Effects of Enhanced Multi-party Tradespace Visualization on a Two-person Negotiation

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www.stevens.edu/sse/CSER2015org

Engineering Negotiation

- Complex systems increasingly frequently pulling in multiple stakeholders
  - Adds 'socio' dimension even if project may originally be viewed as strictly technical

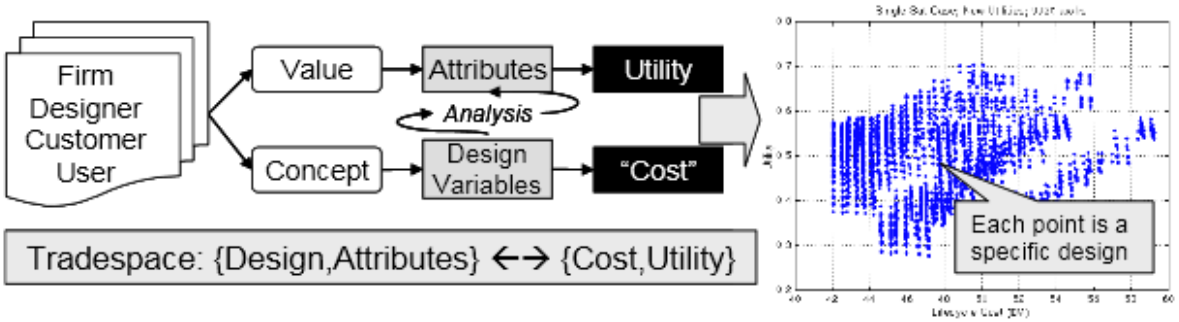
- 'Stakeholder incompatibility' drives project cancellations
  - Can occur despite large feasible domain meeting requirements

http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=5308

Emergent need to improve negotiation between differing interests

Tradespace Exploration (TSE)

- Multi-attribute Tradespace Exploration (MATE) maps system concepts into design variables and stated stakeholder preferences into performance attributes/utility functions



Paradigm emphasizes looking at a large set of alternatives and their outcomes

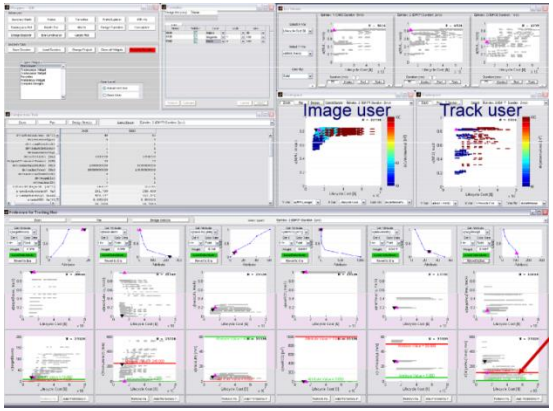
- Key goal: move away from point design analysis to better understand the problem via trends in outcomes (perceived value space)
- Interest in applying to multi-stakeholder problems, as a means of clearly illustrating relationships between varying needs

Can TSE be an effective technique for designing systems shared by multiple stakeholders?

Multi-Stakeholder TSE (MSTSE)

- Tradespace approaches (e.g. MATE) are a natural extension of many of the ideas central to principled negotiation
- Early application of MSTSE was developed heuristically by applying the practices of standard TSE

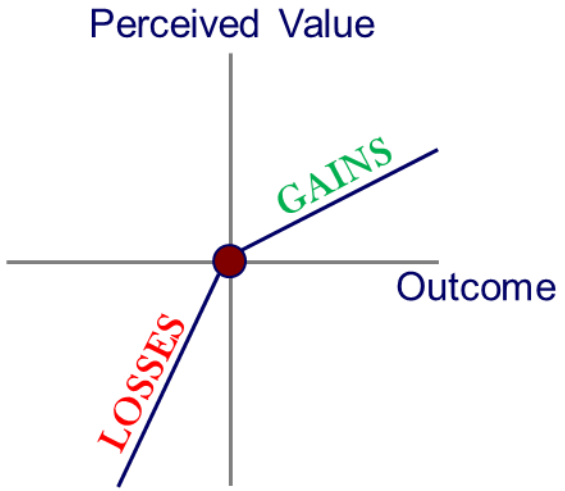
- Depersonalizes differing goals
- Focuses on interests (preferences)
- Uses objective metrics to evaluate choices
- Creates and explores many options



We should revisit MSTSE and evaluate the framing match of TSE techniques for multiple stakeholders

Framing

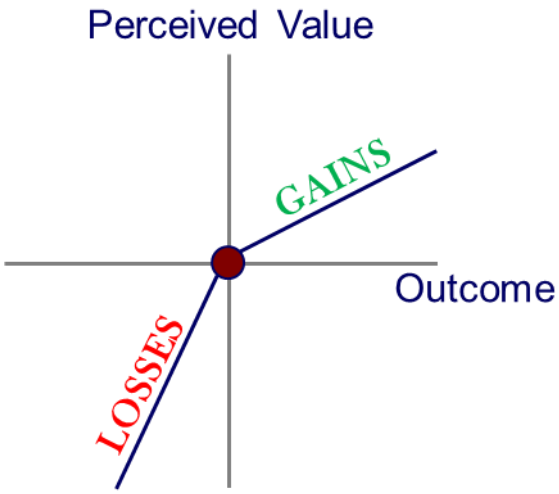
- Framing effects: differences in behavior driven by differences in the presentation of information
- Prospect theory → considerable empirical evidence that people frame decisions using reference points to define 'gains' and 'losses'
- Asymmetrical perceived value around the reference point makes losses more impactful than gains

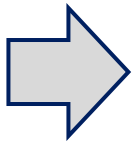


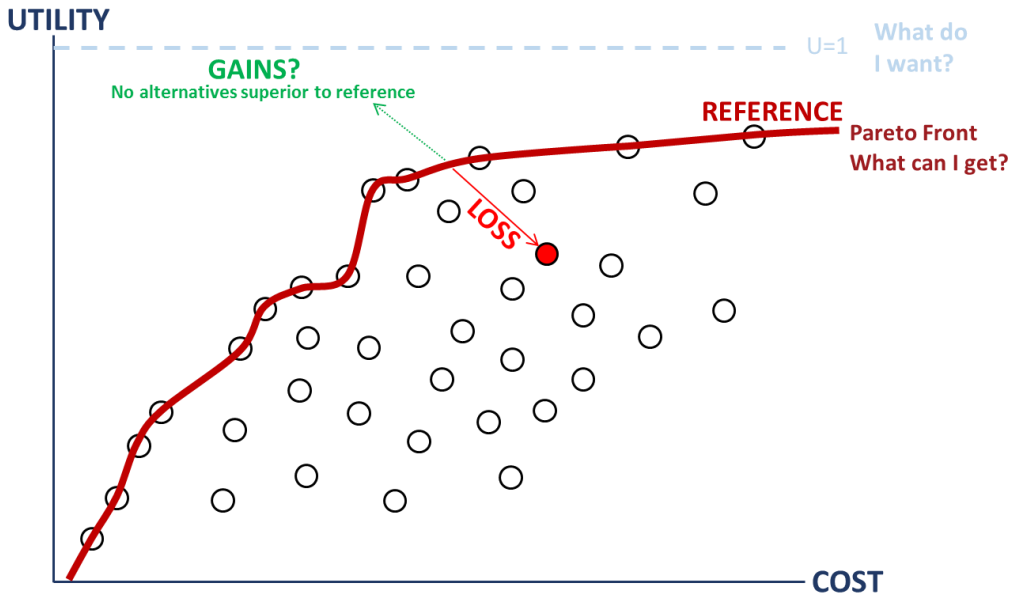
Proper selection of a reference point is critical to good decision making

TSE Framing

- What reference points exist in TSE?
  - Utility = 1, complete satisfaction of needs
  - Pareto front, cost-benefit efficiency
    - Too optimistic for multi-stakeholder problems?







TSE Framing

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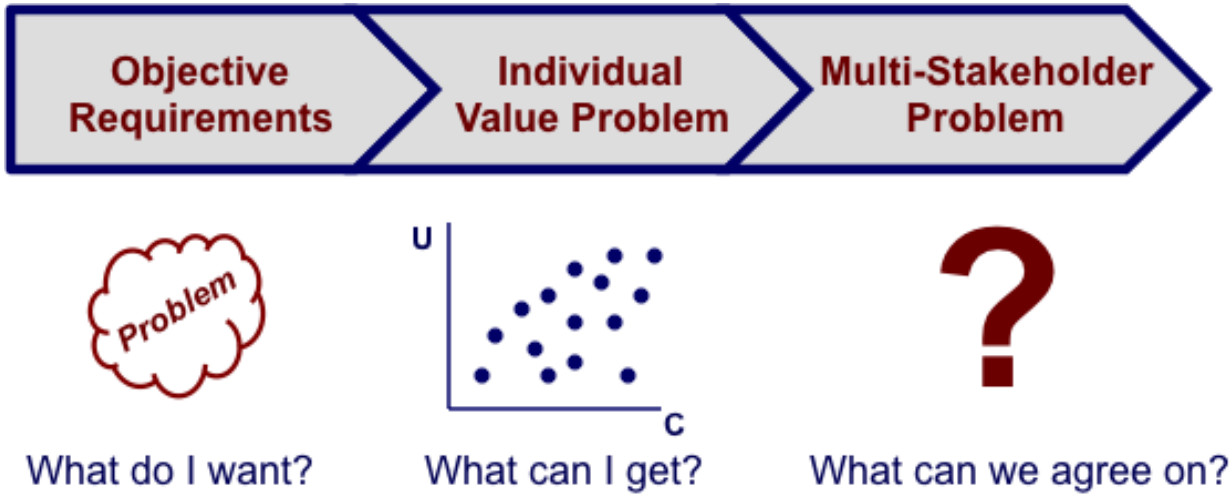
- Problem is increasing in sophistication



Reframing TSE for Multiple Stakeholders

- Best Alternative to a Negotiated Agreement (**BATNA**) as reference point
  - Accepted boundary between true gains and losses in a negotiation
  - Nominally less efficient than Pareto front, or there is no reason to negotiate
  - Must explicitly draw BATNAs into the problem formulation
- Increase information availability of ***group*** problem: other people's interests and preferences
  - Keep value indicators for other participants prominent by exploiting additional dimensions (color, transparency, etc.)
  - Reduce positional bargaining / attachment to one-sided solutions

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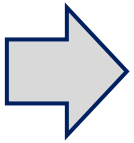

Tradespace axes use BATNA as origin
+
Rotate graph to inhibit trained reaction to seek Pareto front

