PAPER 17

MUNICIPAL READINESS LEVEL FOR AN AGEING AND DETERIORATING PAVEMENT NETWORK FOR MAINTENANCE PRIORITISATION

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1. ABSTRACT

"Municipalities are failing to balance investment in new infrastructure with sound operation and maintenance of existing infrastructure to ensure sustainable service delivery. Inadequate infrastructure maintenance undermines service delivery and contributes to increased backlogs" [1]. The SAICE Infrastructure Report Card rated municipal paved roads as "D-", and unpaved municipal roads as "E".

Research states that delaying road maintenance is a false economy, as the longer such maintenance is left undone, the higher the eventual cost to restore the road to an acceptable condition. Prompt corrective measures are therefore recommended to minimise losses for all parties involved [2].

This paper presents a straightforward piece of research to access the readiness of municipalities to address their ageing and deteriorating road infrastructure. The research includes a critical review of road deterioration principles and current challenges, a case study to access the awareness practices of municipalities in managing their road infrastructure and a conceptual framework for local road infrastructure management.

- Critical Review: Understanding pavement theory, the impact of delaying road maintenance, the challenges in implementing road maintenance, and opportunities for successful maintenance.
- Case Study: Review of municipal Integrated Development Plans (IDPs) and finances to understand their threats and challenges, infrastructure awareness, how they prioritise road maintenance and their maintenance expenditure.
- Discussion: Potential way forward for local municipalities in the management of their roads.

The major threats identified at a local level were road infrastructure deterioration, maintenance budget underfunding and shortage of skills. Furthermore, there are inconsistencies as to the utilisation of their maintenance budget (under-utilised), and prioritising new road construction as opposed to fixing their existing infrastructure.

2. OVERVIEW

The South African road network of over 750 000km is the tenth longest in the world. Municipalities manage over 256 000km of the network, and an estimated 131 000km is unproclaimed. Furthermore, the road replacement cost is estimated at R2 Trillion [3].

Given the extent of the network to be managed, it is essential that preserving infrastructure be a priority. Neglect will result in the deterioration of assets, with deleterious effects on the economy, particularly regarding inflated costs of reconstruction over time. The goal of maintenance is to safeguard an asset, not to upgrade it. Road preservation and strategic maintenance initiatives are crucial for sustaining the life of the asset.

The MISA Strategic Plan [1] states that "Municipalities are failing to balance investment in new infrastructure with sound operation and maintenance of existing infrastructure to ensure sustainable service delivery. Inadequate infrastructure maintenance undermines service delivery and contributes to increased backlogs."

The SAICE Infrastructure Report Card [4] further rated municipal paved roads as "D-" (at risk of failure), and unpaved municipal roads as "E" (unfit for purpose). Prioritisation of road expenditure is occurring within all the provinces and authorities but, there is currently no uniformity in how these maintenance schedules are set, leading to significant differences in approach. It was also reported by SAICE [4], that the majority of roads authorities, provincial and municipal, do not have up-to-date knowledge of the condition of their road systems; with only a limited number of authorities utilising a pavement management system.

The consequences of the widespread underfunding of road condition maintenance are seldom assessed by roads authorities. Pavement engineering principles state that delaying road maintenance is a false economy, as the longer such maintenance is left undone, the higher the eventual cost would be to restore the road.

Sustainable cost management is critical for long term viability. Road repair delays exacerbate road user costs, often surpassing repair costs. Prompt corrective measures are therefore recommended to minimise losses for all parties involved [2]. Repair costs are 6 times higher on poor condition roads, and 18 times higher on very poor roads [5].

3. AIM

The aim of the paper is to understand the readiness of municipalities to manage an ageing local road network, given their internal and external challenges.

4. RESEARCH QUESTIONS

There are 7 research questions to be addressed in this paper:

- What is the impact of delaying road maintenance?
- What are the barriers and challenges in prioritising road maintenance?
- Are there opportunities and strategies in implementing effective road maintenance?
- How are local road assets maintained?
- Do local municipalities know the condition and deterioration of their road network from an engineering perspective?
- What processes and policies are used to manage their road network, and are they appropriate?
- Are municipalities effectively utilising their maintenance budget?

5. METHODOLOGY

Table 1 depicts the methodology used for the subsequent sections on critical review, case study and way forward.

