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ASSESSMENT OF THE TRANSPORT AND OPERATIONAL CONDITION OF ROAD PAVEMENT AND SELECTION OF AN EFFECTIVE REPAIR TECHNOLOGY

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Abstract: The paper proposes a pavement-condition assessment approach based on both distress type and deterioration mechanism. Using the km 46-60 section of road 4R140 as the study object, visual records of cracking, potholes, rutting, settlement, and edge failure are linked to measurements of structural response, roughness, skid resistance, and drainage performance. Because verified diagnostic results were not provided, no invented distress percentages or remaining service life are reported. A differentiated rehabilitation strategy is developed that combines local replacement of failed layers, crack treatment, profile correction, and placement of a new asphalt-concrete layer. An illustrative life-cycle calculation shows how this integrated strategy can be compared with a simple thin overlay without presenting the example as a project estimate. The final pavement design must be supported by deflection and International Roughness Index measurements, friction testing, cores, and laboratory evaluation of the existing materials.

Keywords: asphalt concrete, pavement distress, roughness, skid resistance, structural capacity, rehabilitation technology, life cycle

Introduction

Distress in asphalt-concrete pavement is often regarded solely as a surface problem. However, visually similar cracking may result from thermal contraction, inadequate base strength, loss of interlayer bonding, or moisture action. An overlay placed without identifying the governing mechanism may conceal the distress, but it does not prevent its recurrence [7, 8].

To select an effective rehabilitation treatment for the km 46-60 section of road 4R140, surface condition, structural capacity, and road-user performance indicators should be evaluated together. ShNQ 2.05.02-23 provides the basis for design requirements, while IQN 05-11 establishes the principles of road-condition diagnosis [1, 2].

The principal question in a pavement rehabilitation project is not “Which layer should be placed?” but “In which layer did deterioration begin, and through which mechanism?” Sealing the surface is rapid and produces a visually satisfactory result; nevertheless, if active cracking, a moisture-weakened base, or inadequate interlayer bonding remains, the distress may reappear in the new pavement within a short period. Rehabilitation technology should therefore be treated as an engineering response derived from diagnostic evidence [7-9].

Transport and operational condition is represented by two groups of indicators. Functional indicators include roughness, noise, skid resistance, and water spray as experienced by drivers and passengers. Structural indicators describe the capacity of the pavement layers to distribute loads, together with deflection, thickness, density, and moisture regime. An effective rehabilitation treatment should restore both groups of indicators to their required levels.

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Materials and methods

The submitted graduation project identifies cracking, rutting, settlement, and deformation as general problems on the km 46-60 section of road 4R140, but it does not provide chainage-based quantities or protocols for International Roughness Index (IRI), skid resistance, deflection, or core testing [11]. The section should therefore be divided into segments with uniform pavement structure, traffic loading, and distress characteristics. Within each segment, crack type and length, pothole area, rut depth, settlement, edge deterioration, and repair patches are recorded with their coordinates. The visual survey is organised using the FHWA distress classification and the severity-level approach of the Pavement Condition Index (PCI) method [7, 9]. Because PCI does not directly measure load-bearing capacity, it is supplemented by deflection, core, roughness, and skid-resistance testing [9].

Static or dynamic deflection testing is used to evaluate structural capacity, IRI is used to assess roughness, standardised measurements are used for skid resistance, and cores are taken to examine the pavement layers [4-6]. The drainage system, crossfall, and shoulder condition are also documented. The final rehabilitation treatment is selected according to the dominant deterioration mechanism in each segment rather than from a single average score.

Pavement type, the boundaries of previous repairs, traffic loading, terrain, drainage, and visible distress are considered when segmenting the section. Test locations are selected within segments that have consistent characteristics; however, joints, depressions, bridge approaches, and zones where heavy vehicles brake are treated as separate short segments. This approach preserves the spatial variation of distress instead of assigning one average value to the entire 14 km section.

In addition to pavement thickness, core samples provide information on delamination, voids, moisture intrusion, and mixture structure. Deflection testing represents the overall response of the pavement structure, IRI quantifies the unevenness experienced by a moving vehicle, and skid-resistance testing indicates wet-surface safety [4-6]. These tests are not interchangeable; combining them within a common coordinate system makes it possible to distinguish the causes of distress more reliably.