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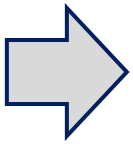
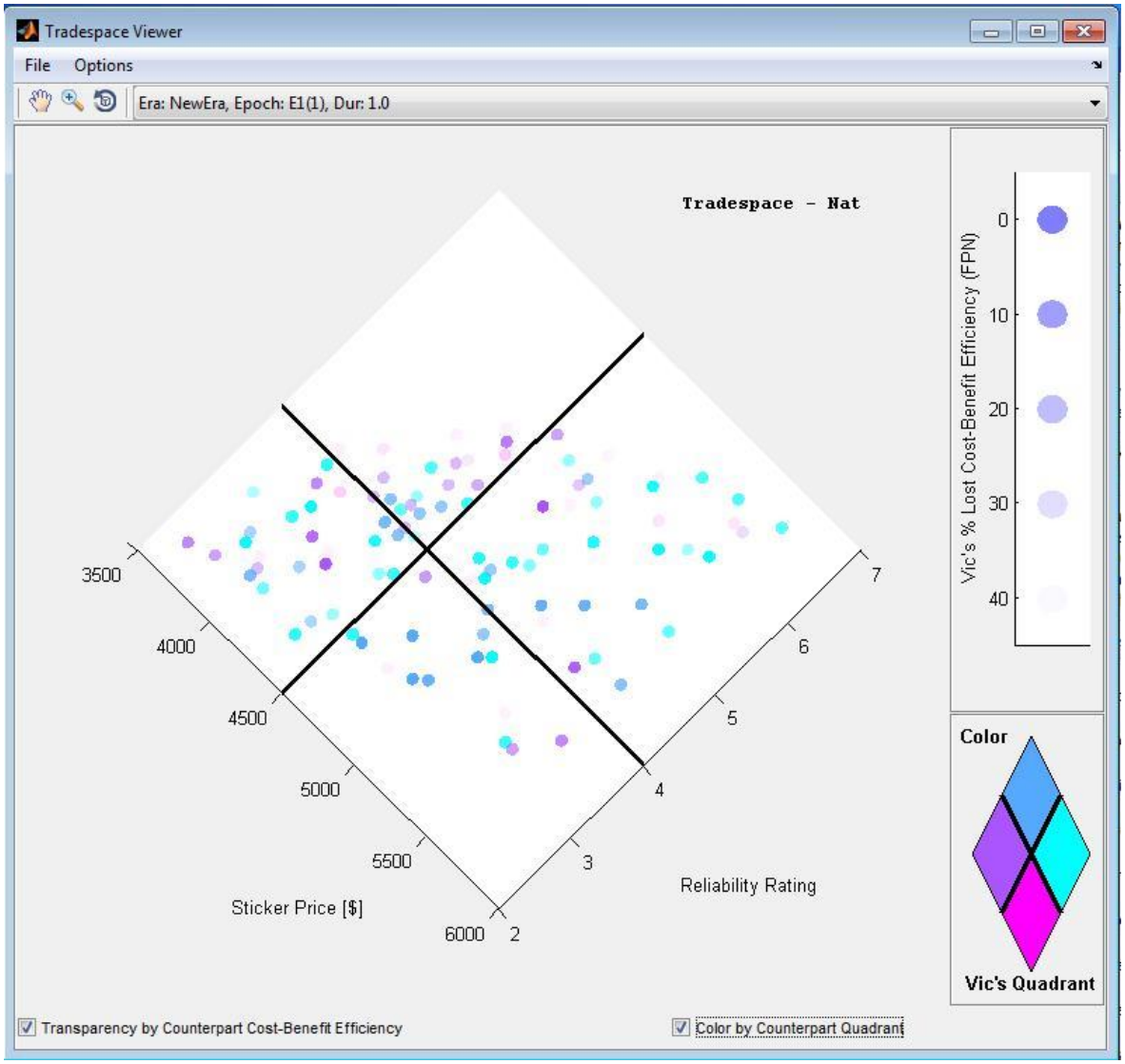
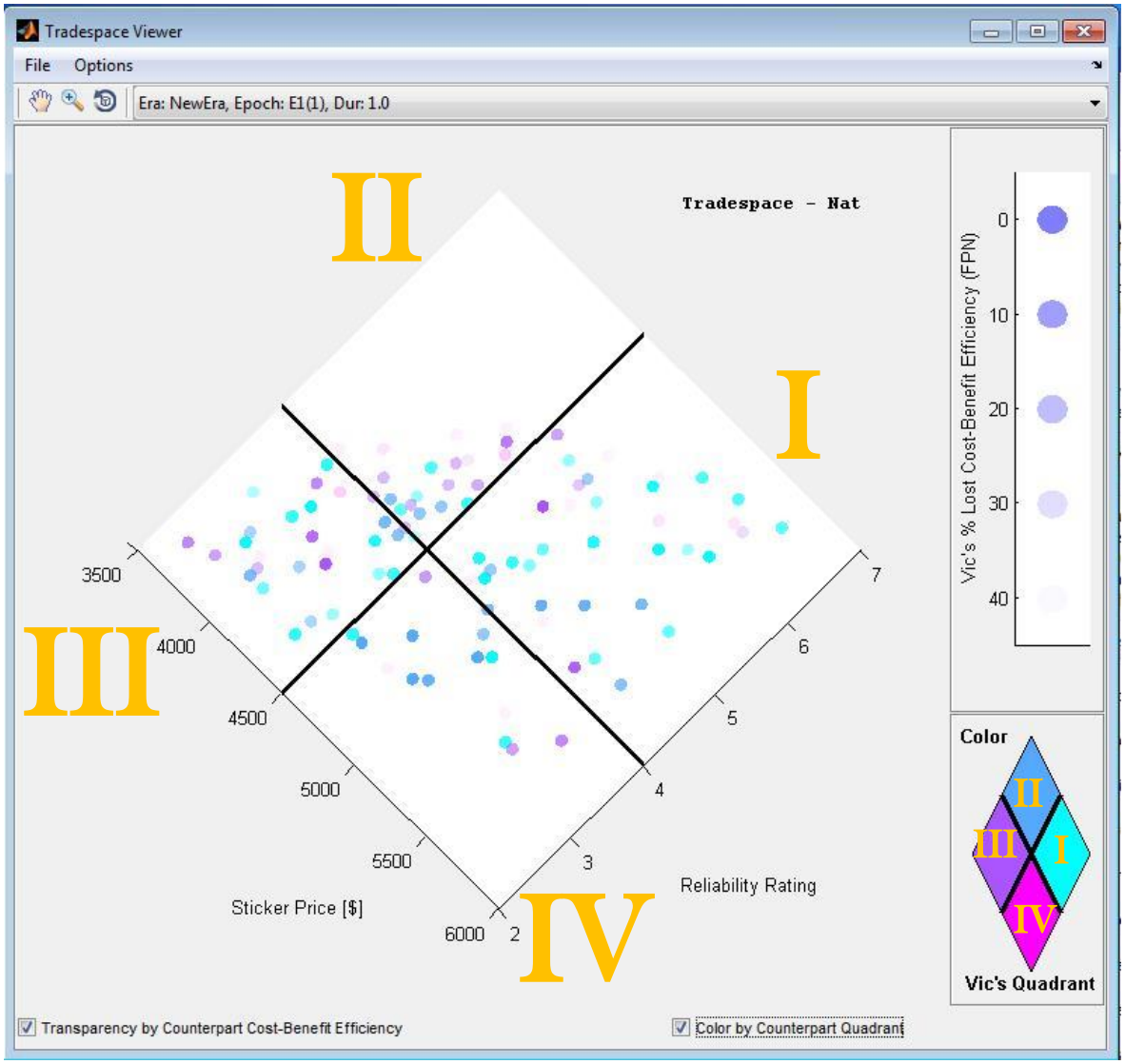


Color by tradeoff type (quadrant)
+
Transparency by efficiency

Experimental Tradespace



Experimental Tradespace



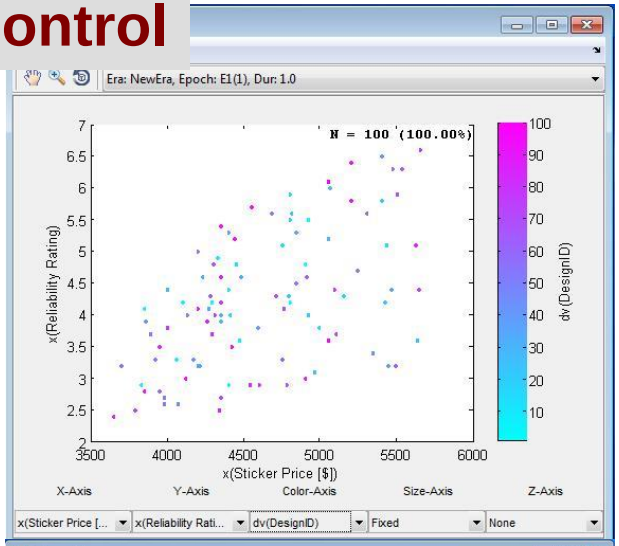
On Pareto Front

40+% removed from Pareto Front

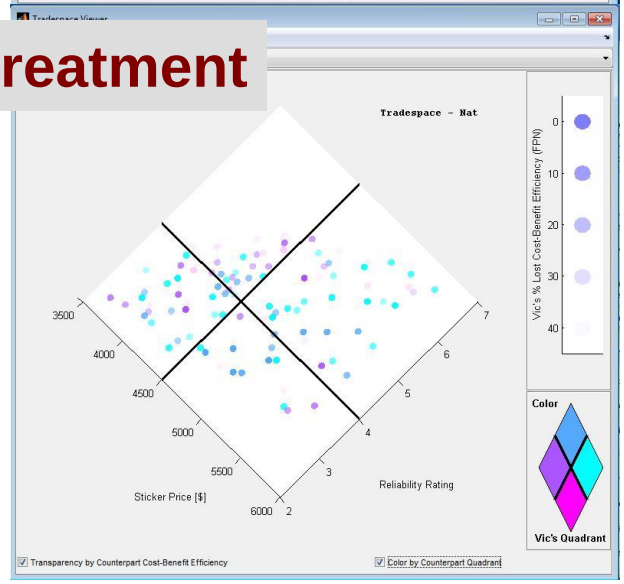
Controlled MSTSE Experiment

- Two-subject "buy a used car" case between roommates ("Nat" and "Vic")
- Separately defined benefit / cost metrics and BATNAs
  - Allowed to impose personal preferences on desired tradeoffs
- Access to basic data visualization (not analytic) tools suite
  - Marking of designs of interest
  - Logical filtering
  - Table view of design attributes
- Treatment determined by use of classic or experimental tradespace view
- 40 minute maximum exploration time
  - Agree on a car or accept BATNA

Control



Treatment



Data Collection

- Questionnaire (closed)
- Questionnaire (open)
- Offers and Outcomes
- Observational Coding

Data Collection

- Questionnaire (closed)
- Questionnaire (open)
- Offers and Outcomes
- Observational Coding

- All Participants verified engineering students / degree holders
- 18 male, 8 female
- Only 4 subjects with TSE experience

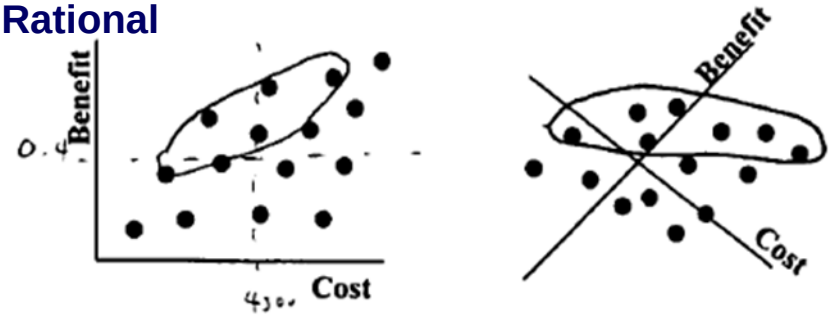
Sample size and student population are the main threats to external validity

