PAPER 10

DRAWBACKS OF POTHOLE FILLING PROGRAMS AS A PREVENTIVE MAINTENANCE MEASURE: STUDY BASED ON NON-INTRUSIVE PAVEMENT DEFECTS INVESTIGATION

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1. ABSTRACT

Recent studies have alerted the South Africa Road Sector and its various stakeholders to the alarming deterioration rate of the road network condition. This is especially the case with the secondary and the tertiary road network where the backlog of maintenance is in the order of hundreds of billions of Rands. Amongst other reasons such as the lack of technical capacity within the secondary and tertiary road authorities, this backlog of maintenance has often been named as one of the major contributors to the poor rating of the lower ranking roads in South Africa. Roads within the secondary and tertiary sectors are either at risk of failure, being unable to cope with the normal demand, subjecting the public to severe inconvenience, or unfit for purpose, having already failed or being on the verge of failure, exposing the public to health and safety hazards.

To ensure all the safety hazards on the road network are removed with immediate effect, preventive maintenance through the filling of potholes can be recommended. However, this approach was never intended to be the substitute for other maintenance or rehabilitation measures.

This paper shows that though the preventive maintenance through the filling of potholes has a merit from a safety point of view, this method does not necessarily address the root-cause that led to the initiation and the generation of such potholes. Using various roads as case studies and through a comparison of their TMH 9 visual assessment strip map to the FWD deflection parameters mapping, this paper recommends that the reactive maintenance should not only follow the rigorous requirements of pothole repairs that extend into the base and underlying layers but should also be taken as a holding measure guaranteeing the safety of motorists until the appropriate rehabilitation or maintenance measure is implemented without further delay.

2. INTRODUCTION

Initiatives by road authorities and the South African road sector to reduce the number of potholes through preventive maintenance measures are on the increase. Road authorities should be commended for such initiatives as potholes can be very hazardous to motorists as well as pedestrian end users. Every effort to reduce the already high level of road accidents related to poor infrastructure in South Africa is welcome.

However, this study also considered other factors that require equal attention to ensure that the intention to address one problem does not result in a consequential creation of another. For example, taken positively, the presence of a pothole could be a clear indicator that communicates to an experienced practitioner the evidence of an unseen and poor underground road condition. Neatly concealed, the same evidence could be tempered with, giving a false impression that the undelaying layers of the road are all sound to carry the traffic loading.

Though the paper acknowledges that there is some benefit of pothole filling that complies with recommended practices [Paige-Green et al, 2010], the paper also proposes actions that should be adopted so that the affordable fixing of a defect through pothole patching today does not result in the postponement of the same problem to a future date, but alas at a highly inflated premium.

3. STUDY ANALYSES

3.1. Pavement engineering background

For this study five (5) actual rehabilitation and maintenance projects were selected as shown in Table 1. All the roads were Category B roads as per the TRH4 classification. The roads were investigated for their visual conditions through the mapping of all their surface and structural defects' respective degrees and extents at 20m intervals. The visual assessments were conducted following the framework illustrated by Figure 1, in accordance with the TMH9 [1992] guidelines.

TABLE 1: *List of case study roads*

Road Name	Province / District	Road Length (km)	Activities
Road 1	Kwazulu Natal / King Cetshwayo	30	Visual Assessment, Instrument Measurements, Geotechnical Investigation.
Road 2	Limpopo / Waterberg	16.2	
Road 3	Limpopo / Blouberg - Vembe	94	
Road 4	Kwazulu Natal / Ugu	25	
Road 5	Kwazulu Natal / eThekwini	15	

Considering that the focus of this study was concerned only with the effectiveness of pothole filling programs, the previous as well as newly constructed surface and structural patches and the identified potholes of degree more than three (3) were selected. These were mapped over the FWD deflection bowl parameters strip map.

