THESIS DEFENSE

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ALUMNI LEGACY LOUNGE
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MACHINE LEARNING BASED FEASIBILITY ANALYSIS OF GEOTHERMAL BRIDGE DECK DEICING SYSTEMS

Bridge decks in cold climate regions such as Montana are especially vulnerable to rapid freezing, snow accumulation, and thermal-induced cracking due to their exposure to ambient conditions on all sides. Traditional deicing methods, relying on chemical salts and plowing, are costly, environmentally harmful, and often ineffective at extreme temperatures. As a sustainable alternative, geothermal bridge deck deicing systems utilizing ground-source heat pumps (GSHPs) have captured growing interest due to their ability to provide continuous, low-energy heating. However, widespread implementation requires a comprehensive understanding of system performance across Montana's diverse climatic and geological conditions. This thesis presents an integrated framework that combines numerical modeling, machine learning (ML), and geographic information systems (GIS) to assess the technical, economic, and environmental feasibility of GSHP-based bridge deck deicing systems. Numerical simulations were conducted using COMSOL Multiphysics, calibrated against experimental data, to evaluate the effects of ambient temperature, wind speed, solar radiation, inlet fluid temperature, flow rate, tube spacing, and bridge length on surface temperature response. These simulations generated a dataset of over 2,000 scenarios used to train and validate several ML models, including Random Forest, XGBoost, and fully connected neural networks (FCNN). The models achieved R^2 scores above 0.95 and enabled rapid, high-accuracy prediction of key outputs such as surface temperature, time to de-ice, and time to reach stabilized temperature. GIS-based statewide feasibility analysis was performed, spatial datasets of geothermal potential, energy demand, borehole depth, installation cost, and environmental impact were evaluated to identify high-potential implementation zones. Results show that GSHP systems are feasible across most of Montana, particularly in regions with high subsurface thermal gradients. This work demonstrates that machine learning, when combined with simulation and geospatial data, provides a powerful and scalable tool for evaluating the feasibility of renewable infrastructure technologies. The findings support the strategic deployment of GSHP systems at key bridge locations and offer a replicable framework for sustainable infrastructure planning in other cold-region environments.

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