Identifying Gains

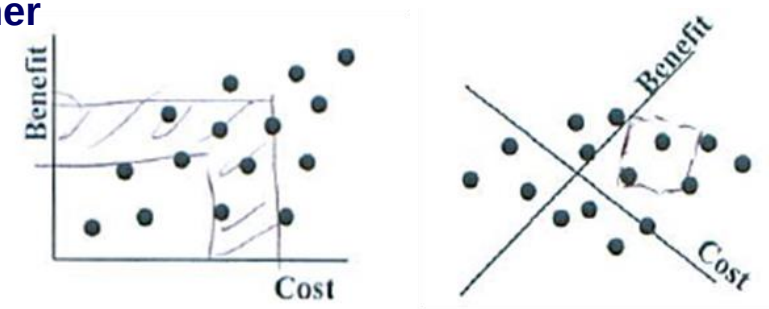
- Subjects asked to circle the region of the tradespace which they would have preferred to the BATNA ("gains" region)
- "Rational" response: **Q2 + optional Q1/Q3 from the Pareto front moving inward**
- 5/12 control, 12/13 treatment (p=0.0095)

Condition	Control	Treatment
Number of Responses	12	13
Areas Highlighted		
Quadrant 1	3	0
Quadrant 2	6	12
Quadrant 3	0	0
Quadrant 1 (Pareto Front Only)	4	4
Quadrant 2 (Pareto Front Only)	3	0
Quadrant 3 (Pareto Front Only)	3	6
Other	1	1

Rational



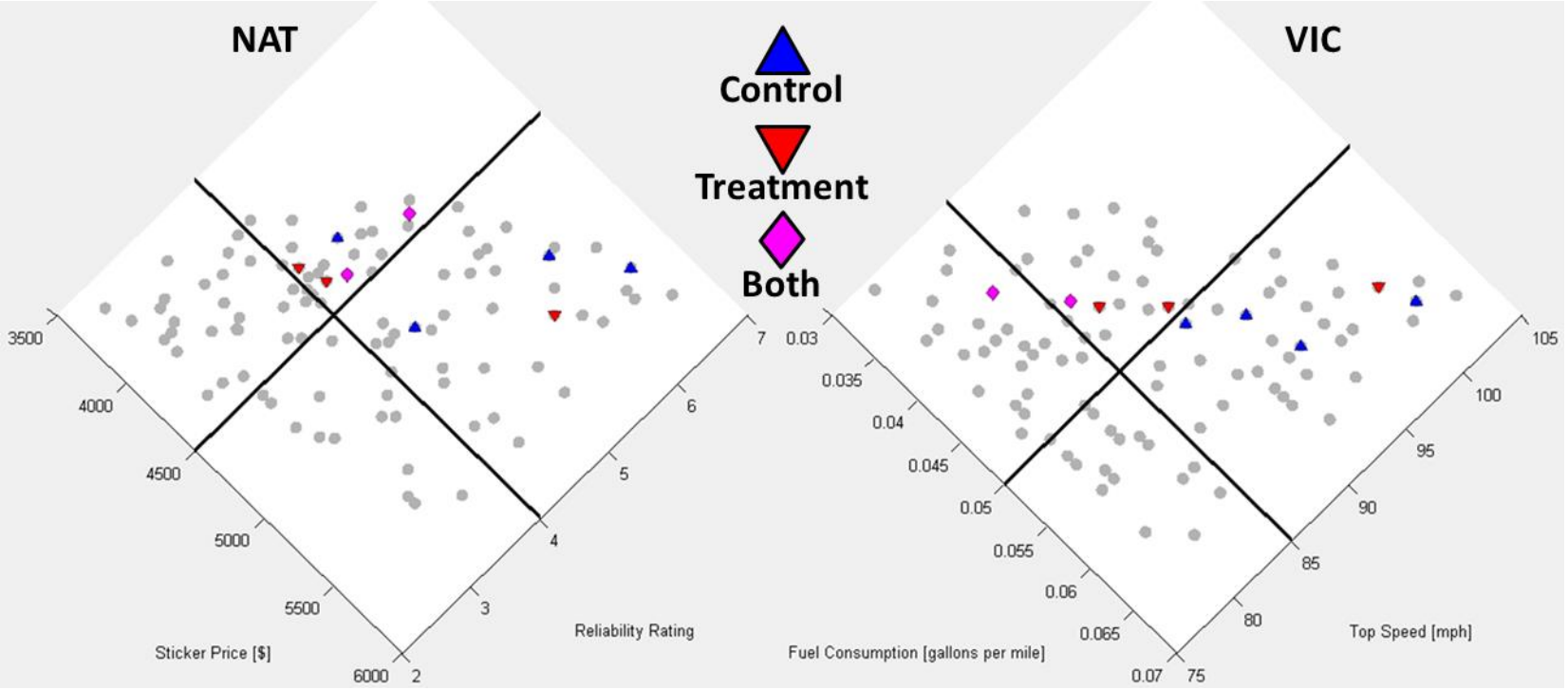
Other



Treatment improves grasp of gains vs. losses

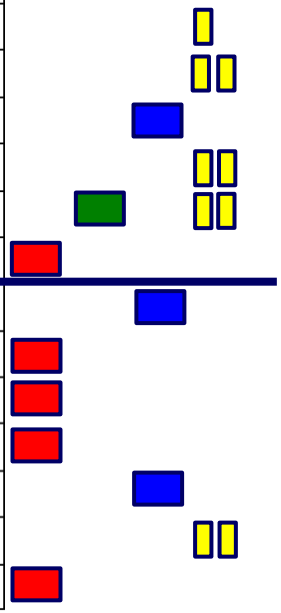
Outcomes

- No significant differences in time to complete or solution quality
  - Good: problem was intended to be easy enough to solve effectively with basic tools



Outcomes (2)

	Trial Number	Condition	Final Agreement Design ID	Time of Agreement (minutes)	Average FPN	Worst FPN
Control	1	Control	34	13	6.8	12.0
	3	Control	44	29	6.0	12.0
	4	Control	42	29	5.6	8.8
	6	Control	56	35	14.7	21.4
	8	Control	26	23	1.7	2.9
	12	Control	11	24	12.4	14.7
Treatment	2	Treatment	42	29	5.6	8.8
	5	Treatment	80	12	11.1	14.7
	7	Treatment	11	33	12.4	14.7
	9	Treatment	86	31	9.6	12.0
	10	Treatment	42	31	5.6	8.8
	11	Treatment	62	31	6.0	11.9
	13	Treatment	80	14	11.1	14.7



- Dual Q2 solutions were chosen 1/6 control, 4/7 treatment trials
- One group found the FPN minimax
- Modal solution is minimax with at least one subject in Q2
- Most Q1 solutions end up being dual Q1 (gold-plated)

Both subjects in Q2

FPN minimax solution (ID# 26)

Modal solution (ID# 42)

One subject in Q1

Treatment group appears to prefer hill-climbing (dual Q2) solutions, while control prefers gold-plated Q1 designs

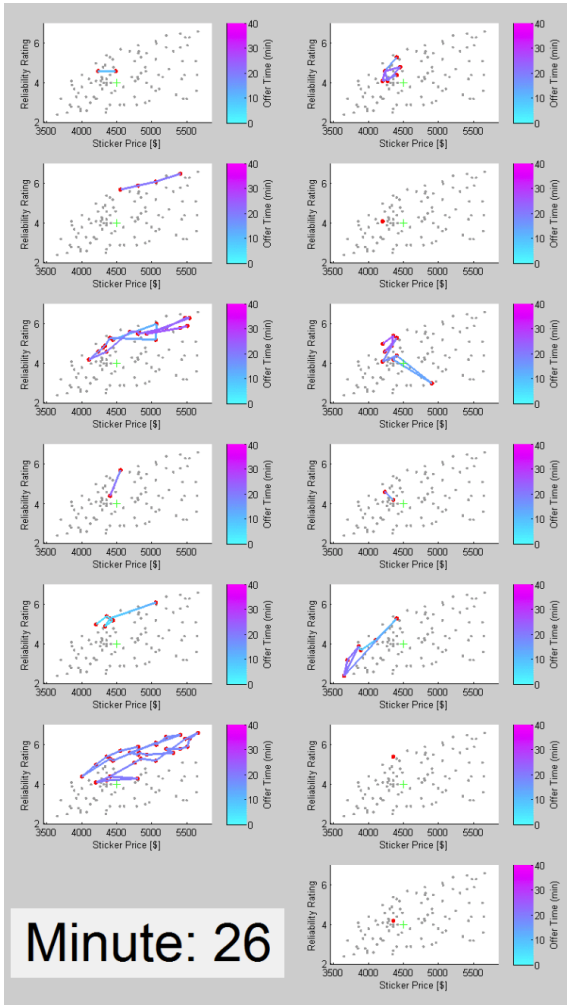
Offers

- Control
  - "Outside-in"
  - Skims the Pareto front
- Treatment
  - "Inside-out"
  - Clusters in Q2
  - May need additional exploration support

