STANDBY 2

PERFORMANCE MONITORING FOR EXECUTIVES IN ROAD MAINTENANCE AND SERVICE DELIVERY

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ABSTRACT

The road network plays a pivotal role in fostering economic growth, social connectivity, and regional development in every country. The quality of the network significantly impacts these. Therefore, it is important for governments and municipalities to ensure that the road network is maintained. Repair methods must be aligned with the scientific principles of road maintenance to ensure they are good quality and effective. Road repairs often fall short of meeting the required quality and design life, rendering them economically unjustifiable.

This study aimed to identify and investigate the relationship between performance monitoring and common technical errors in the maintenance of flexible pavements. This was achieved using a comprehensive exploratory study of road maintenance practices with a multi-faceted approach. Initially, the key performance indicators (KPIs) used by municipalities to manage road maintenance were assessed for specificity, measurability, achievability, relevance, and time specificity (SMART). This was to determine if these KPIs are aligned with the overarching goals of effective road maintenance. The second aspect comprised on-site and remote longitudinal observations of road maintenance practice in the City of Johannesburg, where common issues leading to unsuccessful repairs were identified. By synthesising these three facets, broader conclusions regarding the quality and effectiveness of road maintenance practices in South Africa were drawn.

It was found that although South Africa's guidelines and manuals are in line with current research, pavement repairs that are non-compliant or fail rapidly are common. This was linked to municipalities using KPIs that do not assess quality of repairs nor the condition of the overall network. The pressure for meeting these KPIs overtakes road maintenance teams' resolve to ensure good quality work. In conclusion, by ensuring SMART KPIs are used when developing municipal budget and service delivery plans, it is possible to ensure that workmanship and network quality is maintained.

INTRODUCTION

South Africa has a road maintenance backlog estimated at R135.4 billion for paved roads (Ross & Townshend, 2019), consisting of mostly provincial and municipal backlog. Johannesburg Road Association (JRA) service standards require that 80% of all potholes are repaired within 30 days of being reported, however, in the 2021/2022 financial year, the JRA only achieved 54% within 30 days (JRA, 2022). Additionally, the JRA alone is responsible for 12 000km of road, most of which is older than its intended 30-year design life. Without maintenance and repair, the pavement will reach a terminal condition at which complete reconstruction or rehabilitation may be necessary. This is generally more expensive than a maintenance approach, consisting of routine and periodic maintenance, which can keep the road in good condition well beyond its initial design life.

Road maintenance

Flexible pavements are designed to be able to support predicted traffic volumes for a specified design life. Over time and as the cumulative traffic loads reach the total predicted value, the condition of the pavement deteriorates gradually until the road is in urgent need of either rehabilitation or reconstruction (SAPEM, 2014). The leading causes of this deterioration are traffic loading and moisture ingress, as well as other factors such as climatic conditions, construction processes, design issues, material issues and subgrade conditions (Adlinge & Gupta, 2014).

A pothole is a secondary defect that happens because of water ingress into the pavement layers through a pre-existing defect, such as a crack or surface failure (Marasteanu et al., 2018; Paige-Green, Maharaj & Komba, 2010). Therefore, road maintenance can reduce costs by delaying the need for reconstruction.

The primary objectives of road maintenance are to (1) ensure that the road survives its design life, (2) provide a smooth, comfortable, and quick ride for users, (3) reduce user costs, and (4) ensure that resources required for maintenance are used efficiently (Horak et al., 2004). Furthermore, if good quality maintenance activities are carried out timeously, the life of the pavement can exceed its intended design life. These four objectives can be met through four levels of maintenance activities including i) routine road maintenance which can either be proactive/preventative (e.g. crack sealing, structural patches, surface patches), or reactive (e.g. pothole patching); ii) periodic maintenance which includes maintenance activities that must be performed every 5-7 years (e.g. resealing, surface rejuvenation); iii) rehabilitation which refers to the reworking of pavement layers to restore functionality; and iv) reconstruction of the road. Reconstruction is expected to take place once the road has passed its design life and rehabilitation cannot restore functionality (COTO, 2013; Salih, Edum-Fotwe & Price, 2016).

