



Evaluating Pavement Preservation Performance in Dry Freeze and Wet Freeze Regions Using LTPP Dataset and a Questionnaire Survey

CTIPS-034

Approved 9/15/2024

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Research Needs

Long term pavement performance (LTPP) has an extensive dataset for the performance of pavements. The LTPP program started based on the State Highway Research Program (SHRP) and currently it has more than 2,500 test sections. LTPP has four different climatic regions

(Jackson et al., 2006) as given in Figure 1 (Chen et al., 2019). LTPP database has an extensive dataset related to pavement performance/condition (e.g., international roughness index (IRI)) and pavement preventive maintenance treatments.

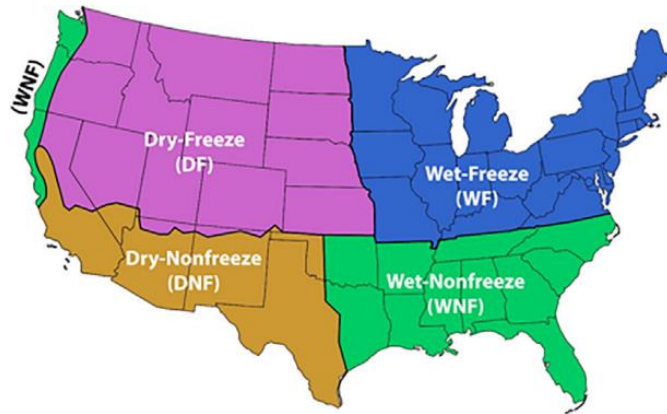


Figure 1: Different Climatic region in LTPP (Chen et al., 2019)

Preventive maintenance is a treatment applied to the surface of pavement to increase its serviceability and delay its deterioration. The importance of this treatment can be judged by the survey in Arizona where the public is willing to pay more taxes in order to get better maintained roads. These preventive treatments are applied at early stages of pavement life. Treatments applied too late are ineffective, failing to prolong the life of the pavement. The preventive treatments applied on flexible pavements include crack filling/ crack sealing, fog seals, slurry seals, scrub seals, microsurfacing, chip seals, thin overlay, and ultrathin friction courses. While, the concrete pavements preventive treatments include full depth concrete pavement repair, joint sealing, crack sealing, rack sealing, joint and surface spall repair, diamond grinding, undersealing and load transfer restoration (Peshkin et al., 2004).

In LTPP, many sections are preserved with thin overlay, slurry seal, crack seal and chip seal. The thin overlay, typically 1-1.5 inch of thickness, is the thin non-structural layer added to the pavement surface to improve pavement surface condition, protect pavement structure, reduce its deterioration rate, correct surface deficiencies, reduce permeability, and improve pavement ride quality. The slurry seal is a mixture of emulsified asphalt, well-graded fine aggregate, water and mineral filler that has a creamy fluid-like appearance when applied. As a hard-wearing surfacing for pavement preservation, slurry seal can be used for sealing aged pavements, filling minor cracks, restoring skid resistance and enhancing aesthetic appearance (Wang and Wang 2013). Chip seal is the application of bituminous binder, immediately followed by the application of aggregate (Wang and Wang 2013). The aggregate is then rolled and embedded into the binder. Multiple layers may be placed, and different types of binder and aggregate can be used to address specific distress or traffic situations.

The effectiveness of pavement maintenance can be measured as the immediate improvement in pavement condition (i.e., performance jump (PJ)), the extension in service life (ESL), or area under the curve (AUC) of pavement performance (Labi and Sinha, 2005). Index benefit is another indicator used to evaluate the effectiveness of pavement preservation, which is a difference between the AUC of pro-treatment deterioration curve and do-nothing curve (Arezoumand et al., 2024). The effectiveness of chip seal has been found to be different in wet

no freeze and wet freeze climatic zones. In the former, it extends pavement life by 6 years, while in the latter, it extends pavement life by 2 years (Vargas-Nordbeck et al., 2019). Chip seals have positive effects in reducing the cracking rate (Luo et al., 2021). Other research recommended chip seal as the most preferred treatment choice in freeze region for treating fatigue cracking followed by thin overlay for treating rutting and roughness (Carvalho et. al., 2011). However, chip seal preventive treatment is not highly effective for cold region (Vargas-Nordbeck et al., 2019), heavy traffic roads, or interstates. The use of thin overlay may be the best treatment for improving IRI followed by slurry seal coat as compared to the chip and crack seal (Hall et al., 2002; Bayomy et al., 2006). Idaho reported that thin overlay and slurry seal are best options for improving the roughness whereas chip and crack seal has no impact on the pavement performance. Also, surface treatment is not effective at improving pavement condition such as rutting and cracking (Bayomy et al., 2006). Research in Iowa State reported thin overlay provides the highest service life and patching gives the shortest service life extension for flexible pavements (Arezoumand et al., 2024). Hence, it can be inferred that there is a contradiction between the reported effectiveness of most pavement preventive maintenance treatments.

