Update on Railroad Research Efforts at the Upper Great Plains Transportation Institute: May 11, 2022

Intelligent Transportation Systems Approach to Railroad Infrastructure Performance Evaluation: Track Surface Abnormality Identification with Smartphone-Based App. Inertial sensors, accelerometers, gyroscopic sensors, global positioning systems (GPS), and the wireless communication capabilities built into smart phones can continually monitor railroad assets if these devices are placed on board railway vehicles. In this research effort, an automated screening system for detecting abnormalities in railroad track and equipment was developed and evaluated. The system locates and characterizes possible track surface abnormalities by analyzing the inertial dynamics of hi-rail or in-service rail vehicles using a smartphone data logging application. Although the research effort relies extensively on signal processing, data processing, and signal classification techniques, the methods developed in this project do not rely on adapting sensor configurations and require only a data upload capability. In this approach, smart-phone based sensors compress and upload their geo-tagged inertial data periodically to a centralized processor, where remote algorithms combine and process data from multiple vehicle traversals to identify track abnormalities and localize their positions. The research report is available at https://www.ugpti.org/resources/reports/details.php?id=954&program=mpc

Track Surface Irregularity Position Localization with Smartphone-Based Solutions. This project demonstrates the potential use of low-cost sensors in smart phones aboard hi-rail vehicles to monitor track for inertial events caused by irregular track geometry. The study characterizes and validates its accuracy by comparing the estimated positions of detected irregularities with the actual positions of irregularities observed by track inspectors. A technique called the "ensemble average" is utilized, which leverages a large number of sensor signals collected from multiple traversals of a railway segment to enhance the signal's quality and reduce the detection error. The methods developed in this study increase the signal-to-noise ratio and reduce false positive and false negative rates. Moreover, the signal quality improves continuously with additional data. The developed technique utilizes distance interpolation, heuristics, and correlation alignment to align the signals across the traversals. The algorithm then extracts features from the aligned and filtered signals. The study found that methods with ensemble averaging can be generalized to any sensor data derived from multiple traversals of a track segment. The report is available at https://www.ugpti.org/resources/reports/details.php?id=1049&program=mpc.

Benefit Cost Analysis of Railroad Track Monitoring Using Sensors Onboard Revenue Service Trains. In this research project, several analytical techniques were used to gain insights about railroad accident characteristics and assess the return on investment from safety technology deployments. These techniques include exploratory data analysis, machine learning, and benefit-cost analysis. The exploratory data analysis revealed that derailment accidents consistently approached 1,500 each year and accounted for more than 60% of annual accidents. The top three causes of derailment accidents were human factors, track and roadbed problems, and mechanical failures. Annually, these causes account for 81% of accidents (on average). In addition, machine learning applications revealed that derailment accidents were statistically associated with lower

track classes, non-signalized territories, and areas with restricted limits of movement authorization. The machine learning effort also revealed that derailments are typically the result of track and roadbed problems and are generally not associated with human error. The benefit-cost part of the study indicates that railroads can seek benefits from the positive train control (PTC) systems already deployed by adding onboard sensors to vehicles that could use the PTC network to communicate track and roadbed problems that contribute to derailment risks. The report is available at https://www.ugpti.org/resources/reports/details.php?id=1055&program=mpc.

Highway-Rail Grade Crossing Traffic Hazard Forecasting Model. Crashes at highway-railroad grade crossings are rare but traumatic events. The quantitative modeling of crash risks is challenging because of non-normal data distributions. The statistical models often used for risk assessment have significant limitations. Moreover, the accident/incident and grade-crossing inventory databases are not synchronized in a time-series manner. Nevertheless, an expanded risk assessment model has been developed in this project that considers a wide variety of crossing risk factors including: (1) train traffic: daytime trains, nighttime trains, switch trains, train speed limit, and number of tracks; (2) highway factors: warning devices, highway classification, angle of intersection, highway sight distance, and distance to adjacent crossings/intersections; and (3) highway traffic. Many potential crash prediction models have been evaluated in this project including Poisson, Negative Binomial, Gamma, Bernoulli, and other generalized linear models. In addition to these models, several data mining methods have been screened, such as decision tree, neural network, and gradient boosting models. The results indicate that the latter three methods have relatively accurate forecasting power and strong abilities to model nonlinear relationships between the crossing risk factors noted above and crash likelihoods. Overall, the results of the study point to a new direction for crash likelihood models that will consider a wide variety of contributing factors and offer greater forecasting power and accuracy. The research report is available at https://www.ugpti.org/resources/reports/details.php?id=914&program=mpc.

Great Northern Corridor (GNC) Model. UGPTI is working with BNSF and the Great Northern Corridor Coalition to develop a multistate, multimodal model extending from Chicago to Seattle. The primary objectives are to: (1) develop a GIS network for the GNC in TransCAD (which is a leading transportation planning software system); (2) develop grain, food, and container logistics modeling procedures and integrate them into the GNC model; (3) design simulation, optimization, and benefit-cost procedures to support planning and project analysis; and (4) conduct in-depth analyses of farm, food, and container logistics movements. The initial focus has been on developing the highway network and sources of highway traffic and economic activity data. The reason for this sequencing is that many of the public benefits of making investments in railroads or highways can be expressed as reductions in highway congestion, travel cost, and road maintenance. Once the model is complete, the impacts of traffic shifts from railroads to highways (or vice versa) can be quantified by estimating how the potential shift would affect pavement resurfacing and maintenance costs, highway capacity and user costs, energy efficiency, and the emission of air pollutants, among other things. The model is expected to be fully operational in 2023. However, ad hoc analyses utilizing components of the model may be possible later this year. With the corridor model, the effects on the entire corridor of eliminating a bottleneck can be

analyzed, as well the benefits of a series of projects throughout the corridor (as opposed to an isolated project in an individual state).

National Short-line Railroad Data Inventory and Analysis. In collaboration with ASLRRA, UGPTI is planning a survey of the short-line and regional railroad industries. This project will provide a comprehensive update of the industry's profile including: (1) physical inventories of track and equipment; (2) traffic levels, customer counts, employees, expenditures, and interchange opportunities; and (3) capital needs and investment priorities. The project is expected to begin this summer. Information will be available in 2023.