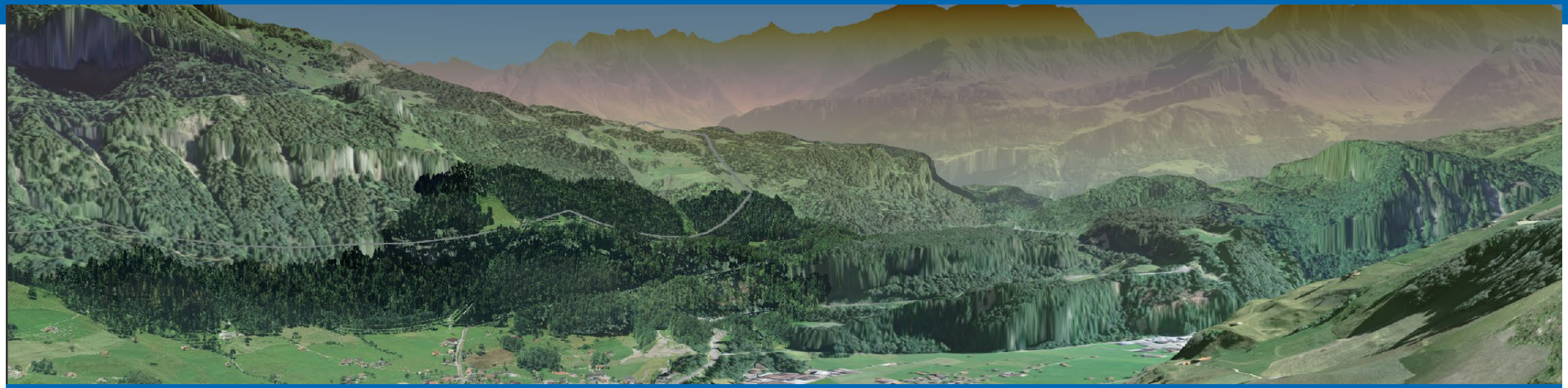
ETH zürich



Enhanced multi criteria decision analysis for planning power transmission lines

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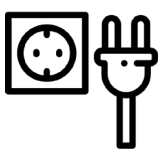
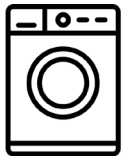
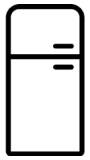
geoinformation engineering ikg eth zurich