Internationally, road maintenance budgets are generally insufficient to maintain high service levels on an entire network and this is unlikely to change significantly (Burningham & Stankevich, 2005; Ross & Townshend, 2019; Salih, Edum-Fotwe & Price, 2016). Thus, road maintenance management systems need to include a process of first determining the severity of distress and what action is required to return the road to an acceptable standard, and then prioritising and optimising the schedule of activities for maximum budget and delivery efficiency. Severity of distress or road condition can be assessed visually using methods described in the Technical Methods for Highways No. 9 (COTO, 2016). However, both the South African Technical Methods for Highways No. 22: Road Asset Management Manual (TMH 22) and the South African Pavement Engineering Manual (SAPEM) suggest that mechanical and electronic surveillance measurement technology offers a more objective method of assessing pavement condition (COTO, 2013; SANRAL, 2014). Road roughness, skid resistance and texture, pavement detection, and rutting are key electronic measurements that can be used to describe the road condition, and these measurements can be used to determine performance indices. Guidelines on these indices have been developed by COTO (SANRAL, 2014).

Performance management

Management of service delivery in South African Municipalities is complex with two main levels of contracts that determine performance requirements. The

Department/Utility is essentially a contractor to the Municipal client and the Contractor is a contractor to the Departmental client (further illustrated in Figure 1). Using the City of Johannesburg (COJ) as an example, the Municipal client is the COJ, the Departmental client is the CEO of the JRA, and the Contractor is either JRA maintenance teams or private contractor companies. Because of this relationship, it is not necessarily in the interests of the Department/Utility executive to enforce quality standards at their level if they are not assessed in the performance contract between the Department/Utility and the Municipality.

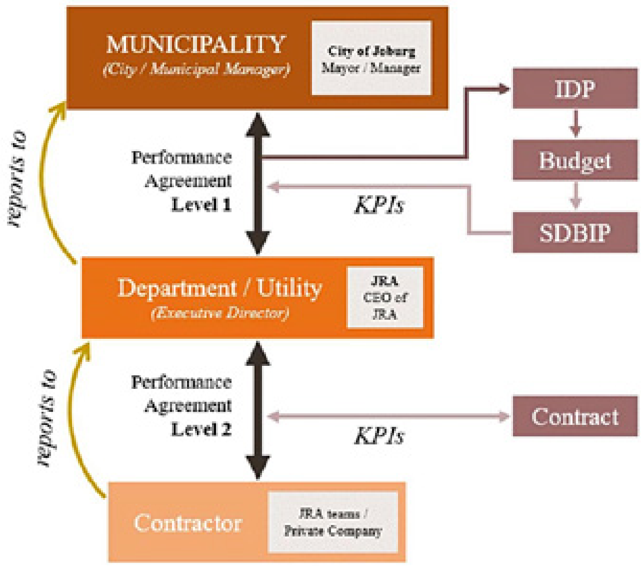

FIGURE 1: *The structures and documents that set KPIs for road maintenance (IDP = Integrated Development Plan; SDBIP = Service Delivery & Budget Implementation Plan. KPI = Key Performance Indicators)*

Performance of road maintenance is assessed differently depending on the performance contract level. At performance contract level 1, the quality of individual projects or repairs is assessed. Individual projects need to be of good quality so that budget, time and resources are not wasted on repeated repairs. Acceptance criteria of different types of pavement repairs are specified in the road maintenance manuals. The CSIR Pothole Guide requires acceptable final riding quality, no depression after traffic compaction but rather slightly raised at completion, an aesthetic and neat patch – checked after completion for level with straight edge (Paige-Green, Maharaj & Komba, 2010). Acceptance criteria from the Standard Specifications are that backfilling must be done in layers to an appropriate thickness, density and level; and the final riding surface should not have undulation greater than 5mm (COTO, 2020). Both the Standard Specifications and the RRMM recommend assessing material quality by collecting and conducting standardised laboratory experiments on samples collected in-situ to check compliance. On site conducted tests and inspections are also recommended. These include using Dynamic Cone Penetrometers or Rapid Compaction Control Devices (RCCD) to measure compaction; using thermometers to check the compaction temperatures of HMA; using camber boards to ensure correct camber; and using a straightedge to check the level of the repair. (COTO, 2020; Paige-Green, Maharaj & Komba, 2010; SANRAL, 2009a). The Standard Specifications lay out the technical requirements and the SANS documents with which repairs must comply and these must be followed throughout execution of the work.

