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Roads seen through the lens of Social Engineering

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ABSTRACT

The Eastern Cape region confronts difficulties in building roads due to a lack of financing, a paucity of competent personnel, and environmental issues. Ensuring safe and sustainable networks is the goal of South Africa's road design guidelines. The goal of the research is to use locally accessible raw materials to engineer durable unpaved (gravel) roads in the Eastern Cape. The goals are to compile information on the materials that are available, assess their acceptability, evaluate design principles based on existing design standards, and create a framework for planning and building these roads inside the province using locally produced raw materials. This work is included in the research's literature review. In South Africa, roads are essential to rural infrastructure because they promote economic development and enhance quality of life. Road network modernization requires the use of asset management systems like RAMS. Engineering indigenization and localization is vital in order to create egalitarian networks, for the roads engineer, this can include incorporating local resources and cultures into design considerations. Road functionality and safety depend on routine maintenance and tributary analysis, which are made more difficult by climate change.

Keywords: Gravel Roads, Climate Change, Rural Roads

1. THE ROLE OF ROADS

Roads are essential to the expansion of every economy because they allow goods, people, and services to travel more easily. However, Africa's progress has been hampered by the neglect of its rural road infrastructure. In order to manage natural disasters and man-made crises, sustain rural livelihoods, increase liveability, spur economic growth, and foster rural connection, rural roads are essential. Gravel road sustainability engineering solutions must consider liveability concerns, particularly in rural areas, and how using context-sensitive solutions could improve the balance between the environmental, social, and economic facets of sustainability (Faiz, 2012). This is because they make it easier for remote populations to access services like markets, clinics, and schools, roads can also have a sociocultural impact. They can promote migration and social mobility, which can provide economic

opportunities for people's livelihoods and general well-being. To improve people' socioeconomic conditions, rural road networks in developing countries must be prioritised and improved. It's still unclear how unpaved or gravel roads are maintained, particularly in rural areas, and what it means for small enterprises (Nkomo *et. al.,* 2016).

It is possible to investigate the social, environmental, and economic aspects of roads engineering. A complicated interaction between clients, consultants, contractors, tools, equipment, and materials occurs throughout construction. Long trips, fuel consumption, and production expenses are all decreased by good roads. On the other hand, there are obstacles in the way of road building, like labour shortages, community unrest, land proclamation, time restrictions, financial constraints, cash flow, lack of resources, and project duration. Effective planning, communication, collaboration with private businesses, and early detection of possible hazards are essential to resolving these problems. Roads have an impact on the environment in a number of ways, including fragmentation of habitat, death of wildlife, and environmental degradation. By promoting mammal-mediated seed dispersal, gravel roads may serve as seed corridors. Additionally, roadside rehabilitation can be promoted and costs can be reduced by employing soil-based dispersers (SLD) (Suárez-Esteban *et. al.*, 2013).

2. HISTORY OF ROAD ENGINEERING IN THE SOUTH AFRICAN CONTEXT

Roads have been around since dinosaur times, with the first being engineered by Romans. Earth's history began 4.7 billion years ago with the emergence of the solar system. The current sixth extinction event, driven by climate change, is a result of human actions (Strayer and Nelson, 2016). The evolution of roads is influenced by the "three Cs": change/continuity, comparison, and connection. Change highlights significant shifts, but continuity highlights things that have persisted over long stretches of time. Making comparisons helps people think about the similarities and differences in human experiences (Brogan, 1964). Africa has experienced significant human revolution, with culture becoming more important than biology. Migration from Africa to Eurasia, Australia, the Americas, and the Pacific islands occurred between 100,000 and 60,000 years ago, leading to diverse roads and transportation networks. Human migration decisions are influenced by pull and push factors, as well as environmental factors (Urbański, 2022).

