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Road Maintenance Strategy for Dodola-Goba Road: A Technical Assessment and Recommendations

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Abstract

Ethiopia's road network is expanding; however, it faces considerable challenges in adequately maintaining its existing infrastructure. Since the launch of the Road Sector Development Program (RSDP), the Ethiopian government has made substantial investment in road expansion initiatives. Nevertheless, the challenge of maintaining current roads through effective strategies remains a critical challenge. This study focuses on the assessment of a road maintenance project by taking Dodola–Goba road segment, a 133 km asphalt surfaced road as a case study. The objective of the study is to evaluate the current condition of the road, identify the probable causes of observed distress and recommend technically sound and economically viable solutions. A comprehensive technical assessment methodology was utilized, which included pavement condition survey, drainage system evaluation, traffic volume analysis, and classification of the road into homogeneous sections based on distress type and severity. Field data was collected through visual inspections, condition measuring and windscreen surveys. The assessment indicated that the overall condition of the road is poor, with significant deterioration observed along most of its length. The predominant defects, arranged by frequency of occurrence, were frequent edge and surface deformation, severe alligator cracking, undulations, gravel exposure on the surface, patch failures, settlement and depressions, localized potholes, longitudinal cracks, and smaller potholes. A quantitative analysis of the condition data indicated that 61.6% of the road necessitates routine maintenance, 22.7% require periodic maintenance and 15.7% demands rehabilitation**.** These findings underscore the importance of adopting an integrated maintenance approach that incorporates routine, periodic and heavy maintenance interventions. The study recommends routine maintenance to slow down deterioration, complemented by periodic maintenance where moderate distress levels are observed and targeted rehabilitation where structural failures are severe. In general, implementing the proposed strategies will minimize future maintenance costs, improve road user safety and support long-term infrastructure resilience in Ethiopia. The outcomes also serve as useful reference for policymakers, engineers and planners seeking to improve the performance and sustainability of the national road network.

Keywords: Pavement deterioration, road maintenance, Dodola–Goba road, rehabilitation, infrastructure sustainability

1. Introuction

Road transport is the dominant mode of transport in Ethiopia, accounting for more than 90% of freight and passenger movements across the country [1]. This dominance is largely due to the country's limited railway and waterway networks, as well as its dispersed settlement pattern and mountainous terrain, which make roads the most practical means of connectivity. Over the past 28 years, Ethiopia's federal paved road network has grown rapidly under the Road Sector Development Program (RSDP). The paved network expanded from 3,708 km in 1997 to 18,238 km in 2023 [2]. This achievement has greatly enhanced national connectivity and supported economic growth. However, rapid expansion has also created a new challenge in maintaining and rehabilitating the existing road assets. As result, a significant portion of these roads are now aging and increasingly require rehabilitation or upgrading to remain functional and safe [1, 3]. Despite the remarkable expansion of the road network, there remains a significant gap in ensuring its long-term maintenance. The Proportion of Federal Asphalt roads in good condition at the beginning of RSDP were 17% whereas in 2023 it was 22%, indicating a much work is required in maintaining the road asset. Over the past 26 years, only 4.4 % of the total RSDP expenditure has been on maintenance of federal roads [3, 4]. This gap in road maintenance calls for a technically and environmentally friendly way of rehabilitating the existing road assets.

Dodola – Adabba – S/washa – Goba road project was in Oromia national regional state, southeast of Addis Ababa which passes through two zones Bale and West Arsi Zone. Robe and Goba towns and the project have an approximate total length of 133 km. The existing road project is Asphalt Concrete Pavement surface and has highly deteriorated, especially the segment from Dodola to Dinsho has failed at many locations. Currently, Shashemene District has been implementing road maintenance to improve surface by natural gravel on Adaba area road segment, this prevents further damage and collapses of the road [4]. This road project has passing through Flat and Rolling terrain for the first 40 Kms, 30 km then traverses through Mountainous and escarpment sections especially at Sebsibe Washa area and the rest 63 km traverses through rolling and flat terrain.

Several studies emphasize the critical importance of systematic maintenance for sustaining road network performance, particularly in developing countries such as Ethiopia. [5] identified the primary types and causes of asphalt pavement failures across the Ethiopian federal road network, highlighting the significant impact of environmental conditions and traffic loading. [6] further demonstrated that variability in traffic loads accelerates pavement deterioration, underscoring the need for targeted, data-driven maintenance interventions. International studies on pavement asset management also provide guidance for best practices in condition assessment and maintenance planning, including the use of structured indices such as the Pavement Condition Index (PCI) and decision-support frameworks[5].

This study aims to identify the causes of asphalt pavement failure along the Dodola–Goba Road segment primarily through comprehensive field surveys. The investigation relies on systematic visual inspections, structural assessments, and traffic analysis to evaluate the existing road conditions and identify visible signs of distress. The field survey provides critical on-

site data for understanding the extent, pattern, and distribution of pavement failures. Based on these observations, the study seeks to propose practical, evidence-based recommendations to enhance pavement planning, maintenance, and asset management practices in Ethiopia and similar context.

2. Methodology

2.1 Study Area

The study road connects the towns of Dodola and Goba, serving as a vital corridor for the movement of people, goods and agricultural products within the Bale Zone. The route also provides access to Bale Mountains National Park, an important ecological and tourism area in southeastern Ethiopia. The road segment passes through varied topographical & climatic conditions, including highland and mid altitude areas, which influence pavement performance due to differences in temperature, rainfall and drainage characteristics. Figure 1 illustrates the map of road segment under study.