TABLE 1: Research methodology to access the readiness of municipalities to address their ageing road infrastructure

Section	Subsection	Methodology
Critical Review	Pavement Theory	Critical review of local and international literature focussing on the criticality to prioritise preventative / routine maintenance, including next steps and best practices.
	Impact of delaying maintenance	
	Barriers, difficulties and critiques in infrastructure maintenance	
	Opportunities, advancements and successes in infrastructure maintenance	
Case Study	Municipal threats and challenges	Case study focussed on reviewing 41 local Integrated Development Plans to understand municipal expenses, challenges, practices and procedures.
	Municipal road maintenance prioritisation	
	Municipal road maintenance expenditure	
Discussion, conclusions and way forward		Analysis of findings and presentation of a conceptual framework for a way forward.

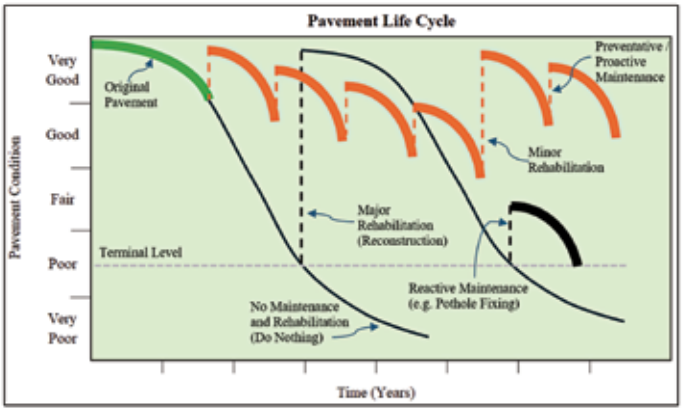

FIGURE 1: *Pavement life cycle*

6. CRITICAL REVIEW

6.1 Pavement theory

A pavement is the combination of sufficient strength materials, which are durable and engineered surface layer systems which function to support vehicular traffic and environmental conditions. There are numerous types of pavements, some of which include flexible (asphalt/seal), rigid (concrete), unpaved (gravel) and block pavements (mortar bricks). South African roads are owned by different authorities which include local municipalities, provinces and the South African National Roads Agency Soc Limited (SANRAL) for national roads.

The 2022 SAICE infrastructure report card highlighted that municipalities are not managing road network at the desired service level [4]. The life cycle of a pavement requires consideration of the behaviour of materials, loading demands, the type and timing of Maintenance and Rehabilitation (M & R) to keep the road at an acceptable level of service for road owners and users. Figure 1 presents a typical design life of a pavement. The pavement is designed by exploring numerous alternatives to select the best option with regards to the life cycle costs. Proactive and preventative maintenance is the more effective maintenance solution, as opposed to spending a larger sum of money for major rehabilitation.

To preserve the level of service, road authorities utilise a Pavement Management System (PMS) and infrastructure Integrated Development Plan (IDP). These systems are utilised to consider the importance of costs in decision making optimum strategies and sustainability.

A well-defined methodology is required to maintain pavement networks at acceptable conditions, such as priority planning, since municipalities have a limited budget and available resources [6]. A study by [7] highlighted that municipalities' main challenge is not what type of M & R is required but it is to **justify that a preservation treatment is in fact necessary. The 3 Rs must be met, "the right pavement", "the right time", and "the right treatment".**

Road failures are measured with reference to road distresses, condition indices, and structural/function parameters such as deflections, Dynamic Cone Penetrometer numbers and surface roughness (International Roughness Index) [8]. The indicators are used to establish a terminal criterion which is used to determine when the infrastructure reaches its level of service. Most decision-making methods or scenarios utilises the "worst-first" criterion for determining the time and type of M & R required.

Preventative and proactive maintenance techniques are generally recommended by researchers and engineers. Pavement management systems can provide agencies with many benefits and management improvements including: an up to-date inventory, current & future road condition, required future M & R, and a sound technical analysis for prioritisation planning based on pavement data [9]. Rampersad et. al [10] further highlighted that different road assessment techniques produce varying results, indicating that method selection is also critical.

A study by Makovska [9] proved that anticipation strategy (preventive) benefits both the agency and road user. Proactive maintenance program can result to mean savings of 8% to 12% in the life cycle**, thus providing the right pavement with the right treatment and at the right time [11]**.

6.2 Impact of delaying road maintenance

The deterioration rate is crucial for prioritisation, as delaying maintenance results in higher cost for structural rehabilitation. Timely maintenance is imperative to keep the serviceability of the road network at the predefined performance level. It is important to be aware that delayed maintenance may impact not only the pavement condition, but in a broader perspective also affects mobility, safety, and agency and user costs [12]. Delayed maintenance leads to challenges such as getting the required pavement maintenance budget in both the short- and long-term which pose an infrastructure threat, by adapting to unclear or non-feasible maintenance guidelines from municipalities [6].

