Second International Engineering Systems Symposium

Comparison of Project Evaluation Using Cost-Benefit Analysis and Multi-Attribute Tradespace Exploration in the Transportation Domain

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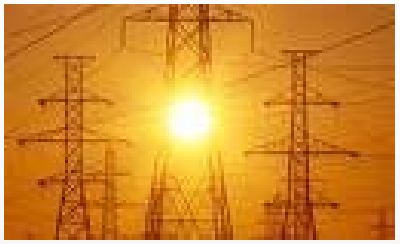
Complexities shared between engineering systems of different domains



- Long lifecycles
- High initial investments
- Unique designs
- Long-term lock-in of consequences of bad designs

Methods for project appraisal need to take these complexities into account.

Exploration of large number of designs during the conceptual design phase increases the odds of investing resources into development of a “good” design.

Research questions

What information about a project design is gained from two engineering decision making methods, Cost-Benefit Analysis and Multi-Attribute Tradespace Exploration?

How do the strengths and weaknesses of both methods compare?

Observations

- Both methods have „blind spots“, but they lie in different areas
- Tradespace generation can support the systematic generation of a large number of designs early on in the design process in CBA
- MATE reveals individual preference patterns of decision makers
- CBA captures dispersed stakeholders and system as a whole

Cost-Benefit Analysis (CBA)

Widely accepted method for transportation project evaluation since the 1950's

Seeking to ensure a net benefit to society

Benefits

- Certain transparency
- Comparison on a common scale

Shortcomings

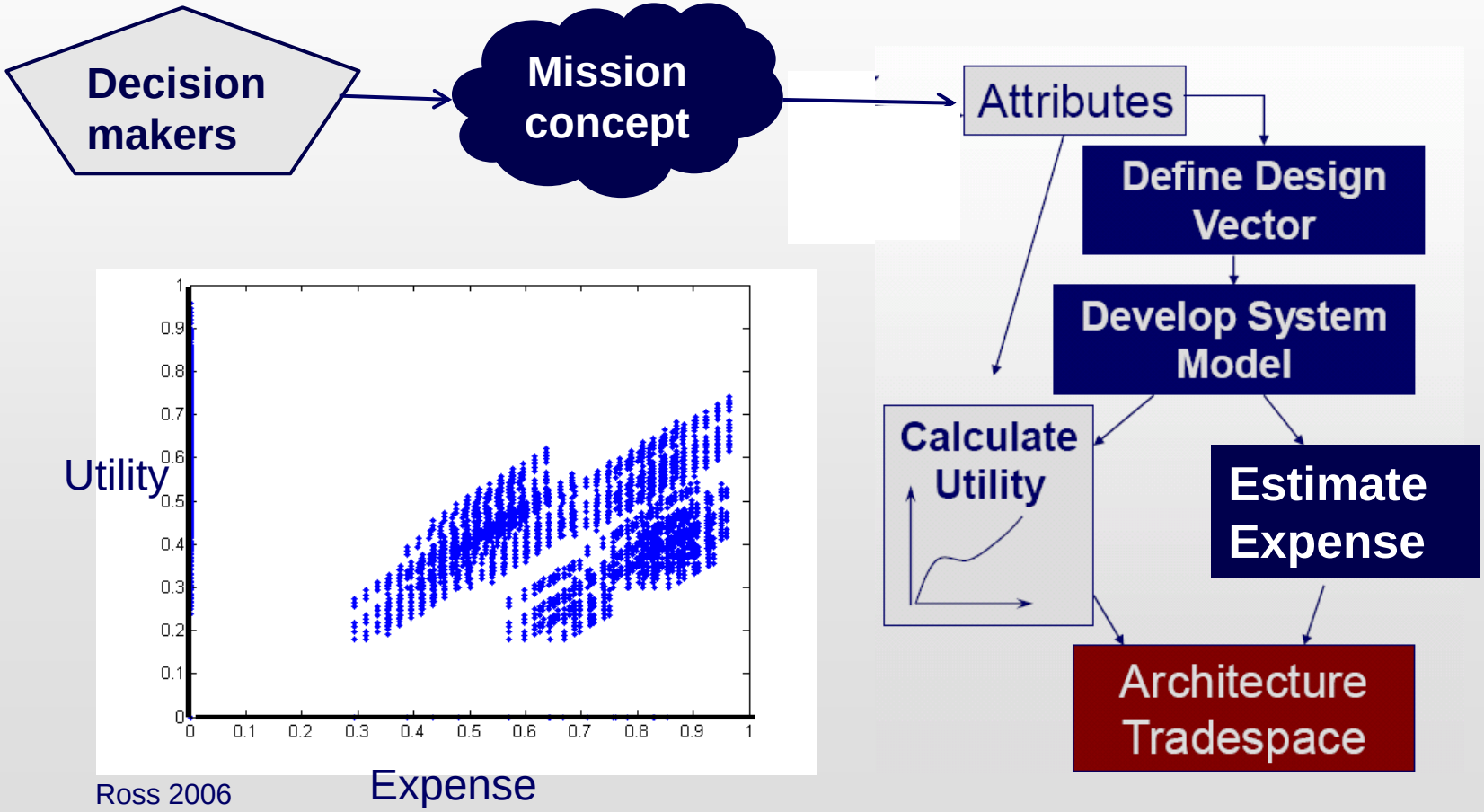
- Interpersonal utility comparisons and loss of information about the distribution of costs and benefits
- In practice analysis often limited to a few point designs