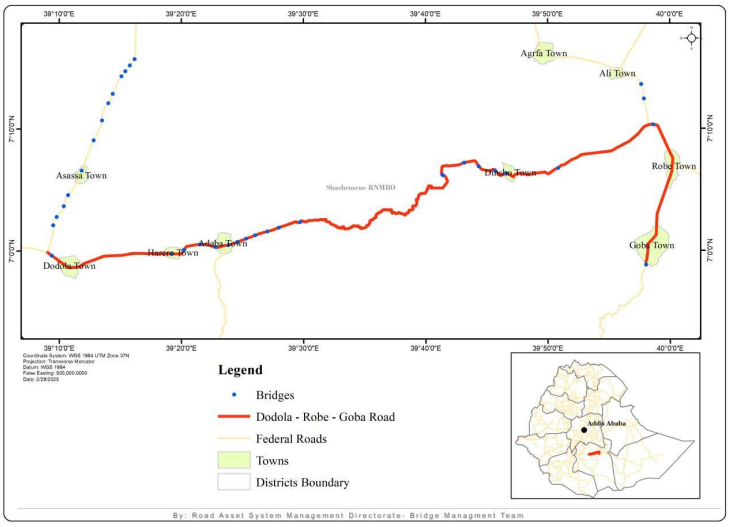


Figure 1 Location map of the study road

2.2 Approach

The methodology adopted in this study is summarized in Figure 2. The flowchart illustrates the sequential procedures followed to achieve the study objectives, beginning with a desk study, followed by field data collection through pavement condition and drainage surveys, traffic data analysis, and finally the development of appropriate maintenance strategies based on the observed pavement condition and traffic loading characteristics. Each stage of the methodology provides necessary information for subsequent stage, ensuring a systematic functional assessment of the pavement.

The study employed three approaches to achieve its objectives: **(i)** desk study, **(ii)** condition survey, and **(iii)** survey analysis as illustrated in Figure 2**.**

A visual assessment was conducted in February 2025 to collect relevant information along the road section to the best possible. The riding quality in terms of international roughness index of the segment was done using the Road lab Pro smartphone-based data collection tool. Road Lab Pro is a mobile-based road condition assessment application developed by the World Bank. It uses smartphone's built-in sensors to measure road roughness and geo reference

pavement condition data in real time. The app automatically calculates International Roughness Index (IRI), which serves as an indicator of ride quality and surface condition [7, 8]. The visual survey & IRI measurements were used together to classify pavement into different condition categories and to identify sections requiring routine maintenance, periodic maintenance, or rehabilitation.

Inspection of the drainage system was conducted to evaluate the effectiveness of both surface and subsurface drainage facilities and to identify signs of ponding, clogged ditches, blocked culverts, inadequate side slopes, and groundwater seepage that could contribute to moisture-related pavement deterioration.

In addition, traffic volume, vehicle composition, and Equivalent Standard Axle Load (ESAL) analyses were performed to evaluate the influence of traffic loading on pavement deterioration. Google Earth and ArcGIS were used to obtain detailed spatial information on the study area and to verify location of observed pavement distresses. Representative photographs were also taken to document the different pavement failure mechanisms observed along the road segment. The investigation of the existing pavement was carried out using a visual windshield survey, during which the extent and severity of each pavement distress were recorded. The windshield survey was conducted from the front passenger seat while traveling at a moderate speed, with frequent reductions in speed and observations from the road shoulder to improve distress identification. The extent and severity of the observed surface distresses were measured using a straightedge and tape measure. The information obtained from these field investigations and traffic analyses formed the basis for classifying the pavement condition and developing the proposed maintenance strategy presented in the subsequent sections.

2.3 Methodology and Rating Criteria

During the visual survey, each distress was identified according to its type, severity (low, medium, or high), and extent following the Ethiopian Roads Administration (ERA) Highway Management System Road Condition Survey Manual. The overall pavement condition rating was established by combining the observed distress severity with the measured roughness values.

RoadLab Pro estimates the International Roughness Index (IRI), which is widely used as an indicator of pavement ride quality. Lower IRI values indicate smoother pavement surfaces, whereas higher values represent rougher riding conditions. Based on the measured roughness and the observed distress characteristics, the road sections were classified into four condition categories: Good, Fair, Poor, and Very Poor as shown in Table 1.

Table 1. Pavement condition rating criteria

Condition rating	Typical IRI (m/km)	Surface condition	Recommended action
Very good	<4	Minor distress	Routine maintenance
Good	4 - 7	Minor distress	Routine maintenance
Fair	7–10	Moderate distress	Preventive maintenance
Poor	10–13	Severe distress	Periodic rehabilitation
Very Poor	>13	Extensive distress	Reconstruction / major rehabilitation

