Application of Multi-Attribute Tradespace Exploration to the Architecting and Design of a Transportation System

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Biography

Julia Nickel is a Master's student in the Engineering Systems Division and Political Science departments at MIT, and a Research Assistant in SEAri. Before coming to MIT Julia studied "Industrial Engineering and Management" at the University of Karlsruhe in Germany. She has work experience with the Chicago Transit Authority, Franz Haniel & Cie. (a German logistics company), the McGovern Institute for Brain Research at MIT, and the Defense Research and Development Canada.

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Related Publications

Nickel J., Ross, A.M., and Rhodes, D.H., "Comparison of Project Evaluation Using Cost-Benefit Analysis and Multi-Attribute Tradespace Exploration in the Transportation Domain", Second International Symposium on Engineering Systems 2009, Cambridge, MA, 2009a.

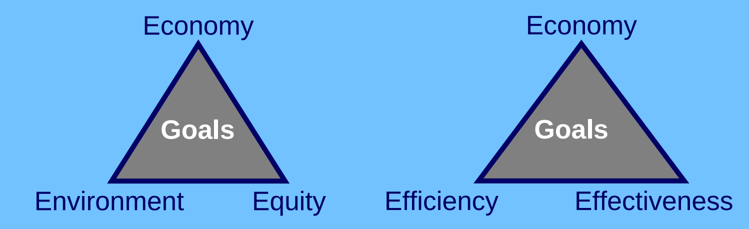
Nickel, J., Ross, A.M., and Rhodes, D.H., "Trading Project Costs and Benefits using Multi-Attribute Tradespace Exploration," 7th Conference on Systems Engineering Research, Loughborough, UK, 2009b.

Nickel, J., Ross, A.M., and Rhodes, D.H., "Cross-domain Comparison of Design Factors in System Design and Analysis of Space and Transportation Systems," 6th Conference on Systems Engineering Research, Los Angeles, CA, April 2008.

Motivation for application of MATE to transportation problem

1) **Transportation and space systems exhibit a number of similar characteristics (high price tags, long development time, unique designs) . Methods that prove useful across domains give hints at fundamental engineering principles.**
2) **Potential new insights for transportation design and decision-making, through:**
   - **Support in the creation (not only evaluation) of designs,**
   - **Visualization and communication of complex system tradeoffs in both technical and preferential metrics,**
   - **Opportunities for learning by key decision makers through process**
3) **Possible revelation of domain-inherent biases in MATE, which may be used to make the method more domain- independent**

Competing goals of transportation system design



Executive Summary

Systematic solution generation is not well supported analytically by current transportation planning methods. Tradespace exploration proves to be a useful tool for high-level, low-fidelity evaluation of a large number of designs in a case study for an Airport Express for Chicago. The application is the first one of Tradespace Exploration to a problem in the transportation domain.

As explored by different authors, MAUT is useful in understanding inner dynamics of interest in transportation projects with ambiguous, competing goals.

The combination of MAUT and Tradespace Exploration in MATE promises a set of interesting new insights for transportation planning (Nickel, Ross and Rhodes 2009a and 2009b). Clear modeling relationships between technical performance and higher level, political stakeholder attributes appear to not yet be well understood for the transportation domain and are the subject of ongoing research (e.g., agglomeration benefits).

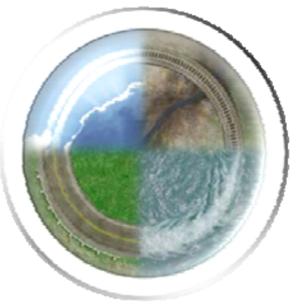
In order to apply MATE to transportation problems, higher-level political attributes need to be broken down into technical ones that can be driven by design variables and constitute "fair" measures of success.

Research Questions

What design methods are used for transportation systems planning? What are their limitations?

What implementation issues arise if MATE as a design method from the space domain is applied to the transportation domain?