US Federal Highway Administration: Need to explore "full range of alternatives". Without a systematic method sufficient exploration of alternatives is left to the judgment and expertise of the analyst.

MATE-Overview

Multi-Attribute Tradespace Exploration (MATE)

Value-based method for system design generation and selection developed at MIT



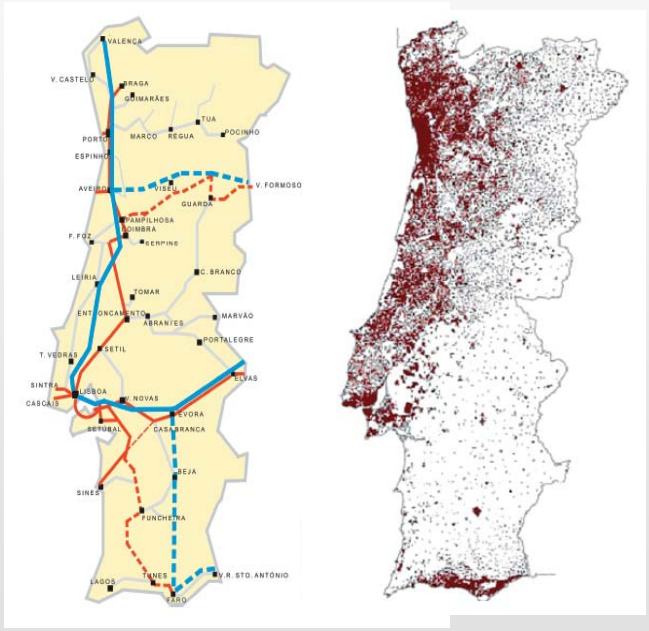
Ross 2006

Comparison of attributes of both methods

Case studies

1. Chicago Airport Express

2. Portuguese High-Speed Rail



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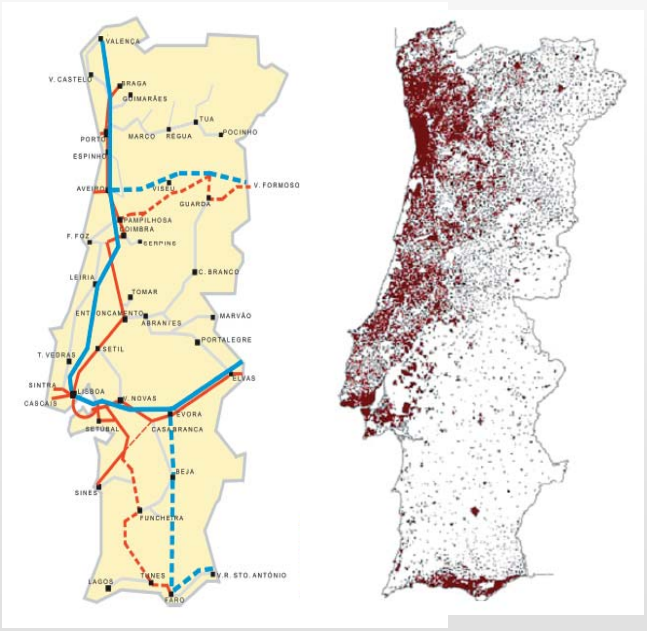

Identification of stakeholders

Decision-making stakeholders

- City of Chicago
- Chicago Transit Authority (CTA)
- Private Operator

Non-decision making stakeholders

- Passengers
- Chicago Public
- Residents adjacent to tracks
- O'Hare International Airport
- Airlines

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Determine which system will be built

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Preferences only indirectly accounted for through decision-making stakeholders

CBA attributes

CBA- Elicitation through use of guidelines for typically relevant costs and benefits, Incl. non-monetary ones (Federal Highway Administration, CalTrans)

Benefits	Costs
Travel time savings (speed and reliability)	Capital cost
- To Airport travelers	Operating cost
- To Blue Line riders	Delays to Blue Line passengers