3.2. Assessment of pavement deflection using the Falling Weight Deflectometer (FWD)

All the roads in Table 1 had a granular base and their deflections could be analysed using the deflection bowl parameter structural conditions rating criteria provided in Table 2, which is an extract from SAPEM Chapter 10 [2013]. The parameters in Table 2 give the condition on a pavement layer depending on the FWD deflection recorded. The deflection bowl parameters considered for the analyses were the maximum deflection (Y-Max), the base layer index (BLI), the medium layer index (MLI), and the lower layer index (LLI). For this specific study, the MLI and the LLI were not

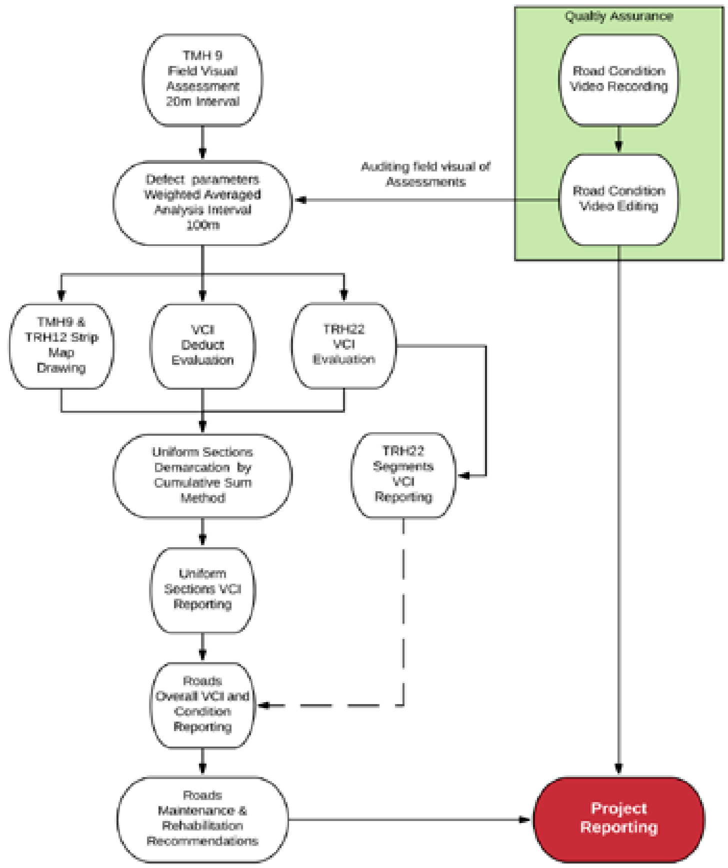

FIGURE 1: *Visual Assessments Process Flow Chart*

considered. The approximate locations within the selected subgrade (SSG) horizon, corresponding to the MLI, and within the subgrade location (SG), corresponding to the LLI, were found to have less probability of interfering with pothole repair excavations. Only the Y-Max and the BLI deflection bowl parameters were analysed by this paper. This is because the Y-Max measures the total pavement deflection from the pavement surface, while the BLI focuses more on the pavement base layer horizon, and the pothole repair activities are likely to be concentrated within the surface, wearing course, or the base layer of a distressed pavement.

Following the deflection bowl parameters criteria provided by Table 2, the structural conditions of the roads in Table 1 were evaluated. For each location corresponding to a FWD measurement, the condition of the pavement was rated as being in a sound condition, a warning condition, or a severe condition. The corresponding colour coding to the conditions as defined by Horak [2008] were hence assigned to each FWD measurement and mapped. The position of the respective road that was in a severe condition due to excessive deflection upon the surface (Y-Max) or excessive deflection within the base layer (BLI) were given a dark brown colour (or black for a grey scale printing). The position of the respective road with a warning condition Y-Max or BLI were assigned an orange colour (or grey for a grey scale printing).

It should be noted that the FWD measurements were undertaken for each traveling direction or lane. As such, the overall measurements of each deflection bowl parameter corresponded to the worse reading between the different travelling directions for the given location or chainage.

Uniform sections were demarcated for each parameter to evaluate sections of similar conditions. In Equation 1 below, an example is given for the Y-Max deflection bowl parameter, but the same principle will similarly apply to demarcate the respective horizon of a pavement structure for the other parameters BLI, MLI and LLI.

$$CuSum_i = X_i - \bar{X} + CuSum_{i-1} \quad \text{------------ Equation 1}$$

Where:

$CuSum_i$	:	Cumulative sum of deviation of variable from mean (Here the variable is *Y-Max*)
X_i	:	Variable at point i (*Y-Max$_i$*)
$\bar{X}$	:	Mean of variable
$CuSum_{i-1}$	:	Cumulative sum of previous point

Graphs of the respective cumulative sums are also provided. Using the slope of the graph, the uniform section or sections of similar behaviour regarding the given parameter (Y-Max or BLI) were demarcated.

