Federated Learning for Railway Safety Analysis and Prediction

Deliverables and Reporting Requirements for UTC Grants Awarded in 2023 (June 2023)

Exhibit D

Recipient/Grant (Contract) Number: University of Texas Rio Grande Valley (UTRGV)/Grant No. 69A3552348340

Center Name: University Transportation Center for Railway Safety (UTCRS)

Research Priority: Promoting Safety

Principal Investigator(s): Ping Xu (PI, UTRGV)

Project Partners: Jia Chen (Collaborator, University of California Riverside (UCR)) and Vagelis Papalexakis (Collaborator, UCR)

Research Project Funding: $44,113 (Federal), $28,056 (Non-Federal Cost Share)

Project Start and End Date: 06/01/2024 to 08/31/2025

Project Description: Railway networks constitute intricate cyber-physical systems, engaging with various transportation entities and additional cyber-physical systems. For instance, a railway crossing necessitates interactions between the railway network and road traffic management systems. This complex web of interactions between diverse entities presents intriguing challenges for research in effectively modeling railway operations through data analytics and enhancing safety measures at railway crossings using data-driven approaches. In our previous work with our partner institution, the University of California Riverside (UCR), we adopted the spectral clustering technique to understand emerging accident patterns from historical data and identify underlying similarities in such patterns. We then adopted kernel ridge regression to predict the number of accidents based on the selected factors from identified patterns, making the first attempt to reduce the number of accidents. However, due to the large volume of data and high computation complexity, the amount of data involved in learning was only 10% of that available. Moreover, our work assumes that all data are centrally available. In practice, data from different transportation entities may not be shared or collected to a center for processing, due to privacy issues. To address these issues, this project proposes to develop a federated learning framework to enable (a) parallel computation when data volume is too large, and (b) local data processing when privacy is a concern.

US DOT Priorities: The proposed work in this project is aligned with five of the six USDOT strategic goals: **(a) Safety:** The project directly addresses safety through predicting accidents from historical data, which can help in future policy making to reduce the number of accidents. **(b) Economic Strength:** Early prediction mitigates accidents and their associated financial costs and train delays. **(c) Equity:** UTRGV is a minority serving institution with an established record of training students from underrepresented groups and placing them in professional positions in the transportation industry. This project will directly employ one graduate student, and indirectly support the employment of several others. **(d) Sustainability:** By enabling proactive preventive prediction, this project aims to mitigate catastrophic accidents, which will preserve the rail infrastructure and the environment. **(e) Transformation:** The developed framework can provide new insights beyond the currently envisioned application, using recent and future advances in machine learning.

Outputs: The expected products include:

1. Research publications, targeted at top-tier data science, machine learning, and artificial intelligence venues.
2. Publicly available source code for the methods developed. Typically, each publication will be accompanied by a link to publicly available source code on a widely used repository such as GitHub.

Outcomes/Impacts: The project's broader impacts are multifaceted, extending beyond immediate railway safety improvements. It promises to foster a data-centric culture within the transportation safety community, encouraging reliance on predictive analytics. The educational aspect is significant, as the research will provide hands-on experience in advanced data analysis and machine learning for graduate and undergraduate students. From an industry perspective, the implementation of predictive safety models has the potential to revolutionize railway operation, leading to long-term sustainability and safety in railway crossings.

Final Research Report: Upon completion of the project, a URL link to the final report will be provided.