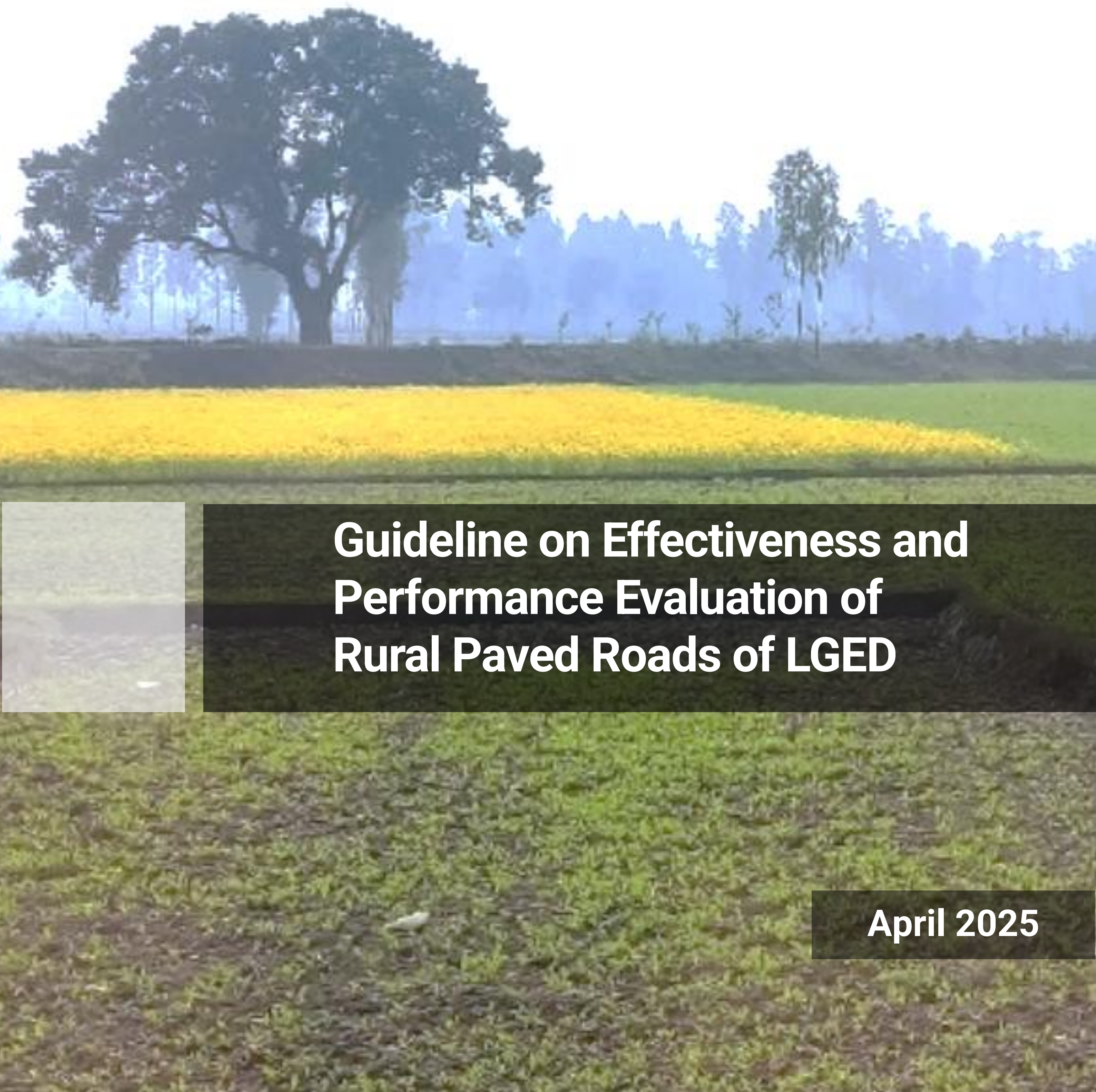
Local Government Engineering Department
Government of the People's Republic of Bangladesh



Guideline on Effectiveness and Performance Evaluation of Rural Paved Roads of LGED

April 2025

Local Government Engineering Department (LGED)
Local Government Division (LGD)
Ministry of Local Government, Rural Development and Co-operatives.
Government of the People's Republic of Bangladesh

FINAL GUIDELINE ON EFFECTIVENESS AND PERFORMANCE EVALUATION OF RURAL PAVED ROADS OF LGED, First Edition

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LGED committee:

Document Version: Version 1.0

Date of Final Version: 01.05.2025

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PREAMBLE

The Local Government Engineering Department (LGED) is entrusted with the critical task of maintaining and developing Bangladesh's extensive rural paved road network, a vital artery for socio-economic progress. To ensure the sustainable functionality and longevity of these assets, regular and reliable performance evaluations are indispensable. These evaluations provide a scientific assessment of road conditions, enabling LGED to identify areas needing immediate attention, prioritize maintenance efforts, and optimize resource allocation. By implementing a standardized evaluation framework, LGED can move beyond reactive maintenance towards proactive asset management, ensuring that limited resources are effectively deployed to address the most pressing needs.

A systematic approach to performance scoring, grounded in scientific methodologies, empowers LGED to make data-driven decisions regarding network improvements. This allows for the development of targeted interventions, such as timely repairs, rehabilitation, or reconstruction, based on objective assessments of road conditions and performance. With reliable performance data at its disposal, LGED can enhance its planning processes, improve the efficiency of maintenance operations, and ultimately deliver a more resilient and effective rural road network that benefits the communities it serves. This report outlines the guidelines for such a framework, aimed at enhancing LGED's capacity to manage and improve its crucial infrastructure assets.

ACKNOWLEDGEMENT

EXECUTIVE SUMMARY

Chapter 1 Introduction

1 Introduction

1.1 Purpose of developing the guideline

The Local Government Engineering Department (LGED) under the Ministry of Local Government, Rural Development & Cooperatives is responsible for planning, developing, maintaining and managing local level rural roads, and urban and small-scale water resources infrastructure nationwide. LGED recognizes that it is essential to manage assets to sustainably deliver appropriate levels of services to the community and to meet the expectations and needs of the present and future generations.

The Local Government Engineering Department (LGED) plays a crucial role in the development of infrastructure in Bangladesh. With its mandate to plan, design, construct, and maintain various infrastructure projects, LGED strives to ensure sustainable and efficient delivery of essential services to the people. LGED is responsible for a vast network of roads that serve as a lifeline for rural and urban communities. To ensure the continued functionality and quality of these roads, it is essential to conduct regular effectiveness and performance evaluations. These rural roads play a crucial role in facilitating access to basic services, transportation of goods, and improving the overall socio-economic conditions in rural areas. Over time, the quality and performance of these roads can deteriorate due to factors like weather conditions, traffic volume, and maintenance practices. To ensure that LGED's efforts are efficient and effective in maintaining rural paved roads, a comprehensive effectiveness and performance evaluation is essential.

LGED created this consulting opportunity to develop *a comprehensive guideline for the systematic effectiveness and performance evaluation of rural paved roads.* The goal of this assignment is to establish a standardized approach of LGED's **road maintenance practices** by developing a detailed guideline outlining the parameters, methodologies, and tools for the effectiveness and performance evaluation of rural paved roads of Bangladesh under LGED.

Infrastructure is a central pillar for sustainable and resilient development. Physical infrastructure assets provide a means for delivering essential services and play an important role in enhancing and protecting the lives and livelihoods of people and for the developing economy to thrive in Bangladesh. The Rural Paved Road network of LGED is the lifeline for the development and prosperity of rural communities of the country. LGED successfully developed a vast network of about 1.5 lakh kilometers of paved roads under its rural road network and maintaining this vast road asset is an enormous challenge.

A comprehensive performance and effectiveness evaluation framework is thus an imperative for LGED. A holistic and comprehensive evaluation framework would ensure cost effective and appropriate data collection and systematic data driven decision making leading to optimization of scarce funding and resources against the monumental task of maintaining the rural connectivity and enabling socio economic growth and development of rural communities of Bangladesh. As an effort to develop an effective evaluation framework, the consultant has worked out the objectives and defined specific tasks for an efficient achievement of the key objectives of the study. The scope of work and tasks are briefly discussed in the following section. This document presents the framework and guideline for performance and effectiveness evaluation of Rural Paved Roads of LGED.

1.2 Broad objective

The broad objective of the study is to develop a performance evaluation framework for rural paved roads of LGED.

1.3 Work Scope

1.3.1 Objectives of the Study

The specific objectives of the study are:

- To develop detailed guidelines for the effectiveness and performance evaluation of rural paved roads managed by LGED.
- To outline clear parameters and criteria for assessing road condition, durability, and functionality in respect to technical, environmental, and socio-economic aspects.
- To provide step-by-step methodologies for data collection and analysis.
- To integrate user-friendly tools for consistent and accurate evaluations.
- To ensure the guidelines are adaptable to varying regional conditions and road types.

1.3.2 Scope of Work

The scope of work of the study are as follows:

- Conduct Literature Review
- Identification of Evaluation Parameters
- Development of Evaluation Guidelines
    - Provide detailed process, parameters, criteria and methodologies for assessment
    - Incorporation of Technological Tools in the guideline
    - Integrate Adaptability and Region-Specific Considerations in the guideline
- Conduct a pilot implementation for pilot performance evaluation and improve the guidelines
- Conduct Capacity Building through trainings and workshops
- Finalization of Performance Evaluation Guideline.

1.3.3 Applications of the guideline

Primary application of the guideline is for evaluation of paved roads of LGED through a systematic and scientific manner for assessment of performance and performance-based ranking of paved roads.

1.3.4 What are LGEDs current practice in this regard

LGED does not have any specific guided method for scoring performance of a road. Currently only maintenance prioritization is done using a ranking of performance.

1.4 Scope of the guideline

1.4.1 Long list of performance indicators

Based on the literature review, and a series of discussions and workshop sessions with LGED concerns, a broad list of themes and criteria were identified. These lists were then grouped into three stages for the implementation.

- **Immediate/ Short term (from 2025, next 3 years)**
- **Near future/ Mid-term (starting from 2028, continue for 5 years)**
- **Future / Long term (starting from 2033, for next 5 years)**

Short term criteria and sub criteria are those for which required data and information can be readily collected by LGED without any major investment in equipment and does not have major dependency on historical records and project specific records. The current report will cover the short-term framework in detail and for the mid-term and long-term framework, will only list the potential criteria and sub criteria. The pilot work and development of the evaluation framework will be limited to the short-term criteria lists presented below. For future development of the evaluation framework the mid-term and long-term phase will have additional criteria and sub criteria in addition to the short-term list. The themes or criteria selected for the performance evaluation framework are listed below

Theme or Criteria	Phase
1. Traffic and Road Safety Assessment	All Phases
2. Pavement Condition Assessment	All Phases
3. Environmental & Climate Condition Assessment	All Phases
4. Drainage Condition Assessment	All Phases
5. Social Impact Assessment	All Phases
6. Economic Impact Assessment	Long term phase

Under each of these themes or criteria, few sub-criteria are finalized for the framework, which are presented below.

Indicator / sub criteria	Phase
1 Traffic and Road Safety Assessment	
1.1 Traffic Volume Count	Short term
1.2 Origin-Destination and Travel pattern	Short term
1.3 Percent encroachment	Short term
1.4 Road Safety and Crash Risk	Short term
1.5 Road signage and marking quality	Mid term
1.6 VRU safety condition	Mid term
1.7 Emergency Vehicle Accessibility	Mid term
1.8 V/C ratio assessment	Mid term
2 Pavement Condition Assessment	
2.1 Crack rate evaluation	Short term
2.2 Pot-hole assessment	Short term
2.3 Rutting evaluation	Mid term
2.4 Layer Thickness assessment	Mid term
2.5 Deflection level measurement	Mid term
2.6 Surface roughness/ Ride quality Assessment	Mid term
2.7 Thermal profiling	long term
2.8 GPR system (void and layer thickness)	long term
2.9 Geophone system (vibration and deflection)	long term
3 Environmental & Climate Condition Assessment	
3.1 Air Pollution increase	Short term
3.2 Noise Pollution increase	Short term
3.3 Road closing days due to climate conditions	Short term
3.4 Flooding severity assessment	Mid term
3.5 Roadside ground water pollution	Mid term
3.6 Saltwater intrusion condition	Mid term
3.7 Roadside soil erosion	Mid term
4 Drainage Condition Assessment	
4.1 Roadside drainage condition	Short term
4.2 Hydraulic structure drainage condition	Short term
4.3 Waterlogging Condition and risk	Short term

Indicator / sub criteria	Phase
4.4 Slope Protection Condition and risk	Short term
5 Social Impact Assessment	
5.1 Agricultural Production increase	Short term
5.2 Industrial Production increase	Short term
5.3 Educational facility connectivity	Short term
5.4 Travel Pattern Changes	Short term
5.5 Health Care facility connectivity	Short term
5.6 Employment Generated by road works	Mid term
5.7 Accessibility induced settlement enhancement	Mid term
6 Economic Impact Assessment	
6.1 Life cycle cost (Construction and maintenance costs) Total and per km costs, for assessing cost effectiveness in initial construction and ongoing construction/ maintenance	Long term
6.3 program completed in budget	Long term
6.4 program completed in time	Long term
6.5 Cost benefit analysis to assess the economic return on investment in maintenance and road improvements	Long term
6.6 Impact on property valuation: changes in property and land value due to improved accessibility and connectivity	Long term

The measures or attributes under the sub criteria are listed below along with their assigned or proposed implementation phase. General attributes / Road Characteristics for sample grouping and comparative performance analysis.

#	ATTRIBUTES	VALUES
A	Road class	Upazila/Union/Village Road A/ Village Road B
B	Pavement type	BC/CC/RCC/BLOCK/HBB/EARTHEN
C	Road type (All weather)	All Weather/Submerged/Regular/Hilly
D	Road length (pilot)*	length in km, considered for pilot data collection
E	Road Design Type	Type 4-8, for Carriageway Width mainly

** For some sites, the road length taken for pilot study assessment is less than the actual road length.*

Table 1.1 List of attributes under each sub criterion with the evaluation framework phase

Sub - criteria	ID	Attributes	Phase
Criteria 1 Traffic and Road Safety Assessment			
1.1 Traffic Volume Count	1.1.1	AADT (Annual Average Daily Traffic) of the Road	Short term
	1.1.2	%Heavy Vehicle or Commercial Vehicle (%CVD)	Short term
	1.1.3	%NMV & %SMVT (Non-Motorized vehicle and slow-moving vehicular traffic)	Short term
	1.1.4	Peak Hour Flow (PCU/hr)	Short term
	1.1.5	Travel speed	Mid term
	1.1.6	Traffic density	Mid term
	1.1.7	Percent followers	Mid term
	1.1.8	V/C Ratio	Mid term
1.2 Origin-Destination and Travel pattern	1.2.1	Difference between %Primary OD pair and %Target OD pair	Short term
	1.2.4	% travel cost increased in 3 years	Short term
	1.2.5	% travel speed decreased in 3 years	Short term
	1.2.7	user satisfaction level (riding quality, safety, mobility)	Short term
1.3 Percent encroachment	1.3.1	% road area encroached by illegal parking or temporary stalls or hawkers	Short term
	1.3.2	% road area encroached by bazar activities, shops fronts, car workshops	Short term
	1.3.3	% road area encroached by permanent structures or shops/ buildings	Short term
1.4 Road Safety and Crash Risk	1.4.1	no. of crashes total per km per year	Short term
	1.4.2	no. of fatality per km per year	Short term
	1.4.3	no. of serious injury per km per year	Short term
	1.4.4	Pedestrian safety condition	Short term
Criteria 2 Pavement Condition Assessment			
2.1 Crack rate evaluation	2.1.1	% cracks on road	Short term
2.2 Pot-hole assessment	2.2.1	No. of potholes/ km	Short term
2.3 Rutting evaluation	2.3.2	% rutting area	Mid term
2.4 Layer Thickness assessment	2.4.1	% change from design thickness	Mid term
2.5 Deflection level measurement	2.5.1	total deflection of road	Mid term
2.6 Surface roughness/ Ride quality Assessment	2.6.1	IRI value of road surface	Mid term
Criteria 3 Environmental & Climate Condition Assessment			
3.1 Air Pollution increase	3.1.1	increase in PM10, compared to acceptable baseline	Short term
3.2 Noise Pollution increase	3.2.1	increase in dB, compared to acceptable baseline	Short term
3.3 Road closing days due to climate conditions	3.3.1	extreme weather related to the inaccessibility of road to users (flood, Cyclone, road or bridge seriously damaged or broken)	Short term
3.4 Flooding severity	3.4.1	flood severity (duration and depth)	Mid term
	3.4.2	flood coverage of road area or % road area flooded	Mid term

Sub - criteria	ID	Attributes	Phase
Criteria 4 Drainage Condition Assessment			
4.1 Roadside drainage condition	4.1.1	drainage condition (flow, continuity)	Short term
4.2 Hydraulic structure drainage condition	4.2.1	flow condition	Short term
	4.2.2	structural stability condition	Short term
4.3 Waterlogging Condition and risk	4.3.1	% of road subject to waterlogging	Short term
	4.3.2	no. of days of waterlogging	Short term
4.4 Slope Protection Condition and risk	4.4.1	structural condition	Short term
Criteria 5 Social Impact Assessment			
5.1 Agricultural Production increase	5.1.1	overall increase in production in the surrounding community owing to the road in the past 5 years	Short term
	5.1.2	% goods vehicle for agricultural goods on the road	Short term
5.2 Industrial Production increase	5.2.1	overall increase in production in union/upazila served by the road in past 5 years	Short term
	5.2.2	% goods vehicle for industrial goods on the road	Short term
5.3 Educational facility connectivity	5.3.1	no. of educational institute directly connected	Short term
	5.3.2	%trips on the road leading to educational institute	Short term
5.4 Travel Pattern Changes	5.4.1	vehicle ownership change	Short term
	5.4.2	increase of motorized trips	Short term
5.5 Health Care facility connectivity	5.5.1	% trips on the road leading to medical facilities	Short term
	5.5.2	no. of medical facilities directly connected by the road	Short term
	5.5.3	no. of facilities that are dependent on this road for access	Short term
5.6 Employment Generated by road works	5.6.1	the number of local jobs generated because of road construction and maintenance work.	Mid term
	5.6.2	is there sufficient program for ensuring gender equality actions through female work group engagements in road works	Mid term
	5.6.3	construction and maintenance work materials supply work for local community	Mid term
5.7 Accessibility induced settlement enhancement	5.7.1	% increase in settlement area within the 2km area surrounding the road	Mid term
	5.7.2	% increase in Nighttime light coverage within the 2km area surrounding the road	Mid term
Criteria 6 Economic Impact Assessment			
6.1 Life cycle cost	6.1.1	Construction costs Total and per km costs	Long term
	6.1.2	Routine and periodic maintenance cost	Long term
	6.1.3	Rehabilitation or upgrade cost	Long term
6.2 program completed in budget	6.2.1	% of program completed in budget	Long term
6.3 program completed in time	6.3.1	% of program completed in time	Long term
6.4 Cost benefit analysis	6.4.1	to assess the economic return on investment in maintenance and road improvements	Long term
6.5 Impact on property valuation	6.5.1	changes in property and land value due to improved accessibility and connectivity (% increase)	Long term