PLUS

3DDSS 3d decision support system

We need electricity for our daily life

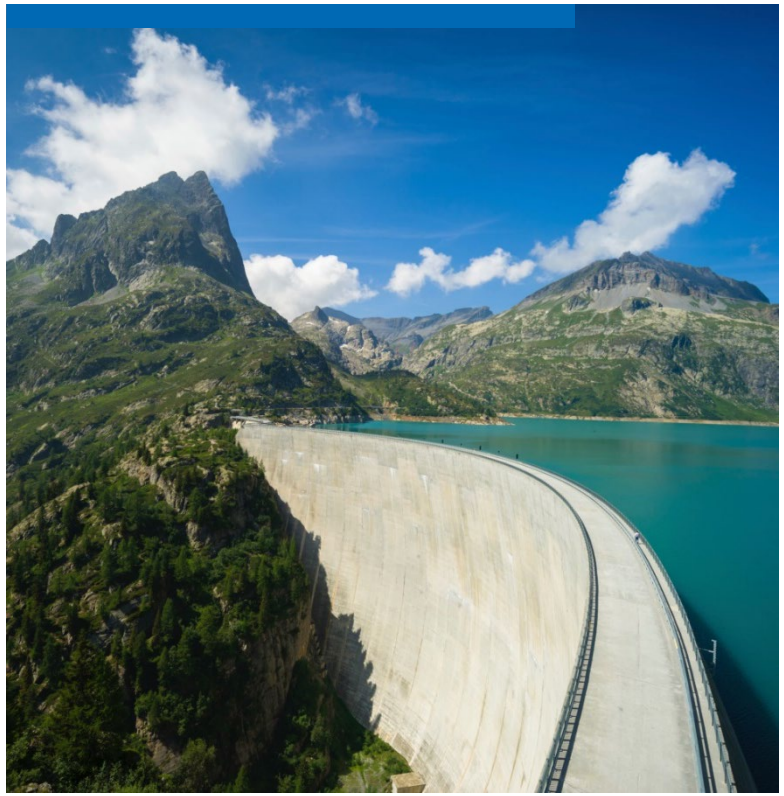


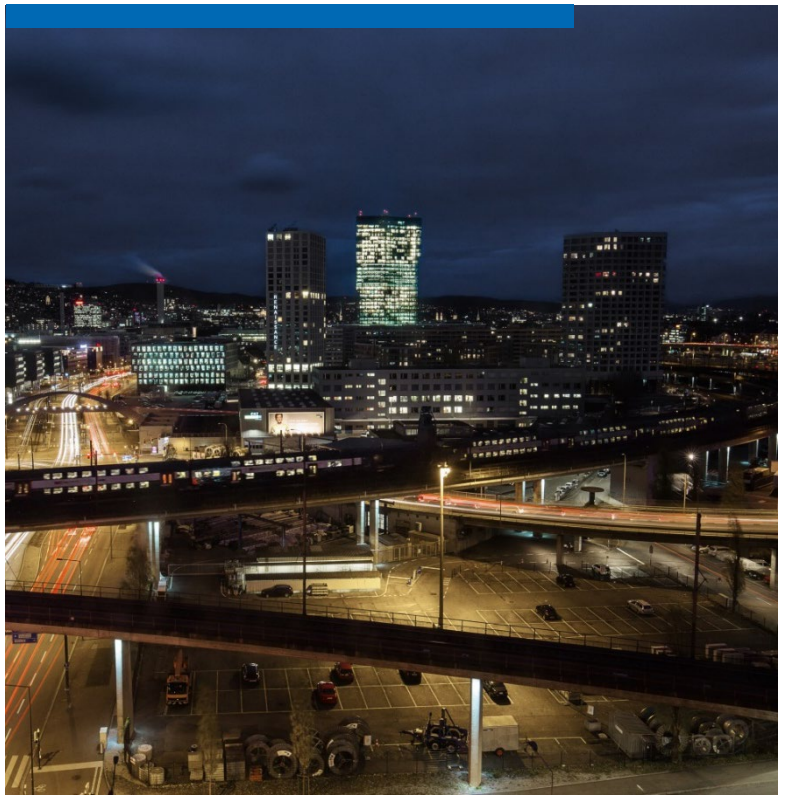


