FROM WASTE TO ROADS: CIRCULARITY AS A CATALYST FOR RURAL MOBILITY AND ECONOMIC GROWTH IN SOUTHERN AFRICA

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ABSTRACT

This essay explores how waste material valorisation can accelerate rural mobility and economic development in Southern Africa through cost-effective, sustainable low-volume roads. Historically central to agriculture and economic growth, rural areas have been overlooked in transport planning, favouring urban centres. A shift is needed to prioritise the rural economy. Through a circular economy framework, locally available waste materials can be recycled for rural pavement construction-creating jobs, reducing environmental degradation, and improving mobility. Case studies from Malawi, South Africa, and Zimbabwe demonstrate the technical feasibility, socio-economic benefits, and implementation strategies of this approach. Findings show that a circular approach can cut costs by up to 40%, lower emissions by 30-60%, and generate 5-7 times more jobs per kilometre than conventional techniques. This essay contributes to the growing discourse on sustainable rural development in the region.

Keywords: Circular economy, Rural mobility, Sustainable pavements, Waste valorisation, Southern Africa.

1. INTRODUCTION

Rural mobility remains a pressing development challenge in Southern Africa, with over half of the rural population living more than two kilometres from an all-season road (Avery *et al*., 2017). This significant infrastructure gap restricts access to vital services such as markets, healthcare, and education, intensifying poverty and economic exclusion. Conventional road construction methods are expensive, carbon-intensive, and heavily reliant on non-renewable resources, rendering them unsustainable for widespread rural application (Sy, 2016). At the same time, the region faces increasing volumes of waste, exceeding 42 million tonnes annually, resulting from rapid urbanisation and changing consumption habits (Roy *et al*., 2024). However, less than 15% of this waste is currently recycled, presenting a major environmental burden and an untapped economic opportunity (Godfrey *et al*., 2020).

Various researchers (Homrich *et al*., 2018; Merli *et al*., 2018; Nobre & Tavares, 2021; Nikolaou & Tsagarakis, 2021) define a circular economy framework as a regenerative system that limits the use of virgin resources, waste disposal, embodied carbon emissions, and energy leakages through slowing, closing, and narrowing material and energy loops. Circular economy strategies can be achieved through durable pavement designs, the reuse and recycling of waste materials (Nikolaou & Tsagarakis, 2021). The same authors (Homrich *et al*., 2018; Merli *et al*., 2018; Nobre & Tavares, 2021; Nikolaou & Tsagarakis, 2021) also define sustainability as a complementary concept, which aims for the triple

bottom line approach, integrating environmental resilience, economic performance and social inclusiveness for the benefit of current and future generations.

On the other hand, within the context of a circular economy, waste valorisation entails the transformation of different forms of waste, such as agricultural waste (Zhang *et al*., 2022), mine waste (Girish *et al*., 2022), and construction and demolition waste (Reis *et al*. 2025), into valuable construction materials. The implementation of a circular economy framework for road construction in rural parts of Southern Africa presents an opportunity for addressing mobility challenges while lowering construction costs, reducing the overdependence on virgin resources, promoting environmental stewardship and socio-economic development (Yu *et al*., 2025).

Despite the global shift towards circular economy strategies, the role that circular economy approaches play in rural mobility and economic development through ease of accessibility to markets and social equity in Southern Africa is still under-explored (Council for Scientific and Industrial Research, 2021). This strategy directly supports the African Union's Agenda 2063 and advances key United Nations Sustainable Development Goals 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production), offering a pathway to sustainable development (Godfrey *et al*., 2020).

The concept of circularity in infrastructure development represents a paradigm shift from linear "take-make-dispose" models toward regenerative approaches that maximise resource utilisation while minimising environmental impacts (Nobre & Tavares, 2021). Early applications of circular principles in Southern African transportation infrastructure have shown promising results (Hoosain *et al*., 2023).

It is against this background that this essay proposes a brief transformative approach that reimagines waste as a catalyst for rural mobility and economic development.

2. THE RURAL MOBILITY CRISIS IN SOUTHERN AFRICA

Southern Africa faces a severe rural mobility crisis, with under 30% of rural populations in countries like Mozambique, Malawi, and Zambia having adequate transport access (Porter, 2016). This lack of infrastructure is closely tied to persistent poverty, as households far from all-weather roads earn significantly less income (Avery *et al*., 2017). Traditional pavement construction techniques are sometimes not suited to local conditions, materials and budgets for most Southern African countries with costs ranging from $80,000 (ZAR 1,440,000) to $1,200,000 (ZAR 21,600,000) per kilometre (Centre for Global Development, 2023), well beyond the fiscal capacity of most regional governments (Wang *et al*., 2024).

3. WASTE MATERIAL VALORISATION FOR PAVEMENT INFRASTRUCTURE

Recent advances in materials engineering have established the technical viability of various waste-derived materials for pavement applications in Southern African contexts (Hoosain *et al*., 2023). Table 1 summarises key waste streams and their demonstrated applications in pavement layers.

