The impact of uncertainty on strategic network design projects

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Introduction
• The network design problem answers the question: where to add capacity to a road?
• It is a complex mathematical problem that is traditionally deterministic.
• Common planning application

Motivation
• Drivers make a strategic route choice that accounts for uncertainty in:
  • day-to-day travel demand
  • day-to-day link capacity.
• Ultimately this choice affects design project rankings.

Contribution
• Propose and evaluate a novel formulation for the network design problem to capture user behavior in the face of day-to-day variation in travel demand and road capacity.
• Compare different methods.

Problem Description
❖ The network design problem is commonly formulated using a bi-level approach:

Upper Level Problem: Identify optimal set of links to which to add capacity.
Rank possible network design projects

Lower Level Problem: Equilibrium assignment model to capture the impact of the network changes on user route choice.

❖ Contribution of this work: account for impact of uncertainty on drivers’ route choice

Equilibrium Model
❖ What is it? Lower level problem that accounts for the day-to-day traffic volatility that users face when making a route choice.
❖ How do we account for uncertainty? By using the strategic assignment model, where we:
  • Assume that the travel demand and link capacity follow independent and known probability distributions;
  • Develop a set of mathematical equations to solve for the routes users will choose – concept of strategic equilibrium.

Allows planners to evaluate network conditions under varying levels of demand volatility and road capacity volatility

Network Design Model
❖ The project explores the derivation and equations for the proposed NDP model…not included here.

Solution approach: Genetic algorithm, a heuristic based on principles of natural evolution, common for the traffic network design problems.

Key points:
Network planner: identify optimal design scenario to minimize expected total travel time, stay within budget!
Individual drivers: alter routes in response to network changes!

Demonstration
Compare network design scenario evaluations using four approaches:
uncertainty in travel demand
uncertainty in link capacity
uncertainty in both
no uncertainty (deterministic)

❖ Compare reduction in total travel time and standard deviation of travel time for each approach.
❖ Sensitivity analysis on the total budget and level of network volatility.

❖ The difference between the blue bar and the red point shows how design project performance predictions change when demand and capacity uncertainty is considered!

Conclusion
❖ Sources of uncertainty such as travel demand and link capacity have an unpredictable impact on network design project rankings and evaluations.
❖ Future work will explore more in-depth implications of link capacity uncertainty and incorporating reliability into the strategic route choice decisions of users.