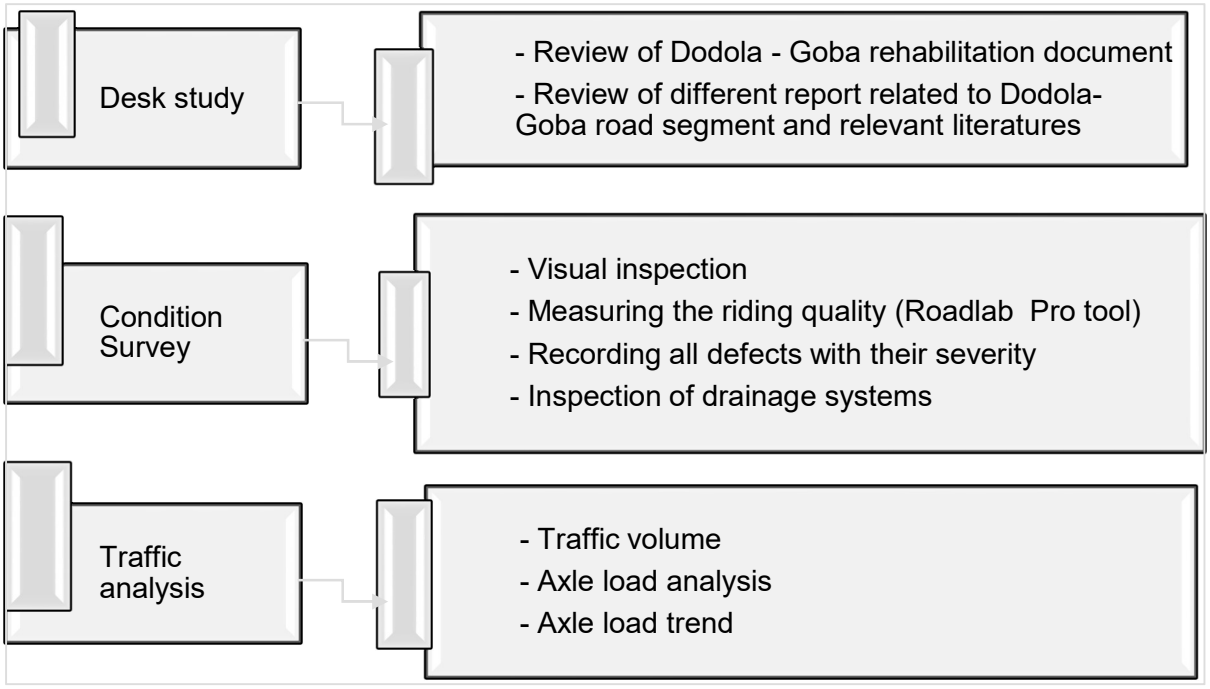


Figure 2 Flow chart summarizing the methods and procedures employed in the study

This study presents a functional pavement condition assessment based on visual windshield surveys, RoadLab Pro smartphone-based International Roughness Index (IRI) measurements, pavement distress observations, drainage condition assessment and traffic loading analysis. Pavement condition ratings were established using the observed distress characteristics and ERA roughness rating criteria. Although these methods provide a practical and cost-effective approach for evaluating long road sections, the visual survey is subject to observer judgment, and the RoadLab Pro application estimates pavement roughness without directly assessing structural capacity. Consequently, detailed structural defects and standard Pavement Condition Index (PCI) or Overall Condition Index (OCI) evaluations, which require comprehensive distress measurements and structural investigations, were beyond the scope of this study. Therefore, the proposed maintenance strategies should be interpreted as recommendations based on functional pavement condition, while future studies should incorporate detailed structural evaluation and life-cycle cost analysis to support comprehensive pavement management decisions.

3 Data Collection

3.1 Condition Survey

The pavement condition survey was conducted to identify and categorize the pavement distresses observed on the road and the extent and severity of the distresses. The potential factors that contribute to respective distress types are also assumed based on the information observed. This data was used as a basis for rating the condition of the road segment there by proposing potential treatment strategies. The detailed visual condition survey covered the road segment from Dodola (km 315+000) to Goba Town km (448+000) covering a total of 133km.

The activities undertaken during the investigation included the following:

- Measurement of pavement roughness using the RoadLab Pro tool. The measured International Roughness Index (IRI) values are presented in Figure 3 and discussed in Section 4.1.
- Visual examination of the pavement condition, including identification of distress types, assessment of their severity levels, and measurement of their extent (e.g., rut depth and pothole depth). Representative measurements obtained during the survey are presented together with the corresponding distress observations in Figures 4.
- Inspection of surface and subsurface drainage facilities to identify drainage deficiencies such as blocked ditches, culvert outlet failures, erosion, and groundwater seepage. The findings are presented in Figures 5 and 6 and incorporated into the proposed maintenance strategy (Table 6).
- Collection and analysis of traffic volume and vehicle composition data for estimating Equivalent Standard Axle Loads (ESALs). The traffic data, ESAL calculations, and loading scenarios are presented in Tables 2 and 3.

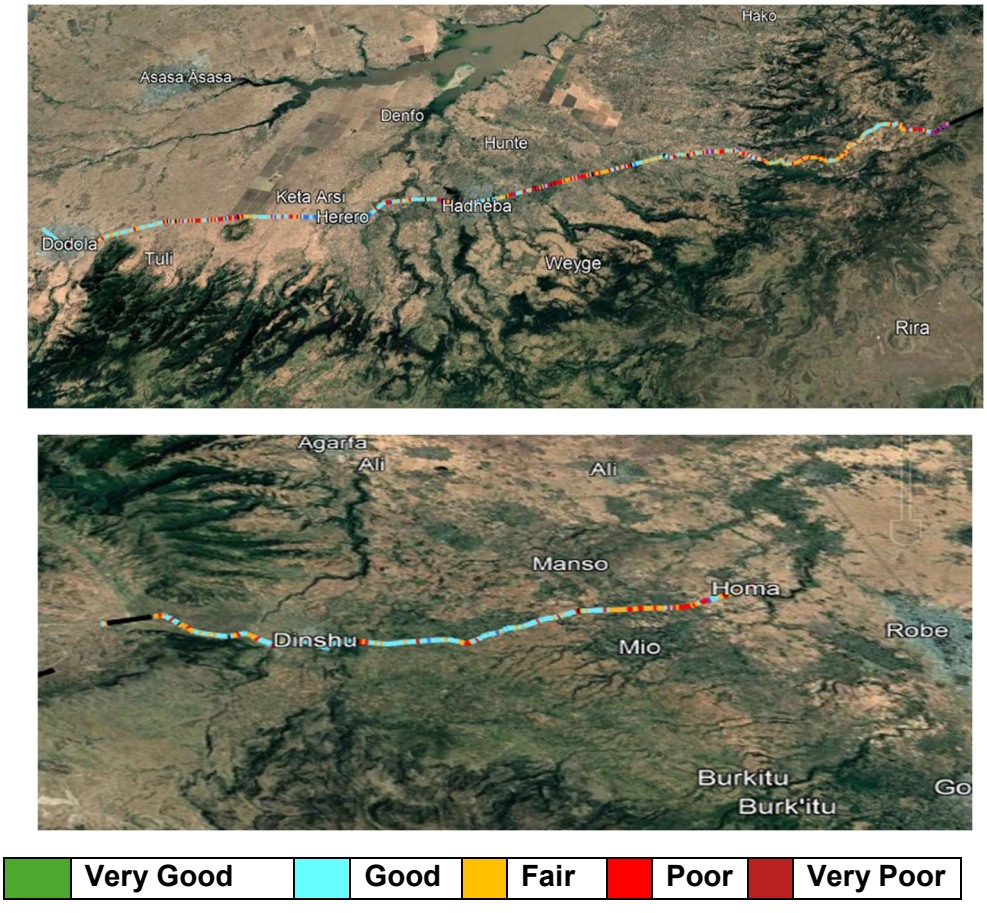


Figure 3 Roughness result from Roadlab pro tool Dodola to Sebsibewasha and Dinsho to Entrance of Robe respectively



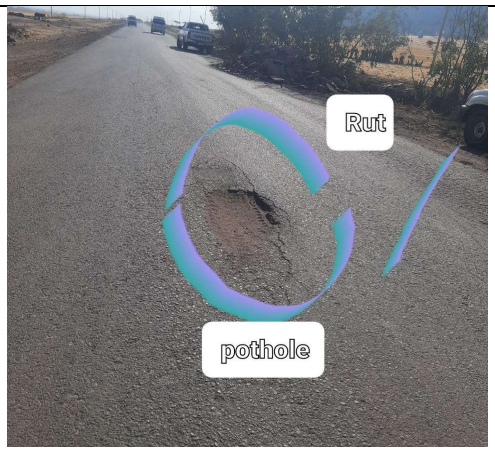


Figure 4 Representative distress observed during the survey



Drainage problem (a)