Table 1.2 Unit and data collection methods for each of the attributes

ID	Attributes	Phase	Unit	Method of data collection
Criteria 1 Traffic and Road Safety Assessment				
1.1.1	AADT (Annual Average Daily Traffic) of the Road	Short term	AADT	traffic survey for 12 hours (AADT) video capture, AI processing
1.1.2	%Heavy Vehicle or Commercial Vehicle (%CVD)	Short term	% of AADT	from 1.1.1 modal share video capture, AI processing
1.1.3	%NMV & %SMVT (Non-Motorized vehicle and slow-moving vehicular traffic)	Short term	% of AADT	from 1.1.1 modal share video capture, AI processing
1.1.4	Peak Hour Flow (PCU/hr)	Short term	PCU/Hr	traffic survey for 12 hours video capture, AI processing
1.1.5	Travel speed	Mid term	kmph	speed delay survey, or video capture
1.1.6	Traffic density	Mid term	veh/km	estimated from flow and speed video capture, AI processing
1.1.7	Percent followers	Mid term	%	survey video capture, AI processing
1.1.8	V/C Ratio	Mid term	decimal	Traffic survey, road configuration data and speed/ density data
1.2.1	Difference between %Primary OD pair and %Target OD pair	Short term	no/low/mid/high	market survey
1.2.4	% travel cost increased in 3 years	Short term	%	market survey
1.2.5	% travel speed decreased in 3 years	Short term	%	market survey
1.2.7	user satisfaction level (riding quality, safety, mobility)	Short term	yes/neutral/no	market survey
1.3.1	% road area encroached by illegal parking or temporary stalls or hawkers	Short term	%	video capture
1.3.2	% road area encroached by bazar activities, shops fronts, car workshops	Short term	%	video capture
1.3.3	% road area encroached by permanent structures or shops/ buildings	Short term	%	video capture
1.4.1	no. of crashes total per km per year	Short term	no.	market survey
1.4.2	no. of fatality per km per year	Short term	no.	market survey
1.4.3	no. of serious injury per km per year	Short term	no.	market survey
1.4.4	Pedestrian safety condition	Short term	safe/neutral/unsafe	market survey
Criteria 2 Pavement Condition Assessment				
2.1.1	% cracks on road	Short term	%	video survey AI processing

ID	Attributes	Phase	Unit	Method of data collection
2.2.1	No. of potholes / km	Short term	No.	video survey AI processing
2.3.2	% rutting area	Mid term	%	video survey AI processing
2.4.1	% change from design thickness	Mid term	decimal	GPR survey
2.5.1	total deflection of road	Mid term	decimal	deflection surveys (FWD)
2.6.1	IRI value of road surface	Mid term	decimal	smartphone based or roughometer 4 based or roadroid based survey
Criteria 3 Environmental & Climate Condition Assessment				
3.1.1	increase in PM10, compared to acceptable baseline	Short term	no/low/mid/high	market survey, handheld device survey
3.2.1	increase in dB, compared to acceptable baseline	Short term	no/low/mid/high	market survey
3.3.1	extreme weather related to the inaccessibility of road to users (flood, Cyclone, road or bridge seriously damaged or broken)	Short term	days/year	market survey
3.4.1	flood severity	Short term	Low/mid/high	market survey
3.4.2	flood coverage of road area or % road area flooded	Short term	%	market survey
Criteria 4 Drainage Condition Assessment				
4.1.1	drainage condition (flow, continuity)	Short term	poor/moderate/good	video capture
4.2.1	flow condition	Short term	poor/moderate/good	inspection survey
4.2.2	structural stability condition	Short term	poor/moderate/good	inspection survey
4.3.1	% of road subject to waterlogging	Short term	% length	market survey
4.3.2	no. of days of waterlogging	Short term	days/year	market survey
4.4.1	structural condition	Short term	poor/moderate/good	video capture, inspection survey
Criteria 5 Social Impact Assessment				
5.1.1	overall increase in production in the surrounding community owing to the road in the past 5 years	Short term	no/low/mid/high	from market survey, level of impact in Agri based production increase
5.1.2	% goods vehicle for agricultural goods on the road	Short term	%	% of freight vehicles, market survey
5.2.1	overall increase in production in union/upazila served by the road in past 5 years	Short term	no/low/mid/high	From the market survey, the level of impact in industrial production increase
5.2.2	% goods vehicle for industrial goods on the road	Short term	%	% of freight vehicles, market survey

ID	Attributes	Phase	Unit	Method of data collection
5.3.1	no. of educational institute directly connected	Short term	integer	google map image
5.3.2	%trips on the road leading to educational institute	Short term	%	% of passenger vehicles with students, market survey
5.4.1	vehicle ownership change	Short term	no/low/mid/high	market survey, household survey
5.4.2	increase of motorized trips	Short term	no/low/mid/high	market survey, household survey
5.5.1	% trips on the road leading to medical facilities	Short term	%	market survey
5.5.2	no. of medical facilities directly connected by the road	Short term	no.	google map image / OSM
5.5.3	no. of facilities that are dependent on this road for access	Short term	no.	google map image/ OSM
5.6.1	the number of local jobs generated because of road construction and maintenance work.	Mid term	no.	based on LGED local office database
5.6.2	is there sufficient program for ensuring gender equality actions through female work group engagements in road works	Mid term	yes/neutral/no	LGED database/ work records
5.6.3	construction and maintenance work materials supply work for local community	Mid term	yes/neutral/no	LGED database/ work records
5.7.1	% increase in settlement area within the 2km area surrounding the road	Mid term	%	LGED database/ GIS map / Sattelite image processing
5.7.2	% increase in Nighttime light coverage within the 2km area surrounding the road	Mid term	%	satellite image processing, need time series data at night
Criteria 6 Economic Impact Assessment				
6.1.1	Construction costs Total and per km costs	Long term	Lakh TK	from LGED database or Asset management system, RAMS
6.1.2	Routine and periodic maintenance cost	Long term	Lakh TK	from LGED database or Asset management system, RAMS
6.1.3	Rehabilitation or upgrade cost	Long term	Lakh TK	from LGED database or Asset management system, RAMS
6.2.1	% of program completed in budget	Long term	%	Completion report of project or programs taken for the road, RAMS
6.3.1	% of program completed in time	Long term	%	Completion report of project or programs taken for the road, RAMS
6.4.1	to assess the economic return on investment in maintenance and road improvements	Long term	ratio	based on life cycle cost, CBA analysis. LGED database maintained for road wise historical cost/ benefit information. RAMS
6.5.1	changes in property and land value due to improved accessibility and connectivity (% increase)	Long term	% increase	from LGED database or Asset management system, roadside land use and land price database, , RAMS

Chapter 2 Performance Indicators

2 Chapter 2 Performance Indicators

2.1 Details of the short-term phase performance indicators

The criteria and sub criteria considered for the short-term phase are listed below. Detail discussion of each criterion is presented in the following sections.

Indicator / sub criteria	Phase
1 Traffic and Road Safety Assessment	
1.1 Traffic Volume Count	Short term
1.2 Origin-Destination and Travel pattern	Short term
1.3 Percent encroachment	Short term
1.4 Road Safety and Crash Risk	Short term
2 Pavement Condition Assessment	
2.1 Crack rate evaluation	Short term
2.2 Pot-hole assessment	Short term
2.3 Rutting assessment	Short term
3 Environmental & Climate Condition Assessment	
3.1 Air Pollution increase	Short term
3.2 Noise Pollution increase	Short term
3.3 Road closing days due to climate conditions	Short term
4 Drainage Condition Assessment	
4.1 Roadside drainage condition	Short term
4.2 Hydraulic structure drainage condition	Short term
4.3 Waterlogging Condition and risk	Short term
4.4 Slope Protection Condition and risk	Short term
5 Social Impact Assessment	
5.1 Agricultural Production increase	Short term
5.2 Industrial Production increase	Short term
5.3 Educational facility connectivity	Short term
5.4 Travel Pattern Changes	Short term
5.5 Health Care facility connectivity	Short term

2.2 Criteria 1 Traffic and Road Safety Assessment

Traffic and road safety assessments have four sub-criteria or performance indicators listed below. The intention of these sub-criteria is to assess the accessibility, mobility and road safety performance of the subject road. Definition and measures for each sub-criterion are also described below. Key parameters considered for this assessment are classified traffic volume count, flow, mode share, % of Origin-destination for the primary/target OD pair, travel purpose, cost, time, frequency, % road area encroached by illegal activities (shops, parking, temp struct.), no. of crashes, no. of fatality & serious injury per vehicle km. scoring equation for criteria 1 is given below.

CR 1 = SC 1.1 + SC 1.2 + SC 1.3 + SC 1.4

2.2.1 SC 1.1 Traffic Volume Count

Definition: Traffic volume count is a key indicator for mobility performance of the road, which will provide a clear indication of the level of use of the road by motorized and non-motorized vehicles, and the current level of service of the road based on flow characteristics. The following measures are considered for measuring the traffic volume count indicator.

How to measure: The indicator traffic volume count has four measures or attributes. The score for Traffic volume count 1.1 will depend on the values of these four measures.

Attribute	Data collection method
1.1.1 AADT (Annual Average Daily Traffic) value	Data collected from field survey and LGED historical database.
1.1.2 Number of Commercial Vehicles per day (bus and trucks)	
1.1.3 %NMT (Rickshaw, van and Bicycle) & %SMVT (Battery Rickshaw & Van, Easy Bike, Autorickshaw, CNG)	
1.1.4 Peak hour flow	

The SC 1.1 value or score will be assessed through summing up the four attributes while considering equal weightages for all. So, equation for performance score of SC 1.1 is

SC 1.1 = GW SC1.1.1 * NV + GW SC1.1.2 * NV +GW SC1.1.3 * NV +GW SC1.1.4 * NV

Here, SC = Sub Criteria, GW = Global Weightage, NV = Normalized Value; The definition and measuring units for these attributes are discussed below.

1.1.1 AADT (Annual Average Daily Traffic) of the Road

The annual average daily traffic we can understand the importance and current performance of the road. In a broad sense, the higher the value of daily traffic, the better the performance of the road. However, only after taking into account the road capacity, the performance of the road can be measured effectively. But that indicator is considered for long term phase.

The first step is to identify the design or intended traffic range of the road, based on road width and other geometry. If a road has a highly varying road configuration, then assessment should be done separately for each major homogenous section. After establishing a range of high and low expected traffic volume of the road, the current average daily traffic observed from survey will be compared to check the increase of decrease of traffic volume from expected range. If traffic is significantly lower than expected traffic volume, then the performance of the road is deemed bad. Same way if the traffic is significantly higher than the expected traffic volume, then the road is performing very well. Hence the significance of the variation from the design / intended range of traffic volume yields the performance of the road. This scoring will depend on the design of the road or class of the road.

Unit of measure: deviation from the lower range of AADT (Annual Average Daily Traffic) in Vehicles per day

Baseline for score: To assess the performance score of a road based on the traffic volume or AADT, the observed or estimated AADT of the road is compared to the expected lower bound of the range presented in the above table. The range is developed for LGED road design type or primarily the carriageway width of the roads.

Table 2.1 Expected AADT range for LGED Road design type and carriageway width

Design Type	carriage way	MV AADT*	MV: NMT	AADT
8	3	<300	50%NMT	0-450
7	3.7	300-600	50% NMT	450-900
6	5	600-670	30% NMT	780-871
5	5.5	670-1000	30% NMT	871-1300
4B, 4A	6.1	1000-5000	20% NMT	1200-6000
4SB	6.7	5000-5250	20% NMT	6000-6300
4SA	7.3	5250-7000	20% NMT	6300-8400

**Derived from RHD road design guideline, comparing the carriageway width and linear interpretation.*

To get the performance score we need to check if the linear difference from the expected or design traffic varies significantly. However, checking the significance of variation from a range for a single value (one road's AADT) is not possible through statistical assessment like Z test or T test. The most suitable or reliable check is the linear difference of a road's traffic value from the lower bound of its relevant range. More difference from lower bound indicates lower performance of the road in terms of traffic or mobility. So, if a road has 5.5 m width, and the traffic volume is 700 AADT, then SC1.1.1 score is | 871-700 | = 171. Now, (171/871) = 19.63% lower than the expected lower bound for a 5.5 m carriageway road. For ranking or comparing the score of multiple roads for the various indicators (heterogenous units) the score will be normalized before estimate the total performance score.

Table: Range for scoring

AADT value compared to range	Condition	Score
Higher than the range	Great	4
Within the range	Good	3
0-20% lower than lower bound	Poor	2
20-50% lower than lower bound	Very poor	1
50-100% lower than lower bound	Extremely poor	0

1.1.2 Number of Commercial Vehicles per day (CVD)

From the traffic composition, the percentage of heavy vehicles can be determined. The greater number of heavy vehicles indicates more capacity or performance of the road to carry heavy vehicles. This scoring will depend on the road design class. If a road carries less than the expected number of commercial vehicles as per its class, then the performance is less compared to a road carrying an expected number of commercial vehicles or more.

Unit of measure: Commercial Vehicles per day (CVD)

Baseline for score: similar to AADT, we check the difference or variance from the relevant lower bound of the respective CVD range from the below table. When variance % is high, or the CVD number is quite low compared to expected range, the performance of the road is considered bad. Calculation and other processes are similar to SC 1.1.1

Design Type	carriage way	CVD
8	3	0-50
7	3.7	51-100
6	5	101-200
5	5.5	201-300

Design Type	carriage way	CVD
4B	6.1	301-400
4A	6.1	401-500
4SB	6.7	501-750
4SA	7.3	751-1000

The following table shows the scoring based on the CVD values for a subject road.

Table: Range for scoring

AADT value compared to range	Condition	Score
Higher than the range	Great	4
Within the range	Good	3
0-20% lower than lower bound	Poor	2
20-50% lower than lower bound	Very poor	1
50-100% lower than lower bound	Extremely poor	0

1.1.3 %NMT & %SMVT (Rickshaw, Battery Rickshaw, CNG Autorickshaw)

From the mode share and traffic composition, the percentage of NMT (non-motorized traffic) & SMVT (slow moving vehicular traffic) can be determined. The more percentage of SMVT indicates more importance of the road in terms of local accessibility and mobility. Higher % of NMT indicates comparatively less importance of the road (less long / mid trips and more short trips). Also, NMT is mostly replaced with battery powered alternatives, hence instead of considering NMT% it is recommended to consider NMT and SMVT % collectively to assess the slow moving local short/mid trip vehicles. Less % means the road has higher motorized / fast moving vehicles. So, this is negatively marked or scored. Vehicles considered for NMT and SMVT are listed below

Vehicle category	Type	Remarks
1. Truck Medium	Motorized traffic	Large trucks (>3.5 ton)
2. Truck Light	Motorized traffic	Small trucks (<3.5 ton)
3. Bus Heavy	Motorized traffic	Large interdistrict buses
4. Bus Mini	Motorized traffic	Small bus/ coaster
5. Bus Light	Motorized traffic	Includes microbus
6. Utility	Motorized traffic	SUV, jeep, Pajero etc
7. Delivery Vehicle	Motorized traffic	Small pickups
8. Car	Motorized traffic	Private car
9. Auto Rickshaw	Slow Moving vehicular traffic	Includes easy bikes, CNGs
10. Tempo	Motorized traffic	Leguna, includes Nasimon-karimon
11. Motorcycle	Slow Moving vehicular traffic	Motorbike and scooters
12. Bicycle	Non-Motorized traffic	cycles
13. Rickshaw	Non-Motorized traffic	Pedal and battery rickshaw
14. Rickshaw Van	Non-Motorized traffic	Pedal and battery vans
15. Animal cart	Non-Motorized traffic	Pushcart/ animal cart

 # Easy bikes and CNG are small slow-moving vehicles which are quite different from fast moving vehicles or larger motorized vehicles.

Unit of measure: % NMT & % SMVT of total AADT

Baseline for score: From the AADT table details, total NMT+SMVT is calculated and then the %NMT&SMVT is estimated. From the expected range of the %NMT the score of the road is assessed.

Design Type	carriage way	%NMT
8	3	30%-50%NMT
7	3.7	30%-50%NMT
6	5	20%-30% NMT
5	5.5	20%-30% NMT
4B, 4A	6.1	20% - 0% NMT
4SB	6.7	20% - 0% NMT
4SA	7.3	20% - 0% NMT

The following table shows the scoring based on the %NMT& %SMVT values for a subject road.

Table: Range for scoring

AADT value compared to range	Condition	Score
lower than lower bound	Great	4
Within the range	Good	3
0-20% Higher than the range	Poor	2
20-50% Higher than lower bound	Very poor	1
50-100% Higher than lower bound	Extremely poor	0

1.1.4 Peak Hour Flow (PCU/hr)

The peak hour flow rate is another key performance indicator for the road, as the peak hour flow rate is associated with the level of service of the road and indicates the traffic characteristics of the road. A high peak flow rate generally reflects an important and high performing road (from mobility perspective). Higher flow rates mean better scores.

Vehicle type	Vehicle class ID	Passenger Car Unit (PCU)
All Trucks	1,2	3.6
Bus	3,4,5	3.0
Utility Vehicles	6, 7	1.3
Car	8	1.0
Tempo/CNG	10	1.0
Auto Rickshaw	9	0.6
Pedal Rickshaw	13 14	1.0
Motorcycle	11	0.4
Bicycle	12	0.5
Animal cart/ Pushcart	15	4.0

Unit of measure: PCU per Hour.

Baseline for score: Peak hour flow value in terms of PCU will be directly used for scoring. The scores for various sites will be normalized before inputting in the performance score equation. For the score assessment the following range table will be used to determine the variation from the expected range for each type of road. Lower than the lower bound means poor performance.

Design Type	carriage way width m	PCU/Peak Hour
8	3	<325*
7	3.7	325-400
6	*5*	*401-1000*
5	5.5	401-1000
4B, 4A	6.1	1001-1400
4SB	6.7	1401-1800

4SA	7.3	1801-2200

**For 3m carriageway there is no value in the table, so a linear interpretation is considered.*

The following table shows the scoring based on the Peak hour traffic values for a subject road.

Table: Range for scoring

AADT value compared to range	Condition	Score
Higher than the range	Great	4
Within the range	Good	3
0-20% lower than lower bound	Poor	2
20-50% lower than lower bound	Very poor	1
50-100% lower than lower bound	Extremely poor	0

Global weightage distribution: AADT is the primary attribute for SC 1.1, hence it is given 50% weightage and CVD is given 25% weightage, %NMT&%SMVT is given 15% and peak hour flow 10%.

Method of data collection: With advancement in AI tools and image / video processing, traffic flow data can be collected in a highly effective and economic way compared to the conventional manual tally method for counting. With plenty of commercial platforms available for digitizing the traffic count data for specific vehicle classes, all that is required is to set up an IP or CC camera at the survey location. AI traffic detection tools have the potential to revolutionize the way traffic volume surveys are done. By removing the need for manual observations or human enumerators involvement, the entire process becomes automated, and a real time data assessment can be achieved. Automatic traffic count detection allows automatic recording of class wise traffic count, directional movement ratios, speed.

Traffic datasheets can be automatically generated / exported out of the video processing platform and then the excel datasheet will be processed to generate the daily traffic datasheet, hourly distribution chart and modal share charts. From these datasheets AADT, CVD, %SMVT, Peak hour flow can be easily determined.

Frequency of data collection: A key criterion for selecting the data collection method would be how frequently the data is required to be collected. Data needs to be representative for each attribute as per standard. Traffic data is expected to be collected every year in the dry and wet season, for hat-day and non-hat day. Alternatively using the suggested AI based auto detection method of traffic through CC cameras, traffic data can be collected throughout the year at some base points. These base points can then be used to establish the necessary traffic factors or patterns to facilitate shorter duration survey data at other satellite points (points surrounding the base point or have similar characteristics as the base point). For every union at least one point can be established for data collection round the year.