Table 1: Waste materials and their applications in pavement construction

Waste Stream	Pavement Application	Performance Characteristics	Reference
Plastic waste (PET, LDPE)	Modified bituminous binders, soil stabilisation	Enhanced rutting resistance, improved water resistance	Karmakar & Kumar (2021)
Agricultural residues (bagasse, rice husks)	Biochar soil stabilisation, natural fibre reinforcement	Improved tensile strength, reduced shrinkage	Zhang *et al*. (2022)
Construction & demolition waste	Base and sub-base aggregates	Comparable bearing capacity to virgin materials	Reis *et al*. (2015)
Fly ash & metallurgical slag.	Cementitious binder replacement, soil stabilisation	Enhanced durability, reduced carbon footprint	Girish *et al*. (2022)
Waste rubber tires	Bitumen modifier, lightweight fill	Increased flexibility, improved thermal properties	Pasalkar *et al*. (2015)

The labour-intensive nature of waste collection, sorting, processing, and application creates substantial employment opportunities, particularly beneficial for rural communities with high unemployment rates (Hoosain *et al*., 2023). Recent projects in Malawi and Zambia demonstrate that waste-based rural road construction generates 5-7 times more employment opportunities per kilometre than conventional approaches (Roy *et al*., 2024). Beyond direct employment in road construction, circular economy approaches accelerate broader enterprise development through waste collection networks, processing facilities, and associated value chains (World Bank, 2024).

As mentioned earlier, there has been growing interest in sustainable construction across the continent, however, literature on the application of waste valorisation in rural pavement construction is sparse (Bamigboye *et al*., 2021; Ohemeng & Amoako-Atta, 2023). Valorised waste materials can serve as stabilisers, base layers, or alternative binders, reducing dependence on virgin resources and promoting circular economy principles (Watson, 2023). Empirical evidence confirms that properly processed waste exhibits comparable engineering performance to conventional materials in low-volume roads (Yuriz *et al*., 2020). However, scalable adoption requires cohesive frameworks taking into consideration technical standards and design guidelines, environmental awareness, and market incentives (El-Assaly & Ellis, 2001).

This imperative is personal. Taking an example of Gokwe, one of the remotest and underdeveloped rural parts of Zimbabwe, poor road conditions often turn a 120 km journey into a five-hour ordeal during the rainy season, an experience that has not changed since childhood. Such mobility challenges exacerbate rural isolation and poverty (Sy, 2016). Yet, successful case studies from India and Brazil indicate that integrating waste into rural roads is both feasible and transformative (Kumar & Garg, 2020; Silva *et al*., 2019). These models present transferable and practical solutions to deliver inclusive, resilient, and low-cost road infrastructure through circular economy frameworks across Southern Africa.

4. FUTURE RESEARCH DIRECTIONS AND RECOMMENDATIONS

Although the adoption and utilisation of waste-derived construction materials has not been completely ignored in Southern Africa, there are numerous lessons to learn from regions where these projects have been implemented successfully. Conserving natural resources while intentionally thinking about bringing “greener pastures” to marginalised areas remains a research priority. However, facilitating a conducive research environment through various funding mechanisms remains a topic of interest. Additionally, collaborative research efforts across different disciplines are the most viable way of achieving these objectives.

Over the years, there have been fragmented efforts in the adoption of waste-based materials for accelerating connectivity through sustainable pavement design (Watson, 2023). It is now paramount to divert focus toward developing frameworks targeted at utilising waste in constructing rural roads in Southern Africa. These frameworks should address the technical performance, environmental, social, and economic impacts of the adoption of waste materials holistically. The aim is to develop and establish sustainable policy frameworks that encourage suitable processing technologies and procurement strategies which actively incentivise the utilisation of waste materials in rural pavement construction.

5. CONCLUSION

The integration of circular economy principles into rural mobility infrastructure represents a transformative opportunity for Southern Africa. Through the valorisation of locally abundant waste materials into rural road construction, countries can simultaneously solve waste disposal challenges, rural mobility problems, unemployment, and the massive urbanisation in search of “greener pastures” – creating a sustainable cycle for future generations.

As mentioned earlier, reports from case studies where waste-based technologies have been implemented across the region demonstrate promising results. With waste-based technologies delivering cost savings of approximately 30-40%, creating 5-7 times more employment opportunities, and reducing environmental impacts significantly, compared to conventional approaches, the adoption of waste materials in pavement design presents a technological breakthrough in Southern Africa.

The full potential of the circularity approach can only be realised when there are coordinated efforts from engineering, policy, technology, financing, and capacity-building dimensions. With the appropriate support mechanisms and implementation frameworks in place, circular economy approaches to rural mobility can be implemented at a regional level, contributing immensely to sustainable development goals, creating resilient rural economies. The circularity approach to rural mobility presented in this essay offers a powerful template of how sustainability challenges can be viewed as opportunities through a systems thinking approach and context-driven solutions.

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