Switch from control "losses" to treatment "gains" frame

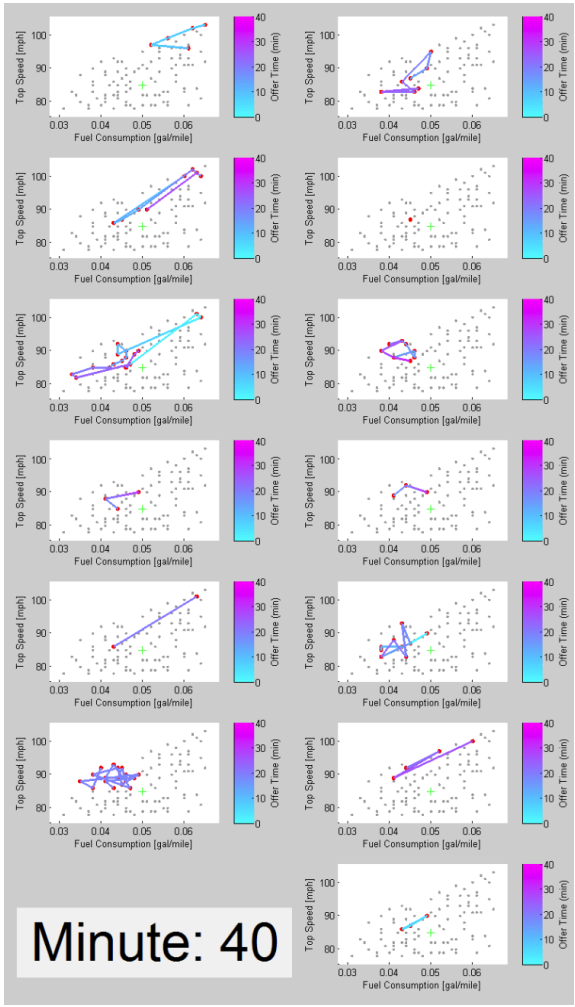
NAT

Control **Treatment**



VIC

Control **Treatment**



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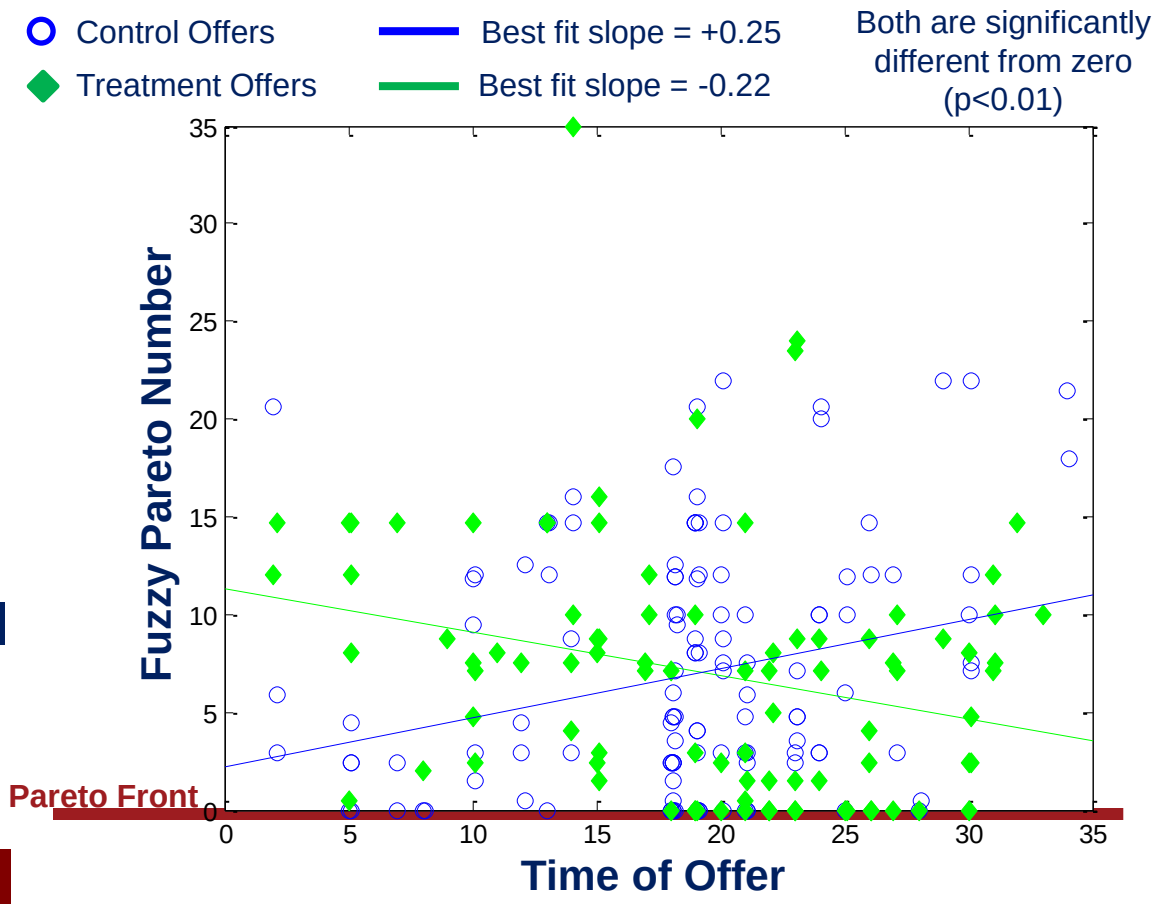


Switch from control "losses" to treatment "gains" frame

Observational Coding

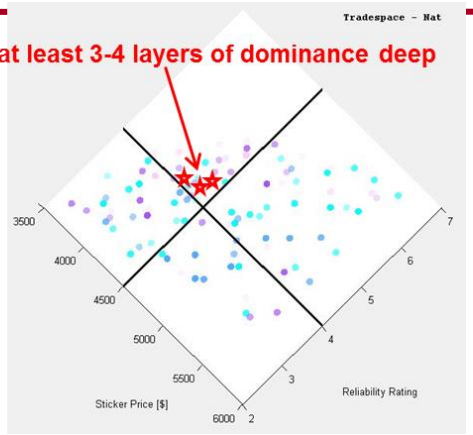
- Significant differences in:
  - Pareto front focus
  - Q2 focus
  - Negativity
- Other patterns:
  - Cost/benefit confusion + optimization language reduced in treatment
  - "Outside the case" action 8 times in treatment (1 in control)

Codes

Pareto front focus
Quadrant 2 focus
Confusion over costs/benefits
Discussion of BATNA
Discussion of preferred tradeoffs
Discussion of fairness
Creation of a tentative agreement
Working individually
Positional Bargaining (back-and-forth)
Appeal "outside the case"
Exhaustive "search and destroy"
Pressure for concession/agreement
Treating problem like an optimization (maximize/minimize)
Negativity about prospects of success
Use of Filter Tool
Use of Comparison Tool
Use of a defined color/shaping scheme in Favorites Manager

Miscellaneous

- 4 trials discussed activation energy
  - Dual Q2 designs not *enough* better to be worth taking?
  - Only 1 of 4 agreed on one



- Power of macro framing
  - Fastest completion result of identical problem interpretation
  - Preconceived notions of competitive or aggressive negotiation

"This would have been a lot more difficult if there were no cars [in Q2 for both people]"

"I don't understand how we're supposed to selectively disclose information + negotiate if both of us can see each others' screens + preferences so easily + openly. I didn't really feel there was much to talk about since (rather unrealistically) my partner and I could see each other's benefits, costs, preferences, etc just by turning around and talking to each other."

- Predominant use of color/transparency was 'toggling'
  - Group that did not toggle worked with "Pareto" front of opaque points deliberately

Conclusion

- Considerable evidence that:
  1. Control group works with Pareto front more than treatment
  2. Treatment works with Quadrant 2 more than control
  3. Treatment is more able to "rationally" identify designs superior to the BATNA
- Sample size and subject population limits ability to draw any more detailed statistical conclusions
  - Results qualitatively support working theory
  - Macro framing can drive MSTSE experience independent of micro framing

Next steps: framing in TSE problem formulation, interface research with practicing engineers, support of exploration goals over hill-climbing, visualizing stakeholder relationships directly

Thank you!

Questions?

Backup Slides

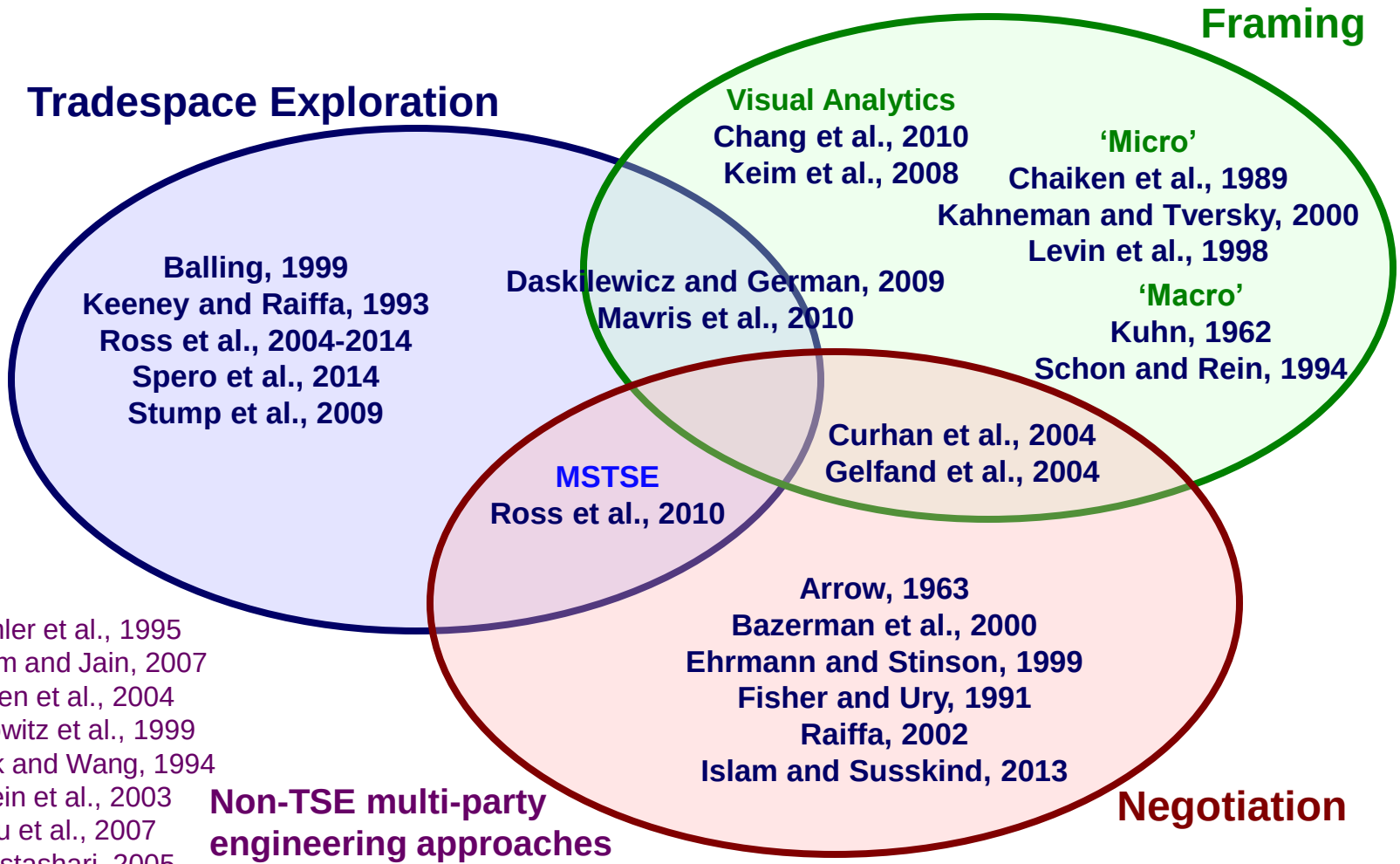
Questionnaire (closed)

- Low sample size limits ability to distinguish treatment groups effectively on Likert-type scale
- Significance within realm of spurious correlation (1/50)
- Majority of questions indicate anticipated directionality of working theory

Three blocks had all questions match hypothesized relationship

- **Understanding the problem**
  - *"I felt that I understood my benefits and costs"*
  - *"I was able to judge whether or not a car was valuable according to my needs"*
  - *"I felt that I understood my partner's benefits and costs"*
- **Problem difficulty**
  - *"It was difficult to find choices that were fair […]"*
  - *"I found the design task to be stressful"*
- **Tools satisfaction**
  - *"The computer software helped me understand the problem"*
  - *"Access to simpler tools […]"*
  - *"Access to more customization […]"*