Cost of data collection: Below is an indicative cost for data collection for various methods as discussed above. Setting up a CC camera with constant power through power bank does not cost much however community engagement is key here as maintenance and preservation of equipment would need active participation from local community or market stakeholders.

Survey system	Cost	Remarks
CC camera setup for a year 365 days 24 hours data	15,00,000/ year	Includes processing data, setup cost, surveyor cost, equipment full price.
CC camera setup for a day 12hours	10,000/ day	Includes processing of data, setup cost, surveyor cost, equipment rent.

The survey will yield all attributes under SC1.1. Prices are indicative only, the budget would highly depend on the packaging of the survey or data collection work (number of fixed stations, duration and other issues like stakeholders' responsibilities and facilities, electricity bill etc.)

Remarks and recommendations: Only challenge for this AI based traffic detection is that the vehicle classes of the software / tools commercially available from reliable vendors does not completely match with LGED standard vehicle classifications. However, this challenge can be easily resolved through specific module development for Bangladesh or LGED traffic classes through a test project. This is particularly needed for unconventional traffic modes plying on rural roads (various versions of battery rickshaw, easy bikes, auto rickshaw etc.). With automatic license plate recognition technologies, it is also possible to get more detail and reliable information of vehicle class by utilizing vehicle registration information. Ratio of registered and unregistered vehicles as well as other key statistics on traffic composition and flow pattern are also possible to assess through integration of such technology.

2.2.2 SC 1.2 Origin-Destination and Travel pattern

Definition: The origin destination is another key indicator of the road performance, which reflects the roads' functional performance in providing the intended accessibility to the community. For OD the following measures are considered. The intention of these measures is to understand whether the road serves its intended purpose or target OD pair as well as understand the travel pattern changes of the road. A trend for increasing travel cost and travel time would mean a lower performance of the road and on the contrary a reduction in travel time reflects better performance of the road.

How to measure: four measures or indicators considered for OD as discussed below.

SC 1.2 = GW SC1.2.1 * NV + GW SC1.2.2 * NV +GW SC1.2.3 * NV +GW SC1.2.4 * NV

1.2.1 Difference between %Primary OD pair and %Target OD pair

An indirect measure to understand the functional performance of the road, whether the road serves its intended purpose. A Upazila road by definition will have major traffic flows towards or coming from the upazila HQ and generally have origin destination routes either connected with RHD highway network or at least with other upazila road networks. Also, the Major OD pair for upazila roads are to be long distance (transfer to highway network). Hence if the major OD pair is short distance and drastically different from the target or intended OD pair (decided by LGED), the performance of the road will be considered poor from a functional / accessibility perspective. So, the intended OD or target OD is determined from the following table and the primary or observed OD is estimated from the FGD or market survey through questionnaire interviews.

Road type	Commercial	Private vehicles
Upazila Roads	Should include Upazila HQ, within district, or long distance via highway network.	Long distance mostly
Union Roads	Within upazila, between union and upazila HQs	Within upazila mostly
Village roads	Village to GC and within village	Within union mostly

The assessment of this attribute is still qualitative, or indicative based on the responses of the market survey. Focus is given on most frequent travel mode and its associated dominant OD pair.

During the market survey, the dominant Origin and destination for commercial and private vehicles are asked for each prominent bazar area. From the responses, the expected OD (as mentioned in the above table) is compared with the observed OD pattern. If the average responses for OD for both vehicle classes match its respective expected OD pattern, it is considered that the road has a good performance in terms of serving its intended OD. Scoring defined in the base of scoring section below.

Base of scoring:

OD pattern compared to Range	Condition	Score
Low variation from expected OD	Good	3
Moderate variation from expected OD	Fair	2
High variation from expected OD	Poor	1

1.2.2 %travel costs increased in 5 years

An indirect measure to reflect the overall accessibility option improvement or change in travel cost between the major OD pair for the last 5 years. A decrease in travel cost generally indicates better performance of the road in terms of accessibility, while an increase of cost means the road has a declining performance in terms of accessibility. Scoring is done on direct values from field (average of the field survey responses). From field survey responses the average travel cost increase is assessed.

1.2.3 %travel speed increased or decreased in 5 years

An indirect measure to reflect the overall travel pattern change or variation in travel speed between the major OD pair for the last 5 years. An increase in speed indicates better performance of the road, while decrease will reflect the road has a declining performance. Scoring is done on direct values from field (average of the field survey responses). From field survey responses the average travel cost increase is assessed.

1.2.4 User satisfaction level on ride quality, traffic congestion and road safety

A user satisfaction level check for the road where the people's perception on ride quality or pavement condition level, traffic congestion level and road safety situation are assessed through the questionnaire survey. Higher satisfaction means better performance of the subject road. Scoring is done on direct values from field (average of the field survey responses). Three classes are defined for scoring to mark the performance of the road as satisfactory, neutral or not satisfactory. Scoring basis is given in the table below.

Base of scoring:

Average User satisfaction Level	Score
Satisfactory	3
Neutral	2
Not satisfactory	1

Note: the following is same for all attributes under SC1.2

Frequency of data collection: Survey to be repeated once every year.

Cost of data collection: Depends on the road length and number of prominent markets or growth centers associated with the road. For a typical road with less than 3 markets associated with the road the survey can be done within one day. Hence a per day rate for covering 3 market surveys could be useful for budget assessment. Rates for per day survey could be 6000 tk considering 1 surveyor. Note the market survey data will collect a lot attributes / indicators information for other sub criteria as well hence the price would be justified for an elaborate questionnaire survey work.

Method of data collection: Questionnaire surveys on digital platforms that can provide quick dash boards illustrating the OD routes or diagrams can be utilized for this measure. A LGED network along with the Key establishments, namely Upazila HQ, Union HQ, GC, Rural market etc. A RHD road network should also be incorporated in the map / application to check the OD of roads that connect LGED network to RHD network. Field OD data will be collected through FGD at local markets where people will be interviewed to identify the most dominant origin and destinations of trip through the route or corridor under survey. Then based on the classification the intended OD will be determined based on the location of the corridor. The questionnaire will include the most frequent origin, destination, trip time and average trip cost for various modes of transportation. It is also essential to cover all OD patterns as trucks or commercial vehicles may have different OD than the NMV.

2.2.3 SC 1.3 Percent encroachment

Definition: The road encroachment negatively impacts the mobility of the road and is detrimental to its performance. In a broad sense, the higher the encroachment the lower the performance of the road.

How to measure: The % of road encroachment is evaluated from three measures, listed below,

SC 1.3 = GW SC1.3.1 * NV + GW SC1.3.2 * NV +GW SC1.3.3 * NV

1.3.1 %road area encroached by illegal parking or temporary stalls or hawkers or agricultural activities (hey stock, cattle tying on roadside).

Most common in bazar or commercial areas of the road. For rural roads in bazar areas, it is observed in general that autorickshaw, van and other vehicles are parked on the road often for loading / unloading purpose of goods or waiting for passengers. In case of prominent bazars power tillers, pickup trucks are also parked directly on the road, narrowing the road width and causing congestion and safety risks. The vegetable and other vendors in bazars occupy the road side / part of the road to setup their stall encroaching part of the carriageway. In most growth centers or rural markets parking facility or arrangement is not planned or available forcing or encouraging people to illegally encroach the road for parking (when road side space is narrow or encroached by other temporary vendors or shop fronts). Hey stocks, paddy drying, tying cattle on the roadside is also a major concern for road encroachment and road safety as these encroachments drastically reduce the effective carriageway width.

Base of scoring: Scoring is done on direct values for the attribute (percent of encroachment). These percentages will be normalized during ranking operation.

1.3.2 %road area encroached by bazar activities, shops fronts, car workshops.

Most common in commercial areas, rural markets and other bazar areas. It is a common malpractice of illegally occupying part of verge, shoulder or road to extend the shop front area. This is notoriously done for automobile workshops or other showrooms. In bazar area many shops / vendors extend their shop fronts by illegally encroaching part of the road, tea stalls / restaurants, fruit shops, and many other retailers or small shops do the same.

1.3.3 % road area encroached by permanent structures or shops/ buildings.

This is a special case and typically rare. But in case of suburban sections or urban areas of a LGED road, people construct permanent structures like market buildings, commercial establishments or residential buildings encroaching part of the road area. This seriously impacts the roadside safety issue as the road width is reduced or narrowed down and shoulders / verge portions are completely encroached. These encroachments are difficult to remove and have long term impact on safety.

***Note**: Base of scoring, Data collection Frequency and costing is same for all attributes under SC 1.3.*

Frequency of data collection: Drive through Survey to be repeated once every year.

Cost of data collection: Depends on the road length. Per road per day an approximate 10000 BDT is proposed considering coverage of more than 10km road length (round trips) and all other costs including all payments for surveyors, data processing, driver etc.

Method of data collection: the percentage of road encroachment can be done in three ways. One is the contemporary manual process where a field team will survey the road to record the areas of the encroachment per category and plot them in a GIS platform or simply calculate the total area of the encroachment in a datasheet to get the % of encroachment. The other methods involve collecting the video of the road and using AI processing to identify the area of encroachment. Another approach would be to utilize the spatial analysis of either satellite image or drone ortho mosaic images. Using advanced image processing and AI tools, from drone ortho mosaic imagery or from high resolution satellite imagery road encroachment area can be identified and mapped at a mass scale. While satellite image use is more convenient, drone images offer more reliability.

Remarks and recommendations: The video capture process can yield both pavement condition assessment data as well as roadside land use, road furniture, road marking and road encroachment information. Hence it is recommended that use of AI processing should be prioritized for getting a reliable assessment of encroachment. However, when drone image or high-resolution satellite image archives are available to LGED, these images can be processed using AI to quickly assess the level of encroachment for the rural road. In future for the mid-term or long-term approach, different scoring for different encroachment types can be adopted for achieving a better comparison between sites.

2.2.4 SC 1.4 Road Safety and Crash Risk

Definition: road safety condition assessment of a particular road can be done through a market interview survey or focus group discussion with the local community at the prominent bazars on the road. As the crash data on the particular road is not available in a systematic manner, as a surrogate measure the community survey can reflect on the existing crash risk scenario at site. Based on the likelihood of a crash and the approximate total number of fatal and serious injuries per year, the road safety and crash risk of a road can be defined.

How to measure: crash risk likelihood and number of casualties in past 3 years. While information for fatalities is collected with more context, the serious injuries information is collected more like a trend / frequency of events rather than actual number or specific details of events. For example, during the survey if there was a fatality on the road, specific information can be sought after, like where the accident was, how long ago, who was involved in the crash. But in case of injury crash events people typically respond that there's multiple events every month, so it is not possible to get specific information on each event, rather a trend is established from the interview, what are the most common type of injury crashes, which vehicles are involved and what is the frequency. Through market survey the number of road crashes, number of fatalities and number of serious injuries are recorded for the subject road. From which a per km number of crashes, fatality and SI can be estimated. However, as these are not accurate figures and are subject to perception and possible exaggeration from the interviewees, instead of using an exact number for the events, the likelihood or risk is used for assigning an appropriate safety score to the road. In case there are multiple surveys done for a single road; the average score would be used in the performance evaluation equation.

SC 1.4 = GW SC1.4.1 * NV + GW SC1.4.2 * NV +GW SC1.4.3 * NV+GW SC1.4.4 * NV

1.4.1 no. of crashes total per km per year

Total no. of road crashes occurred within the portion of the road per year. The measure unit is per km of the road to make this a comparable attribute. The values are collected as a range or likelihood of a crash as presented in the table below.

1.4.2 no. of fatality per km per year

Similar to the crash parameter, from the market interview survey the likelihood of total number of fatalities per year per kilometer is estimated.

1.4.3 no. of serious injury per km per year

The serious injury per km per year data is collected simultaneously with the fatality and crash data. These are approximate values or likelihood of an event instead of accurate figures.

Base value and scoring: For the above three attributes 1.4.1~1.4.3, same base of scoring is applied. the Likelihood of fatalities and serious injuries from road crashes are recorded based on the following table.

Likelihood	Risk	Event frequency for Crash/Fatality/Serious Injury	Score
Frequent	Extreme	Once or more in a month	4
Likely	High	Once or more within the last 6 months	3
Occasional	Moderate	Once or more within last year	2
Unlikely	Low	Once or less within the last 3 years	1

Here, fatality is considered death due to road accident, on spot or in hospital within 30 days of the road crash, while serious injury from a road crash is considered when the victim has to be hospitalized for treatment. The likelihood of slight injury and property damage only accidents are not considered in this assessment.

1.4.4 pedestrian safety condition

People or respondents' perception of pedestrian safety issues, whether they feel safe to walk along or across the road and what do they think of the overall safety condition for pedestrians. This is a qualitative assessment of road user satisfaction of the pedestrian facilities of the subject road.

Base of scoring:

Average Pedestrian Safety Level	Score
Safe	3
Neutral	2
Not Safe	1

***Note**: Data collection Frequency and costing is same for all attributes under SC 1.4.*

Frequency of data collection: Survey to be repeated once every year.

Cost of data collection: Data to be collected during market survey, hence cost is included in SC 1.2.

Method of data collection: Market interview survey or Focus group discussion survey at prominent markets on the road. In future the data should be collected directly from a crash database instead of relying on surrogate measures. However, injury surveys have an extremely high likelihood of being underreported even in a crash database system for a rural road network. Hence for injury events such person or community survey-based approach will still prove useful to compensate for the underreporting of the injury crashed.

Remarks and recommendations: For proper crash risk assessment there's no alternative to proper crash data collection and a modern crash data management system. In an advanced RCDMS crash records are systematically archived and as required queried to present the crash patterns and crash rates along with spatial assessments. GIS integration is a key advantage of using a modern RCDMS. But lack of crash records can pose a serious challenge to safety assessment of rural roads. It is necessary to adopt short term and long-term assessment goals to tackle the issue. For example, utilizing surrogate measures, like FGD, market interview surveys, key informant interview surveys, a rough indication of crash records can be collected for a rural road where proper crash records are absent. However, with advancement in AI tools, it is possible to do text mining from various crash information sources and extract key information fields from social media posts, news and other sources. For RSA and RSI also drone and satellite imagery can greatly benefit the auditor in assessment of the road safety aspects. Image processing and geospatial tools can be utilized to automate identification and assessment of high-risk geometric features of existing roads or a scheme. When the crash records are collected in a systematic manner and with acceptable coverage on rural road networks, the performance evaluation framework may be updated to use the actual crash / FSI numbers instead of the risk/likelihood range scoring.

2.3 Criteria 2 Pavement Condition Assessment

Pavement condition assessments have a total of six sub-criteria or performance indicators listed below. The intention of these sub-criteria is to assess the pavement surface condition, ride quality and pavement structure condition and rideability performance of the subject road. Out of the six, two key attributes are proposed for short term phase framework, while rest of the four is proposed for the midterm phase. All Six key Sub criteria and associated attributes for this assessment are given below.

Sub criteria	Attribute	Phase
2.1 Crack rate evaluation	2.1.1 % cracks on road	short term
2.2 Pot-hole assessment	2.2.1 No. of potholes / km	short term
2.3 Rutting evaluation	2.3.1 % of rutting area	short term
2.4 Layer Thickness assessment	2.4.1 % change from design thickness	Mid term
2.5 Deflection level measurement	2.5.1 total deflection of road	Mid term
2.6 Ride quality Assessment	2.6.1 IRI value of road surface	Mid term

The measurement equation for criteria 2 is given below:

CR 2 = SC 2.1 + SC 2.2 + SC 2.3

Definition and measures for the short-term phase sub-criterion are described below.

2.3.1 SC 2.1Crack rate evaluation

Crack rate evaluation is a critical measure for pavement condition assessment. The % area of cracks per km reflects the surface condition of the road. For this sub criteria the attribute considered is Crack density, or the number of cracks per unit area. This attribute is assessed to understand the extent of cracking for the subject road. The severity levels of cracks are classified as minor (hairline cracks), moderate (partial cracks), and severe (alligator cracks). Minor cracks: Less than 0.5 mm in width. Moderate cracks: 0.5 to 2 mm in width. Severe cracks: Greater than 2 mm in width. Typical road condition surveys (rapid and detailed assessment survey) rely on visual inspections involving manual identification and documentation of surface cracks (area and numbers). While straightforward, this method is time-intensive and subject to human error.

How to measure:

SC 2.1 = GW SC2.1.1 * NV

2.3.2 SC 2.2 Pothole assessment

Pothole assessment involves identifying and measuring the size and depth of potholes using measuring tapes and depth gauges. The number of potholes per kilometer is recorded to assess the severity of the issue. This assessment is crucial because potholes can significantly impact vehicle safety and comfort, and they indicate underlying structural problems in the pavement. Pothole density, or the number of potholes per kilometer, is used to prioritize repair needs. Minor potholes: Less than 50 mm in depth and 300 mm in diameter. Moderate potholes: 50 to 100 mm in depth and 300 to 500 mm in diameter Severe potholes: Greater than 100 mm in depth and more than 500 mm in diameter.

How to measure:

SC 2.2 = GW SC2.2.1 * NV

2.3.3 Review of Relevant Codes and Benchmarks

The ASTM E3303-21 standard specifies how to compute PSCM and PSCI based on measured crack length (L), crack width (w), and the area (A) of each analysis tile:

$$PSCM = (100 * L * w) / A$$
$$PSCI = 100 * \exp(-0.45 * PSCM)$$

The PSCI transforms a physical crack density metric into a standardized index ranging from 0 (worst) to 100 (best). This can be aligned with maintenance decisions, as Nguyen's Singaporean study proposed three severity thresholds: PSCI ≥ 75 (low severity), 50 < PSCI < 75 (moderate), and PSCI ≤ 50 (high severity).

Balzarini (2021) clarified that while PSCI is not a direct replacement for PCI, it functions as an analogous surface condition index. Their methodology split each road segment into standard zones—central, wheel-path, and edge—and further into tiles, each analyzed for crack dimensions using either laser or high-resolution imaging. Critically, this method allows PSCI to be computed even with partial coverage or irregular data—making it ideal for image-based surveys using regular video.

The AASHTO R85 protocol complements this by setting detection performance standards for automated image analysis tools. Systems should identify at least 85% of cracks wider than 5 mm and 60% of those between 3–5 mm, with a minimum detection accuracy of 33% for finer cracks. These standards, although developed for high-fidelity imaging, serve as validation goals for AI-based detection models operating on standard RGB images, including those used for pothole and patching detection.