- To drivers (congestion relief on Kennedy)	Delays to drivers on Kennedy Expressway
Emission reduction	Noise to residents
	Adverse neighborhood impacts from construction
Second order effects	
Long-term and short-term job generation	Job losses (from changes in operation at CTA, cab drivers)
Attraction of new business development	Loss of property value in neighborhoods impacted by noise
Increase in property value	

MATE stakeholder attributes

MATE: Elicitation through interviews with proxy representatives for stakeholders

City of Chicago	CTA	Private Operator
Estimated tax base change	Up front investment required from CTA	Return on investment pre-tax
Generation of employment	Impact on current operations-capacity	Freedom of concessionaire to make operational changes
Availability of outside funding	Probability of recurring delays to curr. operations	Competition agreements
Attraction of visitors	Maintainability	Concession payment
Equity		

Elicited attributes from both methods are very different

Case studies

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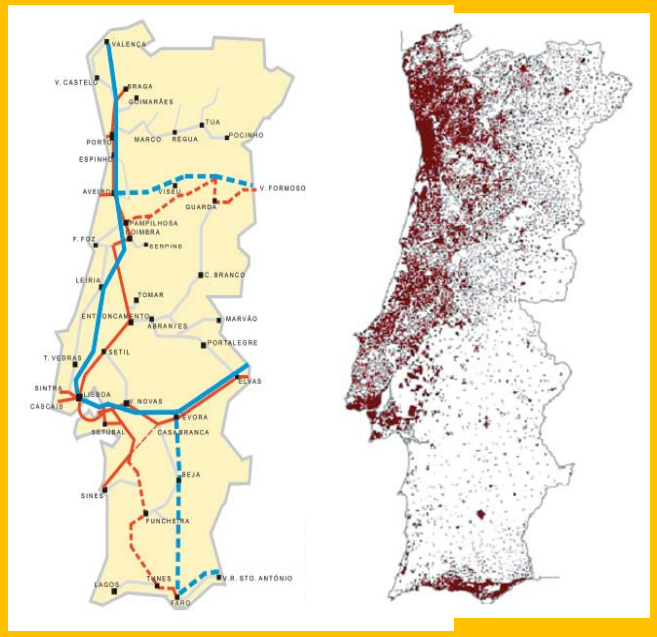

CBA attributes

Benefits	Costs
Travel time savings	Initial construction costs
Savings from reduced externalities (crash costs, emissions)	Maintenance costs
	Operating costs

Transportes Inovação e Sistemas 2007

Focuses on major public benefits (travel time savings, reduction in crash costs), whether decision makers care about them or not.