What methodological insights emerge through the application of Cost-Benefit Analysis and MATE?



Question for future research

What impedes the implementation of pareto-optimal solutions in multi-stakeholder problem spaces? How can these impediments be overcome?

Literature review

Classic decision-making model in transportation planning: **Rational Planning model (Gakenheimer 1976, Weiner 1997, Meyer and Miller 2001)**

Assumptions in Rational Planning Model	Assumption in MATE?	Decision-making model/metthod that relaxes this assumption
1) Unambiguous and clearly definable "goal"	Yes	Incremental Change, Political Bargaining
2) Decision maker acts exclusively in the capacity of rational technician, ignoring other roles such as "advisor, mediator or administrator" (Luzzi 2001)	No	Organizational Process, Multi-Attribute Decision Theory (to some extent)
3) No resource constraints on the obtaining of information (money, time)	Yes	Multi-Criteria Decision Analysis combines with decision conferencing, Satisficing
4) Stable preferences over time	No	Dynamic MATE

Case Application

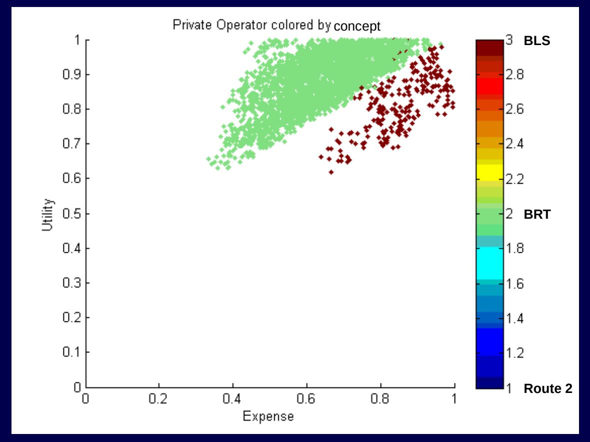
MATE attributes

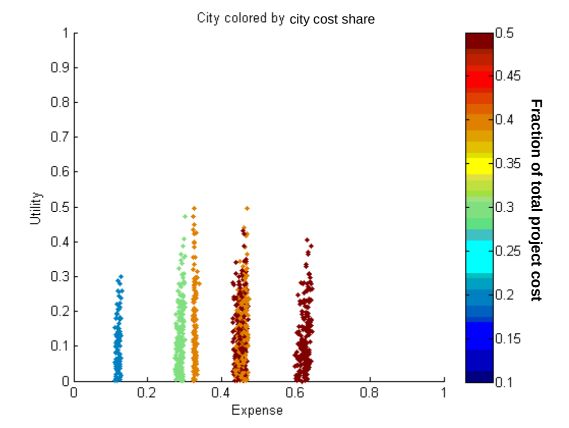
Stakeholders' value propositions for the airport express need to be decomposed to those that the designer can actually influence (shown in pink for the stakeholder City of Chicago)

Weight	City of Chicago high-level attributes	Depend on
0.12	Estimated tax base change	Land value ->Ridership-> Attractiveness -> Quality of Service (QOS)
0.12	Generation of employment	Initial costs, Attractiveness -> QOS
0.12	Availability of outside funding	City's cost share
0.1	Attraction of visitors	Attractiveness -> QOS
0.1	Equity	City's initial costs
0.56	Sum	

Rank	CTA	Private Operator
1	Up front investment	Return on investment, pre-tax
2	Impact on current operations (overall capacity)	Competition (Other CTA services, road construction)
3	Probability of recurring delays to existing trains	Autonomy to make changes (e.g. fares)
4	Maintainability	Concession payment

Comparison of analysis methods MATE and CBA





MATE shows subjective decision-maker utility at expense, CBA savings to society as a whole

Savings to society in CBA depend heavily on the discount rate

In mn 2008 $	Base case	Route 2	BRT	Blue Line Switch
DR=7%	0	-97	-70	718
DR=10%	0	170	-37	447

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