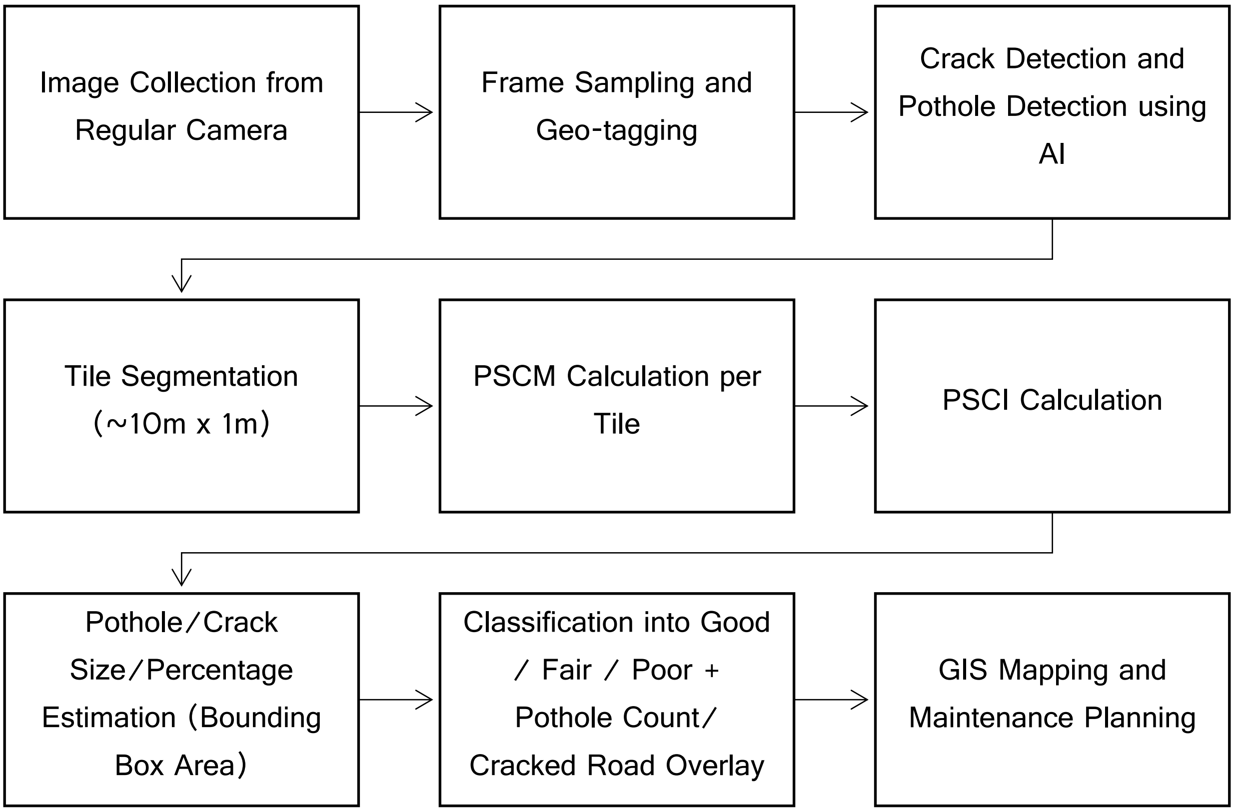


Figure 1 Flowchart PSCM/PSCI Calculation and integration to LGED framework

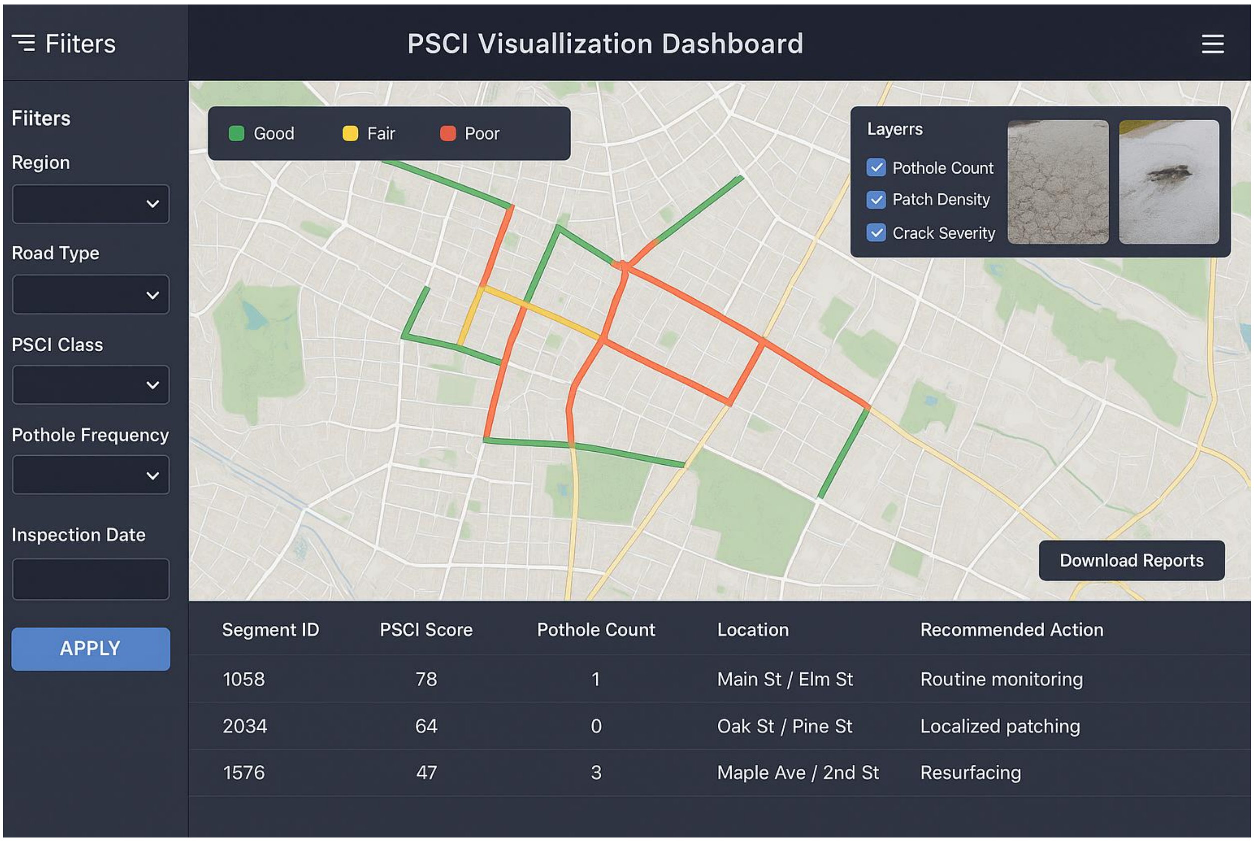


Figure 2 Example Software Capacity

2.3.4 Evaluation of LGED Road from Potholes and Cracking Parameters

3.1 Contextual Challenges for LGED

LGED manages an extensive rural road network composed of both paved and unpaved segments. Manual inspection is time-consuming, subjective, and difficult to scale. Advanced laser scanning systems like LCMS-2 are cost-prohibitive for widespread use in Bangladesh. Therefore, LGED requires an intermediate standard that allows for scalable, repeatable, and objective assessment using accessible tools.

A practical solution involves vehicle-mounted cameras (such as dashcams or smartphones) and AI models trained to detect surface distresses from these images. While the lack of laser resolution restricts precise measurement of crack widths and pothole depths, visual estimation of crack area coverage, pothole size, pattern density, and continuity allows PSCM and thus PSCI to be approximated.

3.2 Adapting PSCI and Pothole Detection for Visual Rating from Regular Cameras

LGED can adopt the PSCI scale as a proxy for crack-based pavement condition and use object detection algorithms to identify potholes. A simplified workflow is as follows:

1. Data Collection: Use standard video cameras to collect pavement surface imagery across 10 m segments.
2. AI Detection: Use neural networks (e.g., U-Net, YOLOv8) to detect cracks and potholes.
3. PSCM Calculation: Use tile-based segmentation to compute estimated PSCM values, interpolated from visible crack data.
4. PSCI Assignment: Convert PSCM to PSCI using:

PSCI = 100 * e^(-0.45 * PSCM)
or the alternative version by Balzarini:
PSCI = 15 + 85 * e^(-0.64 * PSCM)

5. Pothole Quantification: Count potholes and estimate size using bounding box dimensions against lane width references.
6. Condition Rating:
   - PSCI ≥ 75 → Good
   - 50 < PSCI < 75 → Fair
   - PSCI ≤ 50 → Poor
   - Supplement with pothole counts or patching severity as a qualitative layer

2.3.5 SC 2.3 Rutting Area assessment

Rutting evaluation involves measuring rut depths using straight edges and rulers and documenting the extent and severity of rutting along wheel paths. This is usually done annually or after significant traffic increases to ensure that ruts are identified and mitigated before they compromise road safety. Minor ruts: Less than 10 mm in depth. Moderate ruts: 10 to 20 mm in depth. Severe ruts: Greater than 20 mm in depth. Rut depth, measured from the lowest point of the rut to the highest point of the pavement surface, is a key parameter in this evaluation.

How to measure:

SC 2.3 = GW SC 2.3.1 * NV

2.3.1 Rutting area length / km: Data is collected using an action camera mounted on a car / jeep and then by data enumerators visually assess the rutting length from the video. From the geotag the start and the end of the rutting section is noted and then the total length of such sections is calculated. Then by dividing the length of the road, the rutting area length per km of the road is estimated.

Unit: Rutting area length / km

Data collection frequency: Same as for 2.1 sub criteria.

Data collection Cost: similar to 2.1 sub criteria. Video collection will not no extra cost, but per km manual detection cost should be 200 tk (instead of the AI processing rate).

Recommendations: AI based automatic rutting detection methodologies need to be implemented in the midterm and later phases which will remove the need for manual detection and assessment. However, at the moment the technologies available require experimental setup involving laser modules and very high-level accuracy for GPS and these methods are not commercially available or tested on a mass scale or industry level. Hence the guideline recommends adopting a video based manual detection method while proposing automatic detection for later phases when more commercial or industry tested options will be available.

2.4 Criteria 3 Environmental & Climate Condition Assessment

The criteria Environmental & Climate Condition Assessment has three proposed sub criteria for the short-term phase of ethe evaluation farmwork.

Sub criteria	Attribute	Phase
3.1 Air Pollution increase	3.1.1 increase in PM10, compared to acceptable baseline	Short term
3.2 Noise Pollution increase	3.2.1 increase in dB, compared to acceptable baseline	Short term
3.3 Road closing days due to climate conditions	3.3.1 extreme weather related to the inaccessibility of road to users	Short term

How to measure: For these criteria the following measures are considered; increase in PM10 or air pollution due to road activities, increase in sound pollution, number of road closure days per year due to extreme weather-related events. The last sub criteria present the inaccessibility of road to users, due to road section being flooded, road section being damaged or washed away, structure broken or damaged.

2.4.1 SC 3.1Air Pollution increase

The attribute used for short term phase or pilot implementation stage is the increase in PM10, PM2.5 compared to past 3 years. The data is collected from a market survey. Direct measures through portable device were also attempted but the results were not consistent or usable for the pilot assessment work. Hence an indirect or qualitative attribute is used for this sub criteria assessment.

3.1.1. The increase in PM10, PM2.5 compared to past 3 years: during market survey the historical trend or increase in air pollution considering past 3 years is assessed to score the pilot sites in the following range. Key reason behind the increase is also collected from respondents.

- Low level increase score 1
- Medium level increase score 2
- High level increase score 3

Recommendations: Using suitable air quality measurement device that can record the PM 2.5 PM 10 values, directly in a series of events or log basis with acceptable accuracy for outdoor assessment air Pollution Due to Road Infrastructure and Activities can be assessed as a direct measure or attribute for sub criteria 3.1. Details for this attribute is given below.

Air Pollution Due to Road Infrastructure and Activities: Emissions of particulates, gases, and other pollutants generated by road materials, traffic, and maintenance activities that impact ambient air quality.

Unit: Micrograms per cubic meter (μg/m³), Parts per million (ppm).

Data Collection Method:

- **Primary Sources**: Air quality monitoring stations, portable dust samplers, traffic flow analysis.
- **Secondary Sources**: Reliable national and international data repositories, such as:
  - Department of Environment (DoE), Bangladesh: www.doe.gov.bd
  - Bangladesh Air Quality Monitoring Project (BAQMP): www.baqmp.gov.bd
  - World Air Quality Index Project: www.waqi.info
  - World Health Organization (WHO) Air Quality Database: www.who.int
  - NASA's Earth Observing System Data and Information System (EOSDIS): www.earthdata.nasa.gov

Data Collection Frequency: Daily, with emphasis during high-traffic and construction periods.

Understanding the Results: Road material degradation, vehicle movement, and maintenance activities can contribute to air pollution through the release of particulate matter, microplastics, and chemical emissions. Leveraging both primary and secondary data sources ensures comprehensive monitoring, helps identify pollution hotspots, and supports the implementation of dust suppression and sustainable road management practices.

2.4.2 SC 3.2Noise Pollution increase

3.2.1. The increase in noise level (dB), compared to past 3 years: during market survey the historical trend or increase in noise pollution considering past 3 years is assessed to score the pilot sites in the following range. Key reason behind the increase is also collected from respondents.

- Low level increase score 1
- Medium level increase score 2
- High level increase score 3

Recommendations: Using suitable noise level measurement device that can record the ambient decibel levels directly in a series of events or log basis with acceptable accuracy for outdoor assessment noise Pollution Due to Road Infrastructure and Activities can be assessed as a direct measure or attribute for sub criteria 3.2. Details for this attribute is given below.

Noise Pollution Due to Road Infrastructure and Activities: Unwanted or excessive sound generated by road traffic, construction, and maintenance activities that impact human health, wildlife, and the surrounding environment.

Unit: Decibels (dB).

Data Collection Method:

- **Primary Sources**: Noise level meters, sound monitoring equipment, traffic analysis.
- **Secondary Sources**: Reliable national and international data repositories, such as:
  - Department of Environment (DoE), Bangladesh: www.doe.gov.bd
  - World Health Organization (WHO) Environmental Noise Guidelines: www.who.int
  - Global Noise Mapping Projects (e.g., European Environment Agency): www.eea.europa.eu
  - United Nations Environment Programme (UNEP) Noise Pollution Resources: www.unep.org
  - Acoustic research databases, such as the US National Transportation Noise Map: www.transportation.gov

Data Collection Frequency: Continuous or hourly during peak traffic periods and active construction phases.

Understanding the Results:
Noise pollution from roads arises from vehicle engines, tire friction, honking, and construction machinery. High noise levels can harm public health (e.g., hearing loss, stress), disrupt wildlife habitats, and reduce quality of life. Monitoring noise pollution helps identify high-impact zones, implement noise reduction measures such as sound barriers, and develop traffic management strategies to minimize environmental and health impacts.

2.4.3 SC 3.3Road closing days due to climate conditions

Extreme weather-related inaccessibility of roads (flood, Cyclone, road or bridge seriously damaged or broken) is the third sub criteria for environmental and climate condition assessment. The attribute considered for this sub criteria is

3.3.1 Road closures due to extreme weather events: the total number of days per year section of the road is closed due to extreme weather events is collected from the market survey.

Recommendation: This is a critical data or parameter for the assessment of a road's resilience to extreme climate events and climate change.

Table: Summary table for the three sub criteria measures.

Parameters /Conditions	Measures	Primary data collection process	Secondary data collection process
Air pollution	PM10 and PM2.5 (μg/m^3) weekly to compare with standards. Temperature and humidity also affect air quality. Other parameters include O_3, NO_2, SO_2, CO, VOCs, NH_3, and Pb, which are monitored to assess air pollution and its health impacts.	Baseline survey of air/ LGED	Historical data obtain from reliable sources (as mentioned)
Noise pollution	Noise in decibel (dB) weekly to compare with standards	Baseline survey of noise / LGED	Historical data obtain from reliable sources (as mentioned)
Road closures due to extreme weather events	Road accessibility disruptions (days). Extreme weather-related inaccessibility of road to users (e.g. flood, cyclone, hot, cold, road or bridge seriously damaged or broken, etc.)	On-site inspections, road condition surveys (if possible) / LGED	Historical data collection from reliable sources (as mentioned), e.g. BWDB, BMD, Department of Disaster Management (DDM) under the Ministry of Disaster Management and Relief.

2.4.4 Possible Impacts of Climate Change on LGED Rural Roads in Bangladesh

- **Definition**: The effects of changing climatic patterns, such as temperature fluctuations, erratic rainfall, flooding, and extreme weather events, on the durability, functionality, and maintenance of rural road infrastructure.
- **Unit**: Qualitative assessments, frequency and intensity of climate events, road damage metrics (e.g., kilometers affected, maintenance costs, road closures in days, etc.).
- **Data Collection Method**:
  - **Primary Sources**: On-site inspections, road condition surveys, hydrological and meteorological data analysis.
  - **Secondary Sources**:
    - Bangladesh Meteorological Department (BMD): www.bmd.gov.bd
    - Climate Change Cell (CCC), Department of Environment: www.doe.gov.bd
    - Intergovernmental Panel on Climate Change (IPCC) Reports: www.ipcc.ch
    - World Bank Climate Knowledge Portal: climateknowledgeportal.worldbank.org
    - United Nations Framework Convention on Climate Change (UNFCCC): unfccc.int
- **Data Collection Frequency**: Annually and during extreme weather events.
- **Understanding the Results**:

1. **Temperature Variations (High and Low)**:
    - **High Temperatures**: Extreme heat, like the 2019 Dhaka heatwave, causes thermal expansion, leading to surface cracking, rutting, and degradation of materials. Asphalt and concrete may soften, making roads more susceptible to wear.
    - **Low Temperatures**: Though rare, lower temperatures can cause materials to become brittle, leading to cracks, fractures, and increased vulnerability to traffic loads.
    - Roads must be designed with materials that can withstand both thermal expansion and brittleness due to temperature extremes.
2. **Erratic Rainfall and Flooding**:
    - The 2022 Sylhet floods, for example, overwhelmed road systems, causing erosion of the road base and weakening the subgrade. Such intense rainfall patterns may continue to increase, especially during monsoon seasons.
    - Poor drainage and waterlogging exacerbate road degradation. Roads need effective drainage systems to prevent surface water accumulation and foundation weakening.
3. **Cyclones and Storm Surges**:
    - Cyclones like Sidr (2007) and Amphan (2020) caused significant damage to coastal roads through storm surges, wind-blown debris, and saltwater intrusion. Saltwater further accelerates corrosion of concrete and steel structures.
    - With the rising frequency of storms and rising sea levels, coastal and low-lying areas will face increasing risks of permanent road damage.
4. **Soil and Groundwater Impacts**:
    - **Salinity and pH Levels**: Saltwater intrusion and fluctuating pH levels from coastal flooding weaken road materials, accelerating corrosion, especially for roads made with concrete and steel reinforcements. Elevated salinity can also affect the durability of bitumen used in road paving.
    - **Groundwater Fluctuations**: High groundwater levels during the rainy season, as seen in areas like Barisal, can saturate the subgrade, leading to soil instability, road deformation, and pavement cracking. Fluctuations in groundwater depth can cause swelling or shrinking of the soil, affecting the integrity of road foundations.
5. **Drought Conditions**:
    - Prolonged droughts, like those in Rajshahi, cause soil desiccation, which results in soil shrinkage and cracking of the road base. This leads to pavement settlement and increased stress on road structures.

By considering these impacts, LGED can plan for resilient infrastructure by using durable materials, enhancing drainage systems, and implementing regular maintenance schedules. Additionally, proactive monitoring and adaptive design modifications can help maintain the integrity and longevity of rural roads in Bangladesh under changing climate conditions.

2.5 Criteria 4 Drainage assessment

Four sub criteria considered for the drainage assessment as listed below.