Trends in grid expansion due to growth and the energy transition

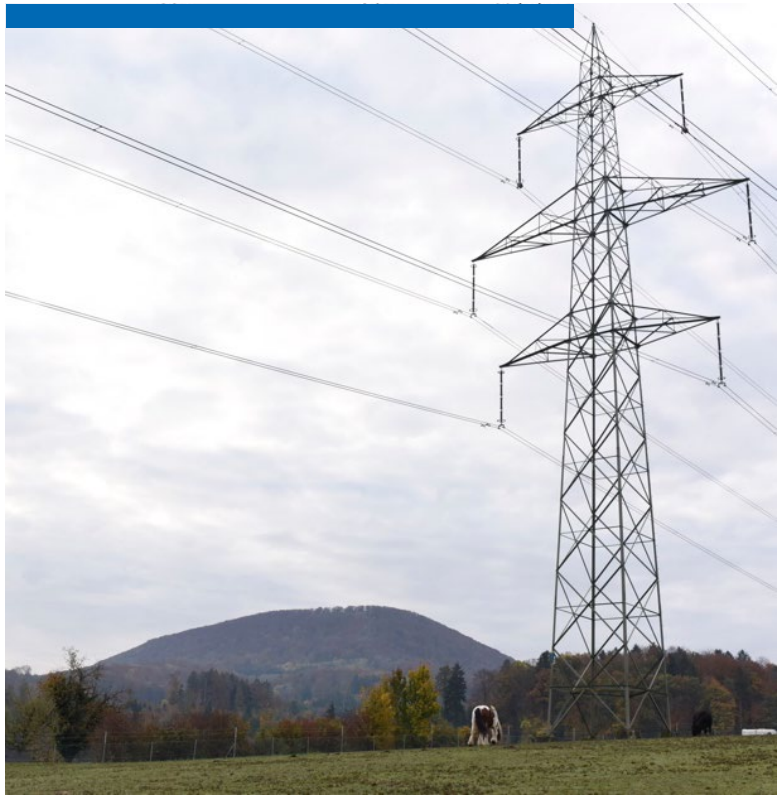
New large power plants



International association



Supply of downstream grids



Delays in grid expansion projects