MATE stakeholders attributes

Stakeholders (left) Attributes (below)	Units	Portugal	European Union	Private Investor	Spain
Total Project Cost	b€	x	x		
Cost Portuguese Share	%	x			
Cost EU Share	%	x	x		
Cost Spain Share (Border Connection)	%	x			x
Private Invester Contribution	mn€	x		x	
Cost Maintenance	€/yr	x			
Cost Operation	€/run	x			
Portuguese Cost Share Operations	%	x			
Spanish Cost Share Operations	%				x
Net Travel Time Sines-Madrid	min	x			x
# Stops	#	x			
Overall Travel Time (Pax)	min	x	x		x
Overall Travel Time (Freight)	min	x	x		x
Quality of Coordination at border connection	[1-5]	x	x		x
Max Troughput (Freight)	ton/day	x			
Max Capacity (Pax)	pax/day	x			
Ease of Transfer to HSR in Evora	[1-5]	x			x
Risk (for private investor)	[1-9]			x	
Security	[1-5]	x			
Prestige	[1-5]	x			

Stakeholders and MATE attributes

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Prestige	[1-5]	x			

Comparison of analysis results for Chicago case of both methods

Calculate Aggregate Cost-Benefit

Models

1.Construction expenses

CTA technical studies and analogy building for BRT

2.Operating expenses

Own model

3.Travel time savings

Own model

4. Emissions savings

CalTrans emissions model

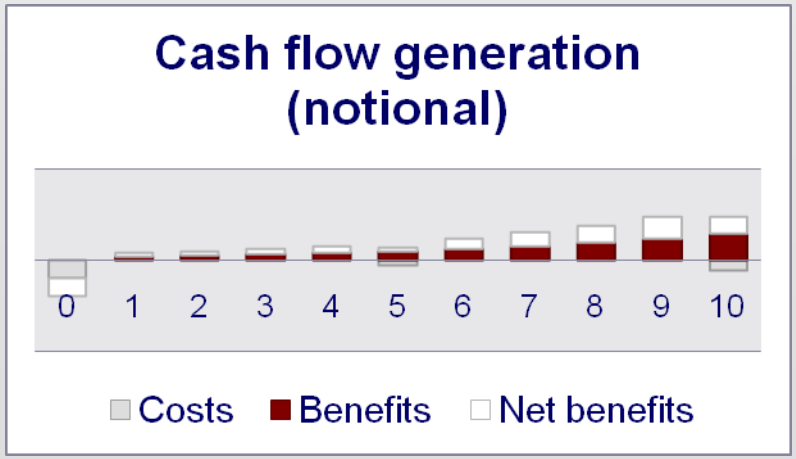
5. Fleet expansion and replacement

3. Net Present Value (NPV)

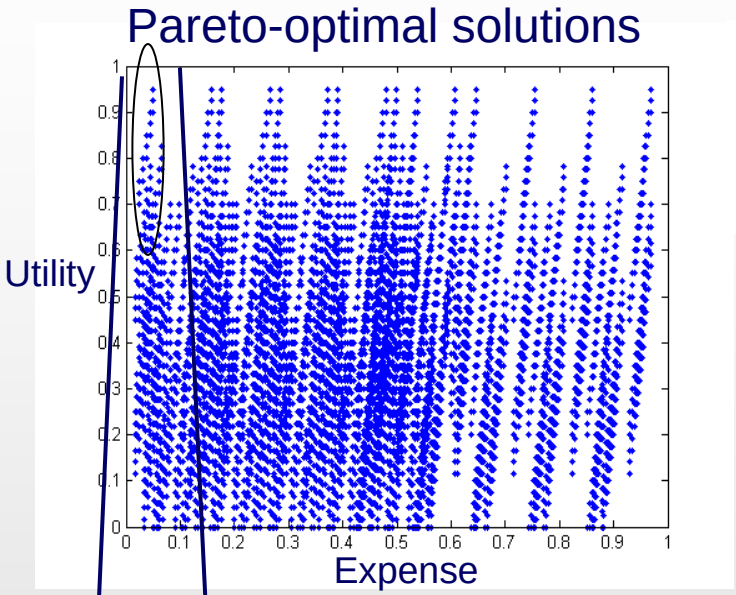
calculation of Cost-Benefit

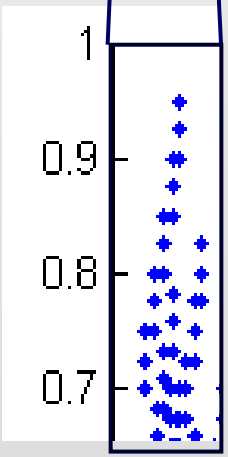
In mn 2008 $	Base case	Route 2	BRT	BLS
DR=7%	0	-97	-70	718
DR=10%	0	170	-37	447

Smaller is better

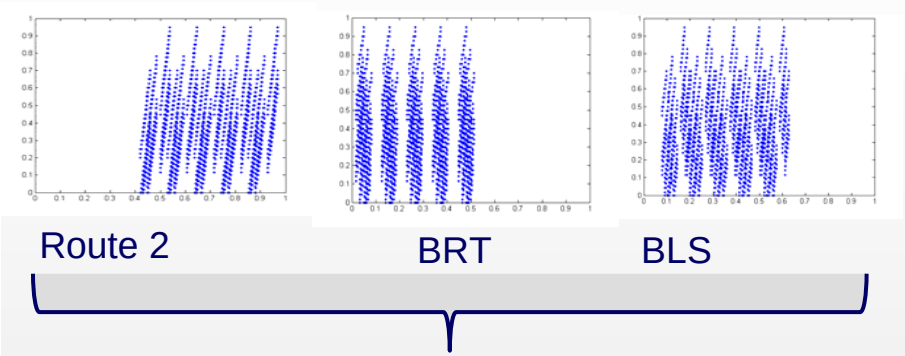


Results from MATE Analysis: City of Chicago





(See paper for ranges and measures of attributes and design variables)



BRT is the preferred concept because it has the lowest up front cost at comparable service levels.

Pareto-optimal solutions for city maximize Quality of Service attributes that have low or no impact on initial expense.

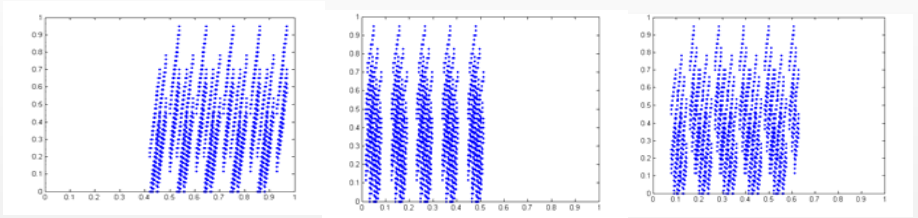
Results from MATE Analysis: City of Chicago

