

A Systemic Perspective on Bias Mitigation in Decision Analysis

Tuomas J. Lahtinen, Raimo P. Hämäläinen, Cosmo Jenytin

tuomas.j.lahtinen@aalto.fi, raimo.hamalainen@aalto.fi Systems Analysis Laboratory, Department of Mathematics and Systems Analysis, Aalto University



Human behavior drives the Decision Analysis process

Behavioral effects are present in all the steps

- Problem framing
- Choice of criteria

Biases influence elicitation of subjective values and parameter estimates

- Weighting
- Estimation of consequences and probabilities



Biases in multi-criteria decision analysis

Biases are widely covered in the decision analysis literature and textbooks



Montibeller and von Winterfeldt (2015) review:

- 175 references to papers related to biases in DA
- 30 biases and ideas for debiasing

Cognitive and Motivational Biases in Decision and Risk Analysis

Gilberto Montibeller¹ and Detlof von Winterfeldt^{2,*}

Behavioral decision research has demonstrated that judgments and decisions of ordinary people and experts are subject to numerous biasse. Decision and risk analysis were designed to improve judgments and decisions and to overcome many of these biases. However, when

Very little work on bias mitigation and debiasing in practice

Debiasing and bias mitigation approaches in multi-criteria preference elicitation

Consistency checks and feedback

Keeney and Raiffa 1976

Use different starting points in interactive multi-criteria optimization

Korhonen et al. 1990

Improvement of a preference elicitation method

Delquié 1997

Averaging responses

Anderson and Hobbs 2002

Adjusting numerical judgments with estimated bias coefficients

Bleichrodt et al. 2001, Anderson and Hobbs 2002

Training

Hämäläinen and Alaja 2008, Anderson and Clemen 2013

A systemic perspective is needed

Not enough to understand and avoid biases in individual steps of the decision analysis process

The overall effects of biases depends on the path followed

Path: the sequence of steps in the decision support process

Biases are critical when they accumulate along the path

Accumulation of biases may create path dependence



Path perspective in debiasing

Try to find paths where the effects of biases cancel out (Examples: Anderson and Hobbs 2002, Lahtinen and Hämäläinen 2016)

Avoid paths where the effects of biases build up



Not always necessary to reduce biases in individual steps



Debiasing techniques need to be evaluated taking into account the complete process

So far, narrow focus in behavioral experiments: Behavioral phenomena occurring at isolated steps

Process evaluations:

We cannot use real decision makers in testing

Even with students it can be very cumbersome to go through all different techniques repeatedly

Computational analysis provides a new approach

Computational evaluation of debiasing methods

Based on models and estimates of the relevant biases

(Bleichrodt et al. 2001, Anderson and Hobbs 2002, Delquié 2003, Jacobi and Hobbs 2008, Lahtinen and Hämäläinen 2016)

- Assume biases and debiasing methods
- Compute the overall impact of biases in different settings

Enables testing of multiple techniques and helps to identify promising ones

New techniques to help create paths with reduced overall bias

- **1. Introduce a virtual reference alternative**
- 2. Introduce an auxiliary measuring stick attribute
- 3. Repeatedly rotate the reference point
- 4. Intermediate restarting of the elicitation process with a reduced set of alternatives

Introduce a virtual reference alternative

 Can mitigate the loss aversion bias (Tversky and Kahneman 1991)

Apartment selection	Alternatives						
Attributes	A	В	С	Virtual			
Rent (euros per month)	700	900	800	800			
Size (square meters)	30	40	35	35			
Condition (constructed scale)	1	2	3	2			

 Different virtual or hypothethical reference points can be used, e.g. trade-off and swing methods, interactive MCO

Introduce an auxiliary measuring stick attribute

Irrelevant attribute can be the measuring stick

Can mitigate the measuring stick bias (Delquié 1993) in trade-off judgments

Attributes	А	В	С
Rent (euros per month)	700	900	800
Size (square meters)	30	40	35
Condition (constructed scale)	1	2	3
Commute time (minutes)	60	60	60

Alternatives

 Trade-offs are widely used: estimation of attribute weights, pricing out, Even Swaps method

Repeatedly rotate the reference point

• Loss aversion bias can build up if the same original alternative defines the reference point in every attribute