Chang, et al. [12] investigated the impacts of delayed maintenance, no M & R, preventative M & R, and M & R for roads in good, fair and poor conditions. The results indicate that the road condition index is a critical parameter for the prioritisation of pavement maintenance. Roads in the poor condition class resulted in a higher backlog cost and total agency cost when compared at the end of the analysis period to fair and good roads classes. The 2-years delayed maintenance scenario, resulted in higher agency cost compared to preventative methods. Delayed maintenance affects pavement conditions, mobility, safety, transportation agency and user costs. Proactive and preventative maintenance provides the best results. **It is imperative to provide "the right treatment," at "the right location," and at "the right time."**

Pavement Life Cycle Cost (LCC) analysis is a process of determining the cost related to a pavement, which considers factors such as construction cost, M & R cost and salvage cost [13]. The LCC for different pavement options is usually determined and compared to determine the best economical alternative with reference to agency and user costs. The quality of the planning and budgeting process has a major impact on the condition of the pavement network and on the life-cycle cost of maintaining it. It is estimated that 20 – 50% of infrastructure cost is associated with maintenance [14].

The design for cost-effective pavement options should be conducted in a holistic manner and life cycle costs must consider long-term impacts of accelerating or postponing projects from one year to another [15]. When conducting studies such as Life Cycle Assessment (LCA) and LCC, it is recommended to consider a flow chart for different requirements, distress, performance, strategic importance of roads, decision-making process, comfort, environment, safety, road agency costs, and road user costs.

The do-nothing strategy results to premature failure, reactive maintenances are estimated to cost 4 to 5 times the cost of conducting preventative/proactive maintenance. Delaying M & R is not recommended, and research shows that **"You either pay early or prepare to pay more at a later stage"** [16].

6.3 Barriers, Difficulties and Critiques in Infrastructure Maintenance

Table 2 describes the selected challenges in implementing strategic road maintenance at a local and international level. The review is classified with an identification for local (L) and international (I) source, as well as a barrier (B), difficulty (D) and critique (C).

The following definitions are to be noted:

- Local: South African related literature, studies and findings on municipal infrastructure maintenance.
- International: Other related literature, studies and findings on municipal infrastructure maintenance.
- Barrier: Key roadblocks, out *of the control* of the local municipality or managing agency.
- Difficulty: The local municipality or managing agency has *some level of control* to rectify.
- Critique: Mediocre performance or management by an agency which is *within their control.*

6.4 Opportunities, Advancements and Successes in Infrastructure Maintenance

Table 3 describes a potential way forward in implementing strategic road maintenance, utilising selected local and international literature. The review is classified with an identification for local (L) and international (I) source, as well as opportunity (O), advancement (A) and success (S). The following definitions are noted:

- Local: South African related literature and best practices in implementing strategic road maintenance.
- International: Other related literature and best practices in implementing strategic road maintenance.
- Opportunity: Areas in which managing agencies can leverage for road maintenance, potential scoping.
- Advancement: Developments in research, technology and strategies, for potential adoption.
- Success: Developments in research, technology and strategies, successfully implemented.

7. CASE STUDY

7.1 Background

This case study examines 41 local municipalities across South Africa to assess the current state of municipal road infrastructure and the readiness of these municipalities to address their aging and deteriorating pavement networks. A selection of at least 3 local municipalities from each province was made, utilising the 2023/24, annual reports, audited financial statements, Integrated

TABLE 2: Barriers, Difficulties and Critiques in Infrastructure Maintenance

ID*	Description of barrier / difficulties / critique	Ref
L-B	The road maintenance backlogs are immense, particularly within the provincial and municipal networks.	[17]
L-B	Community unrests and labour disputes, poor and inadequate planning, capacity constraints and lack of qualified personnel to manage projects, government regulations and policies, financial challenges.	[18]
L-D	Planning, fiscal management, effective human resources management, corruption control, political interference, vandalism.	[19]
L-D	Limited funding and budget constraints, lack of infrastructure data and asset inventory, resistance to change and traditional practices.	[20]
L-D	Poor planning, a lack of approved standard operating procedures, high vacancy rates in service delivery units, procurement irregularities and poor financial controls.	[21]
L-C	Low-quality construction materials, insufficient institutional capacity, limited private sector contribution, low development of advanced technologies, corruption.	[22]
L-C	Current practices hindering the ability of urban municipalities to provide road maintenance at an acceptable rate of delivery and at an acceptable standard.	[23]
L-C	The auditor general report states that there is a lack of standardized performance indicators for the core municipal functions (such as roads).	[21]
L-C	Not choosing the correct infrastructure projects, projects have not been completed on time / budget.	[24]
L-C	The institutional model for municipalities is not necessary at fault, but the way in which it is managed	[25]
I-B	Multi-infrastructure asset management: Data quality, availability and interoperability, uncertainties in modelling, problems of scale.	[26]
I-B	Governments should be aware of the impacts of road maintenance investments.	[27]
I-D	Adapting to unclear or non-feasible maintenance policies / guidelines from municipal councils / politicians, receiving the budget in time.	[28]
I-C	Municipal lack of capacity, no established horizontal linkages with other municipalities.	[29]
I-C	Problems in design stage, lack of monitoring and control, funds for maintenance, skill of staff, data inventory, time taken to solve complaints, standardised specifications and procedures, use of maintenance and technology.	[30]
I-C	Technical, financial, institutional, political capacity, social challenges.	[31]