Furthermore, multiple factors may influence the effectiveness of preventive maintenance. The pre-treatment pavement condition affects the efficacy of preventive treatments (Dong and Huang, 2015). Additionally, the effectiveness of preventive maintenance treatments depends on the climatic region in which they are applied. There is a strong correlation between pre-treatment pavement performance and environmental factors (Perera et al., 1998). For example: In wet-freeze environments, the crack seal treatment outperforms that in other regions (Carvalho et. al., 2011). Therefore, the factors affecting the effectiveness of preventive maintenance treatments should be thoroughly identified and their statistical significance assessed in cold climatic zones.

Research Objectives

The main goal of this proposed research project is to assess the effectiveness of different preventive maintenance treatments in cold regions including dry-freeze and wet-freeze regions. This will be achieved through the following methodology:

1. Review the relevant state-of-the-art and established practices.
2. Collect pavement condition and preventive maintenance datasets.
3. Create a questionnaire survey to determine the current preventive maintenance techniques and their effectiveness in the US cold regions.
4. Conduct statistical analysis to assess the significant factors affecting the effectiveness of preventive maintenance.
5. Assess the effectiveness of different preventive maintenance treatments in terms of performance jump or the immediate improvement in pavement condition right after treatment application.

Research Methods

The following research task is proposed for research project:

- Literature review for state of art pavement preservation in LTPP dataset.
- Check the quality of data for cold climatic regions.

- Collect the distress data such as IRI, rutting and percentage of cracking data for cold climatic region and choose the best distress for the analysis based on incremental damage.
- Surveying the different agencies/DOTs in cold region for the current state of preventive maintenance and its effectiveness.
- Determine a suitable statistical method for data analysis.
- Recommendation of specific preventive treatment type for cold climatic regions/state.

Figure 1 illustrates the different climatic region in the LTPP dataset and specifically cold region that will be used for achieving the objective of this research project. The preventive maintenance performance effectiveness may vary in cold climatic regions such as dry-freeze, and wet-freeze regions. First, existing literature reviews will be conducted from published journals, TRB conference, LTPP reports and others. Secondly, the quality of the data plays a significant role in this research. So, data would be collected for all LTPP test sections with preventive maintenance in cold climatic condition and checked for applicability. The data checks would include verifying the performance data such as IRI, rutting and cracking for different states with respective preventive maintenance. The distress type and pavement performance would vary based on the treatment type. Thereafter, appropriate statistical methods would be applied for the dataset based on cold climatic regions/state. Finally, specific preventive maintenance would be recommended based on climatic conditions such as dry-freeze and wet-freeze states. Figure 2 shows the flowchart of the study.

