

# New England University Transportation Center



NE University Transportation Center  
77 Massachusetts Avenue, E40-279  
Cambridge, MA 02139  
Phone: 617-253-0753  
Fax: 617-258-7570  
web.mit.edu/utc

**Principal Investigator:** Nicholas Lownes  
**Title:** Assistant Professor  
**University:** University of Connecticut  
**Email:** [nlownes@engr.uconn.edu](mailto:nlownes@engr.uconn.edu)  
**Phone:** (860)486-2717

**Co-Principal Investigator:**  
**Title:**  
**University:**  
**Email:**  
**Phone:**

## Final Report

*Project Title:*

# Hypernetwork Generation for Multi-modal Transportation System Modeling

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## **Introduction**

The transportation debate has evolved in recent decades to include ideas such as sustainability and livability alongside mobility and safety. Definitional complexities aside, there is no doubt that this evolution has created a national transportation agenda that is heavy on multi-modal transportation systems. Multi-modal systems can, and should be, more than disconnected auto, train and bicycle networks operating in parallel. A holistic, systemic viewpoint requires that these modes complement each other as part of an integrated whole. Current network design models and methods of addressing transportation network design problems tend to be unimodal in scope and therefore limited. The plethora of economic, topographic, political, social and environmental variables that play a role in transportation networks have necessitated a reductionist viewpoint, the breaking of the system into more manageable components.

This project challenges the traditional notion of transportation network design – by approaching the problem as integrated and multi-modal from the start. Hypernetworks enable one to model the transportation system not only as a set of links and nodes, but as a network of interconnected decisions that face travelers as they traverse the network. This concept has been deployed successfully in several public transit applications (which are inherently multi-modal), though it is only beginning to be explored in a multi-modal network design. Not surprisingly perhaps, hypernetworks are not trivial to generate for even small networks. The primary foci of this project are:

- i. Integrate new diverse ideas from complementary fields of inquiry into the framework of multi-modal network design. Calls for integrating the transportation system are coincident with calls for accountability through performance-based management. Tools are needed to evaluate transportation system design holistically in order to serve these pressing needs.
- ii. Formulate new models of multi-modal transportation network design that explicitly account for multi-modal paths through the use of these interconnected decision sets. The network design problem is well-studied, though at the scale of multi-modal transportation networks it is still an emerging concept.

## **Research Contribution**

The contributions of this research are:

- Improvements to the generation and application of hypernetworks in network design.
- Improving the ability to analyze and optimize a multi-modal system.

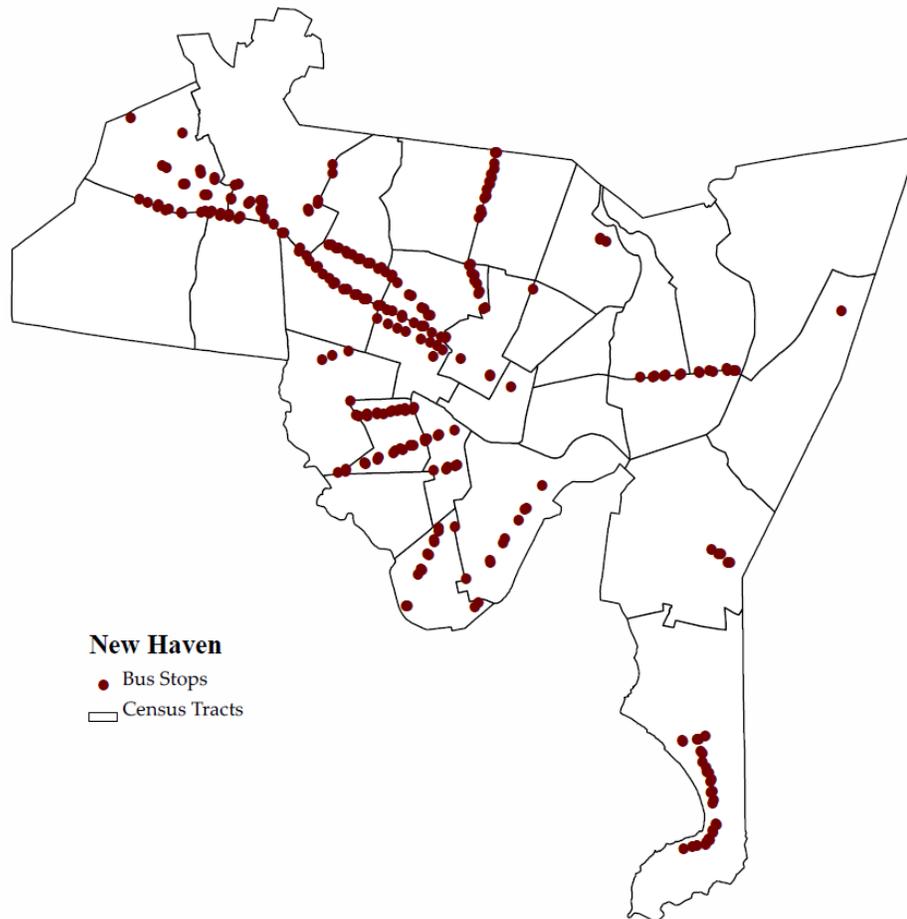
## **Technical Approach or Methodology**

There are numerous fields and studies that influence the topic of this research. Most directly, this work builds on the ideas of using strategies for transit assignment (Spiess and Florian 1989), which was extended to the concept of hyperpaths by several researchers, including Wu, et al. (1994) and to capacitated networks by Hamdouch, et al. (2004). The proposed work pulls in concepts of multi-modal hyperpaths (Sumalee, et al. 2010), time-dependent strategy subgraphs (Hamdouch and Lawphongpanich 2008), and time-variant paths (Opasanon and Miller-Hooks 2006).

## **Results**

A new model of transit network design was developed that incorporates multiple modes, and the systemic access and connectivity of the modes. This model is built with the concept of

multi-modal paths for individual users embedded. An application of this model on New Haven CT is shown below, depicting the highest-priority stops for maintaining both access and connectivity in the city. A multi-objective formulation was built to evaluate and optimize the tradeoffs in access and connectivity made through stop location configuration.



## References

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