** L / I: Local / International* ** B / D / C: Barrier / Difficulty / Critique*

TABLE 3: Opportunities, advancements and successes in implementing strategic road maintenance

ID*	Description of opportunities / advancements / successes	Ref
L-O	Utilisation of local economic development funding (National Infrastructure Plan). Target of R1.2 trillion.	[32]
L-O	The integration of innovative technology into road infrastructure management systems. Consider life cycle of the road. Integrate decision making process, limit data to be collected, publish performance statistics, deploy simple software.	[22]
L-O	Systematic road maintenance programmes, preferably conducted within the framework of a Pavement Management System. Knowledge gain through Road maintenance forum: Research, strategies, developments, techniques, advances.	[33]
L-A	There is a need to structure key performance targets and indicators to ensure higher quality repairs: Relevancy to the science of road maintenance.	[23]
L-S	Using automated full spectrum continuous road evaluation for meaningful savings.	[34]
I-O	Systematic management plan, staff development program, technology and technical capabilities.	[35]
I-O	Securing funding and budget allocation, improving data collection and asset management, building support and overcoming resistance.	[20]
I-A	Use of machine learning techniques to evaluate road conditions.	[36]
I-A	Current predictive approach as used in industry (data science): knowledge based, data driven, physical model, digital twin, area of contribution: maintenance planning, degradation-based decision making, risk estimation.	[37]
I-A	Developed countries are now moving towards a circular economy where waste materials are minimised and kept in use for as long as possible.	[38]
I-A	New innovations in pavement materials and engineering: green and sustainable pavements, intelligent pavements, technology, modelling	[39]
I-S	Pavement preservation techniques, crack sealing and filling, recycling and reclamation, asset management systems, training and education, comprehensive maintenance planning, utilise data driven decision making, embrace technology and innovation, plan for long term sustainability.	[20]
I-S	Some of the cities run sophisticated models through asset management software programs for their roads.	[31]
I-S	Two stage maintenance: determining maintenance priority through data analysis and pavement ranking.	[8]

** L / I: Local / International* ** O / A / S: Opportunity / Advancement / Success*

TABLE 4: Distribution of the 41 selected municipalities for the case study

Density (Population / km²)	Number of Municipalities	Paved Network (km)	Number of Municipalities	Gravel Network (km)	Number of Municipalities
< 50	18	0 - 150	10	0 - 1,000	22
50-150	18	150 - 250	8	1,000 - 2,000	6
150-250	2	250 - 400	11	2,000 - 3,000	7
250-350	2	400 - 700	3	3,000 - 4,000	2
>350	1	≥ 700	7	≥ 4,000	2
		Unclassified	2	Unclassified	2
Total	**41**	**Total**	**41**	**Total**	**41**

Development Plans (IDPs), MFMA Section 71 and population data obtained from the municipalities of South Africa website [40]. To ensure anonymity, only the distribution of the selected municipalities is depicted (Table 4).

7.2 Municipal threats and challenges

78% of surveyed local municipalities report that their road networks are deteriorating. Municipalities also indicate they are chronically underfunded (68%). Most roads require routine maintenance and improved stormwater drainage systems. Table 5 discusses the challenges expressed by the municipalities.

Key observations of common infrastructure threats faced by local municipalities (as per IDPs) include:

1. **Infrastructure crisis:** Aging, failing, and underdeveloped infrastructure is a critical challenge, intricately linked to service delivery collapse and protests.
2. **Financial vicious cycle:** High dependency on grants, low revenue collection and insufficient budgets create a severe financial constraint hindering all other functions.
3. **Governance weaknesses:** Issues such as lack of trust, parallel structures, inconsistent audit findings, and staffing problems indicate significant institutional challenges.
4. **Climate vulnerability:** Drought, floods, fires, and broader climate change impacts are consistently highlighted as major threats affecting resources and infrastructure resilience.