Table 1

Relationship between distress mechanisms and rehabilitation decisions

Distress indicator	**Investigation**	**Condition for the corresponding treatment**
Isolated and block cracking	Crack width, activity, and evidence of moisture	Seal cracks and renew the surface if the pavement structure is sound
Alligator cracking and potholes	Deflection, cores, and base moisture	Replace the weak layer locally, then reinstate the pavement courses
Rutting	Rut depth, deformation in cores, and deflection	Mill the plastically deformed layer or strengthen the lower layers

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Distress indicator	Investigation	Condition for the corresponding treatment
Settlement and edge deterioration	Levelling survey, shoulder support, and drainage	Restore the subgrade, strengthen the shoulder, and provide an outlet for water
Poor roughness or skid resistance	IRI and skid-resistance measurements	Correct the profile and place a textured new layer under controlled quality

Source: compiled by the author.

Main section

Cracks are classified into three groups. Top-down thermal or ageing cracks can be managed through sealing and surface renewal. Alligator cracking caused by repeated loading may indicate weakness in the base or subgrade; in such locations, treatment of the surface course alone is insufficient. Propagation of an existing crack through a new layer produces reflective cracking, which requires crack treatment, local milling, and, where justified, a geosynthetic interlayer [3, 8].

A pothole usually results from the combined effects of water ingress, material disintegration, and repeated wheel impact. Rutting may be associated either with plastic movement of the asphalt mixture or deformation in the lower layers; the responsible layer cannot be identified without core and deflection testing. Settlement and edge failure are commonly investigated in relation to shoulder support, drainage, and subgrade uniformity.

On this basis, a differentiated rehabilitation technology is proposed: failed areas are opened and replaced down to sound material; active cracks are cleaned and sealed; rutting and unevenness are milled to restore the profile; a tack-coat emulsion is applied at the specified rate; and an asphalt-concrete layer selected through pavement design is placed and compacted. Mixture type and gradation are determined according to applicable material standards and laboratory testing [3].

During preparation for rehabilitation, the crack map and milling depth are established. If the visibly weakened material is not removed completely, zones of nonuniform stiffness remain beneath the new layer. The milled surface is cleaned of dust and loose particles, after which the bonding agent required for interlayer adhesion is applied uniformly. An insufficient application rate can permit slippage, whereas excessive application can cause bleeding and reduced stability.

During asphalt-concrete placement, haul time, mixture temperature, uninterrupted paver operation, roller sequence, and the compaction window are interdependent. Additional rolling after the layer has cooled may fail to achieve the required density and can instead crush the aggregate. Quality control should therefore extend beyond cores taken from the completed layer; process parameters are recorded in the work log by time and chainage.

Drainage and shoulder rehabilitation should be carried out concurrently with the pavement works. If the carriageway is renewed while the shoulder remains too low or the crossfall remains inadequate, water and impact loads accumulate at the pavement edge. This accelerates edge cracking, ravelling, and pothole formation. The pavement, shoulder, and ditch elevations should consequently be designed and accepted as one integrated cross-sectional profile.

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Results

Table 1 links the rehabilitation decision to the cause of distress. This approach is more targeted than automatically prescribing a layer of uniform thickness along the entire 14 km section: surface function is restored in structurally sound segments, while structural strengthening is applied to weak segments. Serviceable existing material is thereby retained, and deep rehabilitation is directed only to locations where it is required.

Three acceptance criteria are essential for the final design: reduction of IRI after rehabilitation, restoration of skid resistance to the required level, and limitation of calculated deflection to the allowable value. Thickness, density, and interlayer bond are additionally verified using cores [10]. Without these measurements, a conclusion that service life has been extended would not be evidence-based.

The differentiated solution is divided into three practical categories. A thin protective or functional layer may be sufficient where the pavement is structurally sound but has poor surface characteristics. Where deep distress is localised, the damaged material is replaced to the boundary of sound layers. In segments with extensive fatigue cracking and excessive deflection, strengthening of the base and an overlay of calculated thickness are required.

Acceptance results are compared with the design requirements by chainage. Thickness, density, and interlayer bonding indicate structural quality, whereas IRI and skid resistance indicate operational quality. A satisfactory result for one indicator does not compensate for a deficiency in another. For example, a high-density layer with a smooth surface texture may still fail to provide adequate wet-weather safety.