On the other hand, the performance of the overall network is assessed at contract level 2. Quality of localised repairs and other maintenance activities affects the overall quality of the network, and the network quality is used as a measure of performance at the second performance contract level. This is monitored by measuring key performance indicators against set targets. TMH 22 recommends the use of key performance indicator (KPI) targets in strategic planning to aid in securing sufficient resources for maintenance. The manual gives a few examples including the percentage of road networks in a poor or very poor condition, the percentage below a certain level of serviceability, and surfacing cycles for surfacing types (COTO, 2013). These KPIs assess the overall condition of the road network and are relevant to performance contract level 2. The manual also recommends the use of several different indices and their measurement to construct KPIs.

Horak, et al. (2001) wrote a paper shortly after the formation of the JRA in January 2001. The paper motivated the use of residual or changing asset value as a KPI over the exclusive use of the Visual Condition Index and Remaining Pavement Life KPIs which were used at the time. However, in 2004 Horak et al. (2004) conducted a study on a provincial routine road maintenance unit that included identifying ways to improve productivity. The study found that the unit made use of input indicators and no output indicators. The paper recommended the increased use of output indicators as opposed to input indicators where input indicators measure resources being invested into an activity such as budget, while output indicators measure the actual work that has been done. The paper also suggested the implementation of 'performance-based contracts' as this showed significant potential to reduce the degree of risk to the client and a possible 40% improvement across a range of factors including service level, business opportunity, road user perceptions and productivity. Performance-based contracts (PBCs) are contracts that tie supplier payment to performance through evaluation and specification of outcomes or outputs. Selviaridis and Wynstra (2015) assessed how PBCs could be applied to operations and supply management (OSM) and found that the concept is highly relevant. PBCs can ensure alignment of supply chain actors' incentives and thereby realising end customer outcomes through facilitation of coordination and collaboration between the client and the contractor. Argentina has had success with implementing PBCs for road rehabilitation and maintenance, citing improved efficiency and public accountability as well as greater long-term funding being secured (Liautaud, 2001). The Central Asia Regional Economic Cooperation (CAREC) released a reference note encouraging and providing guidance on the use of PBCs for road maintenance at the second performance contract level (Zietlow, 2017). The note recommends that performance levels need to be aligned with the objectives of road maintenance, relevant to existing standards and regulations, objectively and easily measurable, affordable, understandable, clearly defined, and have a low data collection cost. In other words, KPIs need to be specific, measurable, achievable, relevant, and time bound (SMART).

Problems in South African road maintenance management

There is a lack of literature critically reviewing South African methods of road maintenance management and implementation practices. The practices currently employed may hinder the ability of urban municipalities to provide paved road maintenance at an acceptable rate of delivery and at an acceptable standard – specifically within the context of a developing country with minimal road maintenance budget. Motivating expenditure on road maintenance is a problem experienced globally and the service tends to be underfunded. This means that efficiency is a priority. Repeated repairs to localised failures within a relatively short period of time is a common occurrence in urban areas of South Africa. This suggests that there is a poor level of service when it comes to localised repairs.

This study examines the link between performance management in urban municipalities and the quality of road maintenance activities, by reviewing key performance indicators and goals set in Service Delivery and Budget Implementation Plans (SDBIPs) of metropolitan municipalities in South Africa against recognised performance management best practice.

METHODOLOGY

The broad aim of this study is to identify and investigate the relationship between performance monitoring and common technical errors in the maintenance of flexible pavements. This will be achieved through meeting the following objectives:

1. Evaluate observed road maintenance practices for quality and compliance.
2. Assess the technical relevance of key performance indicators used by road maintenance service providers in South Africa.

The study employed three primary methods of research, namely critical review, desk studies, and field observations. Firstly, 25 randomly selected cases of localised repairs were identified for analysis. From this, possible reasons for the failure of the repair were identified. Thirdly, in a further desk study of annual reports, Service Delivery and Budget Implementation Plans (SDBIPs) of several metropolitan municipalities and SANRAL's Declaration of Intent were analysed to identify key performance indicators used to measure road maintenance performance. These observations, desk studies and critical reviews were used to draw conclusions on the quality and effectiveness of road maintenance procedures used in urban areas of South Africa.