TABLE 5: Challenges expressed by the 41 municipalities as per their IDPs (Roads and Stormwater)

Challenges	Key challenges	Frequency	Percentage
Road infrastructure deterioration	Aging assets, overloaded vehicles, stormwater damage, and lack of maintenance.	32 / 41	78
Chronic underfunding	Insufficient funding for maintenance and high maintenance backlogs.	28 / 41	68
Lack of technical skills	Shortage of skilled personnel and lack of structured training.	25 / 41	61
Aging equipment	Lack / ageing construction equipment and frequent breakdowns.	19 / 41	46
Governance: Policy failures	Non-compliance to governance policies and standards, lack of road maintenance plans	15 / 41	37
Revenue collection and fiscal management.	Poor billing, high debtors, ineffective credit control, cash flow problems, negative audits.	12/ 41	29

5. **Socio-economic burden**: Poverty, unemployment, disease, and substance abuse form a complex socio-economic burden that fuels other threats like crime, non-payment, and service demands.

7.3 Municipal road maintenance prioritisation

The 41 municipal IDPs [40] were reviewed to understand how their road assets are prioritised. Table 6 describes what tools, systems and processes are used by municipalities to manage their road network.

Local governments should be able to leverage their existing knowledge, skills, and resources to meet their goals effectively. Achieving this requires stronger institutional capacity to manage operations and service delivery. However, most municipalities currently lack the capability to consistently produce reliable and transparent performance reports, highlighting significant institutional weaknesses [41]. A limited number of municipalities have appropriate systems and policies in place to manage their road network.

Furthermore, 59% of municipalities are unaware of their road network conditions (Table 7), primarily due to missing assessment systems.

7.4 Municipal road maintenance expenditure

Figure 2 highlights the local municipal road expenditure (2023/24) [41] for road networks that can be maintained and constructed per their budget. Municipalities, on average, spend more on newly constructed roads as opposed to maintenance of existing roads. This trend highlights the widespread underinvestment in infrastructure prioritisation.

Municipalities are struggling with insufficient financial resources to adequately maintain and upgrade their infrastructure assets. The low expenditure levels suggest that many municipalities lack the budget necessary to meet acceptable service delivery standards for road networks. Since the 2020–21 financial year, audit outcomes for local municipalities have remained poor. This can be attributed to failure in disclosing irregular expenditure which points to a lack of effective systems and controls [41].

Relevancy: Having the correct performance criteria

It is important to understand the municipal spending habits on road maintenance. However, a step further is to rationalise the type of maintenance to be conducted. Preventative and proactive maintenance is more beneficial to the municipality as opposed to conducting reactive maintenance (e.g., fixing potholes). It is better not to count how many potholes are fixed, but rather how many kilometers are under preventative or reactive maintenance programs.

Figure 3 shows the percentage of road networks in which municipalities can maintain, and construct based on their budgets. The graphic uses published data for activities such as periodic and routine maintenance as well as strengthening. Routine maintenance clearly shows that a larger percentage of road network that can be maintained with any given budget. Thirty-eight percent (38%) of municipalities can maintain their entire network through routine maintenance. Only one of the thirty-nine (39) municipalities, with available data, can add more than 10% of roads to their network.

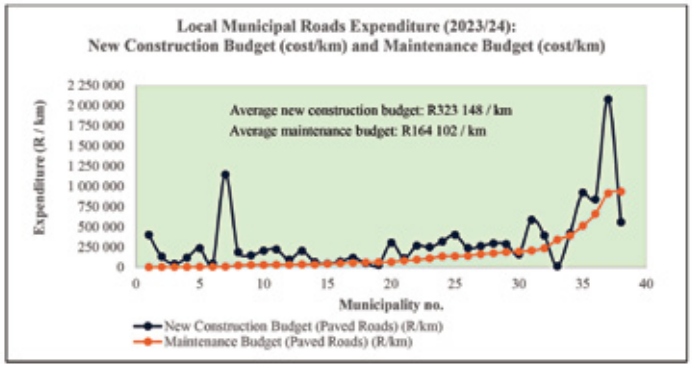

FIGURE 2: *Local Municipal Roads Expenditure per municipality: New Construction and Maintenance Budget*