- SC 4.1 Roadside drainage condition
- SC 4.2 Hydraulic structure drainage condition
- SC 4.3 Waterlogging Condition and risk
- SC 4.4 Slope Protection Condition and risk

2.5.1 SC 4.1 Roadside drainage condition

Poor drainage can lead to serious damage to pavement and degrade road performance. So, to assess the drainage condition at the road or site, flow condition, continuity of drainage structures, or surface runoff, adequacy and absence of drainage structures are all significant. Surface drainage condition assessment can be done through AI image or video processing from video captured from a car mount camera. Similarly, roadside drainage structure or roadside drainage condition can also be assessed from video processing. However, during the pilot implementation work the assessment is done by manual observation of the video instead of using an AI tool. Reason behind the rural roads of LGED has little to no road side drain structures and it is very challenging to find a suitable tool that can do the needed assessment for conditions similar to LGED rural roads. Hence for short term phase manual detection from video is considered the most suitable option (faster and reliable than the field survey tally sheet, as the video capture method has the advantage of easily accessible evidence).

How to measure: two attributes are defined for measuring the flow condition and continuity of drainage structure as well as judging the adequacy of drainage structures for the subject road. However, the adequacy part is proposed for later phases.

4.1.1 drainage condition (flow, continuity): from the captured video, the overall drainage flow condition is assessed and the continuity of the drainage structures is also assessed. Scores are assigned in three categories,

- Poor condition, score 1
- Moderate condition, score 2
- Good condition, score 3.

Recommendation: Use of Video processing AI tools for with better road side condition assessment and road furniture detection and condition assessments.

2.5.2 SC 4.2 Hydraulic structure drainage condition:

Mainly assessed to see the structural stability and overall condition of the hydraulic structure (bridge or culvert). The flow condition of the structures as well as the size and placement adequacy judgement for the bridge or culvert is very important for performance measure of rural roads, as small bridge and culverts are the vulnerable to a lot of climate hazard and risks when they are not well designed or well maintained.

How to measure: two attributes are defined for measuring the flow condition and structural stability condition, as well as judging the adequacy of size and placement of hydraulic structures (bridge and culverts) for the subject road.

4.2.1 Average flow condition of structures: From the on-field structure inspection the average flow condition through all the structures on the road is assessed. Scores are assigned in three categories,

- Poor condition, score 1

- Moderate condition, score 2
- Good condition, score 3

4.2.1 Average structural stability condition: Both from the on-field structure inspection and the captured video from the car mounted action camera, the overall structural condition of the bridge or culvert is assessed. Scores are assigned in three categories,

- Poor condition, score 1
- Moderate condition, score 2
- Good condition, score 3

Recommendation: Use of drone Video processing using AI tools for with bridge or culvert structural health assessment. There are established methodology and platforms that can reliably perform crack detection and other defect assessment for bridge structures. This a rapid assessment process compared to the physical inspection or testing methods. Such improvements can be adopted in mid term phase for priority structures.

2.5.3 SC 4.3 Waterlogging Condition and risk:

from a climate and drainage perspective it is essential to understand the extent, severity and duration of the waterlogging on a rural road. Water logging poses a serious threat to the pavement structure and greatly hinders the traffic flow and causes road users' discomfort and hassle. Two attributes are checked under this sub criteria; total area of waterlogging and no. of days of waterlogging.

4.3.1 Percentage of road subject to waterlogging: through market survey the primary locations of water logging risks are identified. Then a tentative area/ length is mapped to get the total percentage of road length that has been subject to waterlogging in past 3 years. The unit of measure is % road length, so the total approximate length of waterlogged section of road divided by total length of the road.

4.3.2 Total Number of days of waterlogging per year: Similarly, through market survey the total number of days the road section remains waterlogged is approximately assessed. The measure unit is days/year.

Recommendation: use of satellite image and secondary databases would result in a more data driven evidence-based approach to identify the waterlogging areas as well as the duration of the waterlogging events. However, this is recommended for mid term phase, for LGED to plan, collect and archive the necessary satellite image in desired quality for such assessment.

2.5.4 SC 4.4 Slope Protection Condition and risk:

Although this indicator is very critical for the performance of a rural road, the collection and assessment of the data is not very easy to collect in a traditional way. Hence here also using the AI tools it is necessary to establish an economic/ cost effective and feasible solution to record and identify erosion and roadside slope protection. The presence/absence and continuity of the hydraulic structural condition.

How to measure: two attributes are defined for measuring the structural condition and erosion risk of the slope protection structures. The attributes help to measure the structural condition of slope protection structures, as well as in assessment of the erosion risk of the road side embankment or slope protection.

4.4.1 structural condition: the assessment is done through utilizing the video captured by the car mounted action camera. Manual observation-based assessment is proposed for the short-term phase. Similar to the hydraulic structure condition scenario the slope protection condition is also not suitable or easy to assess through AI video processing tools. The visibility of the slope structure and the various nature or appearance of the structure makes this very challenging, hence short-term phase does not recommend AI tool use for this. Scoring of results are done the following way

- poor slope protection structural condition, score 1
- moderate slope protection structural condition, score 2
- good slope protection structural condition, score 3

4.4.2 erosion risk: Assessment of the erosion risk of the road side embankment assessment of the erosion risk of the road side embankment or slope protection or slope protection structures is assessed by the location of the road and the road side land use. Also, the drainage system of the surrounding area. Based on the erosion risk of a road the following scoring range is proposed for the evaluation framework.

- no erosion risk, score 0
- low erosion risk, score 1
- mid erosion risk, score 2
- high erosion risk, score 3

Note: The following section is applicable for all the above attributes under SC 4.

Data collection frequency: Should be carried out at intervals of not greater than a year or immediately after periods of flooding or other natural disasters.

Data collection methodology: Structural condition survey and drive through video data collection survey will be used for the criteria 4 assessment. The survey to be carried out using digital forms where pictures are also recorded using smartphone or tab and archived in cloud storage. Drive through video data to be used as a cross-check method for assessing the reliability of the form-based data collection.

Note: For phase 1, no image processing or AI tool is proposed, hence no cost considered for the same. In future phases when drone based structural assessment would be possible by LGED, the costing framework should be updated accordingly.

Cost for data collection: For the Structural condition survey per day 5000 BDT for one surveyor should be considered. Drive through video data collection survey cost is covered in criteria 1 and 2.

2.6 Criteria 5 Social Impact Assessment

The sub criteria considered under the social impact assessment related to road performance are briefly listed below.

Sub Criteria	Phase
SC 5.1 Agricultural Production increase	Short term
SC 5.2 Industrial Production increase	Short term
SC 5.3 Educational facility connectivity	Short term
SC 5.4 Travel Pattern Changes	Short term
SC 5.5 Health Care facility connectivity	Short term
SC 5.6 Employment Generated by roadwork	Mid term
SC 5.7 Accessibility induced settlement enhancement	Mid term

However, two sub criteria are proposed for the mid-term phase of evaluation rather than short term phase. The sub criteria SC 5.6 requires historical database to properly assess the impact. It also requires a lot of project or program related detailed information for the road construction or maintenance work. The sub criteria SC 5.7 Accessibility induced settlement enhancement requires historical custom tailored satellite image dataset (Particular time, frequent, high resolution, images with high interval or frequency), and for this reason this sub criteria is proposed for mid-term phase instead of short-term phase.

How to Measure: through market survey key measures for the social impact of the road is assessed. These measures include overall increase in agricultural and industrial production directly influenced by the subject road, % goods vehicle on the road, no. of educational institutes on the road, % of trips on the road leading to educational institutes, vehicle ownership change, increase of motorized trips, % trips on the road leading to medical facilities, no. of medical facilities directly connected by the road, no. of facilities that can be accessed via this road.

2.6.1 SC 5.1 Agricultural Production increase:

This is an indirect measure to assess the impact of the subject road on agricultural production in the connected communities or marketplaces. From market survey it is possible to identify an approximate estimate of the volume of trucks or goods vehicles (trucks or pickups) per day carrying agricultural goods via this road. The same can be cross checked with the volume count data on the road. Also, the major agricultural goods carried via the subject road are assed along with the location of the source to the market and other destinations from the market. Based on the volume of goods vehicles carrying agricultural products, a qualitative assessment of the subject road's contribution to the increase in agricultural production can be assessed (As good connectivity is one of the driving factors for increase in agricultural production).

5.1.1 overall increase in agricultural production in the surrounding community owing to the road in past 5 years: From market survey this information is collected. This is an indirect and approximate measurement, for which the following scale or score is proposed l

- Low increase, score 1
- mid increase, score 2
- high increase, score 3

5.1.2 % goods vehicle for agricultural goods on the road: The approximate share of the % of goods for agricultural products is assessed based on the market survey. This is an indicative parameter to roughly understand the impact of the road on agricultural goods transport. Measure unit is percentage.

2.6.2 SC 5.2 Industrial Production increase

similar to the agricultural production, industrial production increase assessment is also an indirect and qualitative assessment. The number of industrial production establishments directly connected to the road is a key indicator of the road's performance. An approximate volume of goods vehicles carrying industrial products via the subject road also indicates its importance and impact on the increase in industrial productivity of the region. Better connectivity is a key driving factor for industrial productivity and development in an area, hence is directly associated with the performance of a road in the same regard.

5.1.1 overall increase in Industrial production in the surrounding community owing to the road in past 5 years: From market survey this information is collected. This is an indirect and approximate measurement, for which the following scale or score is proposed l

- Low increase, score 1
- mid increase, score 2
- high increase, score 3

5.1.2 % goods vehicle for Industrial goods on the road: The approximate share of the % of goods for Industrial products is assessed based on the market survey. This is an indicative parameter to roughly understand the impact of the road on Industrial goods transport. Measure unit is percentage.

2.6.3 SC 5.3Educational facility connectivity

Number of schools/ college / university / madrasa or other educational institutes directly connected to the road or dependent on this road. Approximate number of educational trips on the subject road. These indicators will be useful to compare between other LGED roads of the upazila / district, for a qualitative assessment of the impact or contribution of the road in the educational development of the community. Good connectivity has a positive influence in performance and development of educational institutes and similarly a road serving many important educational institutes has a high-performance status in this regard compared to other roads in the same network. However, the comparison should take into account the nature or type of the road, as a paved upazila roads performance should not be compared with a paved village road. Approximate volume or number of education trips in the subject road leading to educational institutes.

5.3.1 number of educational institutes directly connected

The open street map and google map is utilized to check the location of the educational institutes. The total number of educational institutes that are directly connected to the project road is counted and marked in the map.

5.3.2 % trips on the road leading to educational institute

This is an indirect assessment, data collected from market survey. Measured in percentage.

2.6.4 SC 5.4Travel Pattern Changes

Travel Pattern Changes: due to the quality of a road (ride quality, safety and geometry), the travel pattern of the associated community is highly influenced. A better performing road encourages an increase of motorized trips and as a result influences the increase in vehicle ownership in the community. With a better paved road connection, people are encouraged to buy motorcycles or even cars (based on the community land use pattern, suburb / rural) which they would not consider if the connectivity were less accommodating for motorized vehicles.

Measures:

- Vehicle ownership change: assessment of whether ownership of bike or car has been increased significantly or marginally.
- increase of motorized trips of locality due to road is construction, improvement or upgraded to paved or widened.

5.4.1 vehicle ownership change in surrounding area in past 3 years: an assessment of bike and car ownership change in past 3 years presented in a scale of three categories as shown below.

- Low change, score 1
- mid change, score 2
- high change, score 3

5.4.2 overall increase of motorized trips in the road in the past 3 years: From market survey the overall increase in motorized trips can be recorded qualitatively. The scoring range is given below.

- Low **increase**, score 1
- mid **increase**, score 2
- high **increase**, score 3

2.6.5 SC 5.5Health Care facility connectivity

like educational institutes, connectivity to health care facilities like hospitals and clinics are also an indirect but good measure for importance and performance of a paved road. To assess this, an approximate number of trips on the subject road leading to medical facilities can be considered. Also, anther critical parameter is the no. of medical facilities directly connected by the road. Similarly, if there are more facilities that are on reliant on the subject road/ route it is also useful to consider the no. of such facilities that are commonly accessed via this road. The following three attributes are considered for this sub criteria.

5.5.1 % trips on the road leading to medical facilities

This is an indirect assessment, data collected from market survey. Measured in percentage.

5.5.2 no. of medical facilities directly connected by the road

The open street map and google map is utilized to check the location of the medical facilities. The total number of facilities that are directly connected to the project road is counted and marked in the map.

5.5.3 no. of facilities that are dependent on this road for access

Similarly other medical facilities within 2km buffer from the subject road that relies on this road for communication is the measure for this attribute.

Note: The following section is applicable for all the above attributes under SC 5.

Data collection frequency: Every year one time.

Data collection methodology: Market survey, digital form questionnaire survey at prominent markets associated with the road. Same as SC1.2.

Cost of data collection: same as SC1.2 (market survey cost 6000 BDT per day).

2.7 Brief overview of other phases performance indicators

2.7.1 Criteria 1

Indicator / sub criteria	Phase
1.1 traffic data assessment • 1.1.5 Travel speed • 1.1.6 Traffic density • 1.1.7 Percent followers • 1.1.8 V/C Ratio	2nd phase
1.5 Road signage and marking quality	2nd phase
1.6 VRU safety condition	2nd phase
1.7 Emergency Vehicle Accessibility	3rd phase
1.8 V/C ratio assessment	2nd phase

Traffic related attributes: For the mid-term phase of the evaluation framework the four attributes (as shown in the above table) will be considered under the 1.1 traffic volume count sub criteria.

First three parameters could be determined from a custom-tailored video processing software using AI tools and based on the results V/C ratio or LOS of the road can be determined. Capacity assessment is proposed for the midterm phase; hence LOS is also to be included from **midterm phase**.

V/C ratio, derived from the traffic volume and road capacity, is a key indicator for measuring the level of service of the road. The higher the V/C (closer to 1), the lower the level of service. If the V/C is more than 1, then it also reflects the high congestion and extremely poor mobility performance of the road. As speed data is not considered in the short-term framework, the level of service will be considered in phase 2. The data required for V/C are Road geometry condition data like lane width, shoulder width, verge width, road top treatment type, shoulder type etc. to determine the capacity of the road. Also, the traffic speed and delay data determine the capacity of the rural road. Then using the volume data 1.1.1, the V/C can be determined. This is considered for phase 2, as the two critical data are missing at phase 1 stage, the speed data for the roads and the geometry data (being updated under a project). It is expected that LGED networks or assets will be managed by a modern GIS based Asset management platform where both volume and geometry data will be updated and managed on a regular basis. Hence the V/C scoring should be possible to include in the performance equation in phase 2.

AI models and other tools can greatly benefit the assessment of the above-mentioned attributes, the technology is already here for capturing traffic speed, gap/ headway but a local vendor is not available at the moment with such capacity, and it will take time for either foreign vendors or local vendors to adapt or improve their model for the local context processing required for LGED roads.

Road signage and marking quality – clear and better condition yields better performance. These can be collected as part of drive through data collection but the processing mechanism for such data is still not easily available. Hence proposed for mid-term phase.

Pedestrian and non-motorized user safety – safer conditions yield better performance. Similar to road signage, the AI based technology is rapidly progressing and expected to have local vendors offering such capabilities in near future. But it is not easily available at current phase implementation. Hence proposed for mid-term phase.

Emergency Vehicle Accessibility: Assess the road's ability to support emergency vehicle access in crisis situations. The indicator is considered for the **3rd phase** as this will require a network level assessment and database to see if an uninterrupted route of minimum standard width and a minimum standard geometry of the alignment is ensured within the road as well as in the connecting roads or junctions. The turning radius in the junctions and minimum parking space required for emergency vehicles are also key indicators for the emergency vehicle accessibility indicator.

2.7.2 Criteria 2

- **Surface roughness/ Ride quality Assessment or IRI:** Reliable IRI data collection would require extensive capacity enhancement of LGED field offices. It is not possible to cover the huge network without enhancing or engaging the field level offices in an elaborate and sustainable data collection and data management plan. IRI data is critical for a RAMS operation, but collection of this data will need many considerations (reliability of the method, ease of scaling, integration with the RAMS platform). Hence it is proposed for the mid-term phase to allow LGED to adapt to a modern RAMS platform and implement a robust, reliable and scalable plan for IRI data collection using advance tools and technologies (AI based modular systems).
- **Deflection level measurement**: Requires LGED to be able to deploy or engage high level of field data collection using FWD or LWD. This would demand a capacity enhancement of LGED field offices in terms of training, equipment and budget and therefore it is considered in the second or mid-term phase.

2.7.3 Criteria 3

- **Disaster Recovery Capabilities:** Time and cost to restore road conditions post-natural disasters. This indicator would require extensive amount of reliable data on project life cycle cost, specific climate related event data, extent of damage, associated cost to rehabilitate repair or reconstruct and other project or program data that are associated to the recovery of the subject road. Reliable data is crucial in this assessment, as quantifying road damage costs specific to natural disasters is not possible without proper asset data management. Also estimating contributing budget or cost to improve or recover the extent of damage caused by natural disasters require a systematic record not possible at the current phase of performance evaluation. Hence this sub criteria can be considered at 3rd phase. A road that can recover more efficiently from a disaster has a greater performance in terms of climate resilience and sustainability.

2.7.4 Criteria 5

- Employment Generated by road works: road works generate direct work opportunity for the local community during construction or upgrading works as well as during routine or periodic maintenance works. If a road can provide such opportunity to female work groups, it would become important in terms of gender equality or empowerment aspect. A paved road through its construction and maintenance works also provides opportunities for small local businesses to supply materials. Hence roads that allow more local community engagement are better performing than roads that require complex maintenance or construction and involvement of bigger corporations / heavy reliance on outside / skilled work force.

- Accessibility induced settlement enhancement: another indirect indicator for road performance in relation socio economic development, is to measure the percentage increase in settlement area within the 2km area surrounding the subject road for the last five years or from the construction of the road. Another measure for the impact of the road on the settlement or development of the community is to measure the percentile increase in nighttime light coverage within the 2km area surrounding the subject road for the last five years or from the construction of the road. Here it is essential to properly identify and demarcate the buffer area surrounding the road and then utilize satellite images / ortho images to process the data for understanding the following
    - Yearly change in settlement area within the buffer area / direct impact zone of the road
    - Yearly change in nighttime illumination within the buffer area or direct impact zone

Collection of high-resolution satellite images (useful in many other indicators as well) particularly for the nighttime historical images is essential for this assessment or measure. However, through a spatial analysis platform like ArcGIS or QGIS, such increase or changes can be easily monitored and used in performance evaluation scoring.

2.7.5 Criteria 6 Economic Impact Assessment

The sub criteria and associated attributes for economic impact assessment are all proposed for the long-term phase of the evaluation framework. A key reason behind is the attributes require properly maintained and easily accessible systematic archive of historical databases for various economic indicators of the road projects (life cycle cost, CBA, change in land valuation etc.)

Sub Criteria	ID	Attribute	Phase
6.1 Life cycle cost	6.1.1	Construction costs Total and per km costs	Long term
	6.1.2	Routine and periodic maintenance cost	Long term
	6.1.3	Rehabilitation or upgrade cost	Long term
6.2 program completed in budget	6.2.1	% of program completed in budget	Long term
6.3 program completed in time	6.3.1	% of program completed in time	Long term
6.4 Cost benefit analysis	6.4.1	to assess the economic return on investment in maintenance and road improvements	Long term
6.5 Impact on property valuation	6.5.1	changes in property and land value due to improved accessibility and connectivity (% increase)	Long term

The primary source for such an assessment should be a well-maintained LGED Rural Road Asset management system, (AMS) which will systematically archive the historical road construction and maintenance related information. Completion or final report of project or programs and the AMS should support the required assessment for this criterion.