Table 2

Process control and acceptance testing during rehabilitation

Stage	Parameter monitored	Evidence	Acceptance criterion
Milling and local excavation	Depth, boundary of weak material, and surface cleanliness	Levelling survey and visual record	Failed material has been removed down to a sound layer
Tack-coat application	Application rate, uniformity, and surface moisture	Distributor log and field inspection	A continuous surface prepared for interlayer bonding
Mixture placement	Temperature, continuity, and layer thickness	Delivery and paving log	A segregation-free layer conforming to the design profile
Compaction	Roller sequence, temperature window, and density	Process log and cores	Design density and a uniform internal structure

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Stage	Parameter monitored	Evidence	Acceptance criterion
Final acceptance	IRI, skid resistance, thickness, and cross-sectional profile	Instrumented test reports	Simultaneous compliance with functional and structural requirements

Source: compiled by the author from pavement diagnosis and quality-control criteria [3-6, 10].

Technical and computational analysis

The general form of the PCI method is written as follows:

$$PCI = 100 - CDV$$

where CDV is the corrected deduct value derived from the types, quantities, and severity levels of pavement distress [9]. PCI represents functional condition but does not directly measure structural capacity.

For a preliminary economic comparison of rehabilitation technologies, the annualised normalised cost is expressed as $I_a = C_r/T_s$, where C_r is the normalised initial rehabilitation cost and T_s is the expected service life. In an illustrative scenario only, if $C_r = 1.00$ and $T_s = 4$ years for a thin overlay, then $I_a = 0.250$; if $C_r = 1.55$ and $T_s = 8$ years for comprehensive rehabilitation, then $I_a = 0.194$. The difference is approximately 22.5%. This is neither a project estimate nor a forecast for road 4R140; an actual calculation must use the discount rate, traffic-related losses, local prices, and diagnostic results.

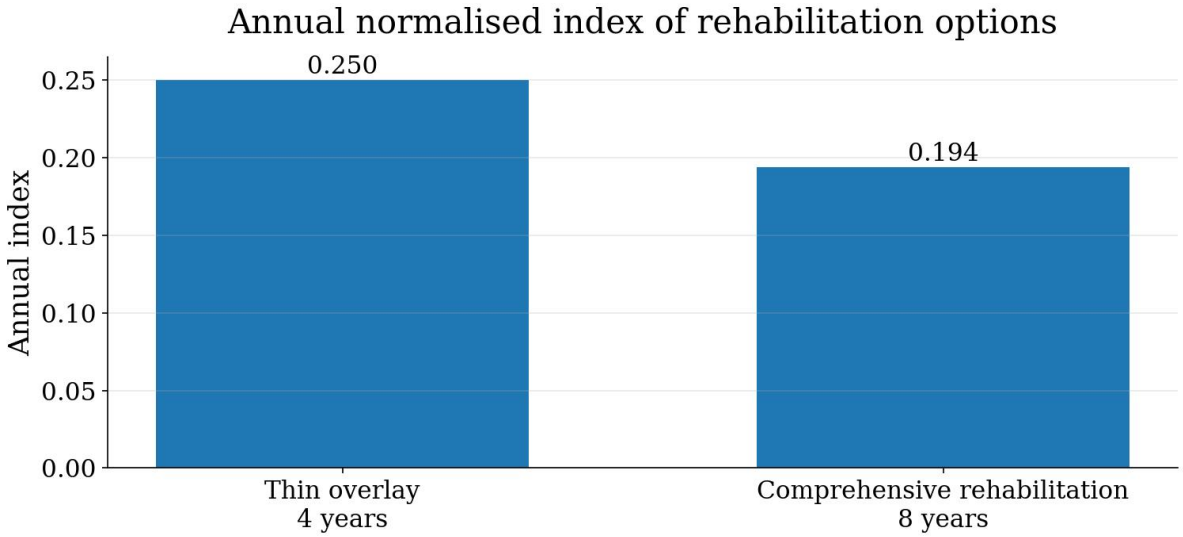


Figure 1 - Illustrative comparison based on initial cost and service life

Note: the values are not an estimate for road 4R140.

The annualised normalised index is useful for a rapid comparison of initial options, but the timing of cash flows must also be considered in the final decision. Life-cycle cost is expressed as C^{Lc}

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$= C_0 + \Sigma[C_t/(1+r)^t]$, where C_0 is the initial rehabilitation cost, C_t is the maintenance or renewal cost in year t, and r is the discount rate. Where road-user costs such as delay, diversion, and crash risk are available, they are added as a separate cost stream.