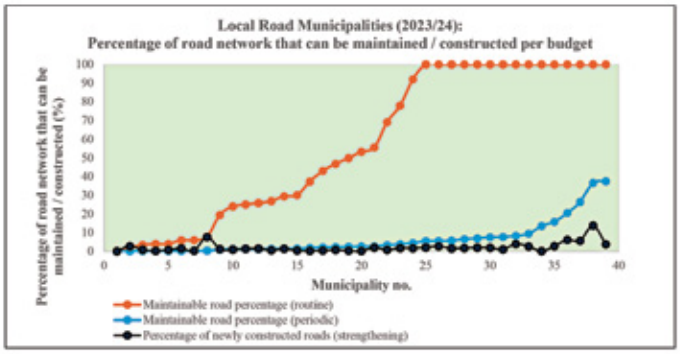

FIGURE 3: *Local Road Municipalities: Percentage of road network that can be maintained / constructed per budget*

8. DISCUSSION

The discussion aims to address the 7 sections under the critical review and case study. The research aims and the research questions are also addressed:

Critical Review:

- *Pavement theory:* There is clarity and accepted scientific consensus that preventative and proactive maintenance are critical in preserving the health of the pavement. This not only benefits the road agency, but the user as well.
- *Impact of delaying maintenance:* Timely maintenance is imperative to keep the serviceability of the road network at the predefined performance level. Delaying maintenance and rehabilitation will result in the agency paying a higher cost at a later stage.
- *Barriers, difficulties and critiques in infrastructure maintenance:* Numerous barriers, difficulties and critiques were noted at local and international level. These range from financial difficulty, ineffective management, capacity constraints and political interference, amongst others. Nevertheless, there will always be challenges until each item specific, within their (municipal) control, is addressed.
- *Opportunities, advancements and successes in infrastructure maintenance:* Despite the challenges in implementing effective preventative maintenance, there are opportunities for a way forward. Although, not exhaustive, municipalities can leverage on infrastructure funding, advances in research and technology, attend developmental programmes or road forums and update their performance criteria, amongst other strategies.

Case Study:

- *Municipal threats and challenges:* Identified threats, as per municipal IDPs range from financial constraint to governance weaknesses and an infrastructure crisis. Road infrastructure (78%), maintenance underfunding (68%) and shortage of skills (61%) were identified as major challenges. It is critical that the agencies not only develop their SWOT analysis but that it is specific to their environment and conditions. Other challenges such as corruption and involvement of the "construction mafia" are not fully addressed but are to be noted.

TABLE 6: Road maintenance tools, systems and processes as used by municipalities

Maintenance tools / systems	Yes	No	Under review	Not Specified	Total
Available integrated transport plan	20	10	3	8	**41**
Available road asset management systems / software (e.g. RRAMS)	14	19	4	4	**41**
Available road master plan	8	20	4	9	**41**
Available integrated infrastructure plan	4	16	5	16	**41**

TABLE 7: Familiarity of municipalities with the condition of their road network

Criteria	Aware	Unaware
Percentage of municipalities that are aware of the condition of their road network	41%	59%

- *Municipal road maintenance prioritisation:* Less than half of municipalities have a road asset management plan, infrastructure plan or transport plan. These are critical in identifying the way forward for the management of their assets. Furthermore 59% are unaware of the condition of their network. Changes in municipal plans are necessary for long-term sustainability.
- *Municipal road maintenance expenditure:* New construction costs outweigh the budget prioritised for road maintenance. Municipalities are struggling with insufficient financial resources to adequately maintain and upgrade their infrastructure assets. Furthermore, routine maintenance clearly shows that a larger road network can be maintained with any given budget.

9. CONCLUSIONS

There are countless challenges and inconsistencies facing the local roads sector, with regard to management, maintenance and preservation. This paper demonstrated the impact of not maintaining a road network, with only an overarching view presented. Challenges at a local municipal level are unique and specific to the local environment. It is also noted that many agencies are not aware of the extent of the problems.

The major threats identified at a local level were road infrastructure deterioration, maintenance budget underfunding and shortage of skills. Furthermore, there are inconsistencies as to the utilisation of their maintenance budget (under-utilised), and prioritising new road construction as opposed to fixing their existing infrastructure.

There are however opportunities, advancements and successes in the municipal infrastructure maintenance field, both local and internationally. These include effective preventative maintenance, leveraging of funding as well as research and development.

This paper presents a straightforward piece of research to access the readiness of municipalities to address their ageing and deteriorating road infrastructure. The research includes a critical review of road deterioration principles and current challenges, a case study to access the awareness practices of municipalities in managing their road infrastructure and a conceptual framework for local road infrastructure management.

This paper aims to encourage change in the processes, systems and management of local roads, so that further deterioration and infrastructure instability can be suppressed, resulting in a longer life for road assets.