RESULTS

Of the 25 case studies identified, 17 are presented in Table 3 with a brief description of each localised repair, and information relating to the characteristics of the road on which the failure is located, including the route class, traffic volume, road gradient, terrain type, and the estimated patch age. Then the Pavement Condition Index (CI_{pave}) and Surface Condition Index (CI_{surf}) of the surrounding pavement are given. These two indices, along with adjacent condition descriptors, describe the condition of the underlying pavement structure and the surfacing layer, respectively. The indices were determined using the methods described in TMH 22 and TMH 9. Table 1 gives the key used for traffic volumes. Table 2 gives the key for the condition indicator descriptors.

Analysis of cases

Identified approaches to localised repairs

From the cases presented in the previous section, a number of key observations can be drawn. Firstly, the edges of structural patches and the edges of service trench reinstatements are a common point of failure. Poor bonding between the new surface and the old surface results in cracks forming that allow water ingress into the base. This can be seen in cases 8, 10, 19, 20, 21, 22, and 24.

The crocodile cracks present in case 14, 19, and 20 have been overlain by cold mix surface patches. While this may assist in preventing water from seeping into the base, it does not address the structural failure causing the issue.

TABLE 1: *Traffic Volume Key*

Traffic Volume	Symbol
Very Low	VL
Low	L
Medium	M
High	H
Very High	VH

TABLE 2: *Condition indicator definition*

Range	Condition	Abbreviation
85 ≤ CI ≤ 100	Very good	VG
70 ≤ CI < 85	Good	G
50 ≤ CI < 70	Fair	F
30 ≤ CI < 50	Poor	P
00 ≤ CI < 30	Very Poor	VP

Smaller cracks surrounding the patches, present at the time the patch was made, were not sealed. This reduces the waterproofing ability of the patch. The Standard Specifications, and the RRMM specify that crocodile cracking must either be repaired with a structural patch or sealed with geosynthetic fabric as a temporary holding measure. None of these methods have been applied in these cases. Crack sealing has also not taken place in cases 7, 8, 9, 10, 15, and 25 where cold mix patches have been used to cover points where the crack has widened to expose the base.

In some cases, the material that was used to repair the failure appears to be different to the surrounding surfacing material. If this material is stiffer than the surrounding material, the patch will cause further cracking owing to the differential stiffness. This can be seen in case 8, and case 22, where cracks were emanating from the patch. Other issues caused by poor materials can be seen in case 10, 18 and 23, where the material has delaminated from the surface below and severe aggregate loss can be seen. In case 23, this happened in less than seven months. Poor compaction during patch installation can lead to settlement, as seen in case 1 and case 21, however moisture issues can also cause settlement.

For most of the cases there was evidence suggesting that the original cause of the failure had not been addressed, leading to the patch failing. In cases 1, 2, 10, 12, 14, 18, 20, and 24 there was evidence to suggest that moisture related issues are the primary cause of the failures and that these issues were not addressed. In some cases, there are vertical and cross-sectional alignment issues that cause ponding on the road surface, and in others there is a history of underlying moisture issues relating to a water or stormwater leak or ground water flow, however in most of these cases there appears to have been no attempt to improve the drainage situation before attempting to repair the patch. This leads to repeated failure and the road authority regularly returning to repair the road surface, as in cases 1, 10, 14, and 20. In cases 9 and 10, the local road authority returns annually to patch the same areas. This approach to road maintenance is clearly reactive with no attempt to prevent the cracks from widening by sealing them. It is possible that teams are sent into the field without all the necessary equipment to be able to ensure that repairs comply with requirements. However, in some areas it is common to see localised failures that have gotten progressively worse over time owing to delayed response or simply a technically inappropriate response. Cases 2, 8, 9, 15, 19 and 20 have deteriorated further for this reason.

