Understanding Environmental Impact of Transportation Systems Through Causal AI

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Previous studies into transportation systems and pollution have shown that transportation systems disrupt ecosystems by polluting our natural resources and making them unusable. Water quality, one of the many natural resources heavily impacted by transportation systems, is usually less talked about due to the monetary, practical, and technical challenges with continuous long-term data collection. A driving force that has contributed to water pollution is modern seasonal practices such as deicing, which have had various economic and societal benefits, but have also contributed to our current environmental dilemma. Deicers, a salt-based compound, have introduced dangerous levels of salinity into our waters via road runoff, which have impacted local wildlife and humans.

Due to these environmental concerns, there has been a growing emphasis on data-driven approaches to analyzing the current state of our ecosystems. With the recent advancements in artificial intelligence and the large availability of historical data, we have the potential to predict future outcomes of our local environment based on current environmental trends. While current machine learning models excel at predicting future outcomes based on historical data, they often fall short when it comes to understanding the underlying causal mechanisms driving these trends. To gain a deeper understanding of our environment and what factors are affecting it, we need a causal approach.

We developed a water quality sensing prototype with an Arduino microcontroller and a range of sensors for measuring the chemical and physical properties of water. Currently, we are in the process of refining and enhancing our prototype to ensure reliability in long-term outdoor deployment by improving the sturdiness, power efficiency, and the hardware/software design. We aim to build a cost-effective and scalable solution for remote real-time water quality monitoring. In addition to hardware development, we have also performed extensive data analysis utilizing data from the National Water Quality Monitoring Council and the National Oceanic and Atmospheric Administration (NOAA). We have analyzed the causal effect of various variables including precipitation and conductivity to better understand the potential effects of road runoff and other activities that can affect the water when it rains. We have also utilized the ability to create counterfactual data for what conductivity could have been if it had not rained at all. Below we have a figure displaying the difference between the actual average conductivity and the counterfactual average conductivity from 2000 to 2023. Here we can see that the two conductivity values diverge as the difference continues to increase. One assumption we can make from these initial results is that the rain may be helping dilute the levels of salt, so when it doesn't rain, the concentration of salts becomes more apparent as more salts are introduced and the surface water evaporates. We aim to continue to explore these findings and dive deeper into what we can understand using counterfactuals.

Our research represents a significant step towards applying modern AI solutions to gain a deeper understanding of the role we play in the environmental change of our local communities. By combining remote sensing platforms with causal data analysis, we aim to better and more easily understand the hidden causal relationships between each variable. Our work has the potential to help influence what we do in order to decrease and prevent further contamination as we aim to achieve a more sustainable future.