10. WAY FORWARD

A concept framework for next steps in local road infrastructure management is presented in Figure 4. This framework presents a potential way forward for local road maintenance practices.

FIGURE 4: *Conceptual framework for next steps in local road infrastructure management*

11. REFERENCES

MISA, 2020. Municipal Infrastructure Support Agent: Strategic Plan for 2020 – 2025. Department of Cooperative Governance. Republic of South Africa.

Trestanto, F., Hadiwardoyo, S. P., Sumabrata, J and Lumingkewas, R. H, 2024. Road repair delay costs in improving the road rehabilitation strategy through a comprehensive road user cost model. International Journal of Engineering.

Department of Transport, 2025. South African Department of Transport. Webpage: www.transport.gov.za.

SAICE, 2022. South African Institution of Civil Engineering, SAICE, 2022 Infrastructure Report Card, South Africa. www.saice.org.za

Freight News, 2021. Crumbling road infrastructure more than doubles truck maintenance costs.

Issa, A. & Abu-Eisheh, S., 2017. Evaluation of implementation of municipal roads' maintenance plans in Palestine: A pilot case study. International Journal of Pavement Research and Technology, Volume 10, p. 454–463.

Mubaraki, M., 2012. Maintenance strategies at project level for low volume urban roads. International Journal of Pavement Research and Technology, 5 (4), pp. 225-233.

Huang, L. L., Lin, J. D, Huang, W. H, Kuo, C. H, Chiou, Y. S and Huang, M. Y, 2024. Developing Pavement Maintenance Strategies and Implementing Management Systems. Infrastructures 2024, 9, 101.

Makovska, J., 2020. Method of evaluation of road routine maintenance strategies. Economics, Finance and Management Review, Volume 4, pp. 106-112.

Rampersad, A., Mvelase, G. M., Simelane, M. N and Harrilall, K. 2023. Variations in pavement performance assessments using the visual condition index and deduct point methods for maintenance prioritization. 13th Conference on Asphalt Pavements for Southern Africa.

Poór, P., Ženíšek, D. & Basl, J., 2019. Historical overview of maintenance management strategies: Development from breakdown maintenance to predictive maintenance in accordance with four industrial revolutions. Pilsen, Czech Republic, Proceedings of the International Conference on Industrial Engineering and Operations Management. https://www.researchgate.net/publication/335444202

Chang, C., Rodriguez, E., Yapp, M. & Pierce, L., 2018. Consequences of delayed maintenance of pavement networks. Pretoria, South Africa, 37th Annual Southern African Transport Conference.

Alipour, A., Shafei, B., Mock, A. & Prajapat, K., 2020. Development of a Life-Cycle Cost Analysis Tool for Improved Maintenance and Management of Bridges. Project TR-737, Iowa State University: Institute for Transportation.

Mao, I. & Haung, R., 2015. Lifecycle Assessment of Maintenance, Repair and Rehabilitation Costs: A Deterioration Modelling Approach for Bridge Components. Journal of the Chinese Institute of Civil and Hydraulic Engineering, 27(1), pp. 47-57.

Anochie-Boateng, J., Sampson, L., Agyekum, P. & Ampadu, K., 2017. Life-cycle cost comparison of alternative surfacing for steep slopes on low-volume roads in Ghana.

Sarsam, S., 2016. Pavement maintenance management system: A review. Trends in Transport Engineering and Applications, 3 (2), pp. 19-30.

Ross, D. & Townshed, M., 2019. The road maintenance backlog in South Africa. 38th Annual Southern African Transport Conference. Pretoria, South Africa. https://repository.up.ac.za/items/e8bef1b9-c070-4529-a7d5-a96d25ce64e5

Maphela, B. & Adanlawo, E. F., 2025. Road infrastructure in South Africa: What is missing? International Journal of Business Ecosystem and Strategy: Vol 7, No 2, pp. 470-478

Shongwe, B. R. & Meyer, D. F., 2023. Service Delivery Challenges within Rural Communities: The Case of the Nkomazi Local Municipal Area. Administratio Publica: Vol 31, No 2, pp. 136-159.

Denison, C., Paramski, D. & Sergesketter, B., 2024. Preserving Roads: Ensuring Municipalities' Sustainable Infrastructure Future. Purdue Road School 2024, Road School Lecture Presentation: Session 177.

AGSA, 2024. Consolidated General Report on Local Government Audit Outcomes: 2023 – 24. Auditor General of South Africa. www.agsa.co.za

Bele, K., 2022. Analysis of impact of maintenance practices on road infrastructure, Johannesburg: University of Johannesburg. Master of Engineering Thesis.

