# DEVELOPING SINGAPORE ROAD PAVEMENT PERFORMANCE SYSTEM (PPS)

## 1 INTRODUCTION

The Land Transport Authority (LTA) spearheads land transport developments in Singapore. We plan, design, build and maintain Singapore's land transport infrastructure and systems. We aspire to strengthen Singapore's land transport connectivity and integrate a greener and more inclusive public transport system complemented by walk and cycle options. We harness technology to strengthen our rail and bus infrastructure and develop exciting options for future land transport.

As we work towards achieving our goals under LTMP2040, we are often confronted with operational challenges driven by a dynamic operating environment. At the same time, we continue to strive towards better cost effectiveness, manpower optimisation, environmental sustainability, reliability and safer operations. These then present us with opportunities to work closely and co-create solutions to address the challenges and requirements with our ecosystem partners/innovators. LTA has launched this Call for Solutions for "Developing Singapore Road Pavement Performance System (PPS)", and we invite interested partners/innovators to collaborate with us.

## 2 PROBLEM STATEMENT

LTA is responsible for managing and maintaining over 9,500 lane-km of roads. A robust maintenance programme is crucial to ensure that the roads remain functional and safe for road users at all times. A critical aspect of the road maintenance framework is the inspection regime, and LTA is currently utilising Video Analytics (VA) and Artificial Intelligence (AI) to identify road surface defects promptly and enable swift action for safety-critical issues (see Fig. 1). Leveraging AI/VA has improved both productivity and detection accuracy.

Inspections also utilise specialised equipment to assess pavement performance, including the Laser Crack Measurement System (LCMS) for evaluating road roughness, rut, surface texture, and cracks; the Sideway-force Coefficient Routine Investigation Machine (SCRIM) or Grip Tester for measuring skid resistance; and the Falling Weight Deflectometer (FWD) for structural integrity assessments (see Fig. 2).

The non-destructive measurement methods collect numerical road condition data to complement visible conditions, providing highly accurate assessments of road pavement performance. These methods involve sophisticated equipment requiring specialised setups and complex data processing.

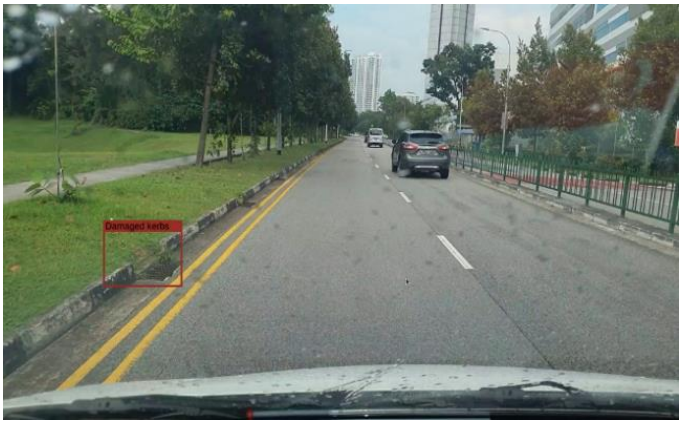
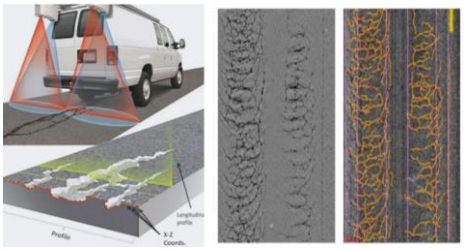



*Fig 1. Detection of visual defects through AI/VA*


LCMS for IRI measurement



LCMS for crack measurement

SCRIM for skid resistance measurement

FWD test for structural capacity check

*Fig 2. Pavement condition survey through specialised equipment*

While this current approach of using AI/VA inspection to detect visible defects and specialised inspection to obtain numerical road condition data has adequately guided maintenance work and planning, recent advancements in equipment technologies, road performance assessment approaches, automated data collection techniques and AI-enhanced data processing methods have enabled LTA to review and expand the use of data to enhance road pavement management.

This project therefore aims to develop Singapore Road Pavement Performance System (PPS). The PPS shall be hosted on a digital platform that enables the Authority to:

a. Understand existing pavement health conditions via a Pavement Performance Index (PPI) system;
b. Recommend maintenance levels and actions required to achieve the minimum road performance level, specify the interventions needed to address road defects; and
c. Via a road deterioration model, predict, prioritise, plan and project maintenance works and required budget for the next 3-5 years.

