Existing Research found in light literature search:

Literature Search on Using PMS data for Bridge Deck Evaluation

"Automating Inspection Data from Bridge Management System into Bridge Information Model." *Automation in Construction,* 2025

https://www.sciencedirect.com/science/article/pii/S0926580525001682

This paper presents an approach to enhance the implementation of the Bridge Information Modeling (BrIM) methodology during the operational stage by automating the integration of inspection data from Bridge Management Systems (BMS) into BrIM models. While the data from BMS is available and retrievable from spreadsheets, the 3D bridge model is represented according to the Industry Foundation Classes (IFC) data model. Then, this paper introduces an algorithm that ensures seamless interoperability between the spreadsheets and the IFC data model. The semantically enriched BrIM models are achieved through a set of rules and procedures that are established to simplify the matching of the modeled objects with the components that characterize the bridge in the BMS. The openness of the IFC data model allows the identification of appropriate entities to store the corresponding information that comes from the BMS. This automated process removes the need for manual attachment of inspection data into IFC files, which is prone to errors, reduces the complexity of moving towards BrIM-based bridge management practices, and increases the efficiency of creating BrIM models for existing bridges. Finally, the proposed approach is a scalable and transferable solution that transportation agencies worldwide can adopt to manage bridge assets.

"Data-Driven Insights into Bridge Deck Condition Dynamics Using Cluster Analysis of National Bridge Inventory Data" *Computing in Civil Engineering,* 2025

https://ascelibrary.org/doi/10.1061/9780784486436.042

Transportation infrastructure is critical to ensuring safety and efficiency. Among its components, bridges play a pivotal role, necessitating effective maintenance and evaluation to preserve their functionality. However, with a vast number of bridges, constrained budgets, and limited resources, state departments of transportation face 2 significant challenges in maintaining their bridge networks. This study analyzes bridge deck deterioration in Colorado using data from the National Bridge Inventory (NBI). Temporal trends in bridge conditions are measured with dynamic time warping, and similar deterioration patterns are grouped through agglomerative clustering. These patterns are associated with structural attributes and environmental conditions identified through a random forest model to highlight key factors such as traffic metrics that influence deterioration. The study identified 14 distinct deterioration

patterns using agglomerative clustering, with a random forest model achieving 92% accuracy in predicting cluster assignments. The findings enhance understanding of bridge deterioration dynamics and support targeted, cost-effective maintenance.

"Digitalizing Bridge Inspection Processes Using Building Information Modeling (BIM) and Business Intelligence (BI)" *Applied Sciences*, 2025 https://www.mdpi.com/2076-3417/15/20/10927

State Departments of Transportation (DOTs) face challenges with traditional bridge inspections that are time-consuming, inconsistent, and paper-based. This study focused on an existing research gap regarding automated methods that streamline the bridge inspection process, prioritize maintenance effectively, and allocate resources efficiently. Thus, this paper introduces a digitalized bridge inspection framework by integrating Building Information Modeling (BIM) and Business Intelligence (BI) to enable near-real-time monitoring and digital documentation. This study adopts a Design Science Research (DSR) methodology, a recognized paradigm for developing and evaluating the innovative Smart Bridge to address pressing bridge inspection problems. The method involved designing an Autodesk Revit-based plugin for data synchronization, element-specific comments, and interactive dashboards, demonstrated through an illustrative 3D bridge model. An illustrative example of the digitalized bridge inspection with the proposed framework is provided. The results show that Smart Bridge streamlines data collection, reduces manual documentation, and enhances decision-making compared to conventional methods. This paper contributes to this body of knowledge by combining BIM and BI for digital visualization and predictive analytics in bridge inspections. The proposed framework has high potential for hybridizing digital technologies into bridge infrastructure engineering and management to assist transportation agencies in establishing a safer and efficient bridge inspection approach.

