Dr. David M. Levinson and his research team at the University of Minnesota have developed a series of models that interpret the evolutionary growth of transportation networks. Their models capture the outcomes of independent decisions made by entities such as travelers, firms, property owners, developers, professionals, and public jurisdictions at different levels. The research provides a new understanding of transportation development. It demonstrates in a scientific way how numerous independent decisions could result in a coherent network of facilities on the ground. This work complements the traditional planning efforts of metropolitan planning organizations (MPOs), which focus on top-down decision-making.

The research involves close collaboration among a range of fields including transportation engineering, urban planning, geography, economics and network science. The researchers developed a holistic framework using multidimensional concepts and methods to represent network growth as an open and complex process based on interacting initiatives. They used an agent-based modeling approach to represent the underlying mechanisms regarding the growth of transportation networks.

They specified and estimated component models explaining travel behavior, pricing and investment policies, and location decisions of employment and residence. These components were integrated into the holistic model. Their work demonstrates the feasibility of abstractly modeling the growth of transportation networks to reveal basic properties. The researchers developed an accurate and realistic representation of actual transportation network growth: statistical analyses were conducted to correlate changes to transport infrastructure to the physical status of the network, traffic demand, budget constraints, and land use. They also applied and validated simulation models on real networks such as the Minnesota Twin-Cities road network and the downtown Minneapolis skyway network.

This model framework enables one to display, capture, and analyze important topological and economic attributes on a collective level throughout the temporal course of transport development. This approach is in sharp contrast to complicated, all-encompassing models that lack an explicit perspective. The team implemented several methodologies from different perspectives to examine the evolution of transport networks, including self-organization, network degeneration, and sequential connection. They found that network attributes such as network hierarchy, collective geometric patterns and spatial concentration are intrinsic properties of networks. The team determined that new measurements were necessary to capture these attributes. The research also demonstrated on both theoretical and empirical levels that it is critical to evaluate the long-range effects of different (centralized versus decentralized, public versus private) decision-making processes on transportation infrastructure.

Both the estimation of individual component models and their integration into a simulation of network growth (and decline) increases our limited understanding of network evolution processes. This new understanding will have broader impacts on transportation planning practice, and ultimately on the shape of cities and regions. In particular, it will provide a tool to illustrate the implications of current decisions on the future shape of the network, a consideration that is lacking in most planning and engineering studies.

**Primary Strategic Outcome Goal:**
- Discovery: Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering.

**Secondary Strategic Outcome Goals:**
- Learning: Cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens.

How does this highlight address the strategic outcome goal(s) as described in the NSF Strategic Plan 2006-2011?

(1) Discovery. This work is at the forefront of discovering at a theoretical and empirical level the underlying mechanisms that drive the evolution of transportation networks, and (2) Learning. Online simulators have been developed based on the research and have been included in the graduate and undergraduate curricula to enhance classroom leaning and to equip students with state-of-art concepts and tools with regard to the dynamics of transportation networks.

Does this highlight represent transformative research?
Yes

Agent-based modeling could be transformed to a new approach, forecasting the travel demand on a daily basis as well as guiding transportation and urban design in the long term.
Program Officer: Edward Jaselskis

Award Title: CAREER: The Evolution of Transportation Networks: Empirical Research and Agent-Based Models

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