3.3. Effect of old patches on pavement performance

Before the future anticipated performance of any pothole repair could be predicted, the performance of the old patches was evaluated. As shown in Figure 2, it was often observed that poorly constructed patches invariably performed poorly than even the older pavement structure they were intended to improve. This is often the case due to substandard construction techniques, and the use of different materials than was initially used within the adjacent older pavement structure, leading to differential settlement, or differential consolidation. It should also be noted that pothole repairs are often confined, making the uniform compaction of the patched area difficult to achieve.

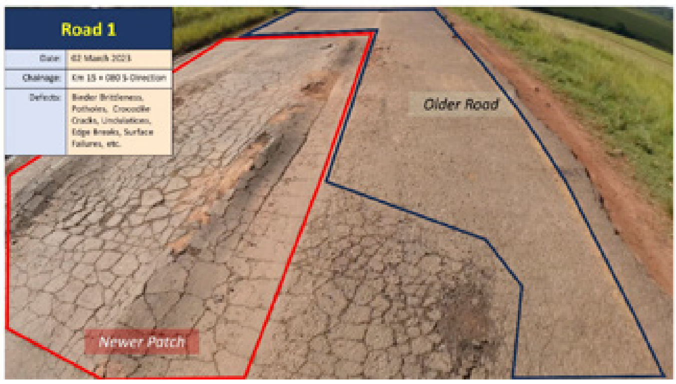

FIGURE 2: *Road 1, Patch performing worse than adjacent older road*

TABLE 2: *Deflection Bowl Parameter Structural Condition Rating Criteria*

Pavement Base Type	Condition Rating	Colour Coding		Deflection Bowl Parameters				
		RGB Printing	Grey-scale Printing	Y - Max (μm)	RoC	BLI (μm)	MLI (μm)	LLI (μm)
Granular	Sound	Grey	White	< 500	> 100	< 200	< 100	< 50
	Warning	Orange	Grey	500 - 750	100 - 50	200 - 400	100 - 200	50 - 100
	Severe	Brown		> 750	< 50	> 400	> 200	> 100

RGB (red, green, blue); RoC (radius of curvature)

The other typical observation was that new pothole repair patches would sometimes highlight how old ones that were intended to serve the same purpose have underperformed and failed to improve the condition of the road. Hence, failing to prevent further deterioration in subsequent years. As depicted by Figure 3, the pothole repairs of previous years resulted in a patch marked as "older patch", which could not prevent further failure in subsequent years. If the older pothole repair had been efficient, this would have assisted in preventing the new pothole repair, such as the one marked as "newer patch" in Figure 3.

FIGURE 3: *Road 1, Older patch indicating poor performance.*

3.4. Patches, Potholes, and FWD parameters mapping

The observations illustrated by Figure 2 and Figure 3 were further confirmed by analysing the condition of the roads covered by this study based on their FWD deflections. For ease of comparison, the previous pothole repairs based on the evidence provided by the old structural patches observed through the visual assessment of the road were superimposed on the FWD strip map as shown in Figure 4 to Figure 8. Both the patches (old and new) and the potholes were plotted along the abscissa axis of Figure 4 to Figure 8. The patches were plotted as black dots, while the potholes were plotted as white dots.

For Road 1, it was evident that from about km 4+500 to about km 10+500 and km 11+500 to km 14+500 that previous years' pothole repairs (now evidenced by old patches) did not prevent the severe deterioration condition of the road, as illustrated by the dark brown Y-Max deflection bowl parameters recording over the given stretches in Figure 4. The BLI deflection bowl parameters were also dark brown over the same area of Road 1. This indicated that the previous years' patching did not assist to prevent the deterioration of the base horizon of the pavement structure. The same pattern was observed for Road 3 in Figure 6, Road 4 in Figure 7, and Road 5 in Figure 8 as structural patching or pothole filling did not prevent the poor Y-Max and BLI readings.

The only difference with Road 2 in Figure 5, was that the Y-Max and BLI deflection bowl parameter readings had a warning rating instead of the severe. However, even this warning rating is still not desirable.

3.5. Anticipated performance of proposed pothole repair

During the visual assessment of the roads listed in Table 1, pothole failures were also identified. The recorded potholes failures with a degree more than three (3) were also plotted as white dots on the abscissa axis of Figure 4 to Figure 8, just above the black dot corresponding to the nearby patch repair when applicable.