Ranking of concepts according to CBA

Shapes for individual corridors

DR=7%

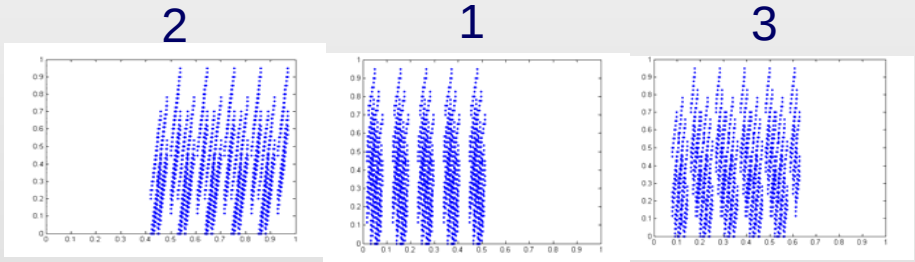
1 2 3



Route 2 BRT BLS

DR=10%

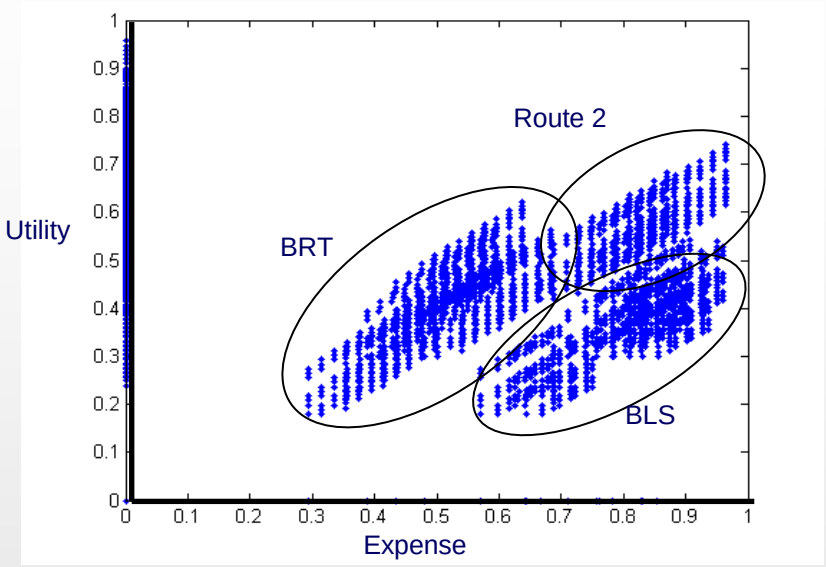
2 1 3

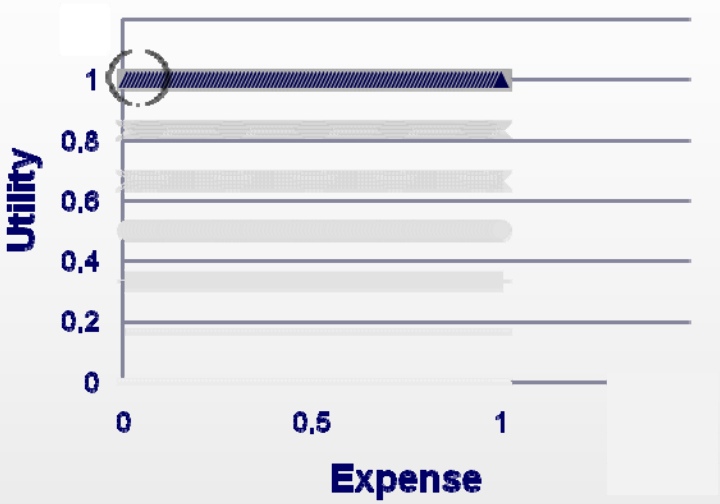


Route 2 BRT BLS

BRT and BLS, more advantageous concepts for the City of Chicago, have not been considered in the actual planning.