Chapter 3 Performance Evaluation Framework

3 Chapter 3 Performance Evaluation Framework

3.1 Overview of the process

The performance evaluation framework is presented below. First the list of criteria, sub criteria and attributes are checked or updated as required by LGED. Once the updated list is available an AHP questionnaire survey is conducted to get responses from LGED officials at various units and various positions. These responses are used in the AHP process to estimate the global weightage for all indicators (criteria, sub criteria and attributes). Once AHP based global weightage is set, the value for each attribute is inserted. Values are calculated or observed based on the specific data measure methods explained in the earlier section. To complete the scoring process, the values are normalized. After these are normalized, then the values are inserted in the equation to get the performance score.

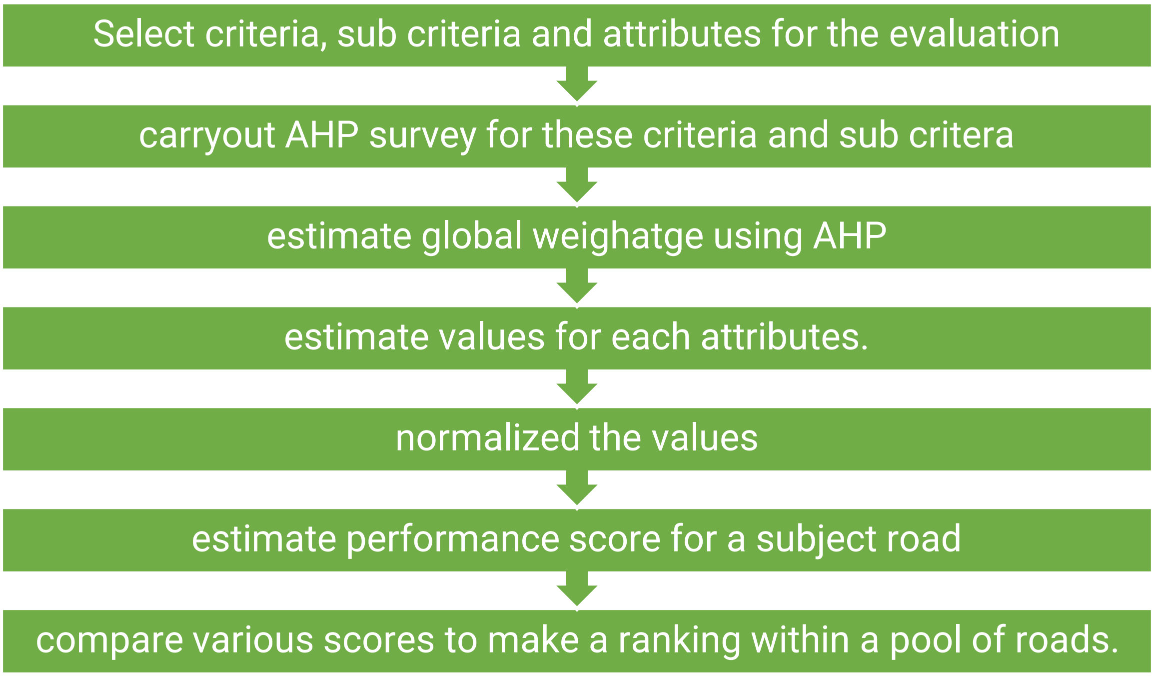


Figure 02 performance evaluation framework

3.2 What is AHP

The Analytical Hierarchy Process (AHP) is a decision-making technique designed to prioritize and rank options when multiple criteria are involved. It is particularly useful in complex scenarios where subjective judgments and expert opinions play a significant role. Through pairwise comparisons, AHP evaluates the relative importance of factors, assigning weights to each while ensuring a logical and consistent ranking. AHP was chosen for prioritizing the performance indicator / criteria due to its structured and systematic approach, which effectively addresses the limitations of other available tools (like Delphi, TOPSIS, or simple scoring/ranking techniques). While the Delphi method is useful for consensus-building, it lacks the ability to quantify priorities or provide precise rankings. TOPSIS, though suitable for multi-criteria problems, is computationally complex and less intuitive. Simple scoring/ ranking techniques lack rigor, as they do not support pairwise comparisons or consistency checks, often leading to subjective results. By translating qualitative expert judgments into quantitative weightages, AHP overcomes these challenges. Its consistency ratio ensures logical coherence, enhancing both reliability and transparency. With its mathematical rigor and accessibility, AHP proved to be the most effective method for deriving credible and actionable rankings for the performance evaluation criteria.

3.3 Summary of the AHP method

The Analytical Hierarchy Process (AHP) steps are presented below.

3.3.1 Step 1: Development of Pairwise Comparison Form

A pairwise comparison survey was designed specifically for this study. The survey included structured questions where participants were asked to compare each pair of main criteria or theme based on their relative importance for road performance evaluation. The comparisons used the standard AHP scale, which is shown in the table below. This detailed scale allowed for careful evaluations and ensured accurate calculation of weights.

Table: Standard AHP Scale

Significance	Equal Importance	Moderate Importance	Strong Importance	Very Strong Importance	Extreme Importance
Scale Value	1	3	5	7	9

3.3.2 Step 2: Participant Selection

To ensure proper judgement, the selection of participants was limited to those expert personnel of LGED who have extensive expertise and a comprehensive understanding of paved road performance evaluation and has good understanding of LGEDs current practices. The list was developed in discussion and considering the recommendations from LGED. The designations and roles of the participants have been presented below. Apart from the senior officials, the list also includes six assistant engineers who are directly involved in planning and maintenance of LGED roads.

3.3.3 Step 3: Data Collection

Based on the participant list, a schedule was taken from each participant for the interview. The interviews were taken in person, where the participant filled out the forms in pen and then provided the filled-up copies to the interviewer. The interviewer provided the participant with an index and definition chart of the performance criteria and sub criteria and supported the process by providing explanation of the criteria as required. All inputs were then converted to an excel database. Respondents signed with date in the hardcopies which were also preserved by the interviewer.

A total of twenty-three responses were collected from various levels of LGED officials (Additional chief engineer, Superintending engineer, Executive Engineers Senior Assistant Engineers and Assistant Engineers). The inclusion criteria prioritized engineers in roles that directly related to road performance issues (road maintenance unit, quality control unit, road design unit and Road database and GIS unit).

3.3.4 Step 4: AHP Analysis

After collecting all the responses from the participants, the pairwise comparison data was analyzed using the following key steps:

1. Matrix Formation and Calculations: A comparison matrix was developed for each participant, with the criteria as rows and columns. Each cell represented the participant's judgment on the relative importance of two criteria. The principal eigenvector of each matrix was calculated using the general balanced-n scale to determine the relative weights of the criteria. These weights reflect the perceived importance of each front based on the judgments provided.

2. Consistency Check: A consistency ratio (CR) was calculated for the aggregated comparison matrix i.e., for the consolidated group. Geometric means were used to aggregate the individual judgements. A CR below 0.2 was considered acceptable for individual responses as suggested by Goepel, K.D. (2013), signifying that the results were consistent.

3. The individual weights from all participants were aggregated to determine group priorities. This involved calculating the geometric mean of the individual weights for each criterion, which

provided an overall ranking. The aggregation process ensured that the group results captured diverse expert opinions while reflecting a consolidated priority structure.

3.4 How AHP is applied for developing the evaluation framework

For developing the evaluation framework, the first step was to conduct a pair wise comparison for the selected performance indicators classified or grouped into 5 criteria and 25 sub criteria. For this, 23 participants from LGED were interviewed for the AHP data collection work or collecting responses for the pairwise comparisons. The questionnaire for the AHP is presented in appendix 10.5. Each participant was approached individually to record their response. Responses were collected in paper forms and then digited in datasheet for assessment. To prioritize the performance criteria and sub criteria, this pairwise comparison was conducted for LGED officials from various levels from various units of LGED. The responses from the experts are used for developing relative weightage of each criterion, a comparison matrix was developed through AHP.

The AHP comparison matrix and derived weightage is presented below,

Criteria	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Weightage
Criteria 1	1.00	1.60	3.50	2.46	3.95	0.36
Criteria 2	0.62	1.00	3.73	2.91	3.99	0.31
Criteria 3	0.29	0.27	1.00	1.18	2.36	0.12
Criteria 4	0.41	0.34	0.85	1.00	3.71	0.14
Criteria 5	0.25	0.25	0.42	0.27	1.00	0.06

Here, the Criteria Names are as follows

No.	Criteria Name
c1	Traffic and Road Safety Assessment
c2	Pavement Condition Assessment
c3	Environmental & Climate Condition Assessment
c4	Drainage Condition Assessment
c5	Social Impact Assessment

Hence the development of the framework of

Performance Score = Value C1 * weightage C1 + Value C2* weightage C2+ Value C3* weightage C3+ Value C4* weightage C4+ Value C5* weightage C5

The list of sub criteria is given below (short term phase)

No.	sub criteria
1.1	Traffic Volume Count
1.2	Origin-Destination and Travel pattern
1.3	Percent encroachment
1.4	Road Safety and Crash Risk
2.1	Crack rate evaluation
2.2	Pothole assessment
2.3	Rutting evaluation
2.4	Layer Thickness assessment

No.	sub criteria
2.5	Deflection level measurement
2.6	Surface roughness/ Ride quality Assessment
3.1	Air Pollution increase
3.2	Noise Pollution increase
3.3	Road closing days due to climate conditions
3.4	Flooding severity
4.1	Roadside drainage condition
4.2	Hydraulic structure drainage condition
4.3	Waterlogging Condition and risk
4.4	Slope Protection Condition and risk
5.1	Agricultural Production increase
5.2	Industrial Production increase
5.3	Educational facility connectivity
5.4	Travel Pattern Changes
5.5	Health Care facility connectivity
5.6	Employment Generated by road works
5.7	Accessibility induced settlement enhancement

Now for the sub criteria under each criteria the AHP process is repeated and the local weightage for these sub criteria is calculated. The AHP comparison matrix and derived weightage for Sub criteria under criteria 1 is presented below,

Sub Criteria	SC 1.1	SC 1.2	SC 1.3	SC 1.4	Local Weightage	Global Weightage
SC 1.1	1.00	2.49	2.45	0.97	0.37	0.132
SC 1.2	0.40	1.00	2.35	1.21	0.25	0.089
SC 1.3	0.41	0.43	1.00	0.96	0.15	0.055
SC 1.4	1.03	0.83	1.04	1.00	0.23	0.084

In the above table the local weightages of the sub criteria are multiplied by the weightage of the criteria to calculate the global weightages for each sub criteria.

Comparison matrix for Criteria 2

Sub Criteria	SC 2.1	SC 2.2	SC 2.3	SC 2.4	SC 2.5	SC 2.6	Local Weight	Global Weight
SC 2.1	0.34	0.44	0.27	0.26	0.21	0.26	0.30	0.092
SC 2.2	0.25	0.32	0.46	0.34	0.29	0.28	0.32	0.100
SC 2.3	0.23	0.12	0.18	0.27	0.20	0.22	0.20	0.063
SC 2.4	0.18	0.13	0.09	0.13	0.31	0.24	0.18	0.056
SC 2.5	0.22	0.14	0.12	0.06	0.13	0.28	0.16	0.049
SC 2.6	0.18	0.16	0.12	0.08	0.07	0.14	0.12	0.038

Comparison matrix for Criteria 3

Sub Criteria	SC 3.1	SC 3.2	SC 3.3	SC 3.4	Local Weightage	Global Weightage
SC 3.1	1.00	3.00	1.11	0.49	0.27	0.033
SC 3.2	0.33	1.00	1.04	0.45	0.16	0.019
SC 3.3	0.90	0.96	1.00	0.97	0.23	0.028
SC 3.4	2.06	2.21	1.03	1.00	0.34	0.041

Comparison matrix for Criteria 4

Sub Criteria	SC 4.1	SC 4.2	SC 4.3	SC 4.4	Local Weightage	Global Weightage
SC 4.1	1.00	2.34	1.47	1.47	0.36	0.052
SC 4.2	0.43	1.00	1.57	1.29	0.24	0.034
SC 4.3	0.68	0.64	1.00	1.57	0.22	0.032
SC 4.4	0.68	0.78	0.64	1.00	0.18	0.026

Comparison matrix for Criteria 5

Sub Criteria	SC 5.1	SC 5.2	SC 5.3	SC 5.4	SC 5.5	SC 5.6	SC 5.7	Local Weight	Global Weight
SC 5.1	1.00	2.41	1.81	2.31	1.35	1.48	1.97	0.23	0.01439
SC 5.2	0.41	1.00	1.28	2.31	1.23	1.49	2.17	0.17	0.01046
SC 5.3	0.55	0.78	1.00	3.24	1.83	1.37	1.78	0.17	0.01103
SC 5.4	0.43	0.43	0.31	1.00	1.54	0.74	1.06	0.10	0.00605
SC 5.5	0.74	0.81	0.55	0.65	1.00	1.77	2.45	0.14	0.00880
SC 5.6	0.67	0.67	0.73	1.35	0.57	1.00	2.04	0.12	0.00764
SC 5.7	0.51	0.46	0.56	0.95	0.41	0.49	1.00	0.08	0.00496

3.5 Performance evaluation guideline for short-term phase

Utilizing the global weightage derived from the practice or AHP process, the following performance score formula can be formulated.

Performance Score PS_s = value SC 1.1*0.1323 + value SC 1.2*0.0887 + value SC 1.3*0.055 + value SC 1.4*0.0836 + value SC 2.1*0.0719 + value SC 2.2*0.0795 + value SC 2.3*0.0501 + value SC 2.4*0.044 + value SC 2.5*0.0371 + value SC 2.6*0.0297 + value SC 3.1*0.0326 + value SC 3.2*0.0187 + value SC 3.3*0.0277 + value SC 3.4*0.0415 + value SC 4.1*0.052 + value SC 4.2*0.034 + value SC 4.3*0.032 + value SC 4.4*0.0264 + value SC 5.1*0.0144 + value SC 5.2*0.0105 + value SC 5.3*0.011 + value SC 5.4*0.006 + value SC 5.5*0.0088 + value SC 5.6*0.0076 + value SC 5.7*0.005

Now the value for each of the sub criteria is to be measured and input in the formula to get the performance score for a particular road. Once the scores are calculated, based on the scores a ranking of the performance for various roads can be performed.

If any new sub criteria are to be added in the formula for performance measure or scoring, the comparison matrix for the relevant criteria / group needs to be updated through another round of pair wise comparison from nominated experts. It is better to leave out the comparison values that are already received or available, if the respondents are same, and update only the new rows in the comparison matrix. In case the respondent is new; it is better to replace the entire response of the previous respondent with the data from the new respondent. Appendix 10.6 has the proposed or draft scoring mechanism presented in a tabular format, from which the respective scores for each indicator can be estimated for a subject road and by putting these scores in the performance evaluation formula, the performance score of a road can be assessed.

After the pilot implementation phase, few of the sub criteria and attributes were dropped from the short-term phase. The global weightage of the remaining sub criteria was readjusted by uniformly distributing the weights of the dropped sub criteria.

No.	sub criteria	Previous global weightage	Adjusted global weightage
1.1	Traffic Volume Count	0.13227	**0.13227**
1.2	Origin-Destination and Travel pattern	0.08871	**0.08871**
1.3	Percent encroachment	0.05503	**0.05503**
1.4	Road Safety and Crash Risk	0.08360	**0.08360**
2.1	Crack rate evaluation	0.07190	**0.15235**
2.2	Pothole assessment	0.07946	**0.15992**
2.3	Rutting evaluation	0.05008	**0**
2.4	Layer Thickness assessment	0.04397	**0**
2.5	Deflection level measurement	0.03714	**0**
2.6	Surface roughness/ Ride quality Assessment	0.02972	**0**
3.1	Air Pollution increase	0.03263	**0.04645**
3.2	Noise Pollution increase	0.01870	**0.03252**
3.3	Road closing days due to climate conditions	0.02765	**0.04147**
3.4	Flooding severity	0.04146	**0**
4.1	Roadside drainage condition	0.05201	**0.05201**
4.2	Hydraulic structure drainage condition	0.03395	**0.03395**
4.3	Waterlogging Condition and risk	0.03202	**0.03202**
4.4	Slope Protection Condition and risk	0.02638	**0.02638**
5.1	Agricultural Production increase	0.01439	**0.01691**
5.2	Industrial Production increase	0.01046	**0.01298**
5.3	Educational facility connectivity	0.01103	**0.01355**
5.4	Travel Pattern Changes	0.00605	**0.00857**
5.5	Health Care facility connectivity	0.00880	**0.01132**
5.6	Employment Generated by road works	0.00764	**0**
5.7	Accessibility induced settlement enhancement	0.00496	**0**

 # The dropped sub-criteria are shifted to mid-term phase equation of the framework.

The updated equation is presented below.

Performance Score PS_s = value SC 1.1*0.1323 + value SC 1.2*0.0887 + value SC 1.3*0.055 + value SC 1.4*0.0836 + value SC 2.1*0.0719 + value SC 2.2*0.0795 + value SC 3.1*0.0326 + value SC 3.2*0.0187 + value SC 3.3*0.0277 + value SC 4.1*0.052 + value SC 4.2*0.034 + value SC 4.3*0.032 + value SC 4.4*0.0264 + value SC 5.1*0.0144 + value SC 5.2*0.0105 + value SC 5.3*0.011 + value SC 5.4*0.006 + value SC 5.5*0.0088

After the weightage is calculated, a normalization process is necessary to perform a Topsis analysis. Through this normalization process the difference between the units or field characteristics of the sub criteria and their attributes is adjusted to derive the performance score of the site. Then a ranking is performed based on the performance scores.

3.6 Performance evaluation guideline for other phases

In order to include the mid-term or long-term phase new/ additional indicators, the following steps are to be followed

- Define the new indicators and update the AHP pair-wise comparison questionnaire
- Carryout survey and do the AHP analysis with new indicators
- Determine the updated global weightage for all indicators
- Update the performance evaluation score equation

3.7 Performance evaluation guideline for short-term phase

The AHP comparison matrix and derived weightage is presented below,

Criteria	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Weightage
Criteria 1	1.00	1.60	3.50	2.46	3.95	0.36
Criteria 2	0.62	1.00	3.73	2.91	3.99	0.31
Criteria 3	0.29	0.27	1.00	1.18	2.36	0.12
Criteria 4	0.41	0.34	0.85	1.00	3.71	0.14
Criteria 5	0.25	0.25	0.42	0.27	1.00	0.06

Here, the Criteria Names are as follows

No.	Criteria Name
c1	Traffic and Road Safety Assessment
c2	Pavement Condition Assessment
c3	Environmental & Climate Condition Assessment
c4	Drainage Condition Assessment
c5	Social Impact Assessment

Hence the development of the framework of

Performance Score = Value C1 * weightage C1 + Value C2* weightage C2+ Value C3* weightage C3+ Value C4* weightage C4+ Value C5* weightage C5

The list of sub criteria is given below (short term phase)

No.	sub criteria	No.	sub criteria
1.1	Traffic Volume Count	4.1	Roadside drainage condition
1.2	Origin-Destination and Travel pattern	4.2	Hydraulic structure drainage condition
1.3	Percent encroachment	4.3	Waterlogging Condition and risk
1.4	Road Safety and Crash Risk	4.4	Slope Protection Condition and risk
2.1	Crack rate evaluation	5.1	Agricultural Production increase
2.2	Pothole assessment	5.2	Industrial Production increase
2.3	Rutting evaluation	5.3	Educational facility connectivity
2.4	Layer Thickness assessment	5.4	Travel Pattern Changes
2.5	Deflection level measurement	5.5	Health Care facility connectivity
2.6	Surface roughness/ Ride quality Assessment	5.6	Employment Generated by road works
3.1	Air Pollution increase	5.7	Accessibility induced settlement enhancement
3.2	Noise Pollution increase		

3.3	Road closing days due to climate conditions		
3.4	Flooding severity		

Now for the sub criteria under each criteria the AHP process is repeated and the local weightage for these sub criteria is calculated. The AHP comparison matrix and derived weightage for Sub criteria under criteria 1 is presented below,

Sub Criteria	SC 1.1	SC 1.2	SC 1.3	SC 1.4	Local Weightage	Global Weightage
SC 1.1	1.00	2.49	2.45	0.97	0.37	0.132
SC 1.2	0.40	1.00	2.35	1.21	0.25	0.089
SC 1.3	0.41	0.43	1.00	0.96	0.15	0.055
SC 1.4	1.03	0.83	1.04	1.00	0.23	0.084

In the above table the local weightages of the sub criteria are multiplied by the weightage of the criteria to calculate the global weightages for each sub criteria.