It is evident that considering recent pothole eradication policies the expectation is for such potholes to be filled in as quickly as possible. However, based on the poor performance of past pothole filling, as was detailed in the sections above, the question is what performance can be anticipated from proposed future pothole repairs. This question remains, even if one had meticulously followed the repair standard recommended by Paige-Green et al [2010]. As shown in Figure 4 to Figure 8, the identified pothole had their locations within the uniform sections that were already showing severe distress both regarding the Y-Max or the BLI parameters.

This shows that for any pothole repair to be effective within the uniform section of severe Y-Max and BLI deflection destress, the pothole repair will need to be carried out by extensive excavation or deep stabilisation thicker than the base layer. In other words, this approach could not be qualified as a pothole filling or pothole repair but rather as heavy rehabilitation. One of the drawbacks of such localised heavy rehabilitation is the difficulty of working in a confined area, preventing the attainment of various layers specified density level. Another drawback is the "chasing after pothole repairs" in isolation, whereby the whole road is not attended to, but rather an isolated area dictated by the presence of potholes, resulting in the introduction of non-uniformity of the pavement structure. Such non-uniform section will present further challenge to the assessment of uniform sections for future maintenance and rehabilitation solutions.

The biggest drawback of "chasing after pothole filling in isolation" is that

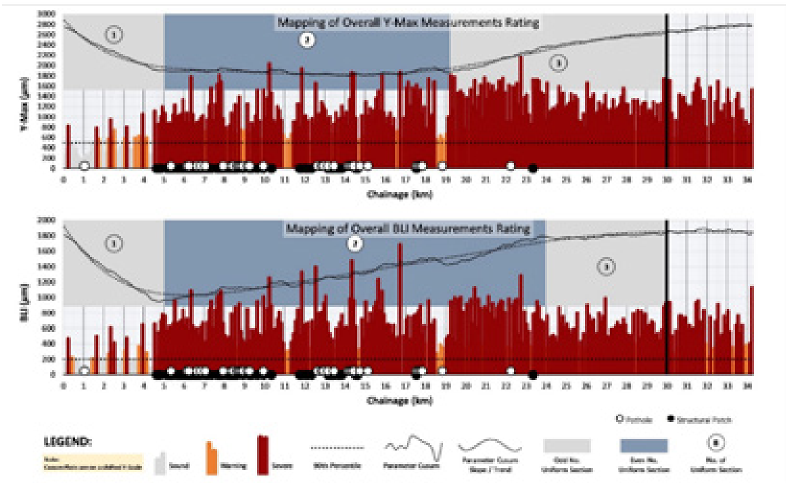

FIGURE 4: *Road 1, FWD strip map with mapping of potholes and structural patches.*

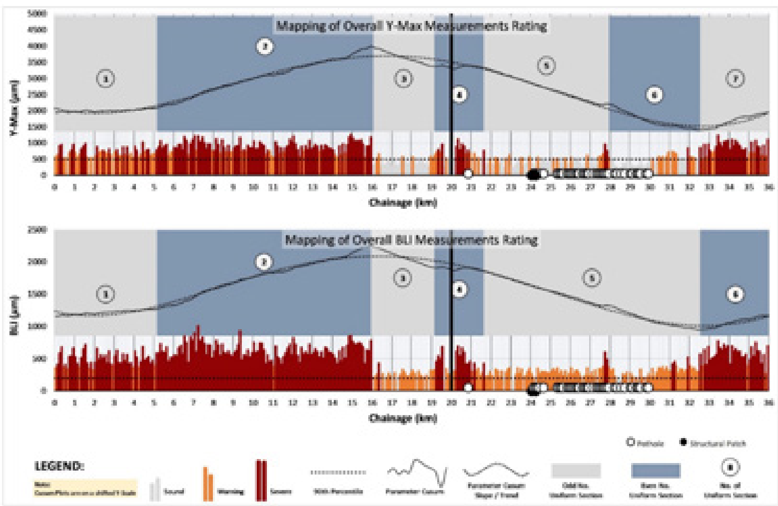

FIGURE 5: *Road 2, FWD strip map with mapping of potholes and structural patches.*

such repair would bandage over a deeper problem if not done properly. As shown in Figure 4 to Figure 8, severe conditions of deflection were recorded for the analysed road even in areas where potholes were not identified by the visual assessment. It is therefore not true that a direct relation exists between pothole formation and road deterioration.