Shoving of AC (b)



Visible water from subgrade ©



The constructed side ditch is unable to prevent road base saturation(d)

Figure 5 (a - d): Illustrations of drainage issues



bridge outlet erosion



bridge approach failure

Figure 6 Illustrations of bridge outlet issues Km 352 + 0 00

4. Results and Discussion

4.1 Measurement of roughness

The measurement of pavement roughness using the RoadLab Pro tool indicated that most of the assessed road sections fall within the fair to poor condition category (Figure 7). These findings are consistent with the results obtained from the visual condition survey, which also identified extensive surface distress across the study segment. The strong agreement between the quantitative roughness measurements and qualitative visual assessments reinforces the reliability of the evaluation approach and confirms the severity of pavement deterioration. The high roughness values can be attributed to the prevalence of defects such as cracking, rutting, and surface deformation, which negatively affect ride quality and structural performance. This correlation highlights the need for timely and targeted maintenance interventions to restore serviceability and prevent further degradation of the pavement.

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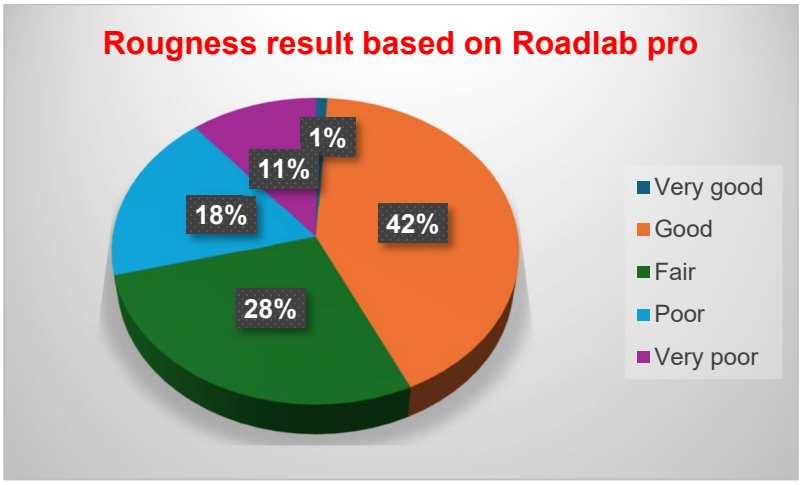


Figure 7 Pavement condition based on roughness

4.2 Categories of Road Conditions

Based on the visual inspection, the condition of the existing road segment was classified into the following major categories:

Segments in Good Conditions; The following sections exhibit low-severity distress, indicating good condition (figure 8).

- From Km361 + 000 to Km 372 (the beginning of Sebsibewash)
- From Km391 + 000 to Km448 + 000 (from entrance of Dinsho to the exit of Goba town)

Road Segments in a good condition	
	
KM 367 + 000	Near Bale

Figure 8 Road segments in good condition

Segments in a Fair and Poor Condition

The following sections are characterized by low to medium-severity distress i.e., fair and poor condition (Figure 9).

- From Km 323+000 (near exit of Dodola town) to Km 340+000 (including small village and Herero Ketema) of the segment routes
- From Km 350+000 to Km 361+000 (including Melka Wakana junction)
- From Km 384+000 to Km 391+000

Road segments in a fair and poor condition	
	
Road in fair condition KM 352 + 000	Road in poor condition @ 346 + 000

Figure 9 Representative illustrations of fair and poor condition

Road Segments in very Poor Conditions

The section from before and after Kelela River which starts from km 340 + 000 to 350 + 000 and the segment near Sebsibewasha from km 372 + 000 to 384 + 000 including the escarpment terrain is rated as very poor (highly severed section) needs heavy maintenance Figure 10.

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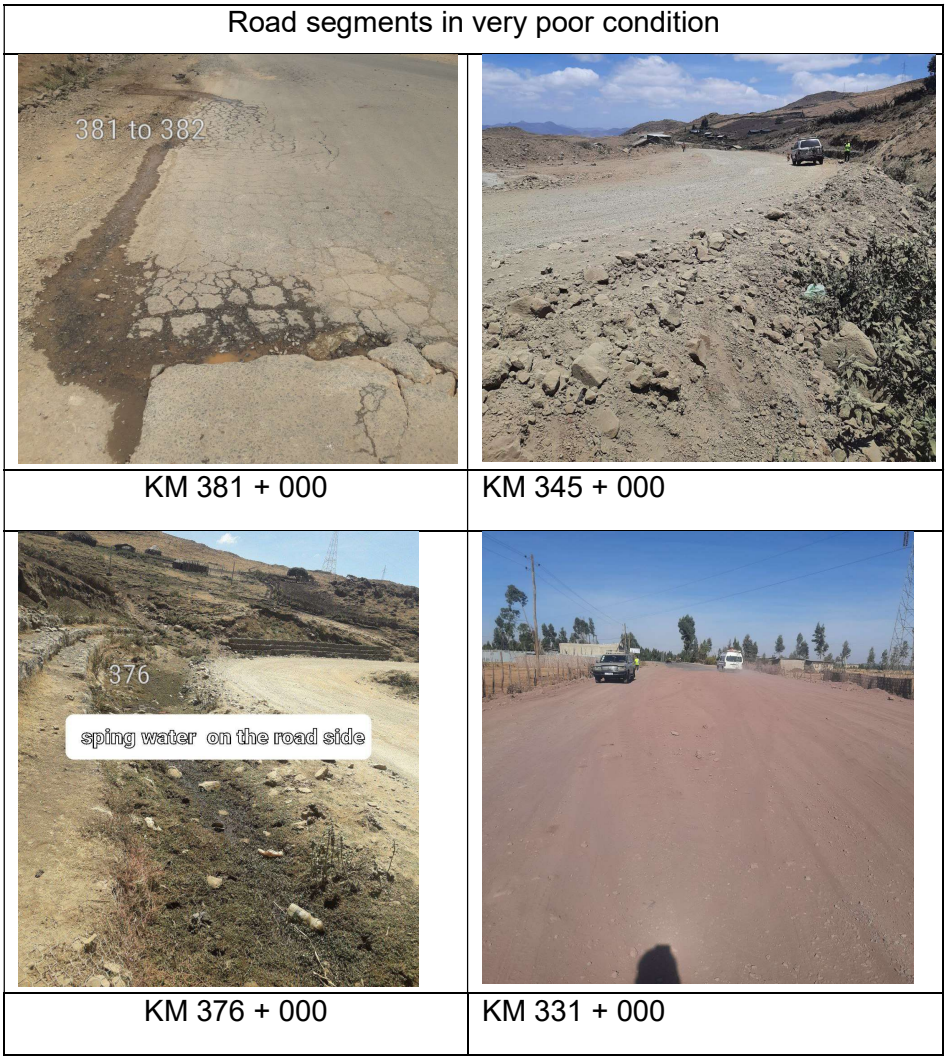