Identified approaches to maintenance management

As per standard practice, it was observed that maintenance along higher class routes is prioritised. As a result, the CIs are generally higher on higher class roads. This is illustrated in Figure 2 and Figure 3 where the CIs of class 2 and 3 routes tend to be higher than those of class 4 and 5 routes. Resealing activities have taken place recently on the more maintained roads while a simple strategy of patching areas of exposed base with cold mix has been adopted on lower class roads. Often, these roads appear to be well beyond their service life and have very poor riding quality. Within the study area, resealing and resurfacing has been prioritised. Resealing and resurfacing improve the surface condition; however, these maintenance methods do not actively improve the lower structural layers. Resealing is appropriate only when the structural condition index remains good to very good, resealing is appropriate. In Figure 4, the range where resealing may be applicable is outlined in red. This figure also illustrates how poorer surface condition is often accompanied by poorer pavement condition. This is owing to deterioration mechanisms described previously.

Key Performance Indicators SMART Analysis

SDBIPs used by metropolitan municipalities are aimed at network level management and specify KPIs and targets relating to road maintenance. The targets and KPIs are largely set by each municipality independently; however, the National Government has published guidelines in conjunction with the Municipal Finance Management Act No. 53 of 2003 (MFMA). Of relevance to road maintenance at a municipal level, is the MFMA Circular 88 first published in 2017. The Circular gave guidance to metropolitan municipalities regarding a standardised set of performance indicators used by municipalities in the preparation of statutory planning and reporting documents required for the 2018/19 cycle onwards. This document and all subsequent addendums recommend using the indicators shown in Table 4 (Sethoabane et al., 2023).

TABLE 3: *17 selected case study summaries*

No.	Description	Route Class	Traffic	Gradient	Terrain	Estimated Age	Pavement Condition	Surface Condition
1	Concave patch near marshy area with missing kerb on one side	5	VL	Flat	Flat	New	F	VP
2	Pothole caused by water leak. Bricks placed in pothole as civilian repair attempt	3	H	Steep	Rolling	Very New	P	P
7	Small surface delamination repaired with cold mix and no crack sealing	3	H	Flat	Flat	Very New	G	P
8	Incongruent repair material leading to patch failure and repair with cold mix	3	H	Flat	Rolling	Very New	VG	F
9	Longitudinal crack that has been repeatedly patched at points where the crack has widened	2	VH	Steep	Rolling	New	F	P
10	A severely distressed section of road where multiple patches of different ages can be seen. Patches applied with no defective material removed.	4	H	Steep	Rolling	Very New	F	VP
12	Unresolved drainage issues lead to pavement failure. A repair patch only lasted a few months as drainage issues remain unresolved	2	H	Flat	Flat	Very New	P	P
14	Multiple surface patches of varying ages applied to an area with unresolved underlying drainage issues	5	L	Flat	Rolling	Old	VP	VP
15	Small cold mix surface patches applied to an area with extensive surface cracking	5	L	Flat	Flat	New	F	VP
18	A large surfacing failure (delamination) that was likely caused by moisture issues	5	M	Steep	Rolling	Old	G	P
19	A patch that successfully repaired crocodile cracking has failed at the interface between the older and newer surfacing	3	H	Medium	Rolling	Very Old	P	P
20	Severe water induced damage repaired inadequately by multiple surface patches of varying age	5	L	Flat	Rolling	New	P	P
21	An exposed service excavation patched using infrared technology has experienced severe settlement shortly after repair.	3	H	Steep	Rolling	Very New	G	G
22	Pothole repaired with concrete. Differential stiffness has caused cracking – repaired with a cold mix surface patch	4	H	Medium	Rolling	Old	P	P
23	Surfacing layer of a service excavation failed within six months of application, likely owing to material issues	3	M	Steep	Rolling	Very New	G	F
24	Pumping of fines indicates underlying moisture issues at this large patch over a stormwater culvert	4	M	Flat	Rolling	Very Old	VP	VP
25	Cracked surface where larger openings have received surface patches while no surrounding cracks have been sealed.	4	M	Medium	Rolling	Very Old	P	P
Note: Very New (<1 year), New (0-2 years), Old (3-5 years) and Very Old (>5 years).								