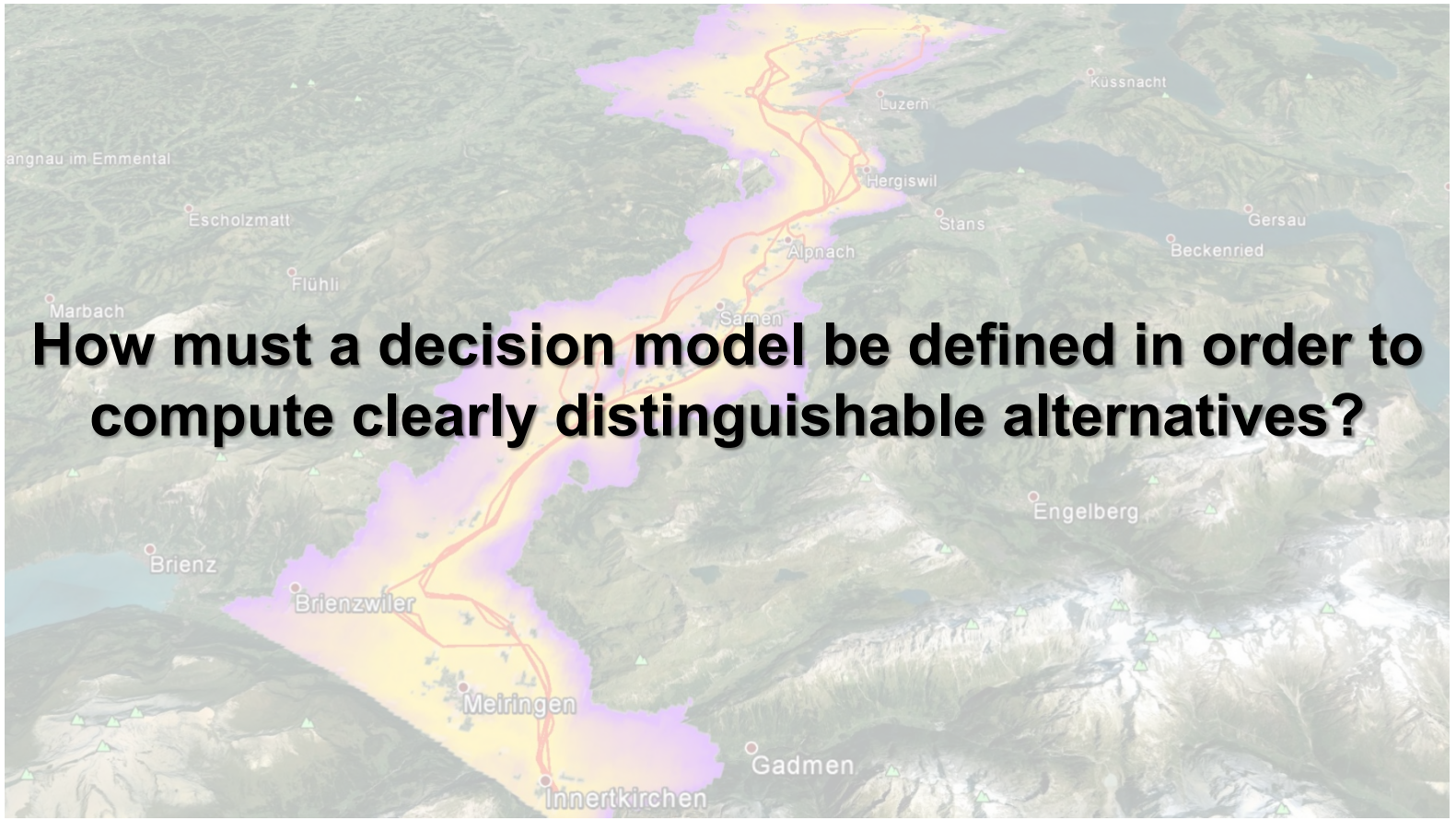
Why?

Affected citizens can object against a new transmission line

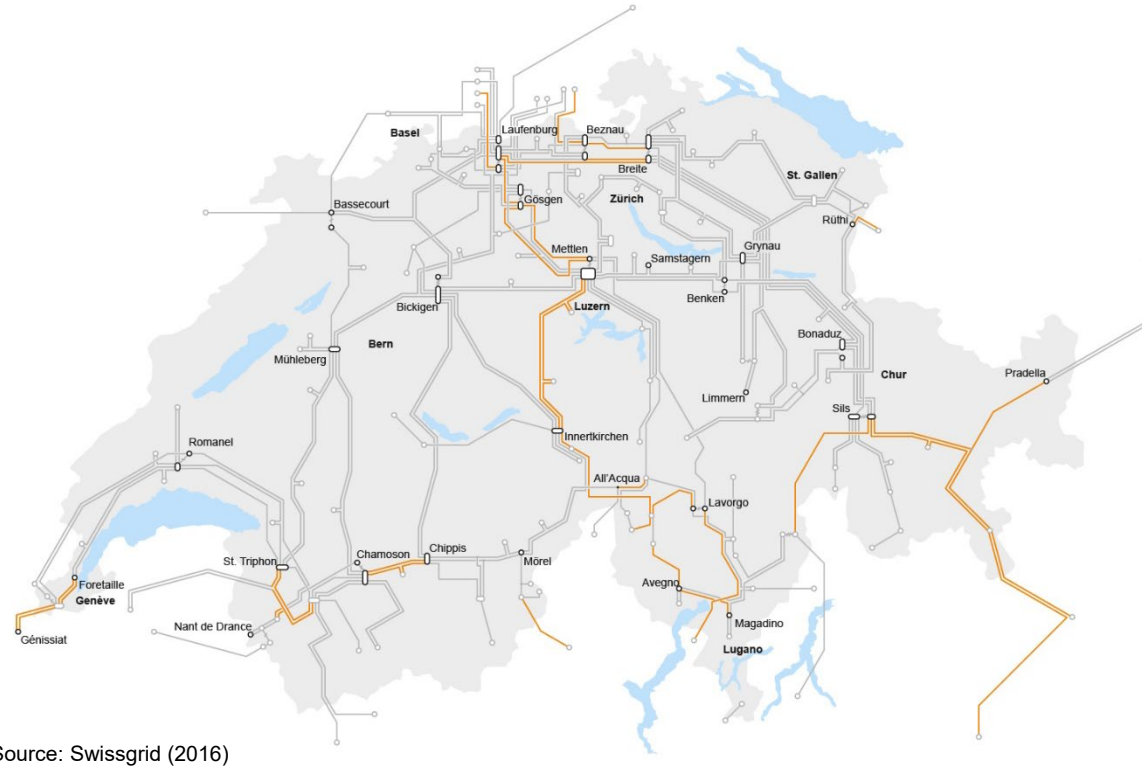
bergrheinfeld-sagt-nein.de (2017)