In some instances, potholes are only the symptoms, and the source of the problems lies deeper within the pavement. Such deeper problems are the reason why poorer Y-Max and BLI are still recorded even in the absence of potholes, as in the case of Road 4 from about km 9+200 to about km 12+500 in Figure 7. This also means that shallow pothole repairs will not necessarily eliminate the underlying and deep-seated source of the problem.

Such deep-seated problems have the tendency of resurfacing at a later stage by reflecting the defects through the shallow pothole repair. In the long run there is a risk of investing scarce financial resources only to end up with a similar result as the one depicted in Figure 2 and Figure 3. Hence, pothole repairs are not guaranteed to always yield the desirable outcome.

3.6. Prioritisation of other surface and structural defects

For Road 2 in Figure 5, the warning rating condition of the BLI also indicates that the pavement is already in need of structural rehabilitation.

A more detailed analysis of Road 1's visual assessment between km 25+000 and km 27+800, as depicted in Figure 9, shows that attention should also be given to other defects. Block failures, surface cracking, surface failures, and aggregate losses might have been the defects that caused the initiation of potholes [Paige-Green et al, 2010]. Water ingress within the pavement structure through the surface cracks combined with traffic loading will always have the potential of reducing the structure bearing capacity and eventually lead to fine pumping and the formation of potholes. This has always been Emery's argument, as he alerted the road sector to the detrimental effect of water ingress through the passage created by surface cracks [1988].

The argument above is further substantiated by the fact that some sections of road without pothole failure of degree in excess of three (3), such as Road 1 from km 24+000 to km 30+000 (Figure 4), still recorded the severe Y-Max and BLI conditions indicating that they were already experiencing excessive deflection within their base layer horizon.

The analyses of the visual strip maps within the areas without pothole failures were like Figure 9.

CONCLUSION

It could be concluded from the result of the analyses, that the previous maintenance patches, which probably resulted from previous pothole filling interventions, did not necessarily improve the reading of the Y-Max and BLI deflection bowl parameters of the respective roads. In most cases, the location of the patches still corresponded to the location of severe Y-Max and BLI deflection bowl readings.

Even in the exceptional case of Road 2, the readings were in the warning condition for the BLI parameter, pointing to the necessity of minor rehabilitation.

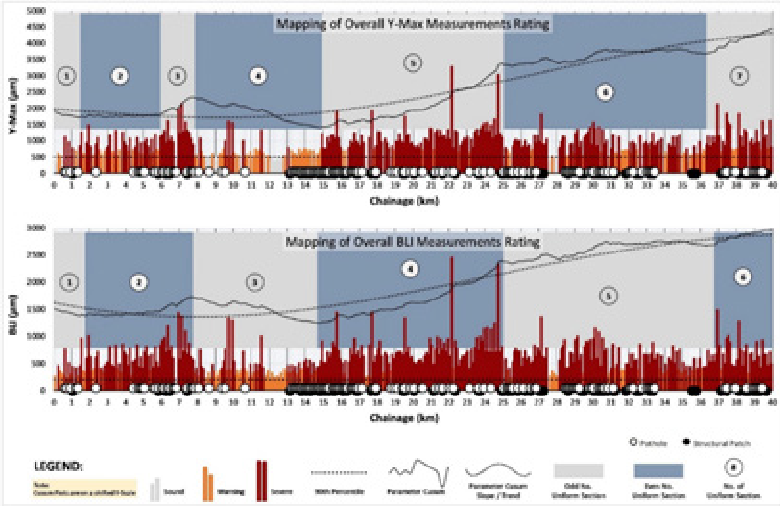

FIGURE 6: *Road 3, FWD strip map with mapping of potholes and structural patches.*