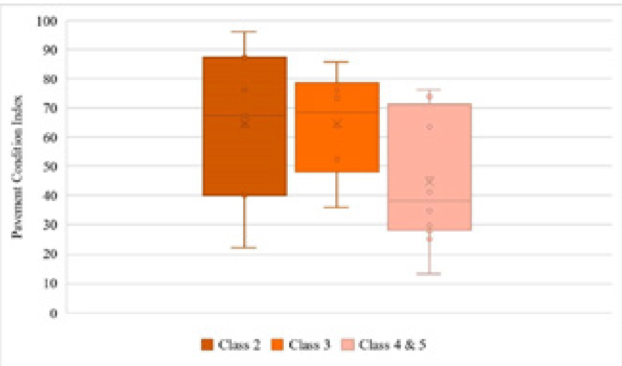

FIGURE 2: *Box and whisker plot showing the spread of CIpave according to route class*

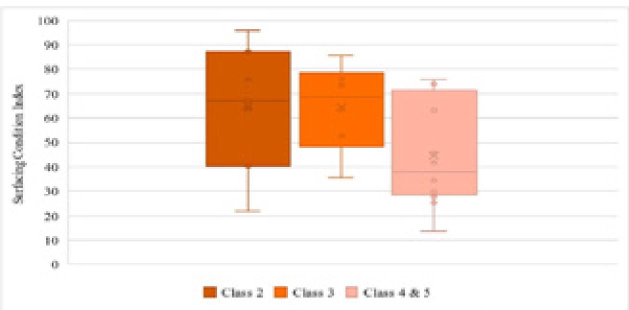

FIGURE 3: *Box and whisker plot showing the spread of CIsurf according to route class*

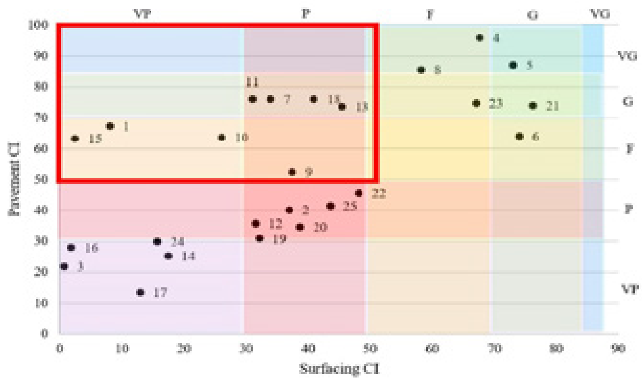

FIGURE 4: *A diagram showing CIpave plotted against CIsurf and the different CI regions*

The KPIs used by South African local authorities are generally set by the municipalities' SDBIPs while SANRAL's KPIs are specified in their Declaration of Intent. Table 5 lists some key performance indicators (KPIs) used by road maintenance authorities in South Africa as well as KPIs recommended by the World Bank for performance-based road maintenance contracts. The first two – group A - are used by metro municipalities and the last three – group B – are used by SANRAL. The KPIs were assessed for specificity, measurability, achievability, relevance, and whether they were time bound (SMART). Ensuring that KPIs are 'SMART' can result in better accountability in terms of quality control.

From Group A, the KPI "Number of Potholes fixed" is measurable and achievable and the target is time bound. However, its specificity and relevance are questionable. The target sets a specific time frame but there is a significant degree of ambiguity around what classifies as a pothole. In terms of relevance, counting the number of potholes repaired is not technically relevant as this KPI has no bearing on the quality of the repair itself nor on the overall condition of the road. For example, in cases 10, 14, and 20, despite there being multiple repairs, the surface conditions range from poor to very poor. In addition, the pothole repairs in cases 10, 12 and 23 did not survive more than a year. Notably, this KPI could also be used to artificially inflate the authorities' performance by reporting a high number of repairs even if the repairs are inappropriate or of poor quality. For example, cases 3, 9, and 10, could act as a continuous source of 'good performance' as the authority returns every year to patch a 'new' pothole. This behaviour has been termed 'malicious compliance'. Furthermore, because a pothole is a secondary failure that usually results from an unaddressed initial issue the number of potholes repaired essentially represents the number of issues that were allowed to become potholes. This shows that the 'number of potholes repaired' is not relevant to ensuring quality service delivery and is often misleading.