The establishment of the PPS will encompass:

a. developing pavement performance index (PPI) for expressways and arterial roads tailored to the Singapore context;
b. developing road performance deterioration model for specified road pavement types; and
c. designing and developing a decision-support tool as a minimum viable product (MVP) that integrates essential inputs for maintenance and budget planning. These inputs include, but are not limited to road performance data including the developed PPI and deterioration model as described under (a) and (b) above, road performance standards to be achieved, various recommended maintenance measures required to achieve the minimum road performance standards including cost rates of those measures.

## 3 WHAT ARE WE LOOKING FOR?

LTA is seeking proposals that cover the following scopes to develop the PPS:

### A. Developing Pavement Performance Index (for Expressways and Arterial Roads) and Road Performance Deterioration Model

A.1. Developing Pavement Performance Index (PPI) for expressways and arterial roads

The objective is to develop road pavement performance indices for expressway and arterial roads respectively, enabling effective assessment, suggesting maintenance plan and scheduling and resources allocation.

The proposal shall cover methodology to develop a Singapore Pavement Performance Index (PPI) to assess the health condition of roads and establish the associated maintenance interventions for each PPI score interval. It shall include, but not be limited to:

a. Data Collection Strategy: Outline an approach for:
    i. Collecting road performance data. Specify the number of data samples required for PPI development, ensuring a confidence level of at least 80% when it is tested with independent dataset.

ii. Selecting and deploying cost-effective and reliable equipment for measuring health condition of road such as but not limited to road roughness, rut, cracks and skid resistance, as alternatives to current equipment.

iii. The proposed equipment and methods is expected to have at least 20% improvements in cost savings and productivity (man-hours) compared to equipment/methods currently in use by LTA. This includes alternatives to the Laser Crack Measurement System (LCMS) Class 1 Profiler for road roughness, rut and cracks, the Grip Tester or Sideway-force Coefficient Routine Investigation Machine (SCRIM) for skid resistance and Falling Weight Deflectometer (FWD) for structural condition assessment. The measurement accuracy of the alternative equipment/method should be at least 80% of that achieved by the current equipment/method.

iv. Selecting an appropriate road segmentation for collecting and analysing road performance data for practical use by road maintenance team.

v. Hosting and presenting the collected data on an interactive visualisation platform.

b. Deriving the Pavement Performance Index (PPI). Outline the approach for:

i. Preparing detailed data input required for deriving the PPI, such as, but not limited to, the extent of road condition, the defect size, the severity, etc. <u>The system should be able to take in data inputs from alternative data sources.</u>

ii. The proposed PPI may encompass various road performance attributes. These may include, but are not limited to, pavement condition, riding quality, road safety and structural condition. Through industrial engagement and based on practical operational considerations, additional performance parameters may be proposed to be included within PPI formulation.

iii. If the proposed method references established and adopted formulas, proposing key modifications necessary to ensure alignment with Singapore's unique conditions and requirements.

iv. Deriving representative weightings for each road performance attributes in the Pavement Performance Index (PPI), include the approach for determining weighting factors based on its severity and impact on relevant stakeholders (this could be done through, but not limited to, a survey and/or focus group discussions with relevant authorities, subject matter experts, road users and the road maintenance industry).

v. Selecting method to normalize the PPI score to a standard performance scale (e.g., 0 to 100) for practical interpretation of PPI results.

i. Testing and validation plan of the proposed PPI.

c. Intelligent scoping of intervention against PPI Levels. Outline an approach for:

i. Developing method that can intelligently define the scope of maintenance intervention required at each PPI level, as well as to assign a prioritisation level for benchmarking across the different interventions.
ii. The scope of interventions will include commendations on effective inspection method & frequency and the proposed types and timing of maintenance actions. This intelligent method should be configurable (e.g. supported by guided self-learning algorithm) as more data becomes available.

A.2 Developing Road Deterioration Model

The objective is to develop a predictive deterioration model which can predict how road pavements will degrade over time due to traffic loads, environmental conditions, and material properties. The model will, but not be limited to, predict road pavement conditions against performance attributes of road roughness, rut, skid resistance, cracks and other structural conditions.

The model will suggest the road pavement conditions at n-year, which will in turn facilitate effective forecasting of road maintenance and budgeting requirements. It should be intuitively visualised for stakeholders' interpretation who are LTA staff as well as appointed service partners/contractors.