"Performance Evaluation of KYTC Bridge Deck Overlays Used for Maintenance Activities" *Kentucky Transportation Center*, 2025 https://uknowledge.uky.edu/ktc_researchreports/1823/3 State departments of transportation use bridge deck overlay systems to prolong bridge deck service lives. Consisting of a thin layer of material applied to a concrete bridge deck surface, overlays form a protective barrier that improves ride quality, protects embedded reinforcement from harsh environmental conditions, enhances structure durability, and improves deck drainage. Over the past 20 years, the Kentucky Transportation Cabinet has made significant investments in overlays, rehabilitating nearly 5,000 bridge decks with them — roughly 1 /3 of all bridges statewide. Given the significant investment in overlays, and the fact they degrade over

time — eventually re-exposing bridge decks to harsh environmental conditions, — it is critical to understand what factors influence their performance and condition. This study sought to identify predictors or metrics that can account for variability in overlay performance throughout Kentucky and support accurate forecasting of future conditions. Using data from the Cabinet's Bridge Management System, along with field inspections, chloride analysis, and imagery captured with a forward looking infrared (FLIR) camera, researchers attempted to identify statistical relationships between variables such as crack width/depth, crack length, average daily traffic, and amount of deck patching, and overlay condition. Limited by the constraints of a small data set (93 bridges), researchers did not uncover robust statistical relationships. Analysis found, however, that epoxy overlays exhibited the least linear cracking as well as the narrowest cracks. Asphalt overlays had the least amount of deck patching, but generally suffered from the deepest cracking. Epoxy overlays were in the best condition overall. The FLIR camera has utility for taking photos of bridge decks, however, image capture must occur under very precise conditions (e.g., no traffic, favorable weather) and image interpretation must be done by trained experts.

"Traffic-induced fatigue damage evaluation of long-span suspension bridge integrating 27-year monitoring data and multi-scale finite element analysis" *Civil Structural Health Monitoring*, 2025 https://link.springer.com/article/10.1007/s13349-025-00936-8

Fatigue damage is a main concern to the safety of long-span suspension bridges, especially when they carry both railway and highway loads. Most fatigue assessment of bridges is based on short-term measurement data or numerical analysis only. This paper takes advantage of 27-year long-term field monitoring data of the Tsing Ma Bridge and evaluates the bridge's fatigue condition with the aid of multi-scale finite element analysis (FEA) at the component and weld levels. First, the stresses of all components are calculated using a global multi-scale model, and their fatigue damage is estimated following the Rain flow algorithm and Miner's law. Second, at the weld level, a refined multi-scale finite element model is developed with a focus on the deck-rib welds of the upper orthotropic deck. Five sub-models of the trough-to-deck joint are established with 4 considerations of varying wheel locations. A sub-modeling technique is employed to calculate the effective notch stress and its fatigue damage. At both component and weld levels, railway and highway loads are applied, and the load combination factors are estimated. The results show that the railway load plays the dominant role in the fatigue damage of the main components, while the highway load governs the fatigue damage of the deck-rib welds. The railway beam is the most fatigue-critical component with a fatigue life of 536 years,

and the most vulnerable weld has a fatigue life of 30 years only. In the study, the monitoring data provides input for the long-term railway and highway loads on the bridge deck and validates the stress results calculated from the FEA. The super long-term field monitoring system provides realistic load and response data, yielding more accurate and reliable fatigue damage assessment of long-span bridges.

"A Condition Assessment Tool for Steel Bridge Deck Pavement Systems Based on Data Balancing Methods and Machine Learning Algorithms" *Buildings*, 2024

https://www.mdpi.com/2075-5309/14/9/2959

The primary challenge in the operation of steel deck pavement systems lies in the inspection and assessment of their condition. Traditionally, manual inspection methods are employed. However, these approaches are not only time-consuming and labor-intensive but also prone to human error. As a result, integrating data-driven machine learning technologies into the evaluation of pavement systems presents a significant advantage in addressing these issues. This study proposes a decision-making tool for estimating the condition levels of steel bridge deck pavement systems by employing classification techniques. To address the issue of class imbalance in the dataset, the SMOTE algorithm is utilized. Additionally, seven different machine learning methods—Light Gradient Boosting Machine, Extreme Gradient Boosting, Random Forest, Adaptive Boosting, K-Nearest Neighbor, Multilayer Perceptron, and Logistic Regression—are applied for training. Comparative analysis reveals that the Light Gradient Boosting performs optimally, achieving classification accuracies of 0.841 and 0.929 on the original and synthetic datasets, respectively.