The rules and regulations controlling road design are the foundation of road construction in South Africa. The Cape Colony established the first formal standards for road design in the late 1800s, and they have since been revised to satisfy the changing needs of the country. After the construction of the first road in 1820, major cities and villages were connected by a network of roadways by the 1870s. The 1950s saw the National Road Board establish the present standard for road design and construction, which saw multiple adjustments in the 1960s and 1970s. The South African Roads Design Standards offer guidelines and standards for the design, construction, and maintenance of the country's road network. All users of the road networks are guaranteed safety, efficiency, and environmental sustainability by these criteria. Road construction in South Africa has its roots in the standards and laws governing road design. The first official standards for road design were created in the late 1800s by the Cape Colony, and have since been updated to meet the nation's evolving demands. The first road was built in 1820, and by the 1870s, a network of highways connected major cities and villages. The National Road Board implemented the current standard for the design and building of roads in the 1950s, which underwent

several revisions in the 1960s and 1970s. The South African Roads Design Standards provide principles and criteria for planning, building, and upkeep of road infrastructure in South Africa. These standards ensure safe, effective, and environmentally sustainable road networks for all users. Nevertheless, there was regional variation in the materials utilised and the design of these roads was not uniform. In order to oversee South Africa's national road network, the South African National Roads Agency Limited (SANRAL) was established in 1998.

The South African road network is owned by the national, provincial, and local spheres of government, with competent authorities overseeing planning, design, building, operating, maintaining, and rehabilitating roads. The Constitution assigns different branches of government responsibilities for transportation and road infrastructure, with the Department of Transportation (DoT) creating integrated policy frameworks. The Road Infrastructure Strategic Framework for South Africa (RISFSA) governs road infrastructure planning and development, considering each road's relevance and contribution to the nation's economic and social goals. Effective access control ensures highways contribute to the economy.

Policy and planning matters pertaining to roads in South Africa are governed under the National Land Transport Act of 2009. The current specifications for road design in South Africa, which range from pavement design to geometric design, are included in the South African Road Traffic Signs Manual (SARTSM). The SARTSM is used by planners and engineers to develop safe and efficient road designs, and it is regularly updated to consider the most recent discoveries in road design research.

3. THE GRAVEL ROAD NETWORKS IN SOUTH AFRICA

With 750 000 km of roads that would cost R2 trillion to rebuild, South Africa has the tenth-longest network in the world as well as the fifth-longest network of unpaved roads (Central Intelligence Agency, 2014). Only 16 percent of the 21 403 km that SANRAL, the South African National Roads Agency Limited, is currently in charge of managing are tolled, while the remaining 84 percent are not. Municipalities are in charge of 51 682 km, whereas provinces are in control of about 47 348 km. There are 591 876 km of unpaved roads and 158 124 km of paved roads in the nation when looking at the pavement profile (National Department of Transport, 2015). Unclassified roads in South Africa are 131 919 km long and unmanaged, resulting in poor condition unless privately maintained.

South Africa's rural roads, particularly gravel roads, are in poor condition, causing discomfort and affecting transportation infrastructure. Factors like material behaviour, drainage capacity, and maintenance activities contribute to degradation. Research focuses on improving paved roads, but limited studies exist on unpaved or gravel roads' impact on rural economies (Vanderschuren *et. al.,* 2015). Poor road infrastructure leads to limited access to social and economic opportunities. As a result, building appropriate rural roads is necessary (Sewel *et. al.,* 2019). Gravel roads are a popular transportation option in Eastern Cape rural areas due to limited resources and low traffic volumes. However, maintaining these roads is costly due to geography, stormwater drainage, and long access routes. Gravel roads are easier to build, cost-effective, and adapt better to their environments (Ross & Townshend, 2018). They can be used for passenger and freight transportation but have drawbacks like degraded pavement quality. The Eastern Cape's road infrastructure faces challenges, including poor maintenance, high maintenance costs, and long access routes. To increase resilience, it is essential to adopt

Table 1. An overview of the South African Roads Network

Authority	Paved	Gravel	Total
SANRAL	21 403	0	21 403
Provinces - 9	47 348	226 273	273 621
Metros - 8	51 682	14 461	66 143
Municipalities	37 691	219 223	256 914
Total	158 124	459 957	618 081
Un-Proclaimed (Estimate		131 919	131 919
Estimated Total	158 124	591 876	750 000

Source: National Department of Transport (2015)

environmentally friendly approaches, involve the community in maintenance, and use appropriate tools and procedures (Eastern Cape Socio Economic Consultative Council, 2020).

