Need for and Uses of Risk Analysis: Technical approaches from the university perspective

Jimi Oke

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Intelligent Transportation Systems Lab | MIT Energy Initiative
Massachusetts Institute of Technology

Introduction

Research question

How will new vehicle technologies and environmental policy affect future urban mobility?

- Can we identify potential vulnerabilities given variability in urban outcomes?

Approach

Discover policy-relevant mobility futures in prototype cities:

- Identify sources of uncertainty
- Generate scenarios by sampling from uncertainty combinations
- Enumerate strategies for exploration
- Simulate activity patterns and movements for all scenarios across strategies
- Evaluate scenarios and determine success based on regret minimization and thresholding
- Find robust policy intersections and determine critical regions of interest

Outcomes

- Determine vulnerabilities in prevailing strategies
- Find critical regions in uncertainty space
- Proper quantification of strategy impacts

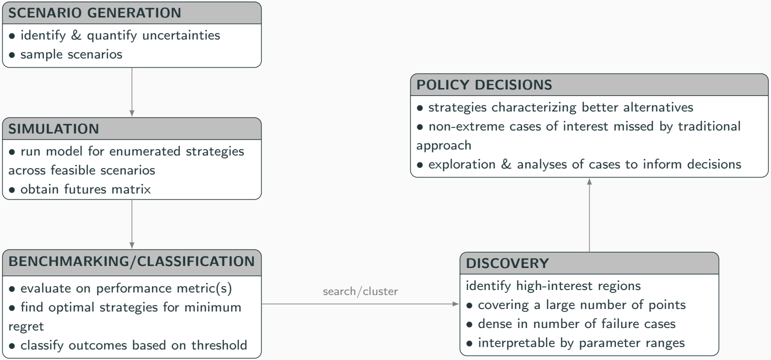
Motivation for scenario discovery

Traditional scenario analysis

- Does not adequately address uncertainties in decision making
- Relies on overly narrow deterministic definition of a small number of scenarios

Scenario discovery

- Provides framework for sampling across space of multiple futures
- Allows for identification of clusters of cases where base strategy fails
- These give rise to robust scenarios



Prior work and significance of current contributions

Notable academic efforts and key milestones

- Foundations: exploratory modeling[Bankes 1993]
- Development of Patient Rule Induction Method (PRIM) for high dimensional clustering[Friedman and Fisher 1999]
- Formalization of scenario discovery/robust decision making[Lempert et al. 2006]
- Demonstration of scenario discovery concept for robust urban planning[Swartz and Zegras 2013]
- Climate change and resource management; Ethiopia[Shortridge and Guikema 2016], Global[Rozenberg et al. 2014], California[Groves 2006]
- Extensions and improvements: data transformation[Dalal et al. 2013], heterogeneous types[J. H. Kwakkel and Jaxa-Rozen 2016], random bagging[J. Kwakkel and Cunningham 2016]
- Software: exploratory modeling workbench[J. H. Kwakkel 2017], many-objective robust decision making[Hadka et al. 2015]

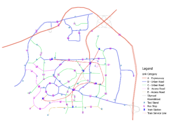
Urban mobility arena

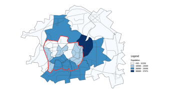
- Current work largely dominated by traditional scenario analysis and limited uncertainty analyses
- Bus lane strategy analyses in Marina Bay, Singapore [Song 2013]
- Current: future urban mobility across global urban typologies

Case study: discovering robust futures for autonomous mobility on demand (AMOD)

Prototype city testbed: dense public transit-oriented network; population 350,000

Uncertainty	**Levels** / *Probabilities*				
Household level of motorization	−20%	−10%	0	+20%	
	0.1	*0.3*	*0.5*	*0.1*	
ICEV proportion	25%	50%	75%	95%	
	0.1	*0.2*	*0.3*	*0.4*	
Fuel price change	−50%	0	+50%	+100%	+150%
	0.25	*0.30*	*0.20*	*0.15*	*0.10*
Smart mobility modeshare change	0	+25%	+50%	+75%	
	0.25	*0.25*	*0.25*	*0.25*	





Strategies

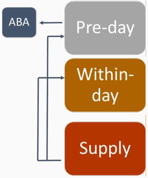
Each of these correspond to a fixed policy implementation:

- Do Nothing (no AMOD, current on-demand levels)
- AMOD as Mass Transit Complement (first/last mile)
- AMOD as Mass Transit substitute
- Full AMOD deployment
- CBD restriction to AMOD and Mass Transit
- Mass Transit Enhancement

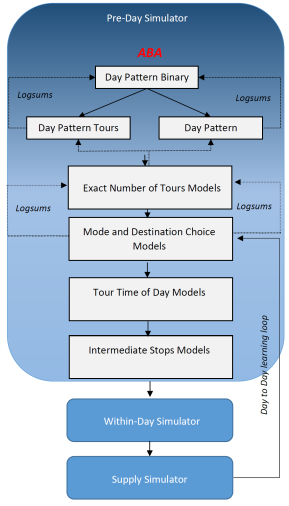
Evaluation metrics

- **Activity-based accessibility**
- Energy consumption
- Network performance
- Vehicle miles traveled

Case study: Simulation and evaluation



- Agent-based urban mobillity simulator: **SimMobility**
- Initial exploration for activity-based model (pre-day)
- 126 scenarios simulated across 6 strategies



Regret

Given a strategy $s \in S$ and a future state $f \in F$, the regret r is given by

$$r(s, f) = Z(s, f) - \min_{s' \in S} Z(s', f) \quad (1)$$

Performance

We define cost function $Z(s, f)$ as

$$Z(s, f) = -\frac{1}{N} \sum_{n} ABA_n(f, s) \quad (2)$$

where ABA_n is the activity-based accessibility for each individual n and N is the population.

Outlook

- Current case study performed for only activity-based accessibility outcomes (results to be presented Wednesday)
- Supply to be simulated for energy and network performance outcomes
- Further experimental design for discovery across 4 distinct prototype cities representing key urban typologies:
  - Auto-Sprawl
  - Auto-Innovative
  - Innovative-Heavyweight
  - Sustainable Anchor
- Key outcomes: levels of AMOD deployment, fuel prices and preferences required for robust strategy implementations given future considerations

Appendix

SimMobility overview: simulation laboratory

- A laboratory for analyzing future urban scenarios
- Integrated/modular agent-based platform
- Mobility-sensitive behavioral dynamic plan/action models
- Local and city-wide multimodal networks
- Multiple spatial-temporal scales