Literature Review



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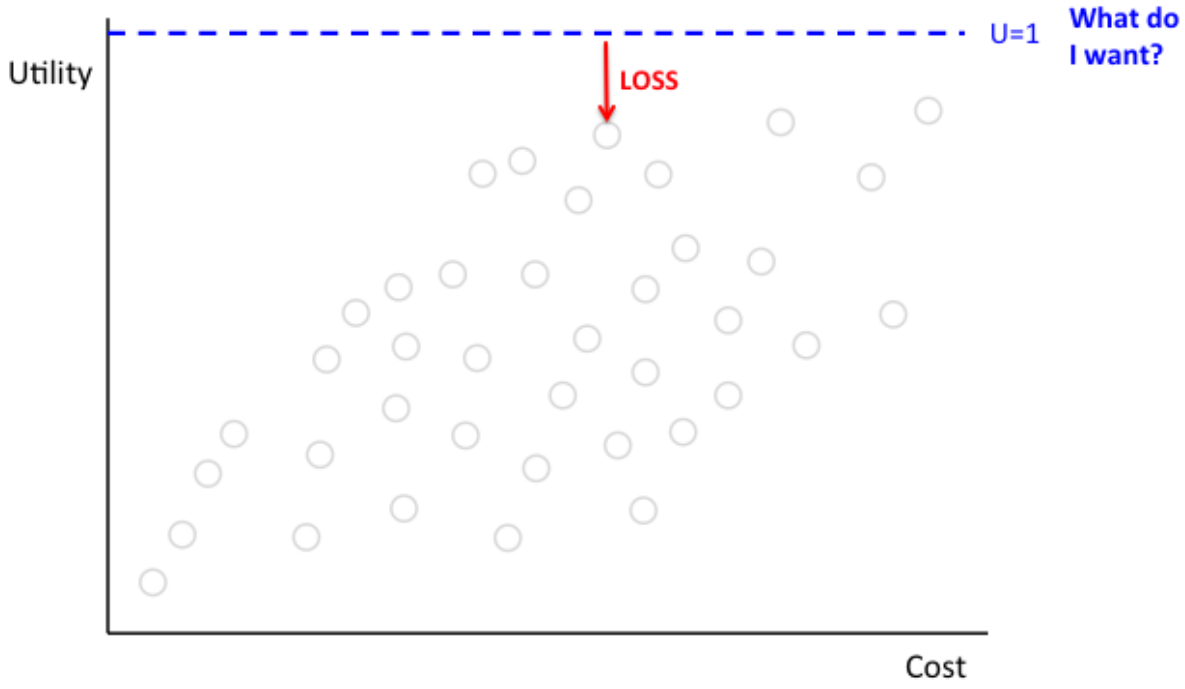
TSE Framing

- What reference points exist in TSE?
  - Utility = 1, complete satisfaction of needs



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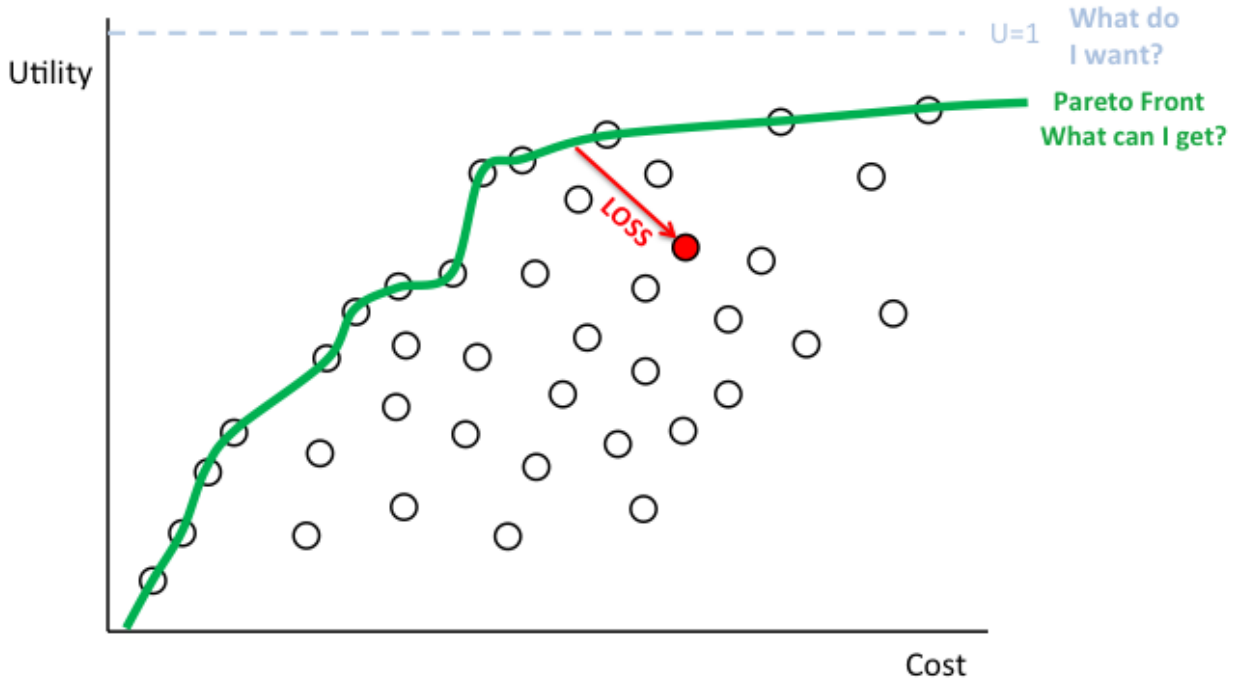
TSE Framing

- What reference points exist in TSE?
  - Utility = 1, complete satisfaction of needs

    Already mitigated → analysis withheld until tradespace shows constraints
  - Pareto front: cost benefit efficiency



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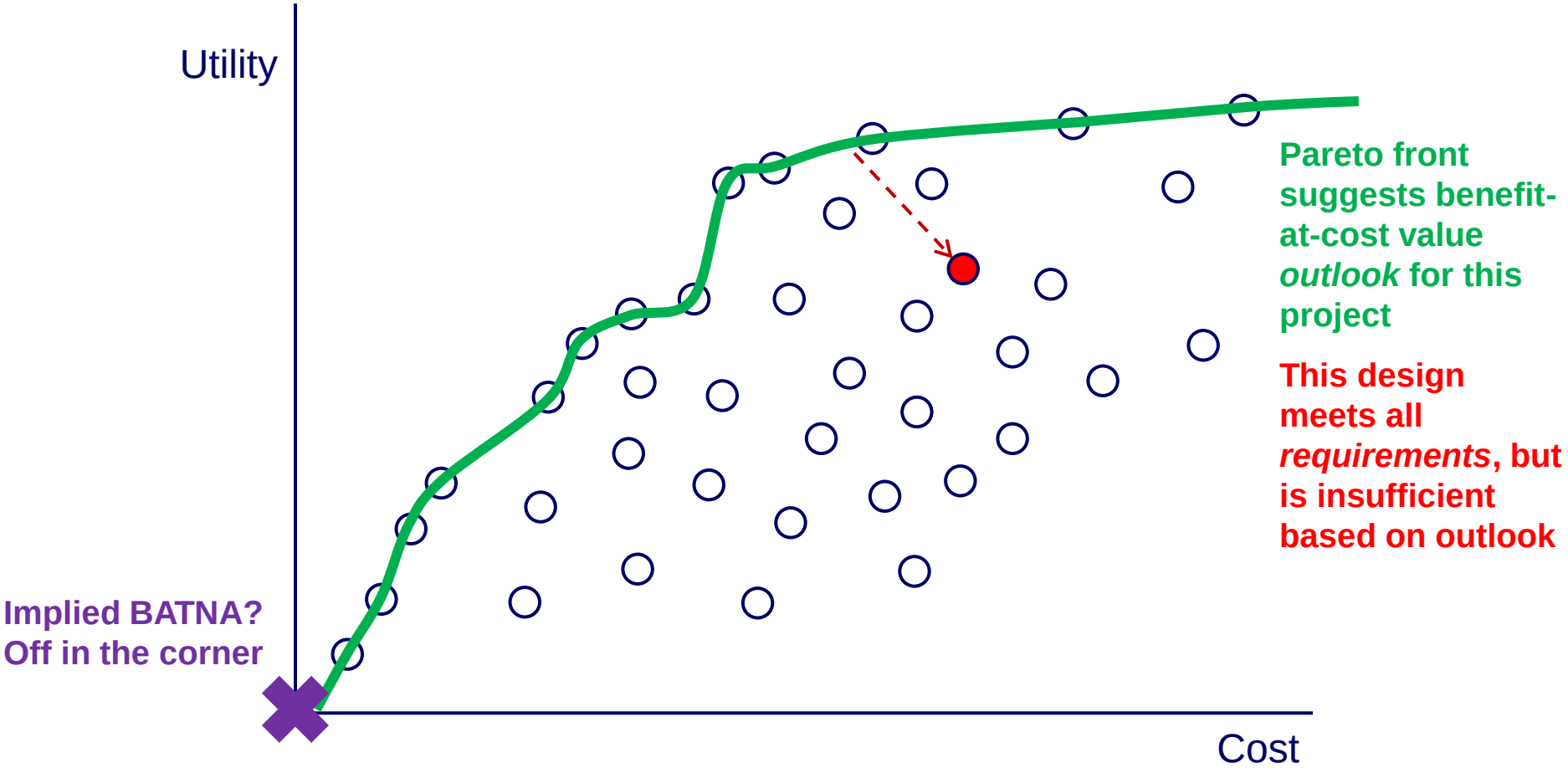
Classic View

- **Basic, single-stakeholder tradespace**



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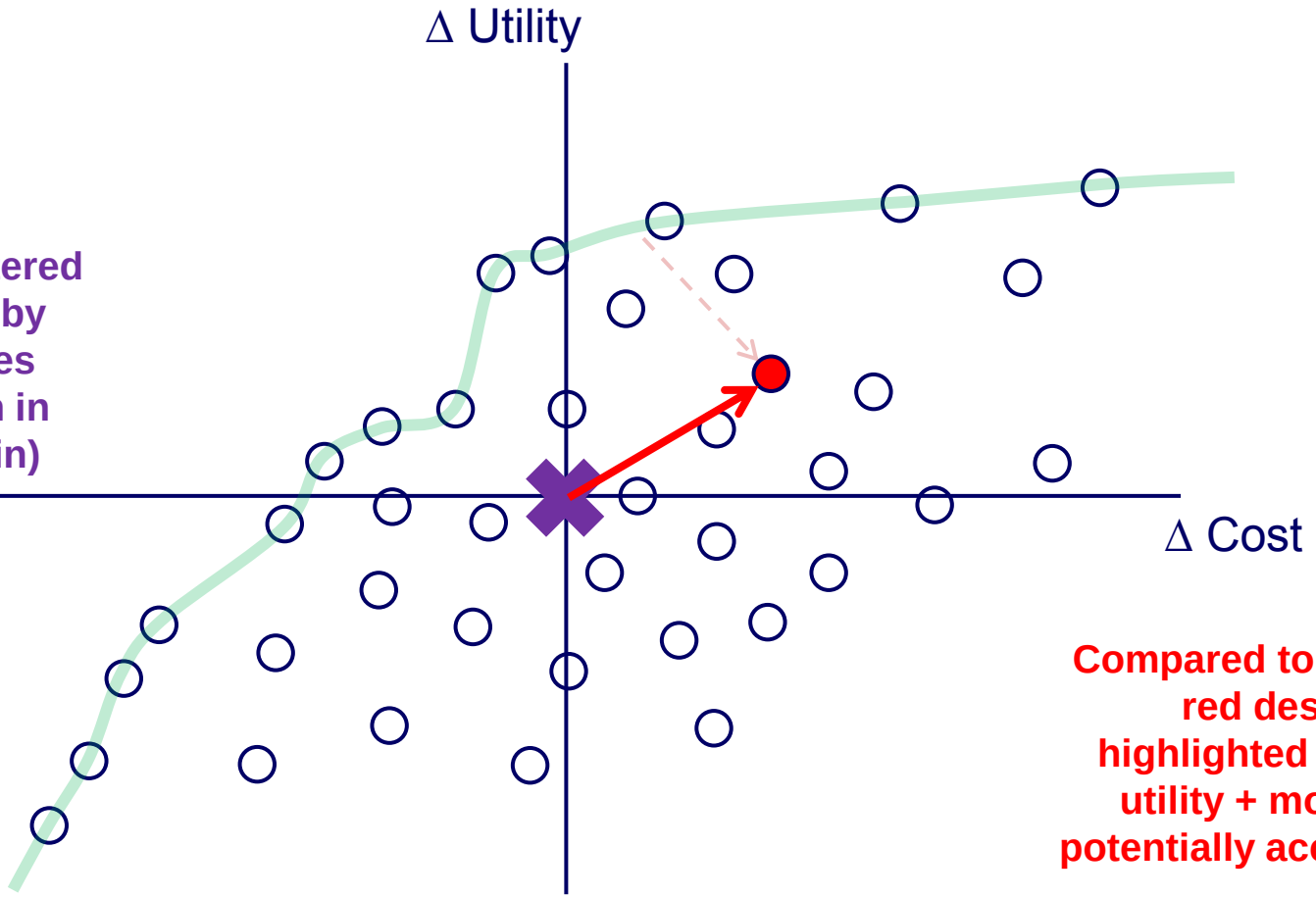
Creating a new view