For South Africa's road networks to successfully modernise, asset management is essential. The nation's network of gravel roads is deteriorating, which is uncomfortable for drivers, especially those who live in rural areas. In the area, hard unpaved roads are typically constructed using crushed rock, sand, gravel, and clay. By combining engineering specialties with sensible business practices and financial theories, the Roads Asset Management System (RAMS) helps road authorities maintain a safe and effective road network in a sustainable and effective manner (Du Plessis, 2021). SANRAL was tasked with updating the COTO guidelines that already deal with RAMS and generating new manuals covering every facet of road asset management in order to assist road authorities with the adoption and operation of RAMS.

4. GOVERNMENT AS AN ENABLER FOR ROADS INFRASTRUCTURE DEVELOPMENT IN SOUTH AFRICA

South Africa has been a significant player in road infrastructure development since the early days of democracy, with Presidents Mandela and Zuma prioritizing it for economic and social goals through the Reconstruction and Development Plan (Williams, 2014). President Ramaphosa introduced private investment and funding for public infrastructure, with the government committing R100 billion to the Infrastructure Fund (National Treasury, 2022). Roads are the primary means of transport for rural communities and transport 80-90% of all passengers and goods worldwide. By 2050, road transport is predicted to account for about 90% of passenger and freight traffic in Sub-Saharan Africa (Dulac, 2013). Between 1998/99 and 2018/19, the public sector spent R3.2 trillion on infrastructure, but expenditure growth has declined due to reduced spending by municipalities and state-owned companies, increased budget deficits, and debt (National Treasury, 2020). The National Treasury has reviewed public-private partnership regulations and guidelines to address challenges and enhance private-sector participation in blended-finance projects, and develop a comprehensive Public Investment Management (PIM) policy (National Treasury, 2024).

5. INDIGENIZATION OF ROADS ENGINEERING

Indigenization of engineering involves incorporating local cultures and resources into engineering practices and technology, often in emerging nations or historically colonized areas (Dong *et. al.,* 2022). This process involves adapting principles, procedures, and technologies to suit the local environment and culture. Involving rural communities in road maintenance can help ensure successful and sustainable maintenance

(Tan *et. al.,* 2023). Other developing countries with similar road networks can provide insights, such as Brazil, India, and Latin America, which have implemented eco-friendly techniques Farida *et. al.,* 2022). However, challenges such as inconsistent regional engineering best practices, lack of investment in local engineering education, and concerns about climate change and sustainable growth can hinder progress. Indigenization is crucial for creating effective, efficient, and equitable road networks.

South Africa faces challenges in planning, designing, and building roads and bridges due to the region's severe climatic conditions. Sustainable graveling practices can help adapt the road network to changing economic and environmental conditions (Choi and Kamalu, 2020). However, climate change may increase floods, landslides, and erosion, potentially damaging the network. To maintain durable and adaptable roads, road management must implement environmentally responsible practices and maintain strong relationships with community organizations (Grant, 2019). Engineered road designs minimize soil loss due to erosion and consider drainage, surface slopes, and compaction levels. Local materials are often used in construction projects, benefiting local businesses and economies. However, climate change and extreme weather patterns can significantly impact the infrastructure of roadways and human settlements. Road managers must consider these factors when building and maintaining structures that cross waterways, including thorough tributary analysis and regular maintenance (Martin *et. al.,* 2021).

South Africa relies heavily on gravel roads for transportation and essential services. Building more resilient roads is crucial for the region's long-term economic and social development (Mekonnen & Boel, 2020). In spite of these obstacles, South Africa can construct more robust roads by utilising a variety of techniques (Karthik & Sivakumar, 2019). Strategies include using high-quality materials, planning maintenance, investing wisely in road projects, and employing skilled workers (Motsi & Mbohwa, 2016). Structural modifications, targeted investments in critical areas, and interventions to improve road surfaces and drainage systems are also essential. New partnerships and collaborations with local communities, non-profit organizations, and private sector partners can help identify innovative solutions and secure additional funding (Rouhi & Besharati, 2019).

6. CONCLUSION

In conclusion, because of the distinctive topography of the region, road management in South Africa faces several difficulties when planning and constructing bridges and highways that cross rivers. Establishing a stable, sustainable, and safe transportation infrastructure in the area requires careful planning, selection of appropriate materials, and implementation of preventative maintenance. These strategies can be used to design and construct a road network that is both highly resilient to the long-term effects of climate change and precisely tailored to the region's particular climatic conditions.

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8. CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

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