In the illustrative calculation, the thin-overlay option has an initial index of 1.00 and a service life of 4 years, while the comprehensive rehabilitation option has an initial index of 1.55 and a service life of 8 years. The resulting annualised indices are 0.250 and 0.194, respectively. Although the initial cost of the comprehensive option is 55% higher, its service life is twice as long and its annualised indicator is therefore approximately 22.5% lower. This example demonstrates only the sensitivity of the method and is not an actual estimate.

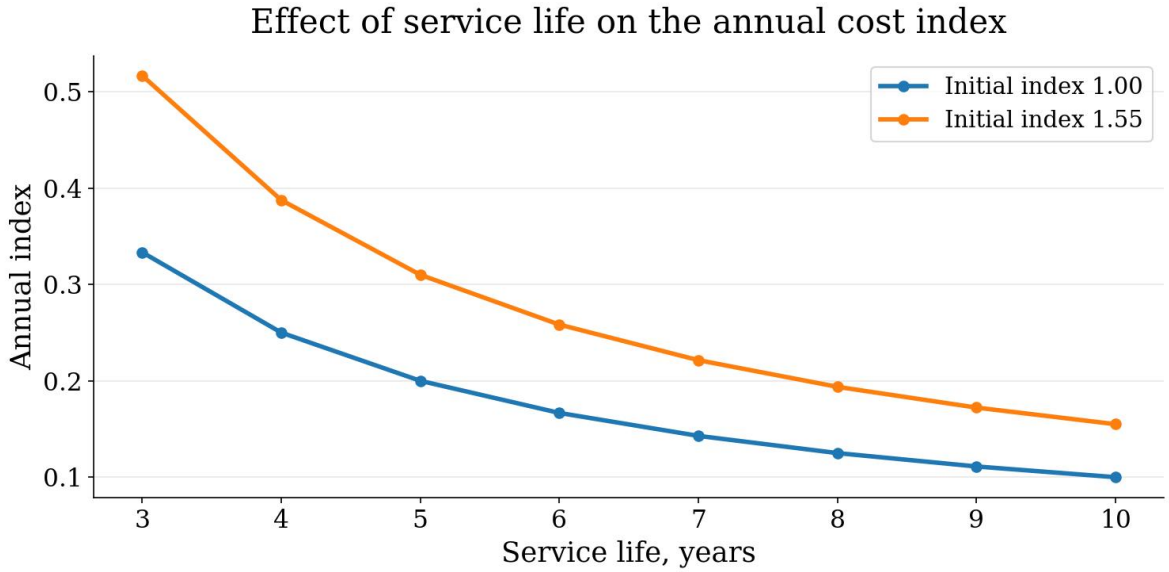


Figure 2 - Methodological sensitivity analysis by service life

Note: the curves represent the relationship $I_a = C_r/T_s$.

Discussion

Using initial price as the sole selection criterion leads to a short-term decision. Conversely, applying comprehensive rehabilitation uniformly to all segments can remove sound material unnecessarily and increase cost. The most appropriate solution is a segment-based combination of functional treatment, local deep repair, and structural strengthening, selected from diagnostic evidence.

The economic indices in this paper are expressed in relative units and do not constitute an estimate for road 4R140. Their purpose is to demonstrate how assumed service life affects the result. A final techno-economic assessment should incorporate local material prices, haul distance, equipment productivity, temporary traffic management, and subsequent maintenance costs.

Conclusions and practical recommendations

1. For the km 46-60 section of road 4R140, the rehabilitation treatment should be selected according to the deterioration mechanism and the structural response of each segment rather than the affected surface area alone.

2. Remaining service life cannot be estimated reliably unless the visual distress inventory is supplemented by deflection, IRI, skid-resistance, core, and drainage investigations.

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3. The proposed differentiated technology retains sound pavement layers and directs deep replacement only to weak locations, thereby reducing material consumption and the risk of repeated rehabilitation.

4. Eliminating water-ingress paths, active cracks, and profile irregularities before placing the new layer helps prevent reflective cracking and early pothole formation.

5. The final techno-economic selection should be based on a local cost estimate, discounted life-cycle cost, and traffic-related losses incurred during rehabilitation.

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