Communicating with affected citizens can help to increase acceptance

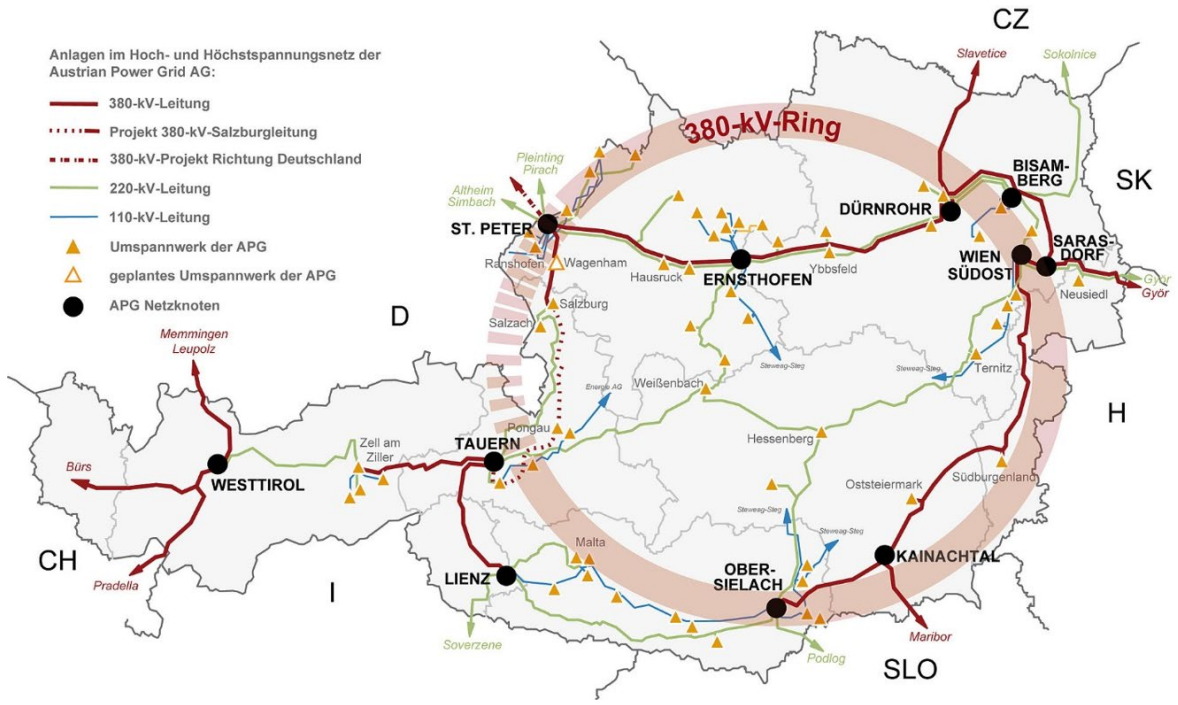
Decision-makers want to decide between few route alternatives, not thousands or millions