TABLE 4: *Performance indicators recommended by MFMA Circular 88 for road network quality assurance.*

Outcome	Outcome indicators	Output indicators
TR 6. Improved quality of municipal road network	TR6.1 Percentage of fatal crashes attributed to road and environmental factors	TR6.11 Percentage of unsurfaced road graded
		TR6.12 Percentage of surfaced municipal road lanes which has been resurfaced and resealed
		TR6.13 KMs of new municipal road network
	TR 6.2 Number of potholes reported per 10kms of municipal road network	TR 6.21 Percentage of reported pothole complaints resolved within standard municipal response time

The second KPI in group A, like the first, is measurable, achievable, time- bound by annual targets but has limited relevance to quality effective service delivery. However, it can be considered specific as the unit of measurement is defined. Although resurfacing addresses the issue of very poor surface condition it is only appropriate if the underlying pavement layers are still structurally sound. It is most applicable in cases where the condition index for surfacing (CI_{SURF}) is low but the condition index for pavement structure (CI_{PAVE}) still indicates a 'fair' to 'very good' condition. Therefore, this KPI also does not guarantee that a good level of service is maintained. In contrast, the KPIs in group B are more likely to guarantee a good level of service at the second performance contract level. This is because as well as specific, measurable, and achievable, the KPIs are also relevant as they relate directly to the overall condition of the road. This means that those actioning the road maintenance will be focussed more on the overall condition of the road rather than only applying repair methodologies that may or may not improve the level of service the road provides. This indirectly ensures quality control of repairs and other maintenance activities. Furthermore, the measurement procedures of the three parameters in Group B are outlined in guidelines published by COTO, thus ensuring the specificity of the targeted KPIs. While these KPIs are not explicitly time bound, they will most likely be assessed at intervals specified in contracts.

The KPIs recommended by the World Bank shown in Table 5 are specific, measurable, achievable, and relevant in the context of individual repairs. Hence, they do reflect the quality of repairs more directly as they include requirements for each different repair type. For example, instead of using the number of potholes repaired as a KPI, it recommends using the occurrence of potholes as a KPI. This is more technically relevant to the mechanisms of pothole formation as it focuses on ensuring that defects are repaired before they become potholes. This is also true for the KPI targets described for cracks and rutting. This group of KPIs may guarantee quality of individual repairs, but they do not directly assess the overall riding quality of the road segment or the overall network condition. However, although the KPI on patching is specific, achievable, and relevant, its measurability is limited as once a patch is completed, the underlying layers cannot be assessed for compliance without destructive tests being conducted. Furthermore, the measurability of the targets of most of these KPIs is limited in the context of extensive networks where maintenance is constrained by limited resources. Without significant development and implementation of artificial intelligence, measuring these parameters accurately requires inspections conducted by trained personnel. High costs make this less achievable in the context of South Africa.

In conclusion, KPIs used in South African municipalities measure service delivery without assessing quality of the network nor the quality of individual repairs. The World Bank's recommended KPIs assess the quality of repairs more directly but may be challenging to implement in practice. The KPIs in Group A are the most effective as they monitor the provision of good network conditions by assessing parameters that are directly dependent on the quality of repairs. For this reason, among others, the roads managed by SANRAL and assessed by Group A KPIs

TABLE 5. *SMART assessment of KPIs*

KPI		Target	S	M	A	R	T
KPIs used by South African road authorities							
Group A	**Number of potholes Fixed**	80% within 30 days	No	Yes	Yes	No	Yes
	Number of Lane kilometres of road resurfaced	122 L km (2022/2023 target)	Yes	Yes	Yes	No	Yes
Group B	**Smooth Travel Exposure (STE)**	95% of travel on less than 4,2 m/km roughness	Yes	Yes	Yes	Yes	No
	Low Rut Exposure (LRE)	95% of travel on less than 20mm rut depth	Yes	Yes	Yes	Yes	No
	High Texture Exposure (HTE)	95% of travel on higher than 0.4 mm texture	Yes	Yes	Yes	Yes	No
KPIs recommended by the World Bank and CAREC Transport Knowledge Series[3]			**S**	**M**	**A**	**R**	**T**
Potholes in Pavements	Maximum dimension of any single pothole		Yes	Limited	Yes	Yes	N/A
	Maximum number of accumulated potholes greater than 100 mm in diameter in any continuous 1,000m section.		Yes	Limited	Yes	Yes	N/A
Patching	Rectangular, level with surrounding pavement, materials similar to surrounding pavement, and no cracks wider than 3mm.		Yes	Limited	Yes	Yes	N/A
Cracking	No cracks wider than 3 mm wide.		Yes	Limited	Yes	Yes	N/A
	For any 50m section the cracked surface < 10% of the pavement surface. (Measurement defined)		Yes	Limited	Yes	Yes	N/A
Rutting	No ruts deeper than [insert value between 20 and 40] mm. 10 mm rutting shall not be present in more than 5 percent of any of the road sections defined in the contract		Yes	Yes	Yes	Yes	N/A

