Dissertation Abstract
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Ex-Ante Analysis of Innovation Policies in Infrastructure System-of-Systems

This dissertation focuses on the creation and testing of a new paradigm in innovation and policy assessment in civil infrastructure system-of-systems (SoS). Many uncertain factors (e.g., economic conditions, public attitudes, political priorities, and business dynamics) affect the creation and diffusion of innovations in civil infrastructure. Policymakers who evaluate innovation policies also face *known unknowns* (policy outcomes whose nature is known but their probability of occurrence is not known) as well as *unknown unknowns* (policy outcomes whose nature and probability of occurrence are not known) due to the adaptive behaviors of the players in the system.

The overarching objective of this dissertation was to create and evaluate an ex-ante analytical framework for micro-simulation of infrastructure innovation policies under uncertain conditions. The developed framework is based on the abstraction and micro-simulation of the activities and interactions of the major players in the system and its application is demonstrated for the assessment of sustainable financial innovation policies. Using the framework and data obtained from a wide range of sources ranging from historical records and case studies to interviews with subject matter experts, the interdependencies of finance and transportation infrastructure were explored. These interdependencies (e.g., the effects of financial market conditions on the debt-related decisions made by state Departments of Transportation) then were used to develop a hybrid agent-based/system dynamics model for micro-simulation of sustainable financial innovation policies. Using this model and Monte-Carlo experimentation, the policy landscape of transportation infrastructure in the U.S. was simulated**.** The model was verified and validated as follows: (1) by using sensitivity analysis and uncertainty propagation analysis, and (2) through face validity by several subject matter experts from organizations such as the World Bank, the U.S. Department of Transportation, and the Federal Highway Administration. The results suggest that the simulated policy landscape is capable of identifying the significant factors that affect policy decisions and explore scenarios for closing the financing gap under uncertain conditions.

This distinctive approach is the first of its kind to simulate the U.S. transportation infrastructure policy landscape by simulating the micro-dynamics of the system. This framework has the potential to be adopted for ex-ante simulation of the landscape of sustainable policies towards expansion of alternative energy systems, enhancing intelligent transportation systems, and improving the resilience of electric grids.

Keywords: Innovation Policy Analysis; Infrastructure System-of-Systems; Financial Innovations; Uncertainty Simulation; Agent-Based Modeling.