Our case study areas: electricity bottlenecks in Switzerland and Austria



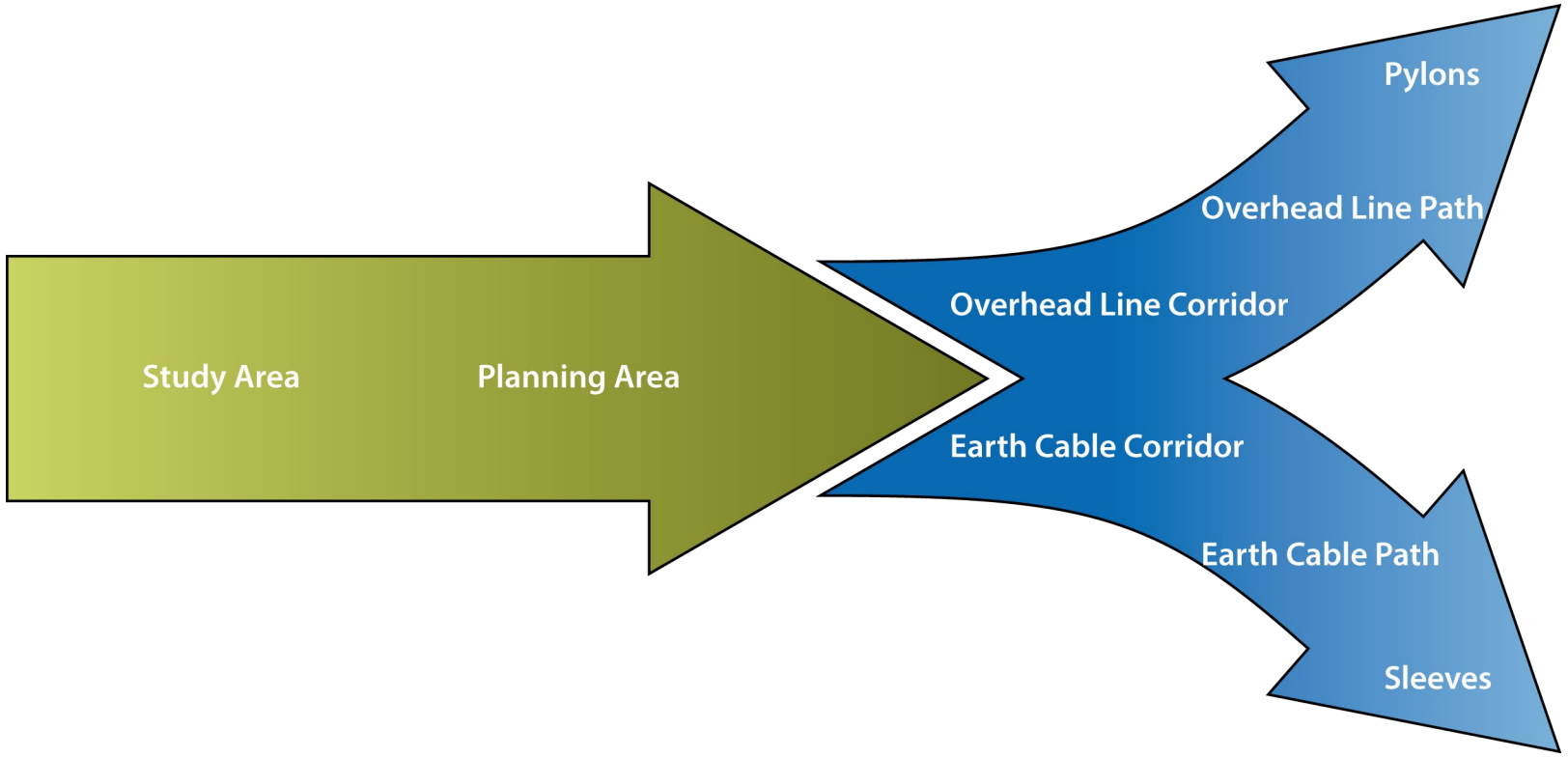
Source: Swissgrid (2016)



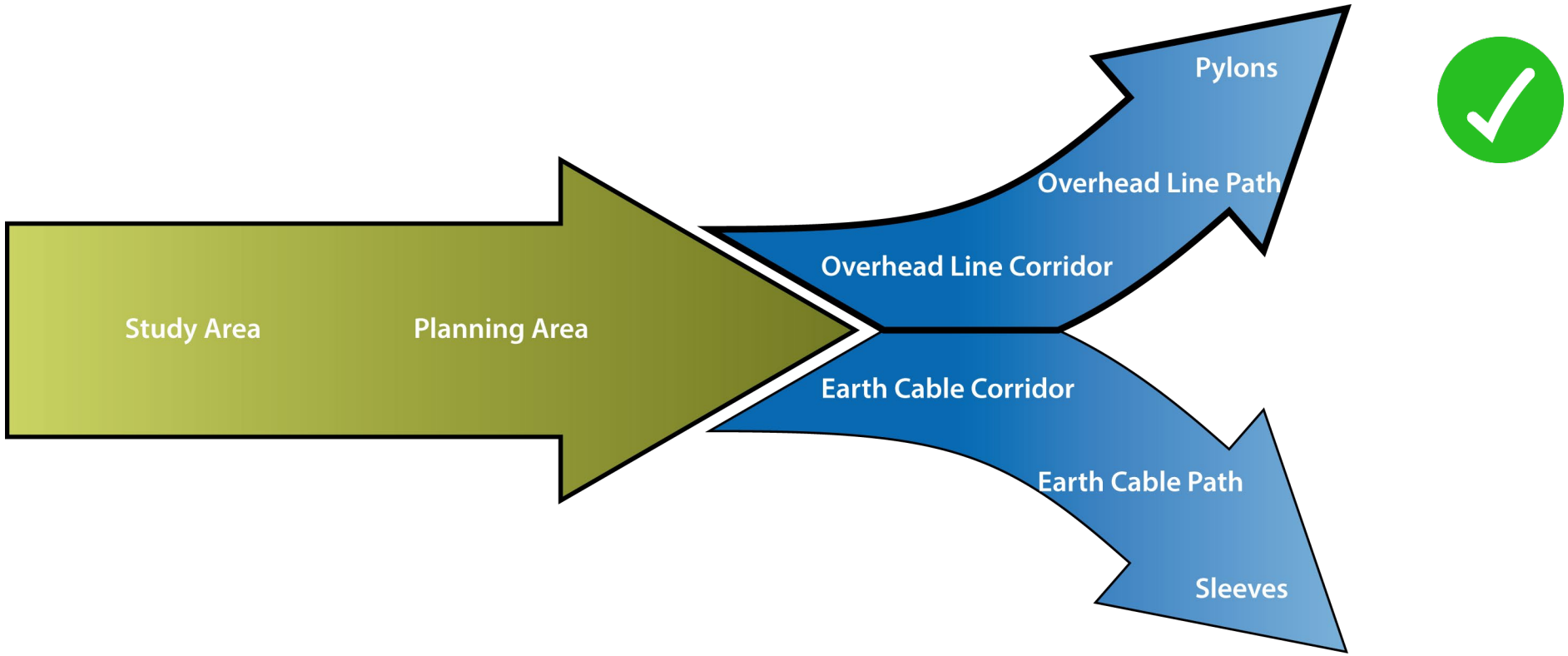
Source: APG (2014)