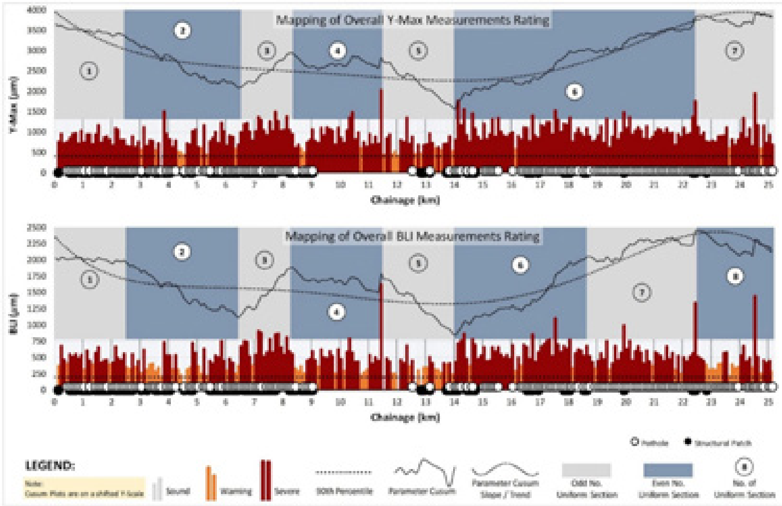

FIGURE 7: *Road 4, FWD strip map with mapping of potholes and structural patches.*

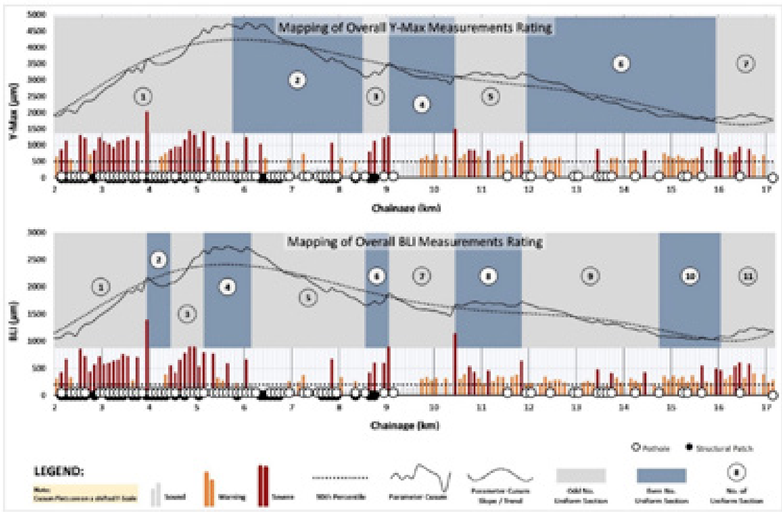

FIGURE 8: *Road 3, FWD strip map with mapping of potholes and structural patches.*

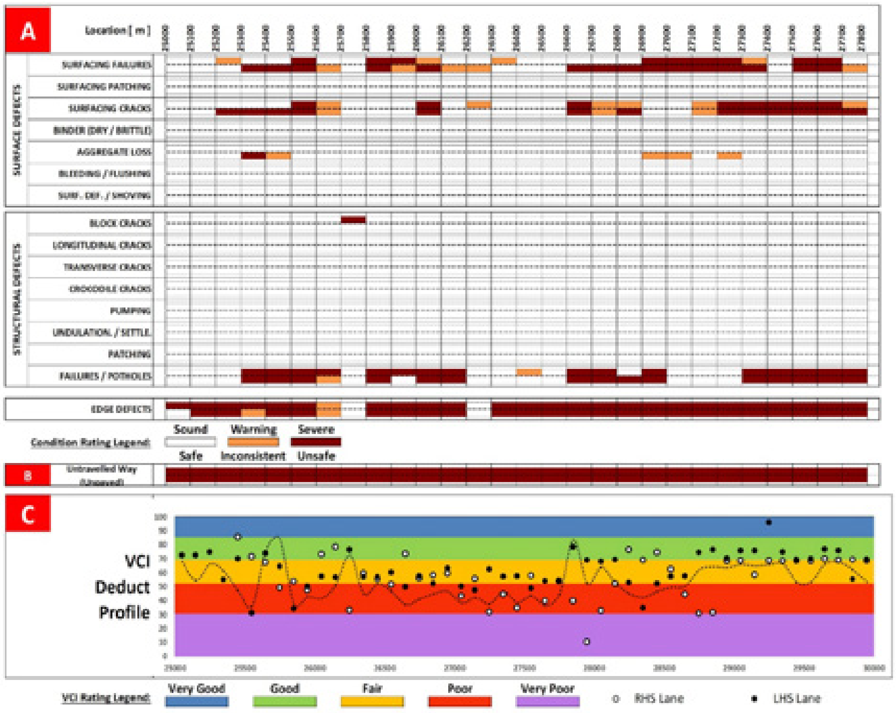

FIGURE 9: *Road 1, Extract of road defects mapping and VCI strip map.*

rehabilitation approach would have been the optimal solution (see Figure 10 below). The risk is therefore that the same defect and hazardous conditions that were meant to be prevented would disappear temporarily, only to resurface within a matter of few years or months in some extreme cases.