Comparison matrix for Criteria 2

Sub Criteria	SC 2.1	SC 2.2	SC 2.3	SC 2.4	SC 2.5	SC 2.6	Local Weight	Global Weight
SC 2.1	0.34	0.44	0.27	0.26	0.21	0.26	0.30	0.092
SC 2.2	0.25	0.32	0.46	0.34	0.29	0.28	0.32	0.100
SC 2.3	0.23	0.12	0.18	0.27	0.20	0.22	0.20	0.063
SC 2.4	0.18	0.13	0.09	0.13	0.31	0.24	0.18	0.056
SC 2.5	0.22	0.14	0.12	0.06	0.13	0.28	0.16	0.049
SC 2.6	0.18	0.16	0.12	0.08	0.07	0.14	0.12	0.038

Comparison matrix for Criteria 3

Sub Criteria	SC 3.1	SC 3.2	SC 3.3	SC 3.4	Local Weightage	Global Weightage
SC 3.1	1.00	3.00	1.11	0.49	0.27	0.033
SC 3.2	0.33	1.00	1.04	0.45	0.16	0.019
SC 3.3	0.90	0.96	1.00	0.97	0.23	0.028
SC 3.4	2.06	2.21	1.03	1.00	0.34	0.041

Comparison matrix for Criteria 4

Sub Criteria	SC 4.1	SC 4.2	SC 4.3	SC 4.4	Local Weightage	Global Weightage
SC 4.1	1.00	2.34	1.47	1.47	0.36	0.052
SC 4.2	0.43	1.00	1.57	1.29	0.24	0.034
SC 4.3	0.68	0.64	1.00	1.57	0.22	0.032
SC 4.4	0.68	0.78	0.64	1.00	0.18	0.026

Comparison matrix for Criteria 5

Sub Criteria	SC 5.1	SC 5.2	SC 5.3	SC 5.4	SC 5.5	SC 5.6	SC 5.7	Local Weight	Global Weight
SC 5.1	1.00	2.41	1.81	2.31	1.35	1.48	1.97	0.23	0.01439
SC 5.2	0.41	1.00	1.28	2.31	1.23	1.49	2.17	0.17	0.01046
SC 5.3	0.55	0.78	1.00	3.24	1.83	1.37	1.78	0.17	0.01103
SC 5.4	0.43	0.43	0.31	1.00	1.54	0.74	1.06	0.10	0.00605
SC 5.5	0.74	0.81	0.55	0.65	1.00	1.77	2.45	0.14	0.00880
SC 5.6	0.67	0.67	0.73	1.35	0.57	1.00	2.04	0.12	0.00764
SC 5.7	0.51	0.46	0.56	0.95	0.41	0.49	1.00	0.08	0.00496

Utilizing the global weightage derived from the practice or AHP process, the following performance score formula can be formulated.

Performance Score PS_s = value SC 1.1*0.1323 + value SC 1.2*0.0887 + value SC 1.3*0.055 + value SC 1.4*0.0836 + value SC 2.1*0.0719 + value SC 2.2*0.0795 + value SC 2.3*0.0501 + value SC 2.4*0.044 + value SC 2.5*0.0371 + value SC 2.6*0.0297 + value SC 3.1*0.0326 + value SC 3.2*0.0187 + value SC 3.3*0.0277 + value SC 3.4*0.0415 + value SC 4.1*0.052 + value SC 4.2*0.034 + value SC 4.3*0.032 + value SC 4.4*0.0264 + value SC 5.1*0.0144 + value SC 5.2*0.0105 + value SC 5.3*0.011 + value SC 5.4*0.006 + value SC 5.5*0.0088 + value SC 5.6*0.0076 + value SC 5.7*0.005

Now the value for each of the sub criteria is to be measured and input in the formula to get the performance score for a particular road. Once the scores are calculated, based on the scores a ranking of the performance for various roads can be performed.

If any new sub criteria are to be added in the formula for performance measure or scoring, the comparison matrix for the relevant criteria / group needs to be updated through another round of pair wise comparison from nominated experts. It is better to leave out the comparison values that are already received or available, if the respondents are same, and update only the new rows in the comparison matrix. In case the respondent is new; it is better to replace the entire response of the previous respondent with the data from the new respondent. Appendix 10.6 has the proposed or draft scoring mechanism presented in a tabular format, from which the respective scores for each indicator can be estimated for a subject road and by putting these scores in the performance evaluation formula, the performance score of a road can be assessed.

3.8 Performance based scoring of pilot sites

The data collected from the pilot field survey work and other secondary sources are utilized to evaluate the performance scoring for each of the pilot site for the list of indicators of the draft performance evaluation framework. The scoring is done based on the standard baseline value and the measure of the same from data collection work. The AHP global weightage for each indicator will be used for evaluating the final score. Once the weightage is defined, the values of the parameters or attributes are normalized to perform a topsis analysis of the survey findings. Through the topsis assessment scoring of the sites are performed. The following summary table presents the scoring and the relative ranking of the pilot sites based on the draft evaluation framework. The analysis process is provided in the appendix.

Table 3.1 Summary of pilot implementation work

Site	District	Road Type	Road no.	Climate hotspot	Score	Rank
Site 1	Sirajganj	Upazila	188942004	Barind	0.8621	1
Site 2	Gazipur	Upazila	333302005	Urban	0.8380	2
Site 3	Dinajpur	Upazila	127643005	Barind	0.7052	6
Site 4	Netrokona	Upazila	372562001	Cross cutting	0.4204	7
Site 5	Cox's bazar	Union Road	422663002	Hill tracts	0.7999	4
Site 6	Sunamganj	Union Road	690473020	Haor	0.3944	8
Site 7	Barishal	Upazila	506322002	Riverine	0.8100	3
Site 8	Bagerhat	Village Road A	20158 4007	Coastal	0.7284	5

Chapter 4 Data Collection methodology

4 Chapter 4 Data Collection methodology

Pilot site data collection will be carried out in two methods, one is primary data collection through field survey and second is secondary data collection from online sources and LGED databases.

4.1 Primary data collection through field survey

Based on the data collection methodologies listed in chapter C, the following field survey works are identified and listed below.

A. Traffic video data collection from fixed points on the road.
B. Drive through video data collection
C. Market Interview Survey
D. Air and Noise pollution data collection
E. Structure Inspection survey

Figure 4.1 Data collection methods for field survey

4.1.1 Traffic video data collection from fixed point on the road.

This will be achieved by putting an outdoor IP video camera at a suitable point beside the road, covering the traffic movement in both directions. Typically, the camera is setup at a vantage point or at least at a height more than 4m, however depending on the nature of the road and roadside development situations, the camera can be setup on Shop roofs, on billboard or tree top or attached to the roadside poles. Video will be collected for 16 hours on each road covering both direction flow.

For rural roads, the nighttime traffic is very insignificant hence 24 hours data collection is not considered in general. However, in case of special site conditions (urban area, nighttime commercial truck activities, cargo movement etc.) if necessary 24 hours data can also be collected. This will be decided based on the filed reconnaissance.

Depending on the length of the road, multiple camera installation might be necessary. Identification of the optimum location suitable for capturing the maximum flow of the traffic is essential for this survey. Camera locations should not be directly on a junction as well as inside the market area. It is preferred to install the camera near / edge of the market avoiding typical UCM and truck parking spots.

Once the data is collected, the video will be assessed to develop the classified traffic count through a manual observation method (conventional method / contemporary practice) that has some advantages compared to the on-site manual tally method (greater accuracy); however, another method proposed is utilizing AI image detection method for automatically classify the traffic count from the video data. Although this practice is very limited or not common for LGED, this AI based tool is extensively used in other countries and this is essential for LGED to adopt to achieve greater accuracy, reliability and cost effectiveness in mass scale traffic data collection programs.

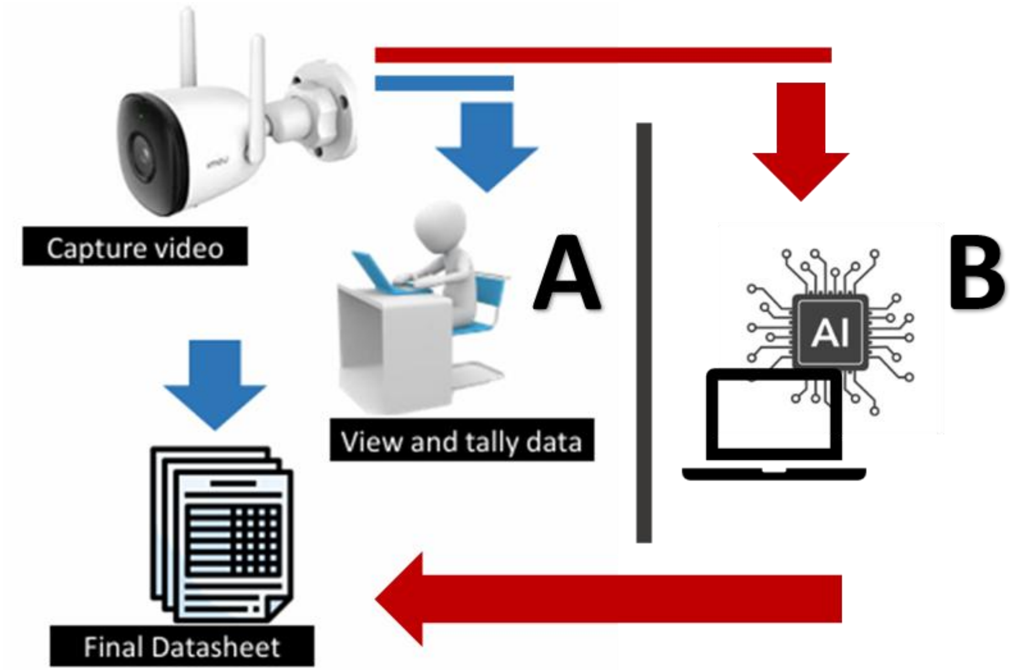


Figure 4.2 traffic volume survey video capture method

The traffic data for the pilot sites were processed through two methods, one is manual counting from observing the video at desk and creating tally sheets. The other method is using an AI model to utilize image processing technique to create traffic data sheet. For the AI system there are many international vendors like Good Vision, Datafromsky and many more. However, for the pilot project a local vendors product has been tested for the application of AI in determining the 15 vehicle classes of Bangladesh.

	
Datafromsky (international vendor)	Video-tracker by polygon (Local Vendor)

Figure 4.3 AI traffic video processing platforms

4.1.2 Drive through video data collection

Consultants will drive through the road, collecting high-resolution video of the road surface, with action camera mounted at front and back of the survey vehicle. The wide-angle view of the action camera will also capture the roadside scenario during the data collection. The video will be collected in an uninterrupted way, for which the data collection time should be chosen during the least traffic period or off-peak period. If possible, a Police vehicle / LGED vehicle should run ahead of the survey vehicle to create a clear view in front of the survey vehicle to allow clear capture of the road surface. A series of three vehicles can ensure this, preferably one being a police patrol vehicle.

The quality and clarity of the captured video is of enormous importance as the success of data extraction through AI image processing will highly depend on the quality of the input.

Apart from the image processing purposes, the wide-angle video collected will also be used for roadside condition and land use pattern observations.

Figure 4.4 action camera for collecting drive through video

The road pavement video data is processed through a AI platform to list all the pavement defect or anomalies in distinct categories like potholes, cracks, raveling, garbage etc. For the pilot data processing "Roadathena" platform is utilized to get the number and percentage of potholes and cracks.

Figure 4.5 AI pavement defect video processing platform

4.1.3 Market Interview Survey

The associated growth centers and rural markets on the pilot site roads will be listed for conducting market interview surveys. For each site, all-important markets on the roadside will be surveyed. The nearest growth center will also be surveyed, considering the subject road has any direct connection to the GC. If the nearest GC is too far / has no connection to the pilot site road, then Growth center survey will be skipped.

The market interview will provide great insight in local traffic travel patterns, Origin destination pairs, travel challenges, traffic mix, road safety and road crash scenarios, adverse weather impacts on road, closing days of the road due to extreme weather events etc.

4.1.4 Air and Noise pollution data collection

A. Air pollution data collection

For air pollution measurement on the road, handheld particulate meter will be used, to measure the PM10, PM2.5 and PM1.0 levels. The device will be kept stationary for 8 hours in start and end of the road and if the road is longer than 5km, then after each 5km the data collection process would be repeated.

Figure 4.6 Air pollution measure handheld device (PM10 and PM2.5)

B. Noise pollution collection

To measure the noise pollution of the road. The reading will be taken at various points of the road, preferably at locations of high and low congestion.

Figure 4.7 Handheld Noise level measurement device

4.1.5 Hydraulic and drainage structure condition survey

The culverts and bridges on the road will be monitored to check the functional condition of the structure and pictures will be taken as record.

4.2 Secondary data collection from online sources and LGED offices

There are two main sources for secondary data collection, one is LGEDs own database, and the other one is various government and non-government organizations. Both sources are discussed below.

4.2.1 LGED Databases

As described in the chapter C, many measures of the performance indicators will be collected from the existing archives and database of LGED. For this purpose, consultant will collect LGED database information from the listed units of LGED.

- LGED's Road and Structure Database Management System (RSDMS)
- GIS division/ GIS portal
- Road maintenance Unit database
- Quality control Unit database
- Field office database (for the selected eight sites).

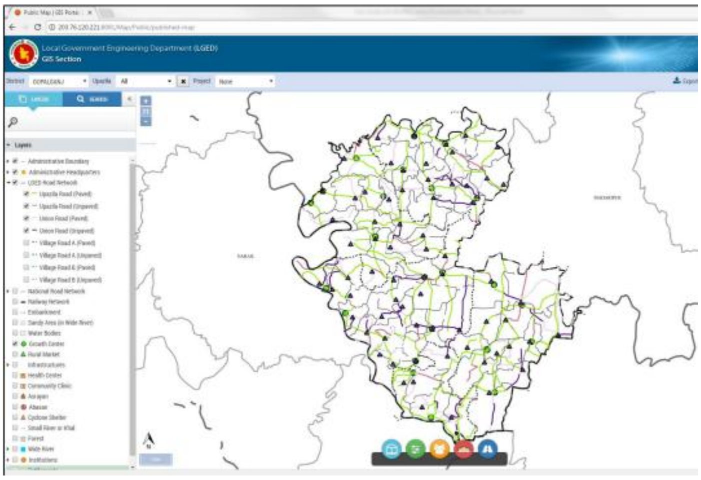


Figure 4.8 LGED GIS PORTAL

These will include construction history of the road, pavement thickness, maintenance history, various investment or improvement projects, road improvement and rehabilitation history, soil reports, traffic and axle load information, roadside settlement information, road furniture and other asset information, bridge and culvert structure information etc.

4.3 Level of effort and cost for each method

Data collection method	Collected data	Level of Effort	Cost per site or Cost per day*	Remarks
Traffic flow video collection	High res. Video Excel datasheet	Field work little Desk work manual high Desk work AI little	8000*	One surveyor One camera set
Drive through video collection for pavement and road condition	High res. Video GIS database	Field work little Desk work AI little	10000*	One surveyor One action camera set
Market Interview Survey	Interview form Excel sheet	Field work moderate Desk work little	6000	one surveyor, digital forms
Noise Level monitoring	8 hrs Reading data in excel	Field work moderate Desk work little	5000	One surveyor, one device
Air pollution monitoring	8 hrs Reading data in excel	Field work moderate Desk work little	5000	One surveyor, one device
Hydraulic structures condition survey	Condition form with pictures	Field work moderate Desk work little	3000	One surveyor and local transport

**Costs include all rent, field expenditure and other costs. Also, rates are indicative only, depending on work volume and the competitiveness of the procurement rates may vary.*

4.3.1 Year wise / or frequency of the data collection

Data collection method	Frequency
Traffic flow video collection	Twice every year (dry and wet season) for 12 hours hat and non-hat day, variable locations Throughout the year at one location in all upazila. (one fix station)
Drive through video collection for pavement and road condition	Once every year (dry season)
Market Interview Survey	Once every year
Noise Level monitoring & Air pollution monitoring	Once every year during the market survey, 24 hours survey work. Throughout the year at one location in all upazila. (one fix station)
Hydraulic structures condition survey	Once every year or after major disasters

4.3.2 Storage and archiving and management of the database

The collected data intended for performance evaluation needs to be archived in the LGED road database system. It is expected to integrate the collected data in a standard modern Road asset management system or RAMS.

4.3.3 Monitoring and evaluation of the guideline implementation

The performance evaluation process should be monitored and reviewed for improvement through out the year. The data collection, processing and using the data to evaluate the performance score of a LGED road need throughout the year monitoring and evaluation and review for improvement and maintaining the quality of work.

4.3.4 CQI of the framework

Few examples are explored below to understand how continuous quality improvement of the performance framework can benefit the overall effectiveness and reliability of the performance equation.

- *The framework could benefit from a filter option or dependent set of variables that are associated with a certain general characteristic of the sites.*
- *For special site conditions, the scoring process should be able to adapt to the new challenges.*
- *Explore and introduce correlation between parameters or attributes.*

Chapter 5 Conclusion

5 Chapter 5 Conclusion

The guideline is developed to assess performance of any rural paved road of LGED. However, there could be special scenarios or cases where the evaluation framework or equation may require updates or modifications. Also, the guideline is proposed for a short-term phase of 3 years and highly focuses on methodology that are easily available to implement, scalable to mass scale programs and requires minimal level of effort and are adaptable to budget constraints. The evaluation process should be updated based on the field observations and implementation challenges through continuous quality improvement process.

5.1 Updates Required

The guideline is detailed for short term implementation and have been established based on the results and observations from a pilot work at eight sites around the country. Thus this guideline may require additional updates while upgrading to mid term phase and while implementing to special scenarios that the pilot work could not encompass. The inclusion of new parameters and changes to proposed parameter evaluation would be possible to accommodate within the same evaluation structure with the following efforts only.

- Update the AHP study to update the global weightage
- Based on new scenario or observations update the measurement method or unit
- Evaluation process or scoring to be updated accordingly.

5.1.1 How to update the AHP

- Update the questionnaire form to include desired changes
- Prepare list of participants and conduct the survey
- Carryout the assessment and derive new global weightages for sub criteria/ attributes.
- Use the new global weightages in the performance evaluation equation

5.2 Actions needs for implementation

5.2.1 RAMS

LGED should establish a modern road asset management system for efficient management of its vast road assets throughout the country and develop a robust asset database through regular reliable data collection efforts compatible with the RAMS.

