Systems Engineering Advancement Research Initiative

Massachusetts Institute of Technology

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

Julia Nickel, SM in Engineering Systems (expected June 2009)

Advisors: Dr. Adam Ross, Dr. Donna Rhodes

Biography

Julia Nickel is a Master's student in Engineering Systems at MIT and a Research Assistant in SEAri. Before coming to MIT Julia studied in "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 Defense Research and Development Canada.

Related Publications

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.

Heinzerling, L., Ackerman, F. "Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection," 150 U. Penn. L. Rev. 1553-1584, 2002.

Ross, A.M., Managing Unarticulated Value: Changeability in Multi-Attribute Tradespace Exploration, Ph.D., Massachusetts Institute of Technology, 2006.

Domain Context: Transportation Planning

Transportation systems deliver a complex set of benefits and costs to different stakeholder groups over long periods of time and under uncertain conditions.

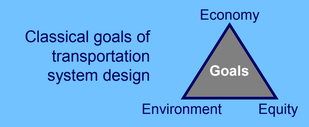
This research addresses the following shortcomings of Cost-Benefit Analysis (CBA):

- Discounting and aggregation of costs and benefits hides information (equity, (re) distribution of C&B, time impact on value/harm) early on in the design process

  Example: Completion of Chicago Airport Express before Olympics in 2016

- Discounting and aggregation of costs and benefits introduces critical value judgments (value of future lives, future damage; interpersonal value comparisons)

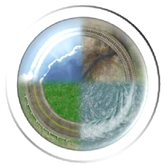
- Decisions are vulnerable to manipulation and error through uncertainty about future costs and benefits



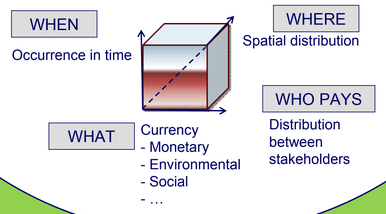
Research Questions

How can different types of costs (e.g. externalities) be incorporated in tradespace studies during the conceptual design of transportation systems?

How can changing environments be considered in the sensitivity analysis of cost-benefit analysis?



Different Cost Dimensions



"New" domain issues in applying MATE

Iterative planning process
- Determined by availability of funding, granting of permits, and other events

Less emphasis on a "mission" that drives a project
- Focus on goals ("benefits") and feasibility ("costs", financial and political)
- Remedial planning: move away from ills rather than towards goals
- Exploratory planning: goals are continually being redefined or newly discovered

More classes of stakeholders
- Losers (compensation, equity issues), stakeholders without decision making power, forced stakeholders

Large numbers of stakeholders (passengers, public)
- Need for aggregate measures (price/demand elasticities, political representation)

Multiple cost types to be considered
- social, environmental (including externalities)

Strong role of inheritance
- Infrastructure constraints: physical and expectations
- Relatively small changes to large legacy system, focus increasingly on managing system instead of physical construction

Market structure
- Market failures (natural monopolies, externalities…) and regulation
- Indirect feedback (e.g. purchase decisions)

Baybrooke and Lindblom (1970): A strategy of decision: Policy evaluation as a social process. Free Press NY, 1970, in: Meyer, M. and Miller, E. *Urban Transportation Planning, 2nd Edition*, McGraw-Hill, New York, 2001

Expected contributions

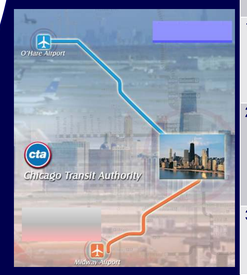
A methodology for incorporating non-monetary costs (e.g. externalities) into tradespace studies during the conceptual design of transportation systems

- Limiting the amount of critical assumptions that are introduced in the design process at the point of evaluation (e.g. equity, time context)
- Allowing for a time-staged exploration of costs by differentiating them as different cost types
- Refining sensitivity analysis through explicitly considering changing environments (Epoch-Era Analysis)

Domain-comparative research
- Uncovering of domain biases (space versus transportation)
- Reciprocating findings for application across domains

Case Application: Airport Express for Chicago

Value Propositions for Airport Express: Revealed as not project-specific



Rank	City of Chicago		CTA		Private Operator	
	Attributes	Measure, Range (min-max utility)	Attributes	Measure, Range	Attributes	Measure, Range
1	Estimated tax base change	% increase in equalized assessed property value downtown (4-10)	Up front investment	$M (100-0)	Return on investment, pre-tax	% (12-35)
2	Generation of employment	# jobs created (20,000-100,000)	Impact on current operations (overall capacity)	% of capacity needed for airport express (25-0)	Competition (Other CTA services, road construction)	Scale 1-5 (3-5)
3	Availability of outside project funding	% local share requirement (50-0)	Probability of recurring delays to existing trains	% (5-0)	Autonomy to make changes (e.g. fares)	Parties to consult (3-1)

- Is this a "solution" looking for a problem? (Classical dilemma)
- "Fuzzy" attributes, complex relationship to design variables
- Attributes trying to minimize losses

MIT Portugal

Possible real case application in cooperation with MPP SCUSSE project:
Exploration of different options for intermediary transit services between automobile and public transportation, such as bus-on-call, car sharing, etc., to help people transition to more public forms of transportation

Improving Classical Cost-Benefit Analysis

Multi-Attribute Tradespace Exploration (MATE) may provide a set of methods for addressing several shortcomings of classical CBA

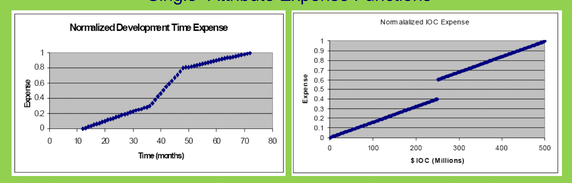
Problems with CBA

- Equity, distributional effects (adding up across stakeholders)
- Time-sensitivity of costs and benefits (discounting)
- Focus on a few point designs
- Vulnerability to manipulation and errors due to uncertainty about future developments

Benefits of MATE

- Explore tradespaces for different attributes that constitute expenses (negative utility) individually
- Differentiate attributes depending on when they occur (e.g. initial and recurring costs)
- Exploration of larger sets of designs
- Epoch-Era Analysis can be used for broad and time-varying sensitivity analysis

Single- Attribute Expense Functions



Diller, N.P., Utilizing Multiple Attribute Tradespace Exploration with Concurrent Design for Creating Aerospace Systems Requirements, 2002

For more information, please visit:
http://seari.mit.edu

For information on the MIT-Portugal Program, please visit:
http://www.mitportugal.org