How our 3D Decision Support System (3D DSS) works

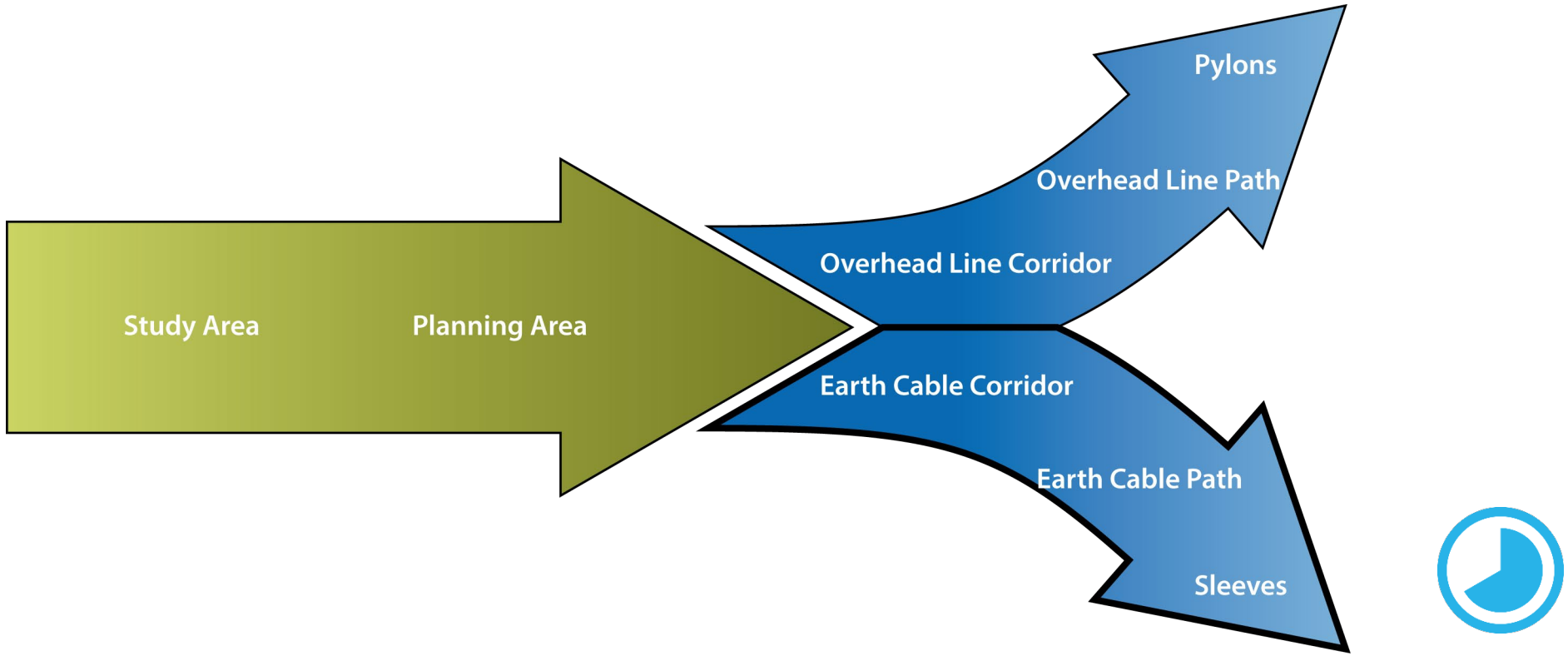
Stepwise procedure



Stepwise procedure



Stepwise procedure



How the most feasible planning area is calculated

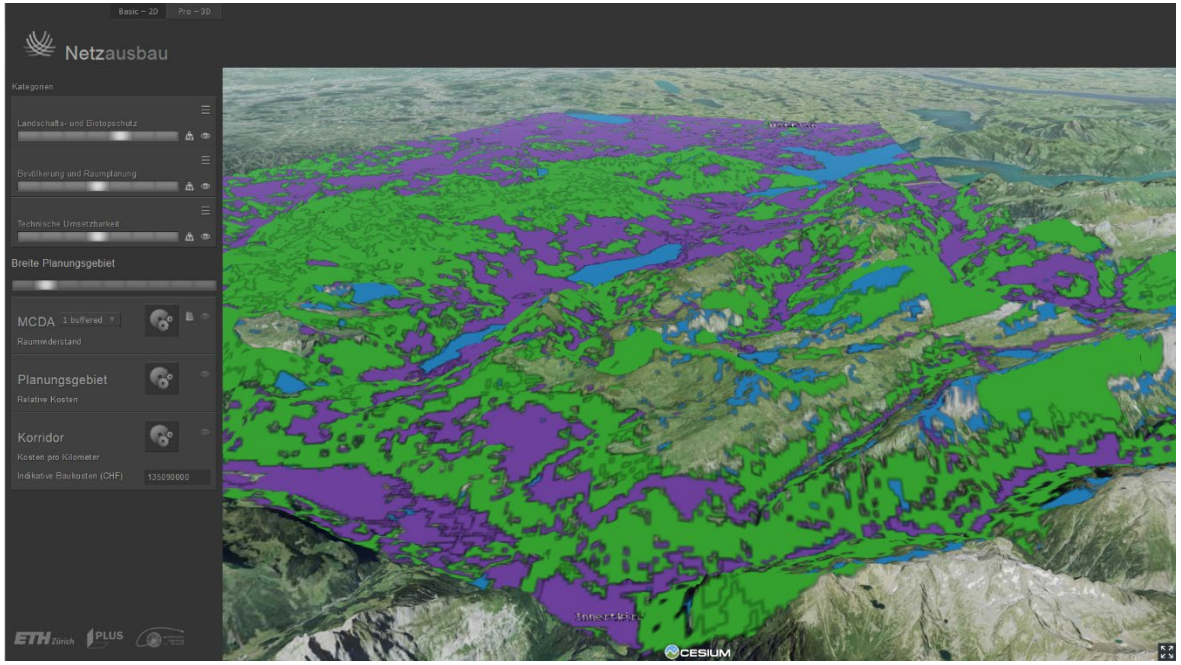
1 *geodata*

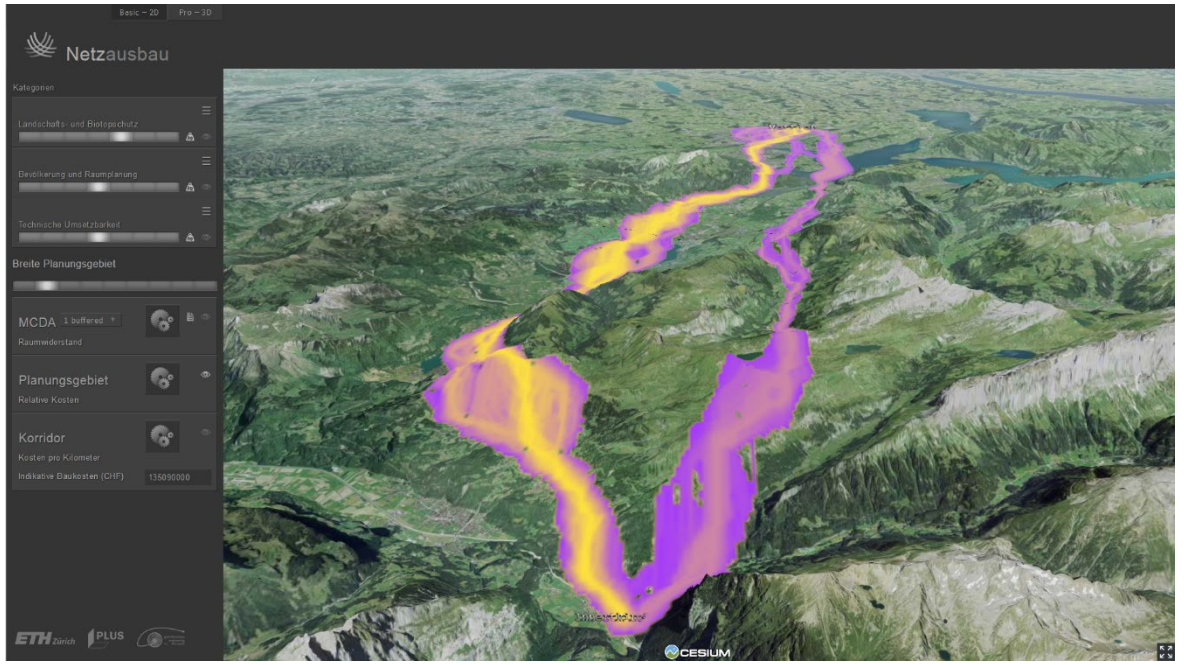
2 *resistance/weight*

3 *MCDA formula*

4 *optimization*

planning area





Basic – 2D | Pro – 3D

