MPC-458
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Project Title:
Application of a multi-agent system with the large-scale agent-based model for freight demand modeling

University:
North Dakota State University

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Research Needs:
Statewide freight demand modeling is important in North Dakota to support agricultural logistics and energy development due to the recent oil boom and the long-term importance of the agricultural industry. We assume that a group of travelers, or agents, would provide a variety of driving patterns. Predicting travelers' behavior has been a cumbersome task in transportation planning because of the wide variation of behavior among travelers. With the advance of simulation and data mining, the agent-based model (ABM) has emerged as a solution. The agent-based modeling technique would provide a high level of detail for travel patterns in a region or state. The ABM includes three elements: agents, agent relationship, and agent's environment (Macal & North, 2011). The individual is known as an agent is an entity for decision-making. When an agent uses a vehicle, ABM is also called vehicle-based modeling. Agents interact with each other and in response to transportation infrastructures and policies. The agent-based freight demand modeling has been emerging as critical component in transportation planning to represent realistic travelling activities throughout the road networks and among facilities. ABM allows aggregations and disaggregation of agent characteristics, behaviors, and interactions under the freight demand context (Harper, et al., 2011). However, the agents should interact with environments for a long term such as in mid-term and long-range transportation planning. By simulating the agents, the freight movement in a large-scale network can be aggregated to provide critical information for statewide freight demand modeling without losing details. As a result, macro-level agent-based modeling benefits statewide freight demand modeling. In large-scale of road networks, the agents interact over space and time in response to information about transportation infrastructure and logistics facilities as well as policy. Thus, the multi-agent system is designed for the statewide macro level in response to the changes in these environments. Agent groups interact with other agent groups, and each agent within a group interacts with others within the group. Thus, the behavior (i.e. principle decision rules and response rules) of the agent group and each agent of a group can be simulated in transportation operations and planning. The multi-agent system includes decision-making rules such as

destination choice, departure time, mode choice, and route choice, and sensitivity to travel impedance.

Research Objectives:
This research will:
- Review state-of-art agent-based modeling in transportation
- Develop an survey instrument
- Determine agents' travel behavior in rural and small urban freight movement
- Design an multi-agent systems
- Apply the agent's travel behavior to statewide freight demand modeling
- Develop scenarios to improve safety and sustainability throughout the rural highway network.

Research Methods:
In this research, an instrument will be designed to estimate the agent's behavior. The survey instrument will include agent's characteristics such as commodity, vehicle configuration, garage locations, and driver. Then, the survey data will be analyzed with statistical software with Bayesian methods and logistic regression. The general rules of the agent will be developed and implemented in an agent-based model simulation such as AnyLogic® simulation software, which integrates for discrete-event simulation, ABM, and system dynamics. The output from the ABM simulation will be aggregated for agent groups and then applied to the freight demand model.

Expected Outcomes:
The research will provide statewide freight demand modeling information to state transportation planners and urban freight demand modeling information to metropolitan planning organizations. The findings from the model can be used for safety analysis and studies of transportation sustainability as well as for research to advance simulation techniques. The study should contribute to the transportation systems and simulation techniques by providing outputs for freight demand modeling.

Relevance to Strategic Goals:
State of Good Repair
The research output provides reliable input sources for the statewide and regional freight demand modeling, thereby supporting long-term transportation planning. The results would support the quality life-cycle cost assessment by enhancing the estimates of model parameters of the demand modeling.

Safety
As the freight traffic increases, the community and transportation planners will have greater concerns for safety in the active traffic regions. By predicting the agents' behavior, the model can provide a proactive approach to crash reduction and decrease safety concerns.

Environmental Sustainability

The travel behavior of agents effects traffic and fuel consumption. The agents' travel patterns can be estimated, so the environmental impact also can be derived from the simulation.

Educational Benefits:
Students will be involved through the class projects and collaboration with public agencies such as the North Dakota Department of Transportation, Fargo-Moorhead Metro Council of Government, and counties. Guest speakers will be invited to the class and the students in the class will have regular meeting with the agencies to discuss about the project scope, project schedule, and project managements. TL755 (Transportation Planning and Environmental Compliance) will provide the guidelines and a pilot project for the transportation operations and planning in light of transportation planning and sustainability including environmental, economical, and social impacts. Then, TL785 (Spatial analysis in Transportation) and TL753 (Transportation Systems Modeling) will engage students in analyzing the data by applying data mining techniques using SAS®, Geographic Information Systems (GIS), and simulation.

The project would be presented during the INFORMS annual conference with the Transportation Science and Logistics Society or the Transportation Research Board annual meeting. The project will also share the modeling technique and findings through the Local Technical Assistance Program (LTAP).

Work Plan:
(1) Literature Review (Month 1)
(2) Survey design and data collection (Month 2-3)
(3) Data analysis (Month 4-5)
(4) Model development (Months 6-8)
(5) Model verification and calibration (Month 9)
(6) Model validation (Month 10)
(7) Sensitivity analysis (Month 11)
(8) Final report (Month 12)
(9) Technology transfer (Month 12)

Project Cost:
Total Project Costs: $128,498
- MPC Funds Requested: $64,249
- Matching Funds: $64,249 (North Dakota Legislators)

TRB Keywords: Travel behavior, Agent-based, Simulation, GIS, Data mining, Freight demand modeling

References:
Harper, T. J., Miller, J. O., Hill, R. R. & Wirthlin, J. R., 2011. *Agent Based Simulation Design for Aggregation and Disaggregation.* Pheonix, AZ, IEEE, pp. 259-270.

Macal, C. M. & North, M. J., 2011. *Introductory Tutorial: Agent-based Modeling and Simulation.* Phoenix, AZ, IEEE, pp. 1456-1469.