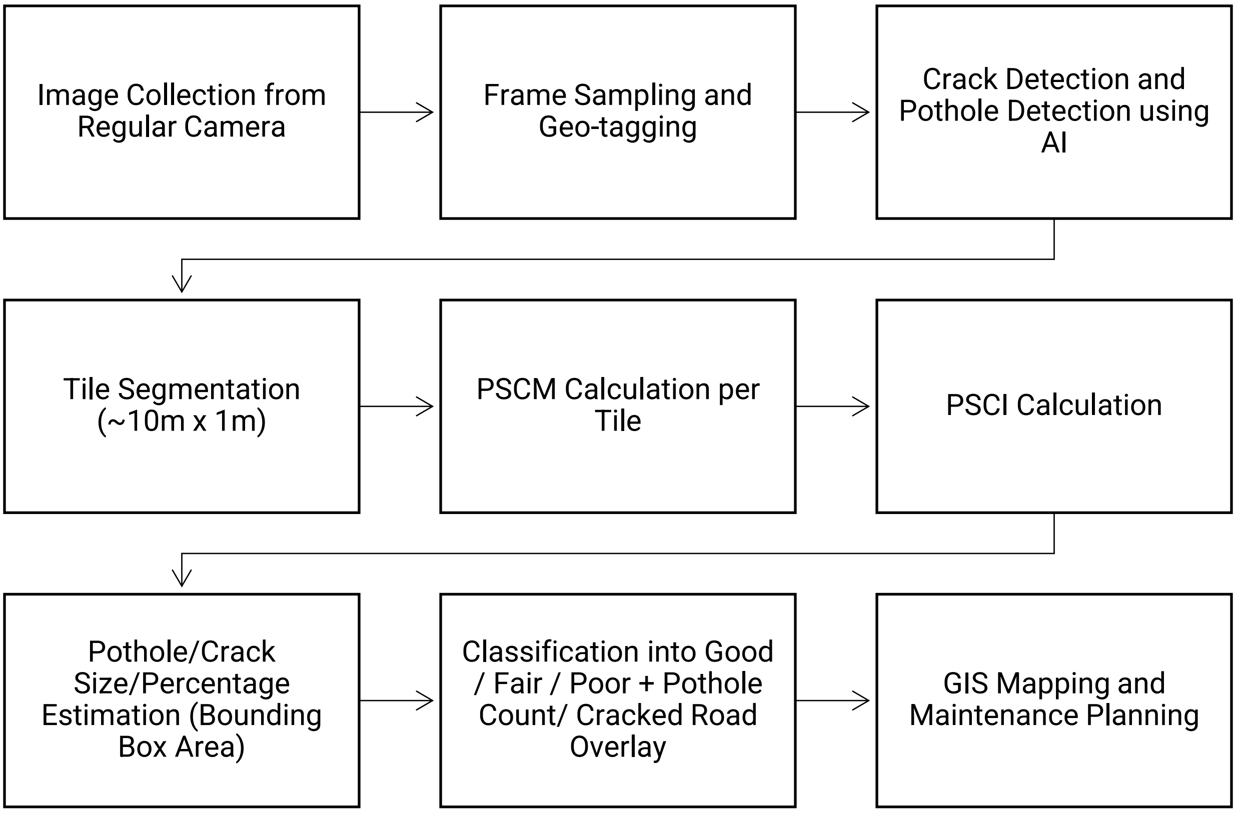
5.2.2 Budget

LGED should develop a comprehensive survey plan for the evaluation of paved road performance and allocate sufficient budget for the field work and assessment efforts. The survey data can be greatly useful to LGED if the data is integrated into the RAMS. The traffic and road condition data would also be greatly beneficial to road development or rehabilitation projects. Updating from the conventional labor-intensive manual data collection practices would eventually prove to be more economical.

Appendix

Appendix A. AI-Based Pavement Surface Evaluation Using Regular Cameras for LGED Roads

1. Literature Review of Automated Pavement Surface Distress Evaluation



Modern approaches to pavement evaluation are undergoing a transition from manual visual inspections and laser-based profilers to flexible, camera-based systems supported by artificial intelligence (AI). At the forefront of this evolution is the application of regular video cameras, including smartphone-grade devices, in combination with deep learning algorithms to quantify pavement surface condition.

Nguyen et al. (2023) highlighted the use of both manual and automated image-based approaches to monitor pavement cracking in Singapore's road network. Their study adopted the ASTM E3303-21 standard, which introduces the Pavement Surface Cracking Metric (PSCM) and the Pavement Surface Cracking Index (PSCI)—both computed solely from images of the pavement surface.

This is significant because the ASTM E3303-21 method does not require crack type classification but focuses on measuring crack length and width within defined analysis areas. While Nguyen's study used high-resolution 3D images from an LCMS-2 system, the standard itself allows for adaptation to 2D image analysis, which means that a network-level application using standard digital cameras is feasible for organizations like LGED, provided AI-assisted detection methods are properly trained.

Balzarini et al. (2021) further validated the PSCM/PSCI concept, simulating thousands of pavement sections with different crack types and dimensions. They demonstrated that PSCI could be reliably used to represent surface distress severity even when traditional PCI calculation was not possible due to limited data or missing input on structural conditions. Importantly, PSCI was found to strongly correlate with PCI when surface distresses dominated the pavement condition.

In parallel, AI-based systems for pothole detection and measurement have also emerged. Many of these systems use object detection architectures like YOLOv5 and YOLOv8, trained on datasets such as RDD2020 and GAPs, which allow real-time detection and classification of potholes in regular video streams. The size and shape of potholes can be approximated using pixel dimensions referenced against known vehicle calibration data or lane markings. Several implementations in countries such as India and Vietnam have demonstrated successful application of these systems using motorcycle-mounted or dashboard-mounted smartphones, validating their suitability for resource-constrained environments.

Together, these studies form a foundation for adopting PSCI and complementary visual distress metrics (including potholes) as practical tools in low-resource settings. The technology stack for this approach includes basic vehicle-mounted video cameras, image annotation, pothole detection, and crack segmentation algorithms using convolutional neural networks (CNNs).

2. Review of Relevant Codes and Benchmarks

The ASTM E3303-21 standard specifies how to compute PSCM and PSCI based on measured crack length (L), crack width (w), and the area (A) of each analysis tile:

$$PSCM = (100 * L * w) / A$$
$$PSCI = 100 * \exp(-0.45 * PSCM)$$

The PSCI transforms a physical crack density metric into a standardized index ranging from 0 (worst) to 100 (best). This can be aligned with maintenance decisions, as Nguyen's Singaporean study proposed three severity thresholds: PSCI ≥ 75 (low severity), 50 < PSCI < 75 (moderate), and PSCI ≤ 50 (high severity).

Balzarini (2021) clarified that while PSCI is not a direct replacement for PCI, it functions as an analogous surface condition index. Their methodology split each road segment into standard zones—central, wheel-path, and edge—and further into tiles, each analyzed for crack dimensions using either laser or high-resolution imaging. Critically, this method allows PSCI to be computed even with partial coverage or irregular data—making it ideal for image-based surveys using regular video.

The AASHTO R85 protocol complements this by setting detection performance standards for automated image analysis tools. Systems should identify at least 85% of cracks wider than 5 mm and 60% of those between 3–5 mm, with a minimum detection accuracy of 33% for finer cracks. These standards, although developed for high-fidelity imaging, serve as validation goals for AI-based detection models operating on standard RGB images, including those used for potholes and patching detection.

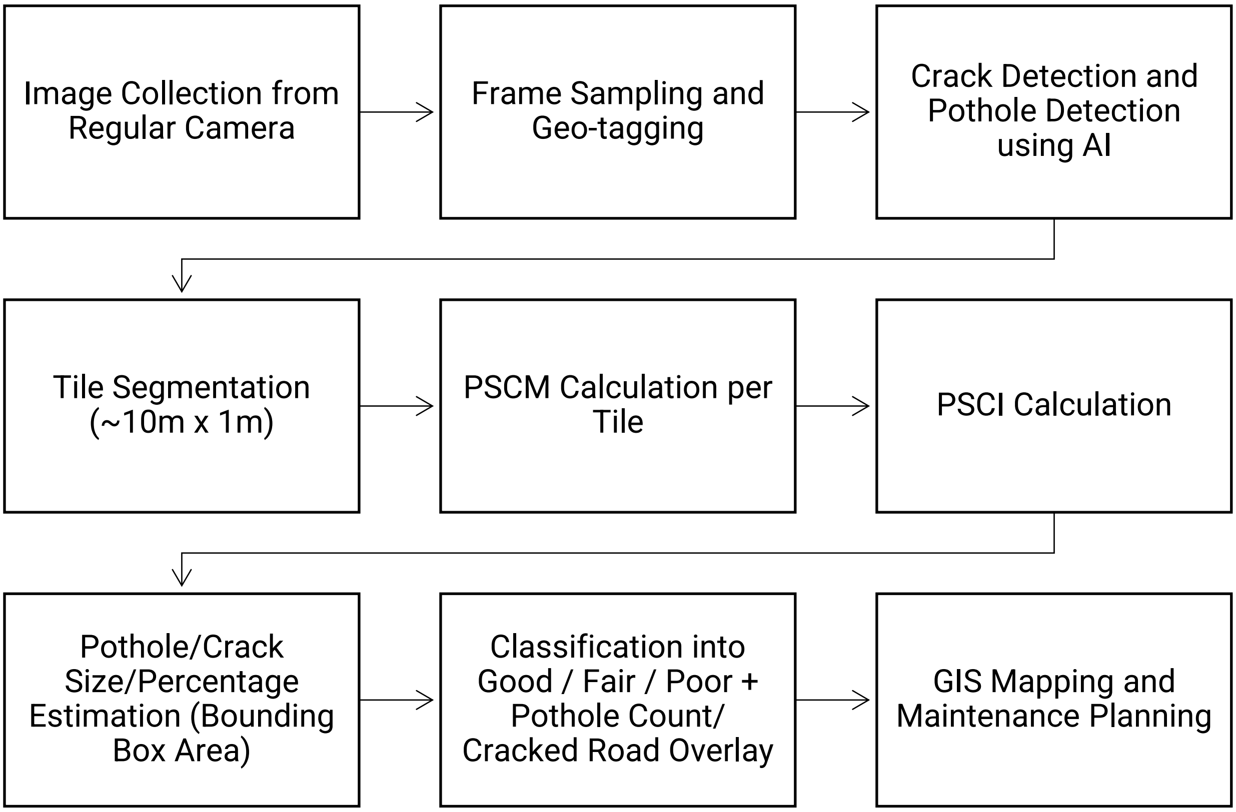


Figure 9 Flowchart PSCM/PSCI Calculation and integration to LGED framework

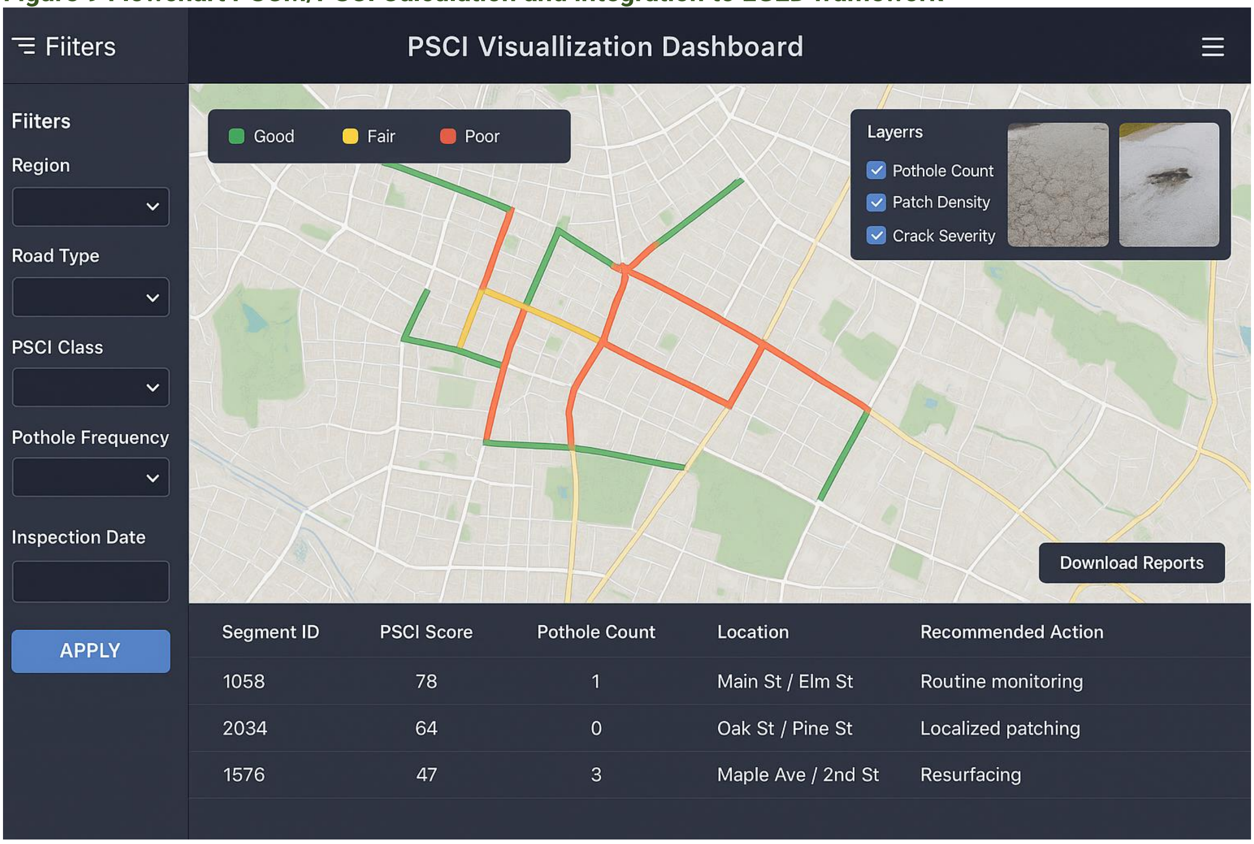


Figure 10 Example Software Capacity

3. Evaluation of LGED Road from Potholes and Cracking Parameters

3.1 Contextual Challenges for LGED

LGED manages an extensive rural road network composed of both paved and unpaved segments. Manual inspection is time-consuming, subjective, and difficult to scale. Advanced laser scanning systems like LCMS-2 are cost-prohibitive for widespread use in Bangladesh. Therefore, LGED requires an intermediate standard that allows for scalable, repeatable, and objective assessment using accessible tools.

A practical solution involves vehicle-mounted cameras (such as dashcams or smartphones) and AI models trained to detect surface distresses from these images. While the lack of laser resolution restricts precise measurement of crack widths and pothole depths, visual estimation of crack area coverage, pothole size, pattern density, and continuity allows PSCM and thus PSCI to be approximated.

3.2 Adapting PSCI and Pothole Detection for Visual Rating from Regular Cameras

LGED can adopt the PSCI scale as a proxy for crack-based pavement condition and use object detection algorithms to identify potholes. A simplified workflow is as follows:

1. Data Collection: Use standard video cameras to collect pavement surface imagery across 10 m segments.
2. AI Detection: Use neural networks (e.g., U-Net, YOLOv8) to detect cracks and potholes.
3. PSCM Calculation: Use tile-based segmentation to compute estimated PSCM values, interpolated from visible crack data.
4. PSCI Assignment: Convert PSCM to PSCI using:

PSCI = 100 * e^(-0.45 * PSCM)
or the alternative version by Balzarini:
PSCI = 15 + 85 * e^(-0.64 * PSCM)

5. Pothole Quantification: Count potholes and estimate size using bounding box dimensions against lane width references.

6. Condition Rating:

    - PSCI ≥ 75 → Good
    - 50 < PSCI < 75 → Fair
    - PSCI ≤ 50 → Poor
    - Supplement with pothole counts or patching severity as a qualitative layer

Bibliography

- ASTM E3303-21. (2021). Standard Practice for Generating Pavement Surface Cracking Indices from Digital Images. ASTM International.
- Balzarini, A., Xu, B., Bennett, C. R., & Branthwaite, M. (2021). Development and calibration of a visual pavement condition index for network-level assessments. Transportation Research Record, 2675(12), 1084–1096.
- Nguyen, T., Lee, K., Tan, J. Y., & Ho, N. Y. (2023). Proposed severity ranking for ASTM E3303-21 protocol to quantify asphalt pavement cracking from automated 3D surveys. IOP Conference Series: Materials Science and Engineering, 1289(1), 012057.
- AASHTO R85-18. (2018). Standard Practice for Quantifying Cracks in Asphalt Pavement Surfaces from Collected Pavement Images Utilizing Automated Methods. American Association of State Highway and Transportation Officials.
- Road Damage Detection Challenge (RDD2020). (2020). IEEE Big Data 2020.
- GAPs Dataset. (2021). Global Asphalt Pavement Dataset for Pothole Detection and Surface Condition Monitoring.

Appendix B. Pilot implementation summary

Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Division	Rajshahi	Dhaka	Rangpur	Mymensingh	Chattogram	Sylhet	Barishal	Khulna
District	Sirajganj	Gazipur	Dinajpur	Netrokona	Cox's bazar	Sunamganj	Barishal	Bagerhat
Upazila	Ullapara	Sadar	Sadar	Madan	Ramu	Jagannathpur	Gouranadi	Mongla
Road Type	Upazila	Upazila	Upazila	Upazila	Union Road	Union Road	Upazila	Village Road A
Road no.	**188942004**	**333302005**	**127643005**	**372562001**	**422663002**	**690473020**	**506322002**	**20158 4007**
Road Name	Hatikumrul R&H-Tarash GC road	Rajandrapur-MirzapurRoad	Ranigonj GC to Motunirhat(Kaharol) GC via-Jamtoli,Nasipurt Road.	Madan-Fatepur (Hatshira) GC Road	Garjania UP Office - Thimchari (Baisari) Road.	Jagdal UP - Kabirpur (Jagannathpur GC)) via Bhurakhali (Jagannathpur part) road	Batazore-Agorpur-Sarikal via Hosnabad-Nalgora-Miarchar road.	Khasherdanga-Dhonkhali
Road length km	**12.38**	**6.65**	**5.75**	**13.39**	**7.7**	**8.00**	**17.18**	**4.3**
• Earthen								
• BC	12.38	5.33	5.75	13.39	7.7		16.18	
• HBB								0.13
• RCC		1.32				8.00	1	
• Uni block								4.17
Bridge/culvert no.	**10**	**3**	**16**	**40**	**23**	**7**	**24**	**5**
Bridge/culvert Length m	**126.05**	**100.2**	**319.7**	**213.8**	**82.9**	**13.4**	**202.7**	**16.4**
GC	None, nearest Boalia hat (5km away)	GC MIRZAPUR BAZAR	GC Raniganj Hat, burir hat bazar	GC Fatehpur bazar, Parashkhila & Balali bazar	Time bazar, Thimchori bazar	None, nearest bazar chilaura bazar	GC Batajor, GC sarikul hat	None, nearest is gopper hat
District/upazila/ Union HQ	Hatikamrul union HQ, Salanga union HQ	Bangla bazar Rajendropur chowrasta bazar	Fazilpur Union HQ	Fatehpur union HQ, Tiasree union HQ, Madan union HQ,	Garjana Union HQ	None	Batajor Union HQ Sarikul Union HQ	None