Figure 10 Representative photos for very poor section

Several types of distresses were observed in the surveyed road segment including:

- Pavement deformation
- Edge deformation and shoving
- Major pavement distortion in the form of subsidence
- Severe alligator cracks
- Localized wide and deep potholes
- Small/low severity & scattered potholes
- Longitudinal cracks
- Damaged graveled surfaces
- Patch failure
- Rutting with and without shoving

4.3 Classification of the road segment into homogenous section

A homogeneous section in a road condition survey refers to a continuous stretch of road where the pavement characteristics,

including distress types and severity, are relatively consistent, allowing it to be analyzed as a single unit rather than individual points along the road, simplifying data analysis and maintenance planning [9, 10]. After detailed identification and observation of the various surface distresses developed on the road, the sections are rated based on the extent and severity of the surface distresses and the existing riding quality of the road as discussed below. The road segment is categorized into four sections: Good, Fair, Poor and Very Poor.

Good Section

Of the total road length, 50.54 km (38%) is identified to be in good condition. Visual observation on this section revealed minor cracks, scattered localized potholes and minor surface defects with no major distress. However, routine maintenance should be applied before defects develop into major distress. As mentioned above, most of this rating was noted in the road section between Dinsho town and Goba town.

Fair Section

About 31.39km (23.6%) of the segment road segment is in a fair condition. This is characterized by small/low severity potholes, minor longitudinal cracks and small patches. Most of this rating was noted in the road section between Dodola town and Sebsibewasha.

Poor Section

The poor road section covers a total length of about 30.2 km, which accounts for about 22.7% of the road length. In these sections, the dominant types of distresses are low severity deformation and alligator cracks, frequent and wide/medium severity longitudinal cracking and rarely rutting and shoving. In some portions of the road, frequent and slightly higher severity and medium to high severity deformation, potholes, alligator cracks and longitudinal cracks were observed.

Very Poor

Very poor sections cover 20.9 km (15.7%) of the segment road segment. On this section, almost all types of distresses were identified. Large area of deformation, major pavement distortion in the form of subsidence/pumping, severe alligator cracks, localized wide and deep potholes, shoving and longitudinal crack. The main stretches include from segment from Sebsibewasha (372+000) to km 384+000 and the sections between km 340 + 000 to 350 + 000 are under this rating. Overall, the conditions of the road segment are summarized in Figure 11.

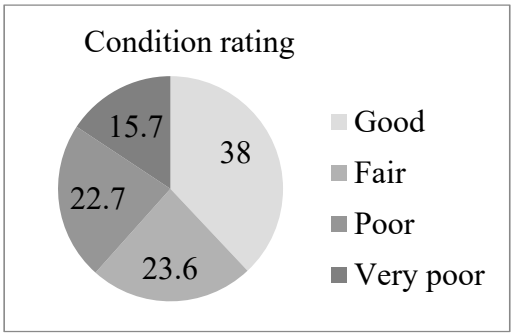


Figure 11 Percentage of Existing Pavement Condition Rating

Using homogeneous sections allows a more accurate analysis and identifies effective maintenance strategies for each homogenous section as a single unit with similar deterioration patterns, rather than analyzing the entire road as one continuous stretch where conditions may vary from location to location. Accordingly, the surveyed 133 km road segment has been classified into 9 homogenous sections as shown in Table 2. Details of the road maintenance requirements are illustrated in Figure 12 for ease of visualizing the conditions of the entire road segment [5].

Table 2 Road stretch with homogeneous section

Section	Chainage	Length in KM
1	315-323	8
2	323-331	8
3	331-340	9
4	340-350	10
5	350-361	11
6	361-372	11
7	372-384	12
8	384-391	7
9	391-448	57
Total	**315-448**	**133**

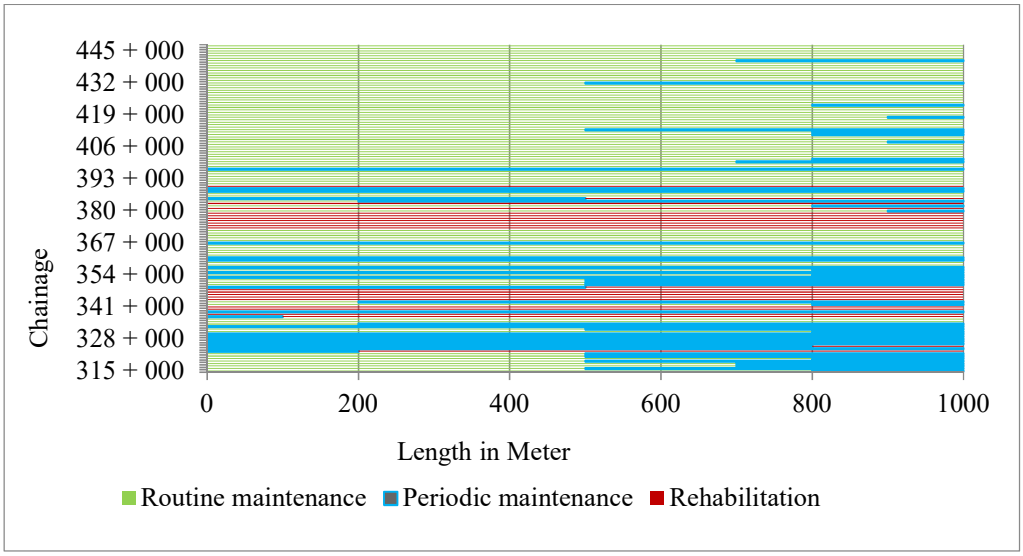


Figure 12 Homogenous section maintenance need Vs Chainag

Table 3 shows the relationship between pavement condition categories (Good, Fair, Poor, and Very Poor) and the corresponding recommended maintenance interventions (routine maintenance, periodic maintenance, and rehabilitation).