Intermediate restarting of the elicitation process with a reduced set of alternatives

- Can eliminate the bias that has built up over earlier steps
- Swing method: Attribute swings depend on alternatives
- Intermediate restarting can help to cope with range insensitivity (Fischer 1995)
 - 1. Assess attribute weights and score alternatives
 - 2. Eliminate low scoring alternatives so that attribute swings are reduced
 - 3. Repeat steps 1 and 2 until range of swings cannot be reduced

A demonstration with the Even Swaps process



Office selection problem

(Hammond, Keeney, Raiffa 1999)

	Lombard	Baranov	Montana	Pierpoint
Commute Time	25	20 25	25	30
Client Access	80	76 72	25 88	75
Office Services	8	<mark>∕∕ B</mark>	_ у∕ в	<mark>≎Å</mark>
Office Size (m2)	700	500	950	700
Monthly Cost (\$)	1700	1500	1900	1750
		An even swa	р	/ \ Dominated
		Commute time	e Office serv	ices by

irrelevant

Lombard

Reference method (attribute elimination method)

- Eliminate dominated alternatives
- Select a reference alternative (Lombard)
- Select a measuring stick attribute (Client Access)
- Make attributes irrelevant: Make all alternatives equal to reference alternative in all attributes besides the measuring stick attribute.

irrelevant

Biases can create path dependence in Even Swaps

Measuring stick bias: Extra weight for the measuring stick Loss aversion: Extra weight for the loss attribute

> What is the equally valuable loss in money if commuting time is decreased by 30 minutes?