It was also observed that the section with patches did not necessarily perform better than those without patches. As shown in Figure 9, other identified surface and structural defects were shown to be equally critical in influencing the deterioration of the pavement Y-Max and BLI deflection parameters. It can therefore be concluded that focusing only on potholes runs the risk of ignoring other defects that could be more revealing about the poor pavement layer conditions.

Regarding the identified and mapped current potholes, these often corresponded to areas of poor deflection characteristics, even as deep as within the base layer horizon. It could therefore be concluded that the patching or filling of such potholes would not improve the poor Y-Max and BLI deflection bowl readings, provided that the pothole repair extends deeper through thicker excavation of the affected pavement layer. From the above, it could also be concluded that when pothole filling is implemented in isolation, one runs the risk of adopting a cheaper preventative maintenance intervention where a minor or major

4. RECOMMENDATIONS

Though pothole filling can be beneficial for the safety of motorists and pedestrian road users, from the vehicle running cost and from the global transportation cost points of views, this study has shown that some roads need other rehabilitation or maintenance solutions because they have already deteriorated beyond the preventative maintenance threshold. Pothole identification and filling by themselves should not be stand-alone maintenance approaches. Recent research has even developed sophisticated ways of georeferencing potholes for repairs. Such user-friendly georeferencing can even be done by a lay person without any pavement engineering background. The only prerequisite being the ability to identify a pothole. Municipalities have rolled out web-based and digital pothole spotting technologies.

Though these are plausible technological innovations, any pothole filling initiative should always be combined with other intrusive or non-intrusive evaluations of the underlying layers of the road pavement. The services of qualified pavement engineering are still required, and the use of other technologies should only be used to complement the valuable services of a qualified and experienced pavement engineering practitioner.

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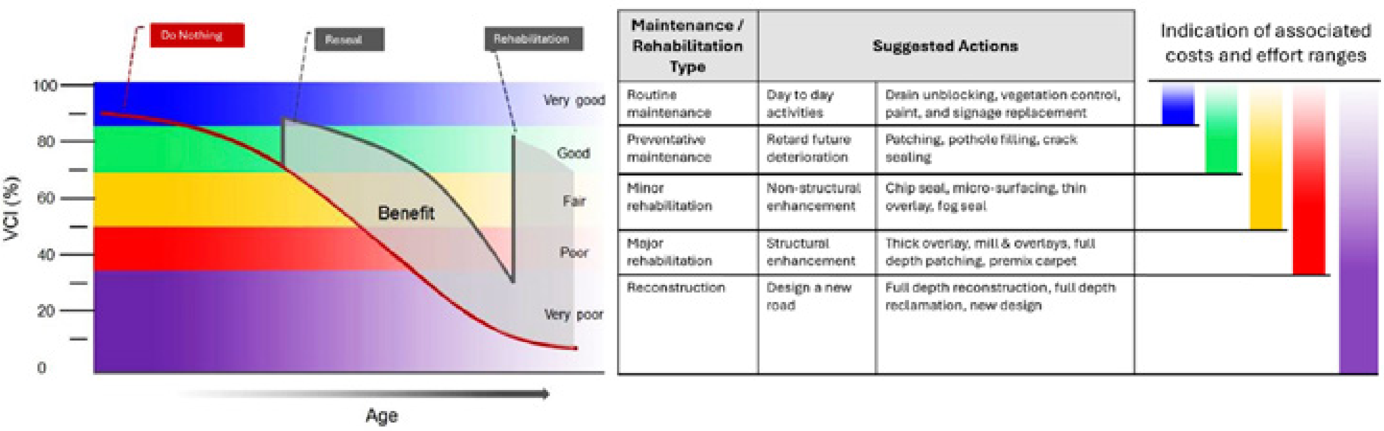

FIGURE 10: *Pavement asset management: area under condition curve benefit.*

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