- **Axes become Utility/Cost differences from BATNA**



BATNA now centered and crosshaired by the axes, occupies physical location in tradespace (origin)

Compared to BATNA, red design now highlighted as more utility + more cost: potentially acceptable tradeoff

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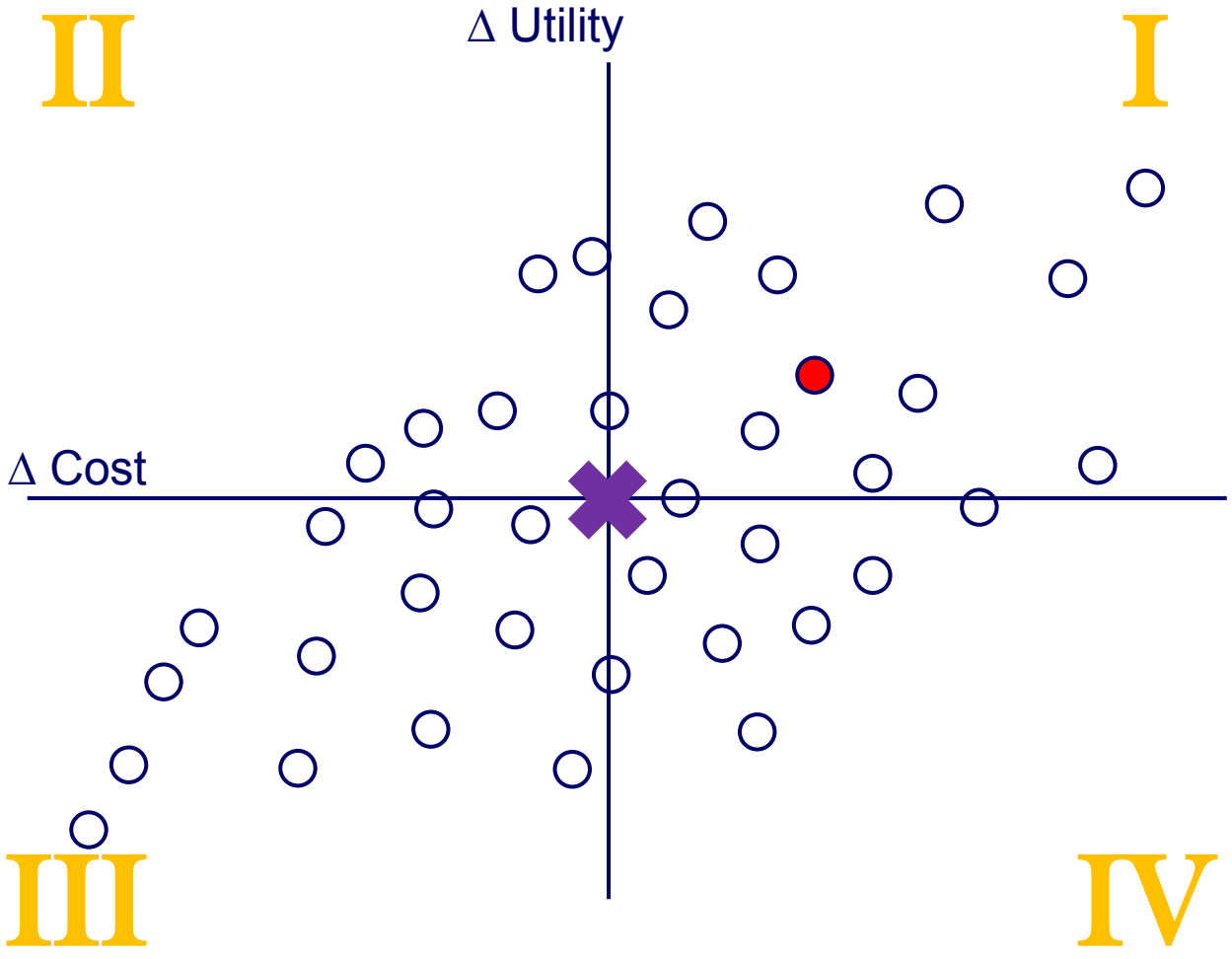
Quadrants View

- **Quadrants have distinct 'categories' appeal**



II

Less cost, more utility. Almost certain agreement (pending fairness/equality)

I + III

Cost/utility tradeoffs. Potentially viable/attractive.

IV

More cost, less utility. Almost certain refusal (unless side benefits to partnership are not captured)

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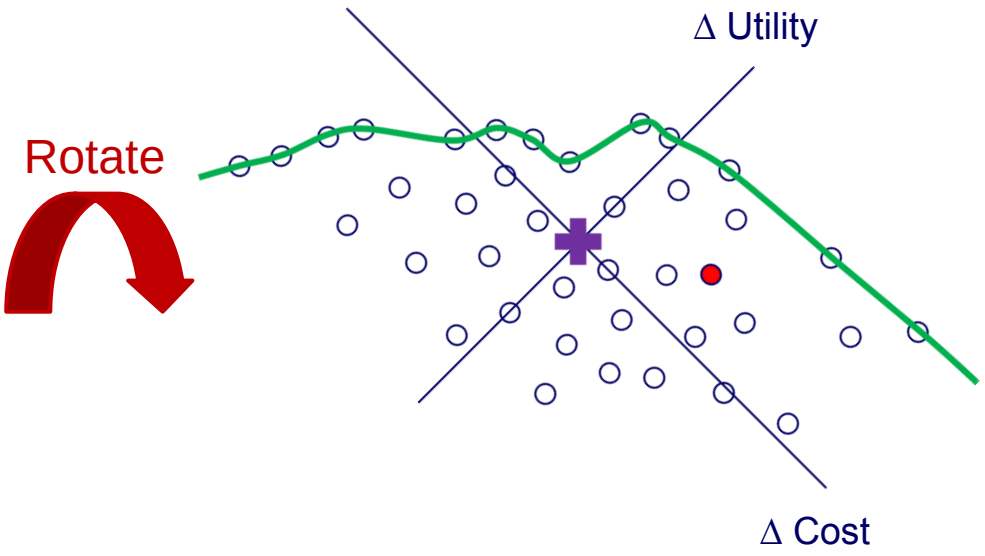
Quadrant II

- Quadrant II is the most attractive, can we emphasize it too?



Advantages

- Up is good instead of up-left
- Left/right = tradeoffs
- New alignment may weaken hold of any "bad habits" of claiming

Disadvantages

- Too different → confusion
- Horizontal loses exact meaning (due to non-ratio scales)

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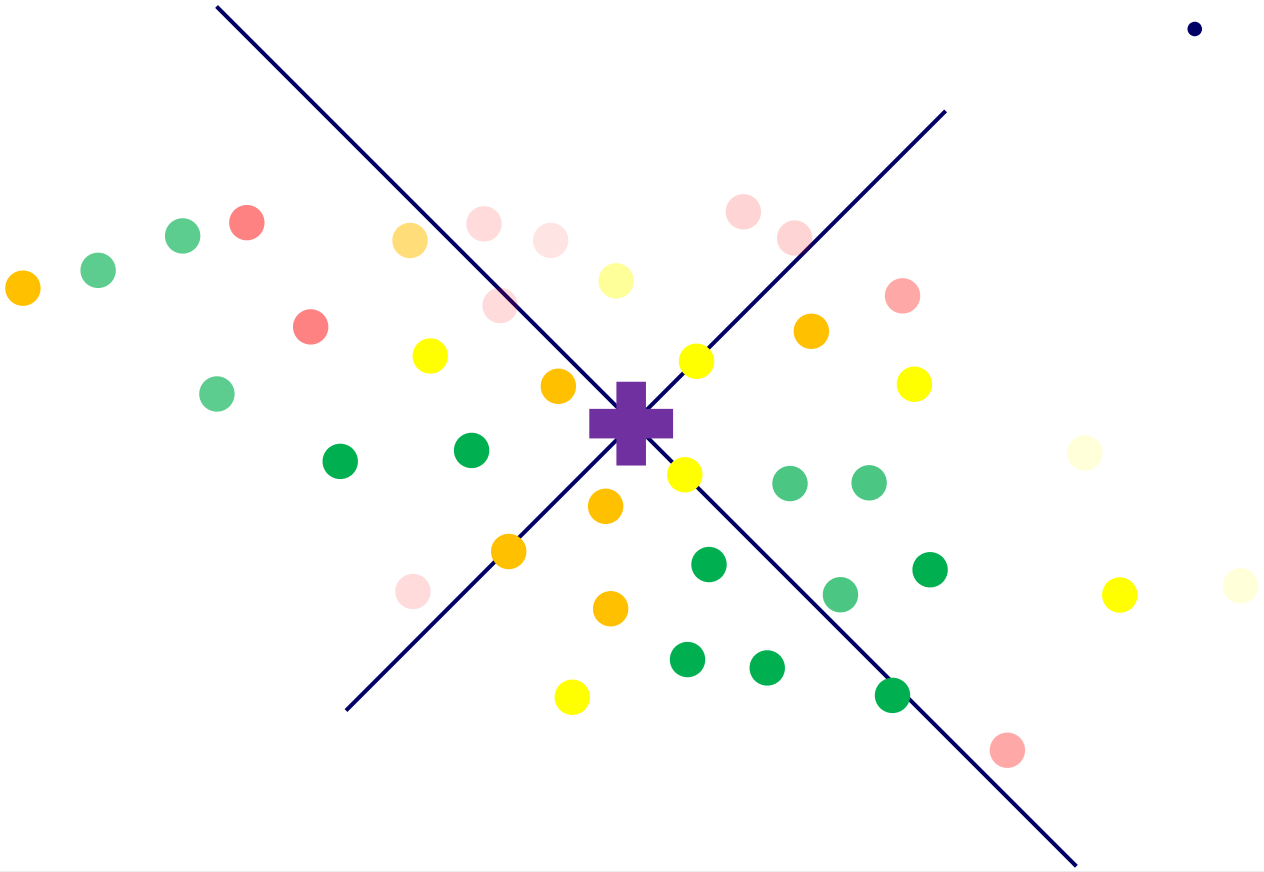
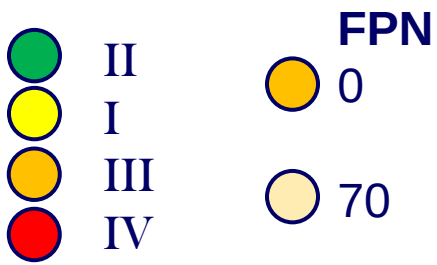
Counterpart Value

