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Ph.D. DISSERTATION DEFENSE

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Title:	Beyond Tunnel Vision: Leveraging Machine Learning for Predictive Analysis of Tunnel Boring Machine Performance
Chairperson:	Dr. George Korfiatis, CEOE, Stevens Institute of Technology
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ABSTRACT

Accurate prediction of Tunnel Boring Machine (TBM) performance is essential for ensuring that tunneling projects are completed on schedule and within budget. However, the generalization ability of machine learning (ML) to other projects is still under-explored. This study assesses the generalization ability of ML techniques for predicting penetration rate (PR) or advance rate (AR) in similar and dissimilar geological conditions, explores whether incremental learning (IL) supports long-term adaptation and impacts generalization.

First, we evaluate how well six different ML models can generalize when trained on data from Line C tunnel and applied to Line S tunnel with similar geological conditions. XGBoost proves notably accurate and robust, achieving R^2 between 0.706 and 0.748 in generalization. In contrast, when XGBoost is directly transferred to the Parallel Thimble Shoal Tunnel (PTST) with substantially different geological features, a "negative transfer" effect emerges, meaning that the initial model trained on dissimilar data degrades prediction performance rather than improving it. To address this gap, we implement an IL framework that continuously updates XGBoost as new tunneling data become available during excavation. Our results indicate that IL markedly enhances model performance over time. Interestingly, IL can improve the performance for the main distribution of PR below 25 mm/rpm, whether the overall dataset is balanced (PR < 25 mm/rpm) or imbalanced (PR < 125 mm/rpm). Despite this improvement, significant geological and operational differences between projects can still undermine the performance. These findings emphasize the importance of project similarity for effective knowledge transfer and highlight the practical benefits of IL in adapting models as new data become available. Ultimately, this research yields critical insights for improving TBM performance forecasts and enhancing data-driven decision-making throughout tunnel construction.