"An Analytical Study Predicting Future Conditions and Application Strategies of Concrete Bridge Pavement Based on Pavement Management System Database" *Sustainability*, 2023

https://www.mdpi.com/2071-1050/15/24/16680

South Korea is implementing various policies to address the aging of infrastructures and improve road infrastructure management. Moreover, numerous research projects aiming at the development of necessary technologies for the proper implementation of these 5 policies are underway. This study specifically aims to overcome existing problems in bridge pavement maintenance, such as the inaccuracy of future condition predictions and the selection of incorrect evaluation indicators. Our goal is to provide a new approach for the improved management of the bridge pavement management system (BPMS). To address the issues of accuracy in future condition prediction and evaluation indicator selection within the existing maintenance system, we utilized particle filtering, a Kalman filter method among machine

learning techniques. This method allows for the prediction of future conditions, based on the nonlinearly collected bridge pavement conditions within BPMS. Furthermore, we proposed a systematic bridge pavement management strategy. This strategy utilizes traffic volume (ESALs; equivalent single axle loadings), a factor that can influence the future condition of bridge pavement, in correlation with the future condition predicted through particle filtering within BPMS.

"Applying Transportation Asset Management to Intelligent Transportation Systems Assets: A Primer" *US DOT*, 2022

https://ops.fhwa.dot.gov/publications/fhwahop20047/fhwahop20047.pdf

As the importance of an integrated transportation system continues to evolve and grow, U.S. transportation agencies are identifying Intelligent Transportation Systems (ITS) assets as critical elements in asset management and long-range planning. Current research continues to suggest that transportation agencies can benefit from including ITS assets in their asset management planning and integrating asset management practices for ITS assets. This primer provides information for applying Transportation Asset Management (TAM) principles to ITS assets in accordance with the Transportation Asset Management Plan (TAMP) requirements.

"An Integrated Asset Management Workflow to Address Transportation Structures Issues" *IRF White Paper, 2022* https://www.irf.global/ebooks/IRF-White-Paper-22_01.pdf

Bridge and maintenance operations represent an enormous part of the asset value of transportation agencies. Inspecting, maintaining, and managing bridges is crucial to public safety and regulatory compliance. These combined tasks require the efforts of multiple teams as well as a tremendous amount of time and money. Yet more often than not, time and money are wasted when communication breaks down between the "bridge side" and the "maintenance side" of operations. This disconnect can cause inconsistent data across teams, delayed bridge repairs, loss of operational efficiency, loss of bridge service life and network performance, and—most importantly—higher public safety risks. 6 Transportation agencies with a mature asset management practice facilitate integrated workflows and seamless communication between the asset inspection teams and the maintenance management teams to ensure asset needs are addressed in a timely, efficient manner. An integrated asset management workflow that coordinates maintenance management and structures management functions is designed to streamline processes and improve the operational efficiency of all structures-related fieldwork—from discovering an issue to performing and verifying the work to resolve it. An asset management system that integrates and coordinates

these processes provides numerous benefits by meeting the needs of the relevant business units, the agency, and, ultimately, the traveling public. In this paper we discuss integrated solution for Bridge structures as an example asset type. But the same concepts and recommendations apply to other structure types.

"Bridge Infrastructure Asset Management System: Comparative Computational Machine Learning Approach for Evaluating and Predicting Deck Deterioration Conditions" *Journal of Infrastructure Systems*, 2020 https://ascelibrary.org/doi/10.1061/%28ASCE%29IS.1943-555X.0000572

Bridge infrastructure asset management system is a prevailing approach toward having an effective and efficient procedure for monitoring bridges through their different development phases including construction, operation, and maintenance. Damage to any structural component of a bridge will negatively affect its safety, integrity, and longevity. Bridge decks are more susceptible to severe deterioration because they are exposed to harsh conditions including heavy traffic, varying temperatures, road salts, and abrasive forces. The ability to forecast the conditions of bridges in an accurate way has been a great challenge to transportation agencies. Many previous research studies highlighted the need to have a data-driven approach in predicting and evaluating the deterioration conditions of bridges. As such, this paper develops a computational data-driven asset management system to evaluate and predict bridge deck deterioration conditions. A multistep interdependent research methodology was utilized. First, the best set of variables affecting the conditions of bridge decks was identified. Second, two computational machine learning models were developed for the prediction of deck conditions using artificial neural networks (ANNs) and k-nearest neighbors (KNNs). Third, a comparison between the developed models is conducted to select the ultimate model with the highest accuracy. The result is a framework that is able to evaluate and predict deck conditions with a prediction accuracy of 91.44%. While this research is applied to bridges in Missouri, the technique can be used on any similarly available data set nationwide. This study adds to the body of knowledge by devising a computational 7 data-driven framework that is valuable for transportation agencies as it allows them to evaluate and predict deck conditions with high accuracy. Consequently, this will help in ensuring proper and effective distribution of funds allocated for the maintenance, rehabilitation, and repair of bridges. Ultimately, this will result in minimizing efforts, time, and costs associated with site inspection of bridge