The deterioration model for respective road performance should have a minimum 70% confidence level when the model is tested with another dataset that is also to be collected during the study, with the potential to be improved to 90% as more data becomes available.

The proposal should outline approaches for collecting essential data, methodologies for establishing the model and procedures for validating the model. It should also cover data requirements and outline approach for validation & calibration.

Data Requirements:

- Types of data to be collected. Data are to be collected using proposed alternative equipment/method stated under Scope A.1.
- Data sources (e.g., sensors, historical records, surveys).
- Proposed modelling techniques (e.g., regression analysis, machine learning, simulation models, etc.) and justification for chosen techniques.

Validation and Calibration:

- Procedures for validating and calibrating the model against actual data.
- Method to assess model accuracy.

**B. Developing Decision-Support Tool for Road Maintenance and Management**

The objective is to develop an MVP that will aid in decision-making for long term (e.g. 3, 5 and 10 years) road maintenance and management. It shall have functional features with visualisation tools (for current and predictive values) to enable identification and analysis of road performance for $n^{th}$ year, suggesting maintenance scopes required (inspection frequency and road repair solutions) as well as projecting maintenance budget.

The proposal shall outline approaches to deliver the following key requirements as follow:

- Intuitive dashboard for easy access to key metrics and reports which are user configurable.
- User friendly for field data entry and output presentation.
- Ability to accommodate and process additional datasets when they become available.
- User-configurable attributes for budget forecasting.

Additionally, the proposal also shall cover the following:

- Outline data integration methods.
- Specify necessary software and hardware resources.
- Describe reporting and analysis capabilities.
- Explain how the system will support maintenance prioritisation and budget allocation.

**Other General Requirements for Project Scope A and B**

Besides providing the proposal on how the requirements would be met, the proposal shall also cover the following:

a. **Milestones and Key Performance Indicators (KPIs)**: to include a detailed description and breakdown of keys tasks and milestones to be completed. The milestones should be organised such that the successful completion of a preceding milestone(s) set the conditions to kickstart a following one(s). As such, the KPIs for each milestone should be clearly defined.

b. **Cost Breakdown:** include an estimated cost breakdown for the development, including logistics, manpower and development cost. It is to be noted that all data collected, algorithm, system developed and any equipment/system hardware/software purchased for the project shall be transferred to LTA after project completion.

c. **Demo:** If available, include video demo of the proposed solutions. Shortlisted partners could be invited for a live demo during proposal evaluation.

d. **Knowledge Sharing/Training**: Proposed knowledge sharing and training sessions on model development, usage and interpretation.

**Project Timeline**

The overall projected timeline for the project scope is 12 months or less. Collaborators could propose alternative timelines for each scope with supporting justification.

**Option to Scale / Implement**

If successful, LTA may follow on to expand the implementation of the developed solution for all expressway and arterial road networks with the awarded collaborator. The developed solution shall be integrated into the end-to-end maintenance workflow to aid the LTA maintenance team in data-driven maintenance planning, from ad-hoc work (short-term) to rehabilitation planning and budget projection (long-term).

## 4 EVALUATION GUIDELINES

The evaluation of the proposal will be guided by the evaluation criteria set out below:

a. Ability to fulfil requirements and KPIs under Section 3;
b. Cost effectiveness of proposed solutions;
c. Project time effectiveness of proposed POC;
d. Good track record of deploying such solutions.
e. Collaborators are encouraged to submit comprehensive proposals encompassing both Scopes A and B. Submissions that comprehensively cover all project scopes will be given more favourable consideration.
   Single-scope submissions (i.e. Scope A or B) will be considered and evaluated with the following conditions:
   - Scope A awardees must be ready to provide technical assistance to Scope B awardees for the decision-support tool development.
   - Scope B awardees must be ready to seek technical assistance from Scope A awardees.

LTA will assess the comprehensiveness, clarity and merits of the proposals, and shortlisted participant(s) will be invited for further Proof-Of-Concept (POC) or trial to implement the proposed solutions.

## 5 TIMELINE

All parties interested to participate in this Call for Solutions are invited to attend a technical briefing to understand more information on the problem statement. The briefing will be held **on 15 Jan 2025, 0930-1130H (SGT/GMT +8).** Each company/organisation is allowed to send a maximum of 2 representatives to the briefing.