Results from MATE Analysis: Private Operator and CTA



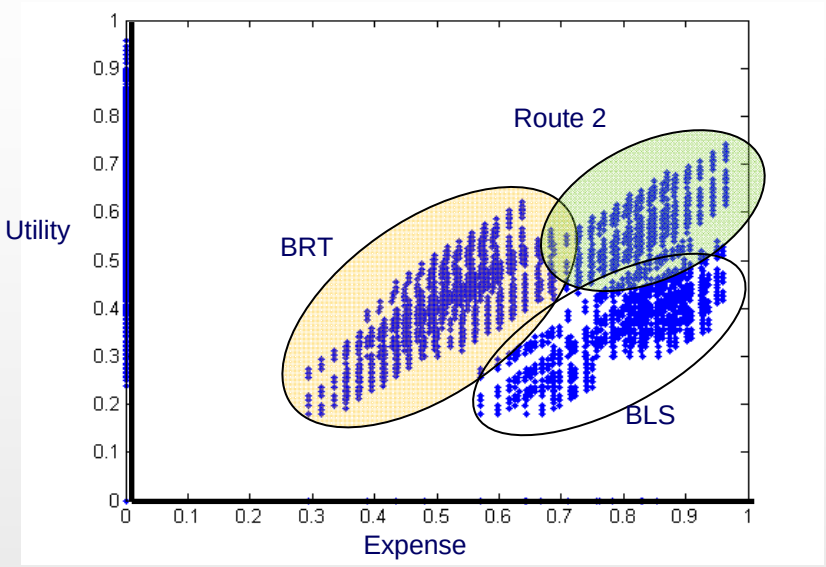


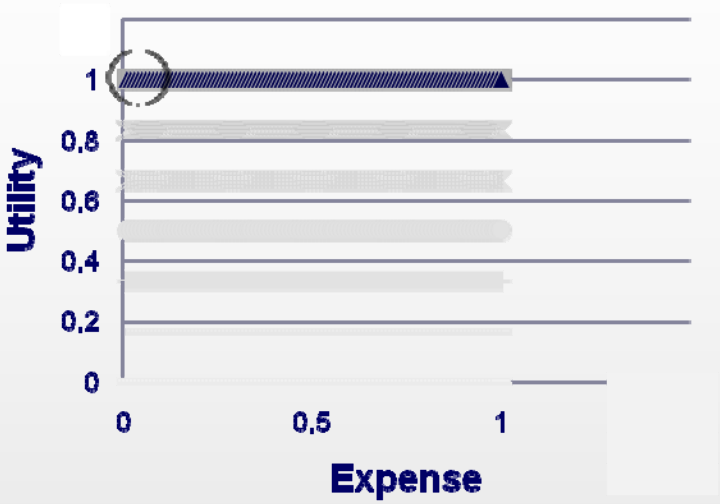
BRT and Route 2 are preferable designs depending on desired level of utility.

A number of attributes are non-monetary and non-technical (potential for efficient compromise solutions).

Preference for low contribution to initial investment and short span of service do not correspond to any specific design concept.

Results from MATE Analysis: Private Operator and CTA





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CBA solution for DR= 7%

CBA solution for DR= 10%

Complementary insights from both methods

1. Tradespace generation is embedded in the process of MATE and allows a broad filtering of a large number of design alternatives early on in the conceptual design stage.

The odds for generating a good design are increased and the risk for suboptimization is mitigated.

Example from case: BRT and BLS were not considered in the original planning by the CTA and City of Chicago.

Complementary insights from both methods

2. MATE sheds light on inner dynamics of interests between stakeholders, facilitating efficient compromise solutions

Examples from cases:

- Chicago/EU only contribute to initial expenses
- Tradeoff between ridership maximization and profit maximization made explicit
- Personal (intangible) motivations revealed (prestige, operational freedom…)

Complementary insights from both methods

3. MATE cannot be relied upon to bring up all important considerations for a decision

Examples from cases:

- Decision makers in both cases did not prioritize travel time savings, which was the largest contributing factor in CBA (aggregate benefit to dispersed group)
- Potential conflicts between public mandate and agency interest

Conclusion

Through the joint use of MATE and CBA, shortcomings of both methods can be mitigated.

The focus of both methods is different (value-driven vs. driven by public benefit) and they should be used in a complementary way.

Future research should address how both methods should be used in a joint process.

Thank you for your attention.