Table 3 Pavement condition and recommended maintenance

Pavement Condition	**Typical Distress**	**Recommended Maintenance**
Good	Minor cracking, isolated potholes	Routine maintenance
Fair	Moderate cracking, localized deformation	Preventive maintenance and patching
Poor	Extensive cracking, rutting, edge failure	Periodic rehabilitation
Very Poor	Severe deformation, pumping, widespread failures	Full-depth rehabilitation or reconstruction

4.4 Traffic Analysis

Traffic analysis is an essential important component in understanding pavement failure. It helps to identify the intensity and distribution of traffic loading, which directly influences pavement deterioration mechanisms such as rutting, cracking, and structural fatigue. By analyzing traffic patterns and loads, the primary causes of failure can be identified. Furthermore, traffic analysis supports the development of effective maintenance and rehabilitation strategies. The pavement condition ratings presented in the preceding section were established from the results of the visual distress survey and the measured International Roughness Index (IRI). The following traffic analysis is presented to examine the influence of traffic loading on the observed pavement deterioration and to provide engineering justification for the proposed maintenance strategies.

Traffic volume

Traffic volume plays a significant role in pavement failure analysis, as it directly influences the loading conditions experienced by the road over time [11]. For this study, the Average Annual Daily Traffic (AADT) data (Table 4) collected from ERA Shashamane Road Network Management Branch Office Directorate over the period from 2023 to 2024 was utilized to assess the cumulative traffic loading and its potential contribution to pavement deterioration.

Table 4 Summary of the AADT along Dodola - Goba Road Segment (2023–2024)

Year	Passenger Car	Land rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer	Total Count
2023	53	69	255	103	137.3	121.0	80	76	894
2024	77	104	343	113	245	200	83	133	1297
Total	**130**	**173**	**599**	**217**	**382**	**321**	**163**	**209**	**2191**
Vehicle comp.	**6%**	**8%**	**27%**	**10%**	**17%**	**15%**	**7%**	**10%**	**100%**
%	**51%**				**49%**				
	Passenger transport				**Freight transport**				

The observed AADT increased from 894 vehicles in 2023 to 1,297 vehicles in 2024, representing approximately a 45% annual increase. This growth rate was calculated directly from the official ERA traffic count records obtained from the Shashemene Road Network Management Branch Office. To evaluate the influence of loading uncertainty on pavement deterioration, ESAL analyses were conducted under three loading scenarios (half-loaded, 75% loaded, and fully loaded). The results demonstrate that even under conservative loading assumptions, substantial traffic loading has accumulated within only two years, indicating accelerated pavement deterioration relative to the original design expectations.

In total, 799,715 vehicles traversed the road during this time. Vehicle classification analysis revealed that Passenger Transport Vehicles (e.g., cars, land rovers, buses) made up 51% of the traffic, while Freight Transport Vehicles (e.g., small to heavy

trucks and trailers) constituted 49%. Heavy vehicles, particularly Medium and Heavy Trucks and Truck Trailers that account for around 32% of total traffic, are especially significant due to their high axle loads, which accelerate structural damage through repeated stress on the pavement layers.

Estimated Axle Loading / ESA Analysis

The axle load evaluation was carried out by converting the actual vehicle counts into Equivalent Standard Axles (ESA) using the Axle Load Equivalency Factors (EF) provided in ERA (2013) Standard specifications. The cumulative ESAs for each vehicle class were calculated by multiplying the Equivalency Factor EF(m) by the cumulative traffic volume T(m) for that class. The analysis accounted for three representative loading scenarios: half-loaded, 75% loaded and fully loaded. By applying EF values to the axle configurations under each loading case, the cumulative and total cumulative ESAs were computed using Equations 1 and 2, respectively.

Cumulative ESA(m) = EF(m)×T(m)…Eqn. 1

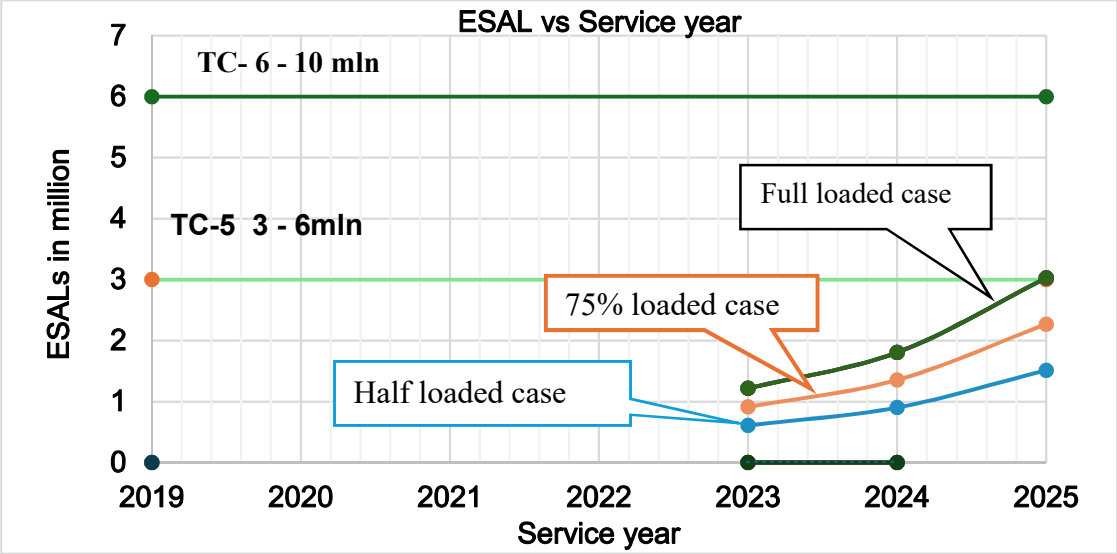
The total cumulative ESA for the roadway was then determined by summing the ESA values across all vehicle classes:

Total Cumulative ESA(m)=∑[EF(m)×T(m)]……..……Eqn. 2

Table 5 presents a summary of the cumulative Equivalent Standard Axles (ESA) calculated for each vehicle class over the analysis period, while Figure 13 illustrates the trend of cumulative ESA plotted against the pavement service years. This graphical representation helps visualize the progressive loading impact on the pavement structure and assess whether the cumulative traffic loading has exceeded the initial designed ESA capacity. The road was initially designed for T-5 traffic class to sustain a cumulative ESA ranging from 3 to 6 million over its design life (20 years). However, under the half-load and the 75% loaded scenario, the road is estimated to have carried 1.5 million and 2.7 million ESAs respectively, over a 2-year service period. Taking the upper boundary of 6 million, the road has carried 25% and 38% of the designed traffic within 2 years, for half-load and the 75% loaded scenario. Similarly, under fully loaded conditions, the ESAs reach 3.03 million. These values fall into the T5 traffic class, it has already sustained the design traffic within 2 years, even ignoring overloading.

