molecules composed of repeating units called monomers. Even though polymers are made up by several monomers they exhibit physical and chemical properties that are different from the monomers. Certain polymers are abundant industrial by-products and are treated as wastes, some of these include lignin, a biopolymer from pulp and paper industry, and fly ash, a precursor of geopolymers (Huang et al., 2021).

Both natural and synthetic polymers have been used to improve soils properties for example to control dust, reduce wind erosion, and improve slope stability. Their use has however been constrained due to their high cost, with engineers opting for more traditional stabilisers such as Portland cement and lime. In successful applications however, polymers have proved to be more environmentally friendly compared to cement and lime (Huang et al., 2021).

Bio-stabilizers

Bio-stabilizers have been investigated in recent years as a potential cost-effective and environmentally friendly alternative engineering approach. Microbial Induced Calcium Carbonate Precipitation (MICCP) binds material through the formation of calcium carbonate bridges between soil grains. Under specific environmental conditions, urease positive bacteria use urea as an energy source, producing calcite. MICCP is novel, natural, environmentally-friendly and durable. This biogenic technology has been used for several engineering applications aimed at improving the engineering properties of soil which include increased unconfined compressive strength and shear strength characteristics and decreased hydraulic conductivity (Smit, *et al.,* 2022).

Accelerate Pavement Testing (APT) to prove performance

APT has been used to investigate the performance of new pavement design and materials in South Africa over several decades. In a recent test with the Heavy Vehicle Simulator (HVS) a Nano-modified Emulsion was tested at road D1884 near Heidelberg (Rust et al, 2020). It was shown that stabilisation of available substandard materials using an anionic nano-silane modified bitumen emulsion compared with the standard approach of importing high quality crushed aggregate can lead to savings as high as 40% - 50% for equivalent performance. In addition, there was also a significant reduction in construction effort and time. This road carried in excess of 5 million Equivalent Standard Axles (ESALs) as applied by the HVS which is more than adequate for LVRRs. This demonstrates the value of having an early evaluation of the likely performance of new materials using APT compared with the monitoring of long-term pavement performance (LTPP) sections that require several years to obtain usable results.

However, HVS testing is expensive and is limited in simulating the environmental conditions that play a more significant role under reduced traffic loads in the performance of LVRRs. Investigations need to be carried into the development of an accelerated testing facility for LVRRs that would simulate temperature effects, rainfall effects, radiation and ageing of the surfacing more accurately. The development of the prototype Traffic Stream Simulator (TSS) which is a modular design and can be used over a short test section may go some way to address the cost limitation associated with HVS testing (Rust and de Beer, 2020.) Recently a standardised APT protocol was developed (Rust et al, 2022), however, an LVRR-specific protocol needs to be added to the document that addresses the balance between trafficking and environmental distress in the performance of LVRRs.

8. Conclusions

Rural access and mobility are critical to rural economic growth and development to meet the international Sustainable Development Goals (SDGs) and needs urgent attention in the next 10 to 15 years in South Africa. Currently, the proclaimed rural road network is generally in poor condition due to deferred and inadequate funding for maintenance along with reduce capacity and skills in many authorities to manage the network. There are, however, examples of good practice in the country that could be built on and implemented in authorities struggling to manage and maintain their networks.

In addition, the large volume of unproclaimed roads providing critical basic access to some rural communities needs to be addressed in terms of the relevant authorities at provincial and local government levels taking responsibility for these roads and tracks.

In an effort to sustain the rural road infrastructure and provide all-season access to the rural population of South Africa the following is proposed:

- Adequate funding and good management are fundamental to sustained economic growth and development in rural area and must be driven through an ongoing commitment from Government.
- All rural communities deserve all-season access to education, health care and other essential services with the eradication of poverty and hunger in all areas.
- Agriculture is a vital component on the South African economy and required rural roads in good condition to transport goods from farm to market.
- The lack of rural development is promoting rapid urbanisation and movement of people, especially young people, to urban centres in search of job opportunities. There is a need for job creation and capacity building in rural areas to redress this trend. Labour-intensive interventions in providing all-season rural access would support this.
- Appropriate technological interventions to provide all-season access need to be implemented based on current knowledge. In this regard, the implementation of appropriate and cost-effective designs using locally available materials should be the norm, supported by climate resilient adaptation measures at vulnerable points in the road network.
- Technological interventions need to be supported by a research capability to investigate and address future needs specific to rural access and mobility. While the SANRAL Research Programme goes some way to addressing this, the programme is primarily focused on the national road network. Consideration should be given to a parallel programme for low volume rural roads driven through the Department of Transport and interlinked to the SANRAL programme to prevent overlap.
- International interventions such as SuM4All should be supported as they provide an important benchmark for South Africa in terms of their progress to providing all-season access to all rural areas and improving their performance against relevant SDGs. Based on the South African Country Dashboard of SuM4All (2022), the overall Sustainable Mobility Ranking is 79 out of 183 countries with a sustainable mobility Index of 47.5. In terms of Rural Access, the latest 2016 figure shows an RAI of 74% of rural population live within 2kilometers of an all-season road. Future improvements should be measured against these indicators.

The next 15 years are critical to rural development in South Africa and is recognised by Government. However, without a sustained plan with adequate funding and suitable management the goals and indicators of progress may not be met.

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