were given a B+ score on the SAICE 2022 Infrastructure Report Card indicating that the network is of exceptional quality. According to the Scorecard, only 7% of SANRAL's network is in either poor or very poor condition (SAICE, 2022).

Scope and Limitations

The study's scope was confined to maintenance activities concerning flexible pavements paved with bitumen/binder-containing asphalt, encompassing routine and periodic upkeep of road surfaces and structures while excluding rehabilitation and reconstruction efforts. It primarily emphasised technical aspects of road maintenance, with considerations made for management, political, and financial factors where applicable. Appurtenant road elements like road markings, traffic signals, and stormwater infrastructure were excluded unless directly impacting the road surface's condition. Case studies specifically targeted failed patch repairs on urban class 2-5 roads within Johannesburg's Regions B, E, and F, potentially restricting the generalizability of findings on road maintenance trends. However, assuming consistent repair methodologies across municipalities in South Africa, the identified challenges are deemed relevant nationwide

CONCLUSIONS

Despite this, it was found that road maintenance carried out by municipalities does not always comply with the methods described in these high-quality manuals and guidelines. This has led to repairs that are ineffective or fail rapidly, as well as repairs that do not address the root cause of the road failure. A great number of resources – including time, materials, and labour – are wasted when this is done as it is often necessary to repair the same failure regularly. The reason for this poor performance was not explicitly directly determined. However, it is possible that this is caused by misguided performance indicators that assess the rate of delivery but not the quality of maintenance. Even if road maintenance teams have an appreciable understanding of the basic science behind road maintenance approaches, the pressure for meeting performance targets overtakes their resolve to ensure quality of work done. Hence, there is a need to structure key performance targets and indicators to ensure higher quality repairs. This can be achieved by ensuring that KPIs are specific; can be measured easily and cost effectively; are achievable in the context of constrained resources; are relevant to the science of road maintenance; and are time-bound through minimum response times and/or periodic assessment. By doing this, even if maintenance teams are under pressure to meet performance targets, the quality of repairs and effectiveness of repairs at maintaining good network condition is not compromised.

In addition, the strategy of only resealing roads without attempting any of the required reconstruction and rehabilitation will only result in greater expenses in the near future. This is because while maintenance is not done, the pavement is exposed to further distress and the deterioration continues. When the roads are eventually reconstructed, it will cost more than it would have cost if reconstruction or rehabilitation was done earlier. Furthermore, prioritising maintenance on higher class roads makes sense as these roads generally carry higher speed traffic for which poor riding quality will have more severe consequences. However, ineffective and failing repairs that are executed on lower class roads result in severe wastage of resources, and increasing costs are associated with delaying reconstruction and rehabilitation. This shows that South African road management at the municipal level has a long way to go before the guidelines and practice are congruent with each other.

RECOMMENDATIONS

Maintenance teams need to be sent to site with the correct equipment and tools to be able to action appropriate repair techniques. This includes diamond saws so that teams can remove defective surface material, material and equipment required for crack sealing, and all necessary equipment to execute structural patches that comply with the existing specification. In addition, it is recommended that the KPIs used by municipalities to monitor road maintenance be redesigned to ensure that the possibility of malicious compliance is minimised. By adopting the KPIs used by SANRAL, ensuring good quality roads and road maintenance will be unavoidable. There is need for more research into the influence of KPIs on downstream performance and compliance.

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