Smart Swaps - Sahids	s_Job.ssf			- 00													
File View Options	Help					Alternativ	e: C										
Problem / Objectives	/ Alternatives	Consequence	Tradeoffs			The decr	ease in Fl	Flexibility									
						from 4	to 3										
Continue the foll	lowing steps t	until the solution	is found:			can be co	mpensate	ed for by an increase in									
To make an Ever	n Swap trade- tree cells from	-off, n the consequen	ces table			from 10	to: 13	3									
or let Sma	art Swaps pro	pose an even sv	vap						Monthly Salary 👷 F	lexibility	Skills Develop	me Vacation Day	rs g Benefits	Enjoymen	nt		
2) When read	dy press Even	Swap-button be	low	1		0	<	A			Bad	14	Good	Good			
				Even swap pr	oposals by			B	2400 2		OR	12	Good	OK			-
Even swap U	Judo Redo	Restart Sa	ve as	Dominance	Irrelevance		Shi	D	Mont	niy balary 👸 F	exibility	Skills Developm	Vacation Days	g Benefits	Enjoyment		
		7						E	A 2000	3		0k	14	Ok	Good		
Mo	onthiy salary	Plexibility	Skills Deve	lopme vacation L	Days Benefits	Enjoyment		L	B 2400	2		dk .	12	Good	OK		
P 20	00	3	Ok	14	Good	Ok			C 1800	3		d K	13	Ok	OK	Dominated	4
0 18	100	4		10	Ok	OK			D 1900	3		0k	15	OK	Good		
			~	10	- OK	- Cit			E 2200	1		Qik.	12	Good	OK	Dominated	
19	100	3	0	15	Ok	Good											
E 22	100	3	God	15	Good	Bad						Irrelevant					
E 22	100 200	3	O G od	15 12	Good	Bad						Irrelevant					
E 22	100 100 N	3 1 Monthly Salary	G od	15 12 Skills Develo	Ok Good Ppme Vacation Days	Good Bad Benefits	Enjoymen	nt		г		Irrelevant					
E 220	100 100 2	3 1 Monthly Salary	G od Flex Illty 3	15 12 Skills Develo Bad	Ok Good pme Vacation Days 14	Good Bad Good Good	Enjoymen Ok	nt		Г		Irrelevant					•
A B C	100 200 2 2 2	3 1 Monthly Salary 2400 2400	O od Flex ility 3 2	15 12 Skills Develo Bad Ok Ok	Ok Good Pme Vacation Days 14 12 10	Good Bad Benefits Good Good Ok	Enjoymen Ok Ok	nt				Irrelevant	י אר	ch		202	Δ
A C D	100 100 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 Monthly Salary 2400 2400 1800 2100	0 G 0d 3 2 4 3	15 12 Skills Develo Bad Ok Ok Ok	Ok Good pme Vacation Days 14 12 10 15	Good Bad Øood Good Øood Øood Øood Øood Øood Øk	Enjoymen Ok Ok Ok	nt				Irrelevant	DM	ch	00	ses	A
E 220	100 200 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 1 2400 2400 2400 1800 2100	O G O 3 2 4 3 3	15 12 Skills Develo Bad Ok Ok Ok	Ok Good Inpme Vacation Days 14 12 10 15	Good Bad Good Good Good Ok Ok	Enjoymen Ok Ok Ok Ok	nt			_) DM	ch	00	ses	A
221 E 221 A B C D E	100 200 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 1 Monthly Salary 2 2400 2400 2400 2100	0 6 od Flex 100 100 100 100 100 100 100 10	15 12 Skills Develo Bad Ok Ok Ok Sk	Ok Good 14 12 10 15 Skills Develop	Good Bad Good Good Ok Ok Vacation Days	Enjoymen Ok Ok Ok Ok Ok	s Enjoyment			_		DM	ch	00	ses	A
р 19 221 А В С О Е	100 100 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 1 Monthly Salary 2 2400 2400 2400 2100 A B	O G od Flex ility 3 - 4 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 9 - 9 - 9 - 9 - 9 -	15 12 Skills Develo Bad Ok Ok Ok V Flexibility 3	Ok Good 14 12 10 15 Skills Develop Bad	Good Bed Benefits Good Ok Ok Vacation Days 14	Enjoymen Ok Ok Ok Ok Benefits Good	nt Enjoyment ok	1	L	_		DM	ch	00	ses	A
A B C D E	000	3 1 Monthly Salary 2400 2400 2400 2100 A B C	O G od Flex Hilly J - Z - J - J - Mo Inity Sala J 2400	15 12 Skills Develo Bad Ok Ok Ok Ok Ok 3 2	Ok Good 14 12 10 15 Kills Develop Rad Ok	Good Bad Good Good Ok Ok Vacation Days 14 12 10	Enjoymen Ok Ok Ok Ok Benefits Good Good	nt Enjoyment dk dk	1	L	_		DM	ch	00	ses	A
E 221 A B C D E	100 100 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 1 Monthly Salary (* 2400 2400 2100 A B C C D	O G	15 12 Skills Develo Bad Ok Ok Plant Plant Itelevelo	Ok Good Ideation Days 14 12 10 15 Skills Develop Bad Ok Ok	Good Bad Benefits Good Ok Ok Ok 14 12 12 10 15	Enjoymen Ok Ok Ok Ok Benefits Good Good Ok	nt dk dk dk dk		L	_		DM	ch	00	ses	A
р <mark>е 227</mark> В 227 В 0 С В С С В С	000 100 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2	3 Monthly Salary 2400 2400 2400 2400 2400 800 800 800 800 800 800 800	o co	15 12 Balls Develo Ball OK OK OK Stills Develo Plant String Plant String String String String String String	Ok Cood 14 12 15 Skills Develop Bad Ok Ok Ok	Good Bad Cood Good OK Vacation Days 14 12 16 15 12	Enjoymen Ok Ok Ok Ok Benefits Good Good Ok Ok Good	s Enjoyment ok ok ok ok ok ok		L	_		DM	ch	00	ses	A
С. 199 Е 221 А. С. С. С. Е	000 100 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 Monthly Salary 2400 2400 2400 2400 2100 A B C D E E	o od od Image: one of the one one of the one of the one one of the	15 12 Skills Develo Skills Develo OK OK OK Skills Develo Skills Develo S	Ok Cool 14 12 15 16 Ball OK OK OK OK OK OK OK	Ocod Bat Bat Cood Ook Ok 12 10 15 12 12 15 12 15 12	Enjoymen Ok Ok Ok Ok Ok Enerits Good Ok Ok Ok Ok	nt Enjoyment dyk dyk dyk dyk dyk dyk tratevant		L	_		DM	ch	00	ses	A
μ ε 222 Α Β Ο Ο Ε	100 100 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 1 2400 2400 2400 2400 2100 A B C D E	0 0 0 0 0 100 100 100 100 100 100 100	15 12 8kills Develo 8kills Develo 0k 0k 0k 0k 0k 0k 12 13 14 12 1	Ok Good 14 12 15 Rad 0k 0k 0k 0k 0k 0k 0k 0k	Ocod Bad Bad Ocod Ocod </th <th>Enjoymen Ok Ok Ok Cok Cood Cood Ok Ok Good</th> <th>nt Enjoyment Gk Gk Gk Gk Gk Gk Gk</th> <th></th> <th>L</th> <th></th> <th></th> <th>DM</th> <th>ch</th> <th>00</th> <th>ses</th> <th>A</th>	Enjoymen Ok Ok Ok Cok Cood Cood Ok Ok Good	nt Enjoyment Gk Gk Gk Gk Gk Gk Gk		L			DM	ch	00	ses	A
р <mark>е 222</mark> В 222 В 0 В В В В В В В В	100	3 4 Monthly Balary P 2400 240 24	0 Ftex illity 7 1 2 1 3 1 4 1 3 1 4 1 3 1 4 1 2 24 1800 2100 1900 1	15 12 Bad 0k 0k 0k 1 1	Ok Good 14 12 13 14 15 16 17 84His Develop 0k 0k 0k 0k 0k 0k 0k	000d Bad 000d 000d 000d 000 000 000 000	Enjoymen Ok Ok Ok Ok Good Good Ok Good	nt Enjoyment dik ok ok melanomi				→ [ЭM	ch	00	ses	A
E 221 Α Ο Ε Ο Ε Ε	00000000000000000000000000000000000000	3 1 2400 2400 2400 2200 A B C D E E	0 10 10 10 10 10 10 10 10 10 1	15 12 Skills Devoto Bad Ok Ok Ok Vitility 2 4 3 1	Ok Good 14 12 10 12 10 13 14 15 16 17 18 0K 0K 0K 0K 0K 0K	000d Bad 000d 00od 00a 0k 0k 0k 0k 114 12 100 15 12	Enjoymen Ok Ok Ok Ok Ok K Benefits Good Ok Ok Ok Ok	nt dys dys dys dys dys dys trainwort	oses	B		→ [ЭM	ch	00	ses	A
μ ε 221 Α Β ο ο ε	00000000000000000000000000000000000000	3 1 Monthly Salary [2 2400 2400 2400 2100 8 8 0 0 0 0 E 2 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1	0 Fiv (H) Fiv (H)	15 12 Skills Develo Bad OK OK V Frokbulty 2 4 3 1	Ok Good Jacation Days 14 12 15 Ektils Develop Bad OK Ok Ok	000d Вас Васебія 000d 000d 000d 000 000 000 000	Enjoymen Ok Ok Ok Eenefts Good Ok Ok Ok Ok	nt dk dk dk dk dk treiseent	oses	B		→ [SМ	ch	100	ses	A