- Still no indication of the missing dimension: what other stakeholders think



- Leverage color and transparency
  - Color: Quadrant in the other tradespace
  - Transparency: Fuzzy Pareto Number (distance from Pareto front)



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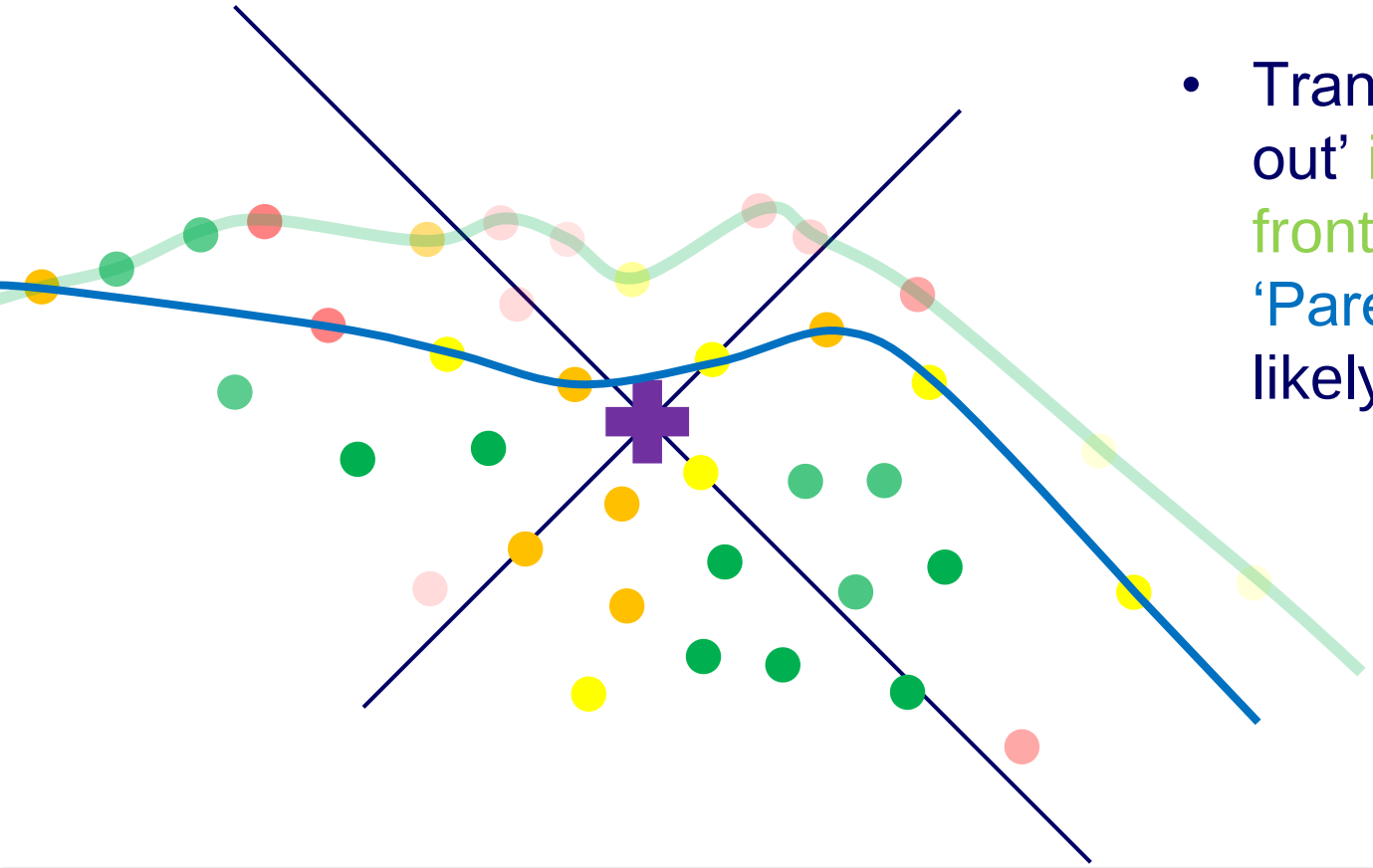
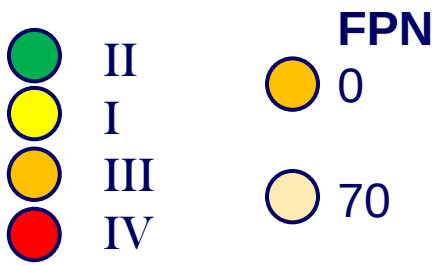
Counterpart Value

- Adds more available information about group problem



- Transparency 'blurs out' individual Pareto front, more solid 'Pareto' front is more likely to be agreeable



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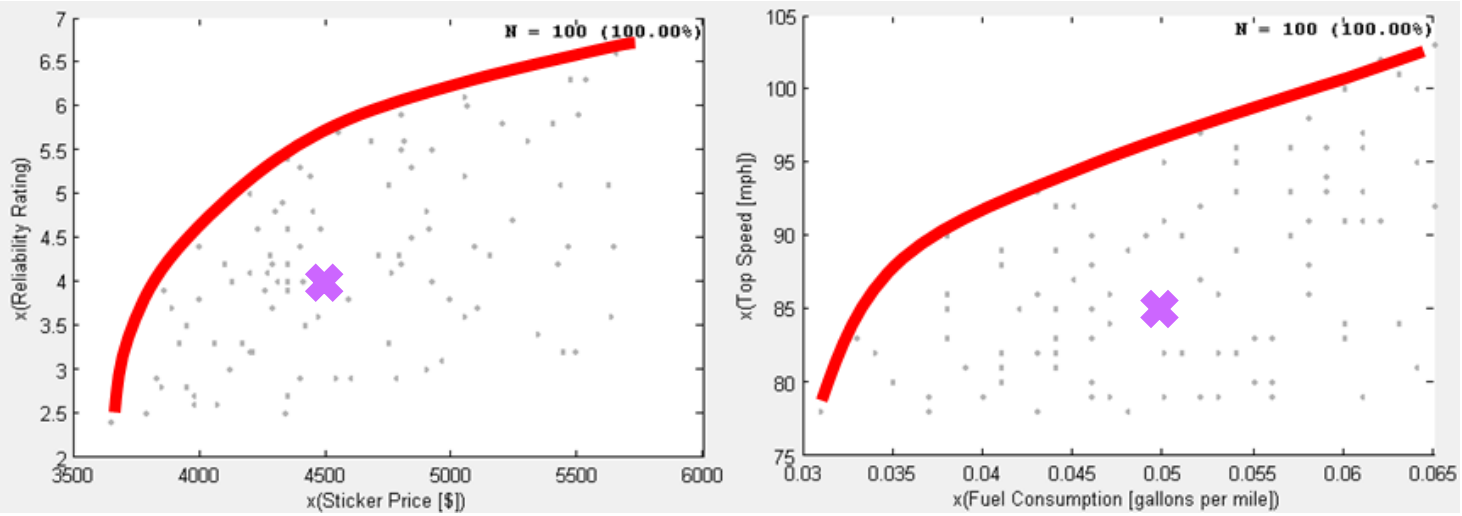
Estimation

- Differences between roles?
  - Marginal significance (p=0.077) for Vic preferring more designs to his BATNA

Pareto front BATNA

Nat



Vic

Tradespace / Pareto front shape may impact perception – requires specific experiment to verify

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Open Response

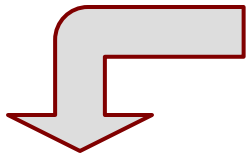
- Themes
  - Positive comments on TSE / VisLab
  - User experience suggestions

"Great tool - quantifying a BATNA and filtering options based on mine & my partner's parameters = super useful. I will try to use this in future decisions. Because I think it's so good at visually demonstrating what's decent for both parties."

"It was relatively simple and straight forward all around. The only real difficulty I had was the sensitivity of the mouse when clicking a point. I think it would be useful to drag and highlight sections of the graph if possible."

"It was a great interface that I'd love to be able to use in real life for similar things. Feature to make it easier such as select all or change all/edit selection or something like that could make it easier."

"I don't understand how we're supposed to selectively disclose information + negotiate if both of us can see each others' screens + preferences so easily + openly. I didn't really feel there was much to talk about since (rather unrealistically) my partner and I could see each other's benefits, costs, preferences, etc just by turning around and talking to each other."



Macro framing may be necessary to support Full, Open, and Truthful Exchange

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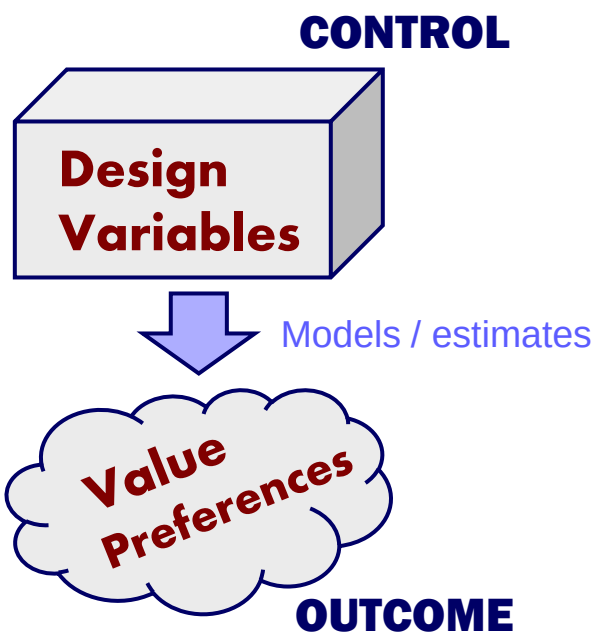
Additional Complications

- Disconnect between design variables and value-creating objectives (control vs. outcome)
  - Traditional negotiation techniques rely on control OF outcome space
  - Complexity can result in loss of situational awareness → risk-aversion prevents agreement



- Uncertainty in preference/utility statements
  - Changing of preferences when exposed to new data has been observed in complex problems
  - Utility elicitation is an "art"

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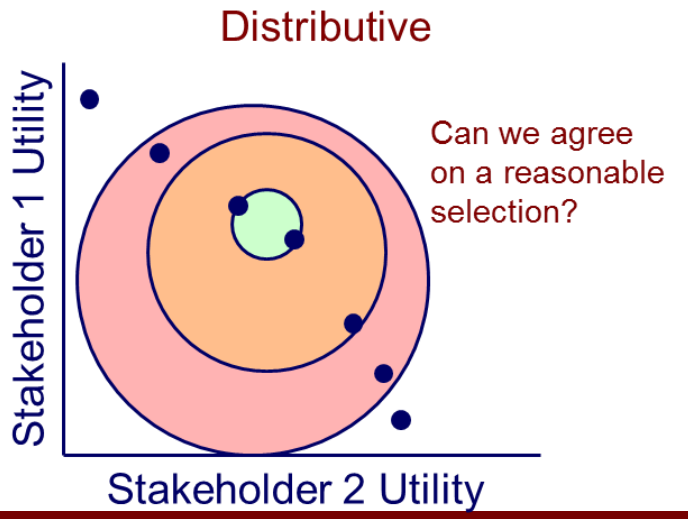
Types of Compromise (1)

- Design Compromising
  - Selection of a design agreeable to all stakeholders, when no choices are optimal for all
  - One or more stakeholders must accept suboptimal value in the name of fostering agreement
  - Corollary to *distributive negotiation*, in which participants try to claim value

Preemptive claiming typically leads to positional bargaining and losses in total value: can we postpone this action?