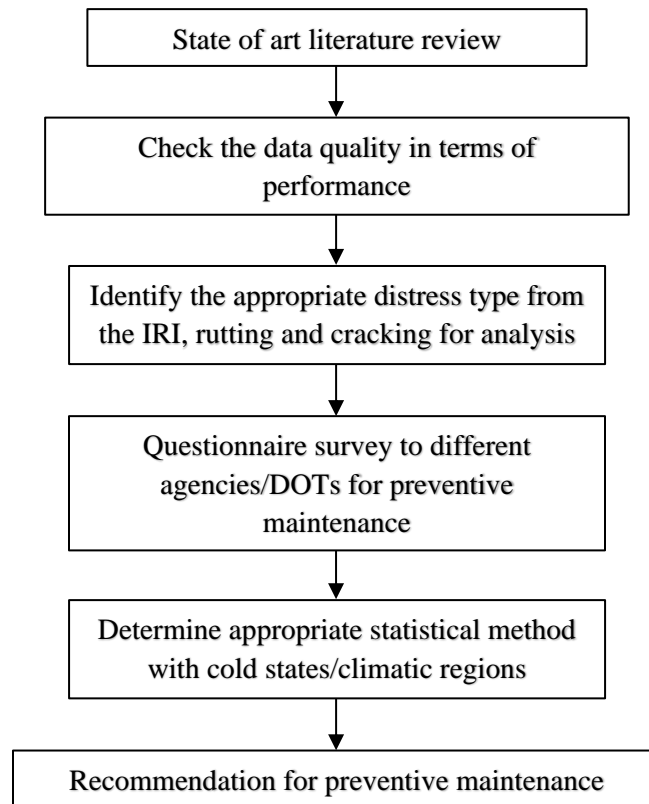


Figure 2. Proposed Research Methodology

Relevance to Strategic Goals

Climate and sustainability are primarily addressed by the proposed project. The primary goal of this proposed project is to determine the effective preventive maintenance technique for a pavement management system (PMS) in cold climatic regions. These regions include dry-freeze climatic zone, which is for the state of Wyoming. This research will help aid decision-makers in making better choices to ensure good preventive maintenance for their roads. This, in turn, supports the CTIPS statutory research priority area by aiding policymakers in preserving their current transportation systems in a sustainable manner. Improving the condition of pavements across dry-freeze and wet-freeze regions including Wyoming will lead to a better allocation of resources and a boost in customer satisfaction. The proposed system aims to help highway agencies in effectively implementing pavement preservation plans to align with the USDOT strategic goals and achieve socio-economic objectives.

Educational Benefits

The study of preventive maintenance for cold climatic region in U.S. will offer several educational opportunities for students specialized in civil engineering, transportation engineering, pavement engineering, or related areas at the University of Wyoming. The anticipated benefits to be attained are as follows:

- Importance of LTPP dataset and its application: The LTPP dataset is a large dataset collected for an extended period of time for studying the material, climatic, design, maintenance and performance of both asphalt and concrete pavement. Additionally, the LTPP program has developed different tools from the existing LTPP database such as LTPP climate tool, LTPPBind Online, LTPP dynamic modulus prediction, forward calculated stiffness method etc. These tools can be a useful resource for teaching students.
- In-class case studies: The University of Wyoming offers courses in such as Transportation Engineering (CE3500), Pavement Management Systems (CE5585), Transport Network Analysis (CE5545), Transportation Planning (CE5570), and Intelligent Transportation Systems (CE5575). The outcome of preventive maintenance could be used for the case studies in pavement courses.
- Research opportunities: LTPP Data that is gathered and analyzed through the process of developing effective preventive maintenance technique can be utilized for further research purposes, aiding students in the creation of new research ideas or the enhancement of existing research ideas that are pertinent to transportation asset management, pavement engineering, and transportation planning. Additionally, more datasets can be explored for developing new research ideas.
- Industry relevance: Effective preventive maintenance can be useful to prolong the overall life of the pavement. The use of different maintenance techniques can have different effects on the performance of the pavement. Understanding effectiveness of preventive maintenance technique in cold climatic region can be critical for pavement management system (PMS). This skill is applicable in the field and can be applied to industry. Therefore, these can be shared with the Wyoming Department of Transportation.

Outputs through Technology Transfer

The results and products of this project, such as developed effective maintenance preventive, decision trees, will be disseminated through peer-reviewed journal articles and showcased at scientific research conferences like the annual Transportation Research Board (TRB). This will help in transferring methodologies, results, and products to the national and international pertinent research communities. Workshops, seminars, and webinars will be arranged to further disseminate the research findings and communicate its outcomes with professionals, practitioners, and highway agencies. The incremental results and progress of this project will be consolidated in a semi-annual progress report. Upon the completion of this project, it will be synthesized along with recommendations and guidelines in a technical report.

Expected Outcomes and Impacts

The outcome of this research project will help to better understand the preventive maintenance techniques utilized in cold climatic regions. It includes the effectiveness of different preventive techniques in two regions of wet-freeze and dry-freeze. This effectiveness will be determined through LTPP dataset and the questionnaire survey. Finally, the outcome of this research can be used by policy makers to implement the best practices of preventive maintenance in their respective region.

Work Plan

The timeline for the proposed research project is provided in Figure 3. This will be the primary timeline, but certain tasks will be ongoing throughout the project. A literature review will be conducted to incorporate recently published information. New research methodologies will be monitored to enhance the proposed methodology and ensure precise and applicable results.

Task	2024 - 2026					
	Q4	Q1	Q2	Q3	Q4	Q1
Task 1. Literature Review	■	■				
Task 2. Collection of LTPP Data for Cold Climatic Regions	■					
Semi-annual Progress Report		■				
Task 3. Data Cleaning and Selecting Meaningful Data		■				
Task 4. Data Processing for Cold Climatic Regions/States			■			
Task 5. Questionnaire Survey for Preventive Maintenance			■			
Semi-annual Progress Report				■		
Task 6. Analysis of LTPP data for Preventive Maintenance				■		
Presentation of Results at Scientific Conference/Journals					■	
Task 7. Recommendations					■	
Task 8. Preparing Final Report						■

Figure 3. Suggested timeline for proposed research project

Project Cost

Total Project Costs:	\$202,096
CTIPS Funds Requested:	\$101,048
Matching Funds:	\$101,048
Source of Matching Funds:	Wyoming LTAP

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