Bias mitigation methods for Even Swaps

Reference method: Attribute elimination method with a fixed reference alternative

Method A: Attribute elimination method with a virtual reference alternative

Method B: Attribute elimination method with a virtual reference alternative and an auxiliary measuring stick

Method C: Pairwise attribute elimination method with an auxiliary measuring stick, rotating reference point and intermediate restarting

Method D: Pairwise attribute elimination method with an auxiliary measuring stick, virtual reference alternative, and intermediate restarting

Method D requires about twice as many swaps as the other methods

Computational analysis

Biased decision makers:

- Weight of measuring stick attribute increased by a factor S (1.1, 1.3 or 1.5)
- Weight of loss attribute increased by a factor L (1, 1.2 or 1.4)
- Non-systematic response error included in half of the settings
- Sizes of the consequences tables varied
 - Number of attributes: 3, 5 or 8 Number of alternatives: 2, 5 or 8
 - 5000 randomly generated sets of alternatives per each case
- Attribute weights varied
 - 100 randomly generated weight profiles for each number of attributes

Performance criterion: Share of cases where method gives the same result as a bias free process

Overall results

- All bias reduction methods A-D perform better than the reference method
 Percentage of cases where a
 - method gives the same result as a bias free process Method D always Reference finds the correct 86 method result if response error is zero Method A 92 Method B 94 Method C 93 Method D 98
- When the value difference of top two alternatives is up to 0.3, the correct solution is not always found with all methods

Performance of the methods in different settings



- Performance of the reference method and Method A decreases with increasing magnitude of measuring stick bias
- Methods A-D increasingly better than the reference method with higher number of attributes

Discussion of results

All of the proposed new techniques help to mitigate the overall effects of biases in the Even Swaps process.