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Types of Compromise (2)

- Preference Compromising
  - Modification of expressed utility function in order to promote agreement with other stakeholders
  - Not a stretch: stated preferences are observed to change when stakeholders are exposed to additional information
  - Corollary of *integrative negotiation*, in which the participants actively seek to work together to find mutual benefit

Mutual value is what makes compromises attractive: can we support this process in order to increase stakeholder satisfaction?

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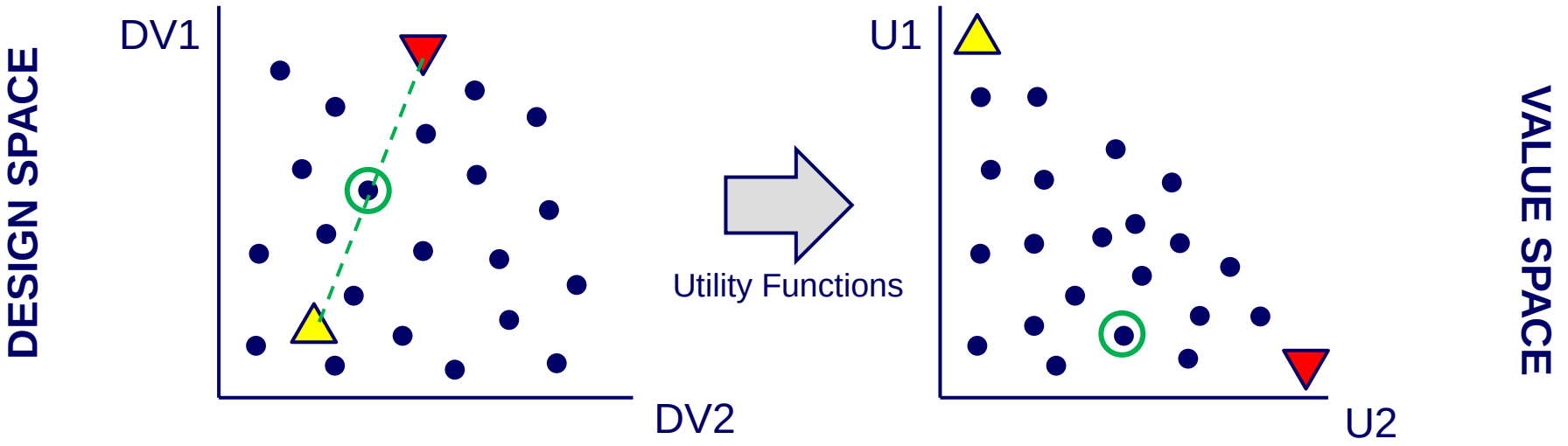
Common Bad Compromises
Midpoint



Stakeholder 1's position

Stakeholder 2's position

Midpoint solution = in-between selections in design space

"MIDDLENESS" DOESN'T MAP TO VALUE SPACE
SIGNIFICANT MUTUAL BENEFIT NOT CAPTURED

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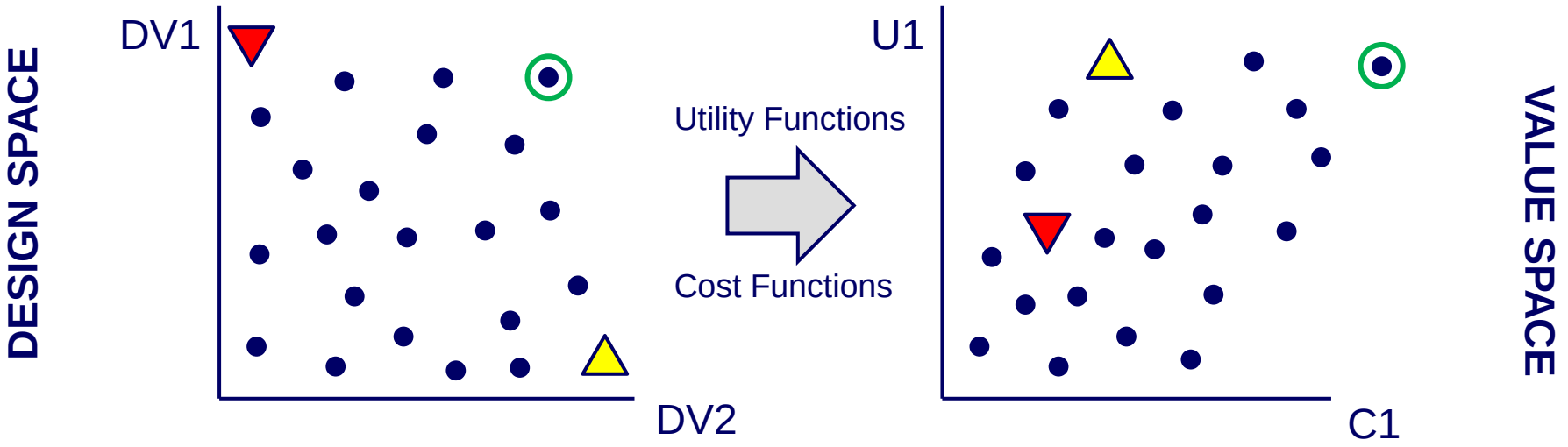
Common Bad Compromises
Gold Plated



△ Stakeholder 1's position (wants lots of DV2, utility unaffected by DV1)

▽ Stakeholder 2's position (wants lots of DV1, utility unaffected by DV2)

○ Gold Plated solution = take lots of both DV1 and DV2

SIGNIFICANT COST ADDED WITH NO GAIN FOR EITHER STAKEHOLDER

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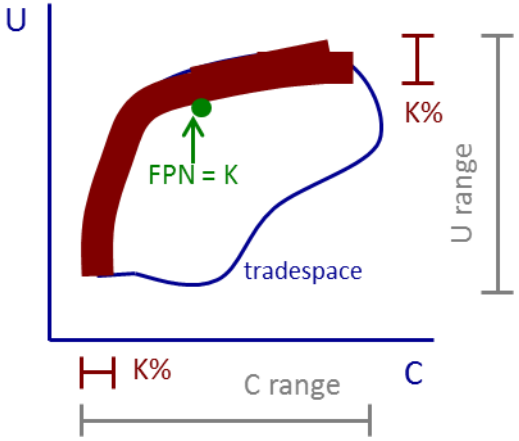
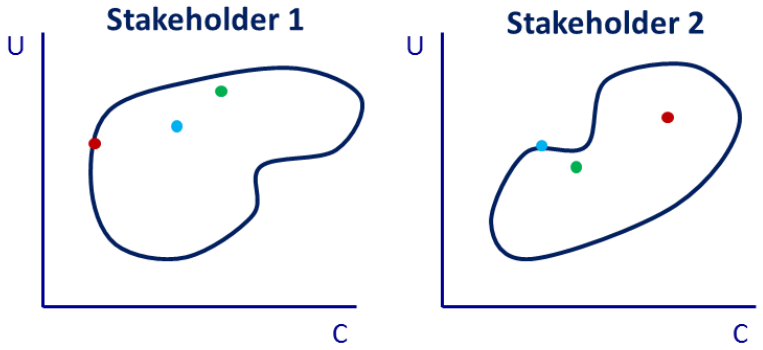
Tentative Value Metric for Compromise

- Potentially replace utility with Fuzzy Pareto Number (FPN) when bargaining "fairness" to capture cost effects on value
  - Especially useful if costs differ substantially between stakeholder for any given design
  - Set of designs "Pareto efficient in FPN" represent the smallest compromises from cost-efficiency necessary for agreement between stakeholders

FPN = minimum K for a design to be considered fuzzy Pareto optimal in a given epoch





Design	Stakeholder 1 FPN	Stakeholder 2 FPN
RED	0	18
GREEN	3	4
CYAN	10	0

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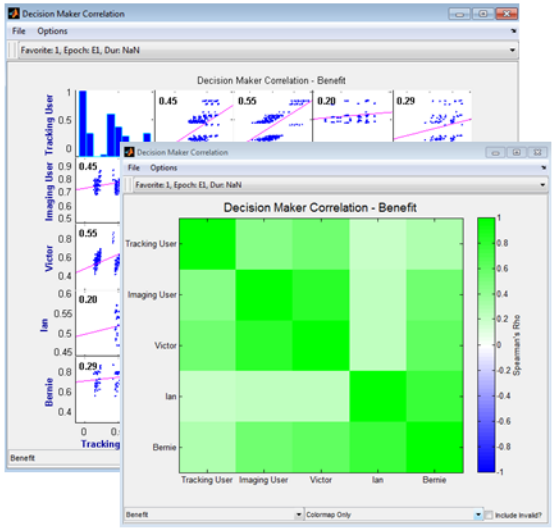
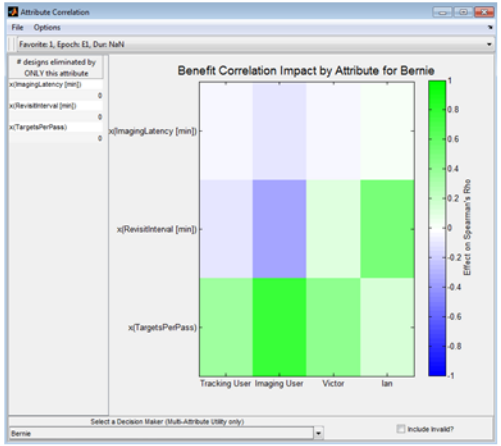
Visualizing Relationships

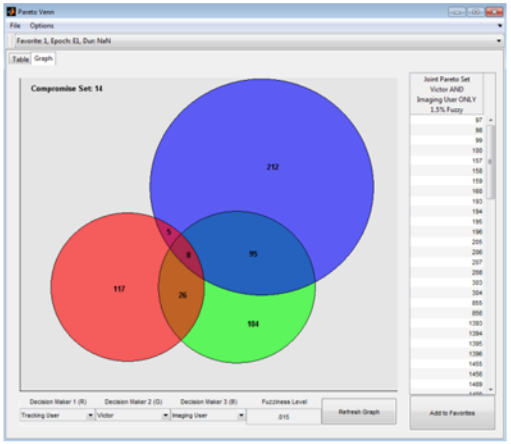
- Classic tradespace is effective at showing alternatives, but requires careful interpretation to capture relationships: especially for 3+ stakeholders
- Additional visualizations specifically designed for multi-stakeholder problems can communicate relationships directly



Value function correlations identify productive coalitions

Breaking value into component parts can highlight individual preferences that are aligned or divergent for targeted exploration





Live manipulation of "fuzziness" to see differential overlaps in sets of benefit-cost efficient designs

- To be utilized in interactive group interviews with practicing systems engineers in upcoming research

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