If you are interested to attend the briefing, please register here **by 10 Jan 2025, 1600H (SGT/GMT +8)**. We seek your understanding that we are unable to accommodate registrations received after said date and time. Kindly note that the briefing will only take place if enough registrations have been received. All eligible registered attendees will receive a confirmation email on 13 Jan 2025.

Technical proposals must be submitted by **14 Feb 2025**, **1600H (SGT/GMT +8) via this submission form.**

We encourage interested parties to visit the Land Transport Innovation Portal for the latest updates.

## 6 GUIDELINES FOR PARTICIPATION

1. The purpose of this brief is to provide preliminary information on the problem statement on "Developing Singapore Road Pavement Performance System (PPS)". Please note that the information provided does not form part of any subsequent contract.
2. To register for this Call for Solutions, you must be from one of the following:
    a. Private company, with local business registration
    b. Tertiary institution based in and operating from Singapore.
    c. Research institution based in and operating from Singapore.
    d. A consortium led by any of the above. For clarity, there is no restriction on overseas partners for the consortium.
3. If you will be registering as a consortium, do appoint a lead member as the main applicant and make all submissions through this lead member. The actions by the lead member of the team will be treated as representative of the consortium. All correspondence will be directed to the lead member.
4. Please provide relevant information on your (or consortium members') past experiences that are relevant for this submission.
5. Do note that all proposals submitted through this call are to be limited to 5 pages for LTA's preliminary evaluation and shortlisting only. If LTA is keen to find out more about your solution after the close of this call, we will contact you for further clarifications. You may be asked to make presentations and/or provide more information on your solution to LTA and/or requested to host LTA at any proposed venue and/or facilities for visits and better understanding of the proposed solution.
6. Eligibility for funding will be considered separately, and if your proposal is shortlisted, you may be asked to fill up further application forms with more details on your proposed solution. Do also note that you may be required to co-fund part of the solution development trial, subject to the respective funding guidelines.
7. Any documents submitted will be treated as confidential and will not be returned. By submitting any documents, you hereby consent to any disclosure by LTA of your documents to the Government of Singapore, the relevant Government Agencies, and/ or government-related agencies, as LTA considers appropriate in our discretion for purpose of evaluation in this Call for Solutions.
8. Notwithstanding any other provision in this Call for Solutions, LTA may amend, suspend or withdraw all or any part of the Call for Solutions or the Call for Solution process, which will be informed via the Land Transport Innovation Portal.

## 7 CONTACT US

Please submit any queries regarding this Call for Solutions via this form no later than **24 Jan 2025, 1600H (SGT/ GMT +8)**. LTA's responses to the queries will be updated on Land Transport Innovation Portal before the close of the Call for Solutions.

## ANNEX

To standardise the evaluation of road performance, pavement engineering practitioners typically employ a unified index that encapsulates different road performance indicators. This index is developed by analysing various road distresses and ranking them according to type, severity, and extent. Additionally, the index helps to prioritise maintenance interventions necessary to sustain the road's desired performance.

ASTM D6433-20 is an internationally recognised standard that outlines the evaluation of pavement condition through the Pavement Condition Index (PCI). Following this ASTM guidelines, each distress type is assigned a specific deduct value based on its severity, and these deduct values are then used to calculate the overall PCI score for the pavement section. The PCI score typically ranges from 0 to 100, with 100 representing a pavement in excellent condition and 0 indicating a pavement in very poor condition.

Many countries, including the United States, use the PCI along with the International Roughness Index (IRI) to assess road conditions and ride quality. China has also established various indices that summarise multiple aspects of road conditions, such as the Pavement Condition Index, Road Quality Index, and Structural Condition Index. The UK's Transport Research Laboratory has developed methods to assess road conditions, including the use of performance indices for maintenance plans and budgetary planning. Some Europe countries also have implemented road management systems that include pavement condition indices to standardise assessments and inform maintenance budgets.

It should be noted that the indices ought to be established to suit local conditions, as they are determined by local factors such as maintenance practices, public perception and governing policies. While the references can still be used to guide the fundamental concept of the evaluation of pavement condition, the formula should be calibrated to suit local conditions, as the weightage for each parameter is locally dependent based on local maintenance practices, public perception, and governing policies. For Singapore's application, it should be benchmarked against the nearest regions or countries that have similar pavement design, traffic and weather conditions, and maintenance requirements.