We evaluated methods based on these techniques across a number of different computational settings.

In a real-life case, the method to be used can be chosen based on more specific information

 e.g., the number of alternatives, the number of attributes, the consequences of the alternatives, as well as estimates of the magnitudes of the biases of the person using the Even Swaps process.

Conclusions

A systemic perspective helps to find effective debiasing methods

It is possible to find paths along which the effects of biases counteract each other leading to low overall bias.

New bias reduction techniques can easily be taken into use in Even Swaps, Trade-off weighting, Swing weighting

New techniques are potentially interesting in interactive multicriteria optimization procedures too

Computational analysis helps to evaluate the effectiveness of different bias mitigation techniques

References

- Anderson, R. M., Clemen, R. 2013. Toward an Improved Methodology to Construct and Reconcile Decision Analytic Preference Judgments, Decision Analysis, 10(2), 121-134.
- Anderson, R. M., Hobbs, B. F. 2002. Using a Bayesian Approach to Quantify Scale Compatibility Bias. Management Science, 48(12), 1555-1568.
- Bleichrodt, H. J., Pinto, J. L., Wakker, P. 2001. Making descriptive use of prospect theory to improve the prescriptive use of expected utility. Management Science, 47(11), 1498-1514.
- Delquié, P. (1993) Inconsistent trade-offs between attributes: New evidence in preference assessment biases. *Management Science* 39(11):1382-1395
- Delquié, P. 1997. "Bi-matching": A new preference assessment method to reduce compatibility effects. *Management Science* 43(5), 640-658
- Delquié, P. (2003). Optimal conflict in preference assessment. *Management Science* 49(1):102-115.
- Fischer, G.W. 1995. Range sensitivity of attribute weights in multiattribute value models. *Organizational Behavior and Human Decision Processes* 62(3), 252-266.
- Hammond, J.S., Keeney, R.L., Raiffa, H., 1999. Smart Choices: A practical guide to making better decisions. Harvard Business School Press, Boston, MA.

Hammond, J.S., Keeney, R.L., Raiffa, H., 1999. Smart Choices: A practical guide to making better decisions. Harvard Business School Press, Boston, MA.

Hämäläinen, R. P., Alaja, S. 2008. The threat of weighting biases in environmental decision analysis. *Ecological Economics* 68(1), 556-569.

Hämäläinen, R. P., and Lahtinen, T. J. (2016). Path dependence in Operational Research – How the modeling process can influence the results. *Operations Research Perspectives*, 3:14-20.

Jacobi, S. K., Hobbs, B. F. 2007. Quantifying and mitigating the splitting bias and other value tree-induced weighting biases, Decision Analysis, 4(4), 194-210.

Keeney, R. L., & Raiffa, H. 1976. Decisions with Multiple objectives: Preferences and value trade-offs. New York: John Wiley & Sons.

Korhonen, P., Moskowitz, H., & Wallenius, J. 1990. Choice behavior in interactive multiple-criteria decision making. Annals of Operations Research, 23(1), 161–179.

Lahtinen, T. J., and Hämäläinen, R. P. 2016. Path dependence and biases in the even swaps decision analysis method. *European Journal of Operational Research*, 249(3): 890-898.

Lahtinen, T. J., Guillaume, J. H., and Hämäläinen, R. P. 2017. Why pay attention to paths in the practice of environmental modelling? *Environmental Modelling & Software*, 92:74-81.

Montibeller, G., and D. Winterfeldt. Cognitive and Motivational Biases in Decision and Risk Analysis. Risk Analysis, 2015

Tversky, A., Kahneman, D. 1991. Loss Aversion in Riskless Choice: A Reference-Dependent Model. Quarterly Journal of Economics, 106(4), 1039-1061.