"High Speed Ground Penetrating Radar for Road Pavement and Bridge Structural Inspection" *Vermont DOT*, 2016

https://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/Final%20Report%20-%20738%20-%20High%20Speed%20GPR%2010-17-2016.pdf

The overarching objective of this research is the development of a systematic methodology of employing GPR, including instruments, subsequent data processing and interpretation that can be used regularly as part of a roadway pavement and bridge evaluation program. Test methodologies and procedures that are suitable for Vermont environmental and infrastructural conditions are explored and evaluated. Moreover, we implement and improve a high speed GPR system that allows driving speed roadway and bridge deck inspection with leveraged inspection resolution.

"Data analysis and visualization for the bridge deck inspection and evaluation robotic system" *Visualization in Engineering*, 2015 https://link.springer.com/article/10.1186/s40327-015-0017-3

This paper reports the automated data collection and analysis for bridge decks based on our novel robotic system which can autonomously and accurately navigate on the bridge. The developed robotic system can lessen the cost and time of the bridge deck data collection and risks of human inspections. The advanced software is developed to allow the robot to collect visual images and conduct NDE measurements. The image stitching algorithm to build a whole bridge deck image from individual images is presented in detail. The ER, IE and USW data collected by the robot are analyzed to generate the corrosion, delamination and concrete elastic modulus maps of the deck, respectively. These condition maps provide detail information of the bridge deck quality.

The automated bridge deck data collection and analysis is developed. The image stitching algorithm allowed to generate a very high-resolution image of the whole bridge deck, and the bridge viewer software allows to calibrate the stitched image to the bridge coordinate. The corrosion, delamination and elastic modulus maps were built based on ER, IE and 8

USW data collected by the robot to provide easy evaluation and condition monitoring of bridge decks.

"Combined Imaging Technologies for Concrete Bridge Deck Condition Assessment"
Journal of Performance of Constructed Facilities, 2013
https://ascelibrary.org/doi/10.1061/%28ASCE%29CF.1943-5509.0000465

Evaluating the condition of concrete bridge decks is an increasingly important challenge for transportation agencies and bridge inspection teams. Closing the bridge to traffic, safety, and time-consuming data collection are some of the major issues during a visual or in-depth bridge inspection. To date, several nondestructive testing technologies have shown promise in detecting subsurface deteriorations. However, the main challenge is to develop a data acquisition and analysis system to obtain and integrate both surface and subsurface bridge health indicators at higher speeds. Recent developments in imaging technologies for bridge decks and higher-end cameras allow for faster image collection while driving over the bridge deck. This paper will focus on deploying nondestructive imaging technologies such as the three-dimensional (3D) optical bridge evaluation system (3DOBS) and thermal infrared (IR) imagery on a bridge deck to yield both surface and subsurface indicators of condition, respectively. Spall and delamination maps were generated from the optical and thermal IR images. Integration of the maps into ArcGIS, a professional geographic information system (GIS), allowed for a streamlined analysis that included integrating and combining the results of the complimentary technologies. Finally, ground truth information was gathered through coring several locations on a bridge deck to validate the results obtained by nondestructive evaluation. This study confirms the feasibility of combining the bridge inspection results in ArcGIS and provides additional evidence to suggest that thermal infrared imagery provides similar results to chain dragging for bridge inspection.

"Integrated Asset Management Tool for Highway Infrastructure" *IABSE Conference*, 2013
https://www.researchgate.net/publication/259065428_Integrated_Asset_Management_Tool_for_Highway_Infrastructure

To enable proper and long-term maintenance planning for a huge and heterogeneous set of engineering structures (bridges, culverts, noise barriers, gantries) the authors developed an integrated life cycle management tool that offers tailored solutions with regard to the given location, involved materials, fabricates and the underlying design code at the time of construction. The core of this tool is formed by a probabilistic ageing model and a comprehensive cost model. Each structural member is represented by a generic ageing

function, which is derived from the major sources of information reflecting impact on 9 structural ageing (visual inspection/ numerical simulation/ structural monitoring and freight traffic progression). Furthermore, the model incorporates VCE's 50 years of experience in the field of bridge inspections and structural health monitoring. Due to defined treatment-trigger-criteria a huge set of maintenance strategies is generated leading to an extensive optimization exercise. The final project output is composed by
tailored maintenance plans for every structure.