Table 5 A summary of the cumulative Equivalent Standard Axles (ESA)

Loading	Year	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer	Total Count
Half loaded	2023	13974.9	37778	37572	110413	174653	234239	608628
	2024	18792.9	41245	67000	182272	181223	412633	903165
	Total	32768	79023	104573	292684	355875	646871	1513819
75% loaded	2023	20962.4	56666	56358	165619	261979	351358	912943
	2024	28189.4	61868	100500	273408	271834	618949	1354748
	Total	49152	118534	156859	439027	533813	970307	2269715
Full loaded	2023	27949.9	75555	75144	220825	349305	468478	1217257
	2024	37585.9	82490	134001	364544	362445	825265	1806330
	Total	65536	158045	209145	585369	711750	1293743	3025612



*Hint 2025 indicates the total ESA for 2023 and 2024

Figure 13 ESAL vs service year along Dodola - Goba Road segment

The analysis clearly reflects a significant increase in axle load burden over time, with freight vehicle classes particularly medium trucks, heavy trucks, and truck trailers contributing disproportionately to the total cumulative Equivalent Standard Axle Loads (ESALs). This trend highlighted the growing structural demands placed on the pavement, exceeding its original design assumptions and contributing to the observed distress.

In general, the observed pavement distresses are closely associated with both traffic loading and environmental factors. Repeated heavy axle loads generate tensile strains at the bottom of the asphalt layer, leading to fatigue cracking and progressive alligator cracking. Continuous traffic loading also contributes to rutting and permanent deformation of weakened pavement layers. In several sections, inadequate drainage, blocked side ditches, and groundwater seepage resulted in saturation of the base and subgrade layers, significantly reducing bearing capacity and causing deformation, pumping, edge failures, and pothole formation. These mechanisms explain the severe deterioration observed particularly within the Sebsibewasha escarpment and Kelela River sections.

Proposed Maintenance Strategy

The Dodola - Goba Road is a critical transportation strategy expected to be in good condition to ensure safe, comfortable, and cost-effective transportation. However, the road shows severe deterioration resulting in road users' dissatisfaction and complaints. The extent of the effort expended to determine the pavement condition is dependent upon the available budget and other resource needs of the project. That is, if sufficient funds are available for rehabilitation, then a higher level of effort should be used to define the pavement and shoulder conditions. Hence, appropriate maintenance strategies are proposed by the team that could be implemented immediately, in the mid- and long-term as discussed below.

Section Requiring Immediate Intervention
Immediate intervention is required for the sections in very poor and poor condition. About 15.7% of the total road segment is in a very poor condition that requires immediate intervention. The main defects and work to be executed for this section are illustrated in Table 6. From the discussion with Shashemene Road Network Management Branch Office (SHRNMBO), it is recognized that there is a critical shortage of resources, mainly equipment to undertake such a work. This requires support at all levels. Generally, it requires emergency work as the condition of some of the road segments is at an unacceptable level. Greater management support on the allocation of resources, mainly budget and equipment as well as commitment from the SHRNMBO at all levels will be required. A special team shall be assigned to support the implementation of the work.

Approximately 22.7% of the total segment length shows severe deterioration. Like the very poor section, this section requires immediate intervention, considered as emergency work, as any further delay to act would lead to a very poor condition. The main defects and works to be executed for this section are illustrated in Table 6. With the availability of the necessary resources, preventive maintenance could be conducted on the sections in fair and good condition. This could be done after the end of the upcoming period. However, activities such as ditch clearing and pothole maintenance shall be managed rapidly.

Maintenance of Major & Minor Drainage Structures
It was also observed that there are structures that are aged and require on-going monitoring of their condition, along with immediate interventions until comprehensive solution can be established (Figure 14 and figure 15). There are frequent drainage structure outlet defects observed along the road. Hence, drainage structures should be maintained as soon as possible.



Active bridge outlet slides km352 + 000



Bridge approach failure

Figure 14 Bridge structure requiring on-going monitoring of their condition



Culvert outlets slide km367 + 000(fill section)



Closed culvert outlet

Figure 15 Culvert requiring urgent intervention

Summary of the Proposed Activities for Homogeneous Section

The proposed maintenance strategies were developed based on the Ethiopian Roads Administration (ERA) Highway Management System Road Condition Survey Manual, the functional pavement condition assessment conducted using visual distress surveys, and the International Roughness Index (IRI) measured with the RoadLab Pro smartphone-based application. The RoadLab Pro measurements were used to estimate pavement roughness, and the road sections were rated according to the ERA roughness classification criteria. The maintenance recommendations were formulated by integrating the observed pavement distress types, severity levels, drainage conditions, IRI-based pavement condition ratings, engineering judgment, and traffic loading (AADT and ESAL) analyses.

