Transportation Cyber-Physical Restoration in the Aftermath of Extreme Events

Suzanna Long, Assistant Professor, Department of Engineering Management and Systems Engineering, Missouri University of Science and Technology, Rolla, Missouri, United States. E-mail: longsuz@mst.edu. Tel # +1 (573) 341-7621.

Problem Statement

The restoration of transportation cyber-physical networks (TCPN) following a natural or man-made disaster is a pervasive challenge for decision makers responsible for the reintegration of regional or national supply networks after emergency response phases have ended. Although most disaster response models include cursory socioeconomic recovery plans, there is no comprehensive model capable of using data and decision variables in real time. Existing models are highly idealized and inadequate to encompass the complexities of an actual urban environment. Moreover, current models do not consider the problem from a systems view and solutions are incremental rather than inclusive of required model elements and data components. In short, existing models lack complexity, do not identify model elements from a systems perspective, and do not have a robust data identification process.

This position statement considers the importance of viewing transportation cyber-physical systems as a complex adaptive systems (CAS) problem and considers the model elements, data needs/element, and metrics required for successful Multi-Hazard Transportation Cyber-Physical Restoration (MHTCPR) for success. This proposed research incorporates *resiliency* and *scalability* into multi-hazards management decision making. By focusing on MHTCPR we directly impact infrastructure identified as critical by the United States by the Department of Homeland Security (Department of Homeland Security, 2009a, b) as well as related infrastructure elements required for socioeconomic growth and livable communities.

Anticipated Outcomes and Broader Impacts:

The position statement includes the following key characteristics as anticipated outcomes and broader impacts.

1. Identifies and integrates economic development, transportation infrastructure element, infrastructure restoration, and geospatial data required to populate multi-hazard transportation infrastructure network models.
2. Creates a comprehensive dissemination plan to interface with local, state, and federal decision makers as well as to assure opportunities for wide-scale adoption by other universities.
3. Develops multi-hazards transportation infrastructure network models.
4. The addition to the realm of engineering conceptual knowledge will create a highly skilled, competitive workforce.

Intellectual Merit:

Existing methodologies for the restoration of transportation cyber-physical systems (TCPS) do not address either geospatial or societal factors that determine levels of resilience and vulnerability of management solutions across regional or national boundaries. This position statement suggests the need to develop an innovative methodology that integrates conceptual knowledge from the domains of multi-modal transportation systems modeling, sustainability, and cyber-physical security with rigorous engineering design. This approach will create an integrated engineering solution capable of addressing requirements for resilience and scalability of the TCPS framework.

In the aftermath of extreme events, short term emergency phases of search, rescue and recovery are followed by longer term socioeconomic restoration phases. Existing decision–making methodologies developed by federal, state, and local government agencies focus on emergency response and address transportation infrastructure network resiliency only as an aid to emergency response functions (Veras and Jaller, 2012; Hale and Moberg, 2005; Horner and Widener, 2011). The intermediate time scale problem of socioeconomic recovery is less well understood. To achieve this recovery, the restoration of the urban center's infrastructure and its reintegration into the national transportation cyber-physical system is necessary.

Decisions are made by independent individuals or groups, and the decisions of one group can result in non-linear effects to the TCPS for members of other groups. Further, most analytical models do not consider behavioral and environmental factors. Despite these issues analytical models are regularly used in practice by policy-makers and include unrealistic assumptions.

Development of a CAS TCPS approach has numerous benefits beyond the scope of the application proposed. The simulation-optimization models will be of a general-purpose nature and the main paradigms that will result from this research will be useful for modeling the reconnectivity of the TCPS for any disaster-struck zone in the country, especially one that is unprepared for disaster. Also, this will pave the way for additional research in the area of disaster-preparedness by the way of systems models that take into account the big picture. It is clear that these models will have significant broader impacts in terms of the influence on society and public policy.

Select References

1. Department of Homeland Security, National Infrastructure Protection Plan, Washington D.C.: 2009a.
2. Department of Homeland Security, Multidisciplinary, Multi-institutional Science and Technology Competitions, Washington D.C.: 2009b.
3. Hale, Trevor, and Christopher R. Moberg., (2005), "Improving Supply Chain Disaster Preparedness: A Decision Process for Secure Site Location," International Journal of Physical Distribution & Logistics Management, 35.3, 195-207.
4. Horner, Mark W., and Michael J. Widener., (2011). "The Effects of Transportation Network Failure on People's Accessibility to Hurricane Disaster Relief Goods: A Modeling Approach and Application to a Florida Case Stud," Natural Hazards Review, 59, 1619-634.
5. Veras, Jose Holguin, and Miguel Jaller., (2011). "Immediate Resource Requirements after Hurricane Katrina." Natural Hazards Review, 13.2, 117-31.