Sutherland, C., 2024. Performance monitoring for executives in road maintenance and service delivery. Cape Town, 2024 Conference for The Institute of Municipal Engineering of Southern Africa, pp. 182-188.

Mabugu, R. E and Rakabe, E., 2024. South Africa's municipalities aren't fixing roads, supplying clean water or keeping the lights on: new study explains why. Article – The Conversation. Published online: 29/09/2024. www.theconversation.com.

Wall, K., 2024. South Africa's municipal roads authority: Are they built on a weak foundation? 2024 Southern African Transport Conference. Pretoria, South Africa.

Daulat, S., Rokstad, M. M., Klein-Paste, A., Langeveld, J and Tscheikner-Gratl, F, 2022. Challenges of integrated multi-infrastructure asset management: a review of pavement, sewer, and water distribution networks. Structure and Infrastructure Engineering, Volume 20 (4), p. 546–565.

Gertler, P. J., Gonzalez-Navarro, M., Gračner, T. & Rothenberg, A. D., 2024. Road maintenance and local economic development: Evidence from Indonesia's highways. Journal of Urban Economics, Vol 143.

Afridi, M., Erlingsson, S. & Sjögren, L., 2023. Municipal street maintenance challenges and management practices in Sweden. Frontiers in Built Environment, Volume 9, ISSN: 2297-3362. https://www.frontiersin.org/journals/built-environment/articles/10.3389/fbuil.2023.1205235/full

Alm, J., Paulsson, A. & Jonsson, R., 2021. Capacity in municipalities: Infrastructures, maintenance debts and ways of overcoming a run-to-failure mentality. Local Economy: Volume 36, Issue 2, pp. 81-97.

Ismail, A., Razelan, I. S. M., Yusof, L. M., Zulkiple, A and Masri, K. A., 2021. An Overview of Pavement Maintenance Management Strategies in Malaysia. Institute of Physics Publishing, Volume 682 (1).

Gibson, J. P. & Marshall, W. E., 2022. Disparate Approaches to Maintaining Roads and Sidewalks: An Interview Study of 16 U.S. Cities. Transportation Research Record, 2676 (9), pp. 553-567

DPME, 2024. Medium Term Development Plan 2024-29, South Africa: Department: Planning, Monitoring and Evaluation.

SABITA, n.d. Information Sheet: Maintaining Surfaced Roads, South Africa: Southern African Bitumen Association.

Tetley, S., Balaram, Y., Schmidt, B. & Lewis, T., 2022. The management of road maintenance in South Africa 2022 - Observation on current practice and a modus operandi towards addressing service delivery. 2022 Conference for The Institute of Municipal Engineering of Southern Africa, Paper 16, Gauteng, South Africa, pp. 146-153.

Dzulkifli, N., Sarbini, N. N., Ibrahim, I. S., Abidin, N. I., Yahaya, F. M and Azizan, N. Z. N., 2021. Review on maintenance issues toward building maintenance management best practices. Journal of Building Engineering: Volume 44, December 2021.

Simelane, M and Rampersad, A. 2024. Evaluation of road condition indices methods and applicability for use in machine learning. 2024 Southern African Transport Conference. Pretoria, South Africa. https://www.researchgate.net/publication/390266872

Sajid, S., Haleem, A., Bahl, S., Javail, M., Goyal, T and Mittal, M., 2021. Data science applications for predictive maintenance and materials science in context to Industry 4.0. Materials Today: Proceedings 45, pp. 4898-4905.

Ferdous, W., Manalo, A., Siddique, R., Mendis, P., Zhuge, Y., Wong, H. S., Lokuge, W., Aravinthan, T and Schubel, P., 2021. Recycling of landfill wastes (tyres, plastics and glass) in construction – A review on global waste generation, performance, application and future opportunities. Resources, Conservation and Recycling: Volume 173, October 2021.

Chen et al. 2021. New innovations in pavement materials and engineering: A review on pavement engineering research 2021, Journal of Traffic and Transportation Engineering, English Edition, Volume 8, Issue 6, 2021, Pages 815-999, ISSN 2095-7564. Article online: https://www.sciencedirect.com/science/article/pii/S209575642100101X

Municipalities of South Africa. Website retrieved: 2025, June 18. Retrieved from Municipalities of South Africa: https://municipalities.co.za/municipalities/type/3/local.

2023-2024 Municipal Finance Management Act: General Report, 2024. Consolidated General Report on Local Government Audit Outcomes. Auditor-General South Africa.