Table 6 Summary of the proposed activities for homogeneous section

Section	**Chainage From**	**To**	**Defects Observed**	**Maintenance Activities Proposed (based on a cause-based mitigation approach, as well as PCI, considering pavement damage, primary causes, and guidelines from the ERA Maintenance Manual)**
1 (8km)	315+ 000	323+ 000	Frequent Continuous alligator crack, edge and patch failure, drainage issue, localized alligator crack, delamination, frequent pothole and undulation in the form of deformation	• Full depth patch for sections with deformation, alligator crack, patch and edge failure as well as large potholes • Localized patch for the isolated potholes and localized alligator crack • Provide adequate side ditch that accommodates the surface water

Section	Chainage From	To	Defects Observed	**Maintenance Activities Proposed (based on a cause-based mitigation approach, as well as PCI, considering pavement damage, primary causes, and guidelines from the ERA Maintenance Manual)**
2 (8km)	323+ 000	331+ 000	Frequent alligator crack, graveled surface, frequent patch, surface failure, Minor undulation, shoulder drops off, longitudinal crack, frequent deformation, edge deformation, pothole with deformation, frequent pothole	• Construct the ditch and the pipe culverts that can accommodate the water from the catchment area and will dissipate outside of the road • Full width and full depth patch for sections with gravel surfacing, deformation, patch failure, extensive alligator • Partial depth patch for longitudinal cracks as well as large pothole • Shoulder re-gravel • Localized patch for the frequent isolated potholes, and minor undulation
3 (9km)	331+ 000	340+ 000	Minor pothole, frequent alligator crack and deformation, alligator crack with pothole patch failure, undulation, longitudinal crack, graveled surface, frequent isolated edge failure, scoured side ditch	• Construct the ditch and the pipe culverts so that the ditch water will be dissipated outside of the road • Full width and partial depth patching for sections with gravel surfacing, deformation, patch failure, pothole, alligator crack and undulated surface • Localized patch for isolated alligator cracks, minor potholes, shoulder re graveling, • crack sealing, edge repairs, • Scour protection like channel lining with more erosion resistance material
4 10km	340+ 000	350+ 000	Detached and moved asphalt, frequent sever deformation and alligator cracking, graveled surface, frequent edge failure, undulation, bridge approach and top graveled surface, drainage problem, frequent pothole, fatigue crack with deformation, formation of galley along the road, longitudinal crack, roadside scouring	• This area needs long stretch rigid pavement on a rocky subgrade fill to allow the ground water to pass through without damaging the pavement • Construct the fill under the shoulder with impermeable fill material to abandon the percolation of water under the pavement layers • Construct ditch and pipe culverts so that the ditch water will be dissipated outside of the road • The subgrade fills under the shoulder should be reconstructed by impermeable material to prevent the percolation of ditch water under the subgrade
5 (11km)	350+ 000	361+ 000	Frequent edge deformation, Full-width deformation (5 m) Frequent deformation with alligator crack, Frequent pothole, Bridge approach deformation, scouring at the outlet of the bridge, graveled surface, edge crack longitudinal crack, shoulder drop off, frequent patch failure, scoured/ damaged paved water way, RHS rutting,	• Collect stream water along its natural path, construct ditches and pipe culverts, and discharge water safely away from the road • Full width and partial depth patching for gravel surfacing, deformation, patch failure, pothole, alligator crack and damaged bridge approaches • Crack sealing, pothole patching, edge repairs, cleaning drainage systems • Reconstruct the outlet wing wall and head wall which can resist the side slope's load • Scour protection like channel lining with more erosion resistance material
6 11km	361+ 000	372+ 000	Frequent localized deformation Edge failure, Minor potholes Culvert outlet slide (needs detail investigation), Roadside ditch scouring, and eroded check dam	• Localized patch for the frequent localized deformation, minor potholes, localized edge failure • Scour protection like channel lining with more erosion resistance material

Section	Chainage From	To	Defects Observed	Maintenance Activities Proposed (based on a cause-based mitigation approach, as well as PCI, considering pavement damage, primary causes, and guidelines from the ERA Maintenance Manual)
7 (12km)	372+ 000	384+ 000	Frequent asphalt failure, (deformation), graveled surface, frequent visible spring water on back slope side, frequent alligator crack, edge failure with and without delamination, shoulder drops off, frequent potholes, landslide activity, severe surface and subsurface drainage problem, subsidence, pavement crossing a subgrade with shallow ground water	• Reconstruct the severely damaged road by filling rock to allow the free passage of ground water and give the pavement a good bearing capacity at subgrade level • Provide at least one layer of rock fill in reconstructed area with shallow ground water • Full width and full depth patching on the area with no drainage problem for gravel surface, edge failure, frequent alligator crack, pothole • Properly manage the surface water with side ditch to exclude surface water running to the pavement, shoulder re gravelling
8 (7km)	384+ 000	391+ 000	Frequent localized potholes and alligator crack, frequent edge failure, graveled surface, frequent edge deformation, localized fatigue, lengthy alligator crack, centerline deformation with fatigue crack, surface and subsurface drainage problem	• Partial depth patching for sections with graveled surface, deformation, pothole, alligator crack as well as edge deformation • Collect the stream water by keeping it in their natural way and construct the ditch and the pipe culverts so that the accumulated ditch water will be dissipated outside of the road • Crack sealing, edge repairs, cleaning drainage systems • Construct rigid pavement for a section with subsurface drainage problem
9 (57km)	391+ 000	448+ 000	Localized alligator crack, frequent scattered pothole, rutting, shoulder drop off, localized deformation and patch failure, frequent edge deformation, graveled surface, edge shoving on RHS	• Localized patch for the frequent isolated potholes, localized alligator cracks, shoulder drop off, localized deformation, edge failure, minor rutting, localized patch failure and for gravel surface • Crack Sealing • Ditch clearing
Total 133 km				

6. Conclusion

- The pavement condition survey carried out on the 133 km Dodola (Km 315+000) - Goba town (Km 448+000) road segment revealed that the road is characterized by varying degrees of distress, requiring different levels of intervention.
- The observed deterioration is highly influenced by drainage deficiencies (inadequate side ditches, water from subgrade, bridge approach failures) as well as structural pavement weaknesses in some segments.
- Without timely intervention, the fair and poor sections will rapidly deteriorate into very poor categories, increasing future rehabilitation costs.
- The rapid accumulation of ESAs suggests that the road is subjected to traffic loading far beyond the original design assumptions, resulting in premature distress such as surface gravelling, deformation, cracking, and pothole formation observed during the visual survey.
- At the current traffic growth rate and loading intensity, the pavement is

unlikely to achieve its intended 20-year design life without major structural strengthening or redesign interventions.

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Author contributions

Conceptualization and methodology were performed by all authors; data analysis and interpretation were performed by all authors; supervision was performed by Dr. Worku Asratie, Yitagesu Desalegn and Getahun Mekonnen and reviewing and editing were performed by all authors. The first draft of the manuscript was written by Kefale Adefris commented, edited, and revised the manuscript. All authors have read and approved the final manuscript.

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