Netzausbau

Kategorien

Landschafts- und Biotopschutz

Bevölkerung und Raumplanung

Technische Umsetzbarkeit

Breite Planungsgebiet

MCDA 1 simple

Raumwiderstand

Planungsgebiet

Relative Kosten

Korridor

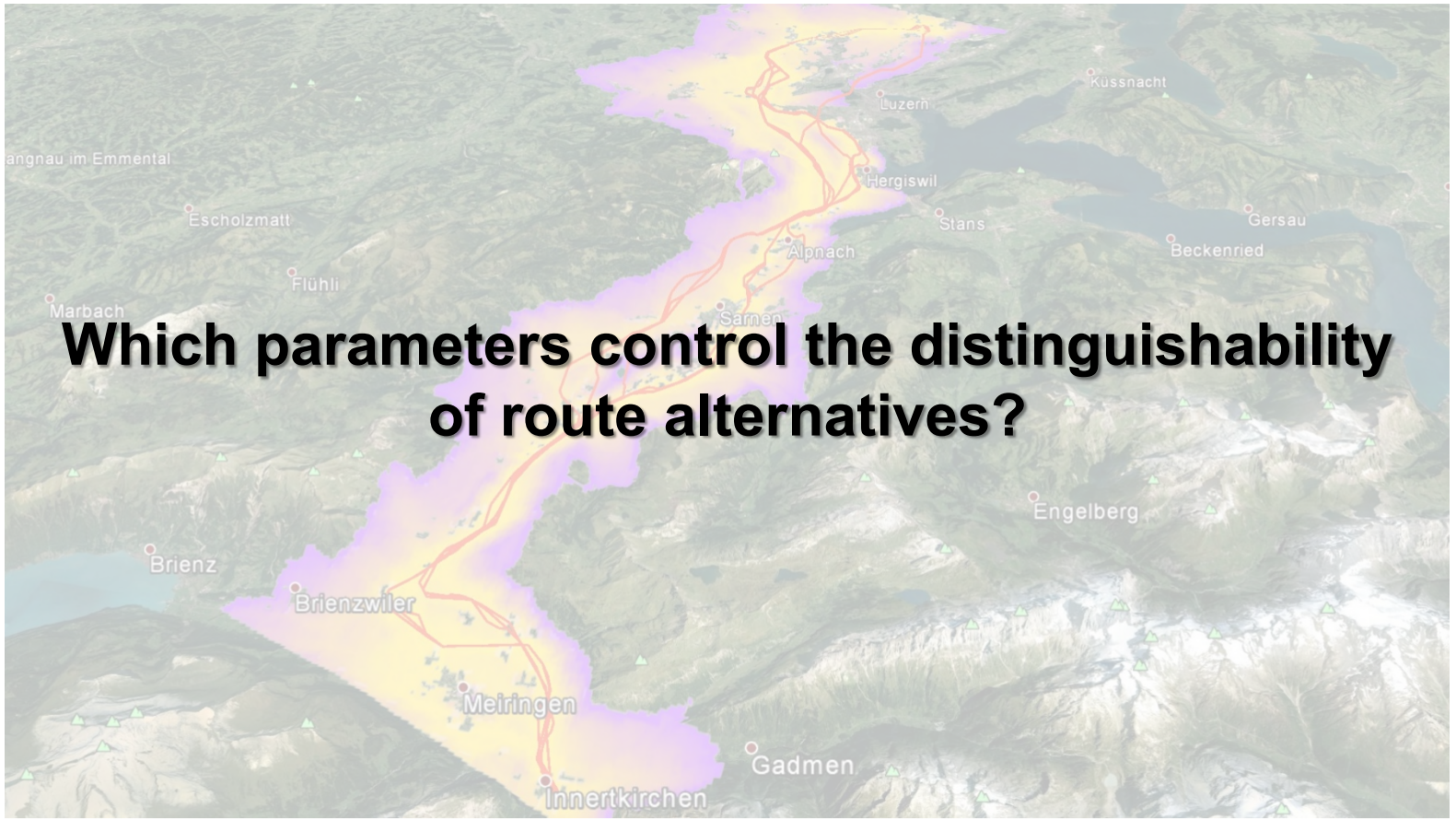
Kosten pro Kilometer

Indikative Baukosten (CHF) 140350000

ETH Zürich PLUS

How we enhance the decision model by altering its input parameters

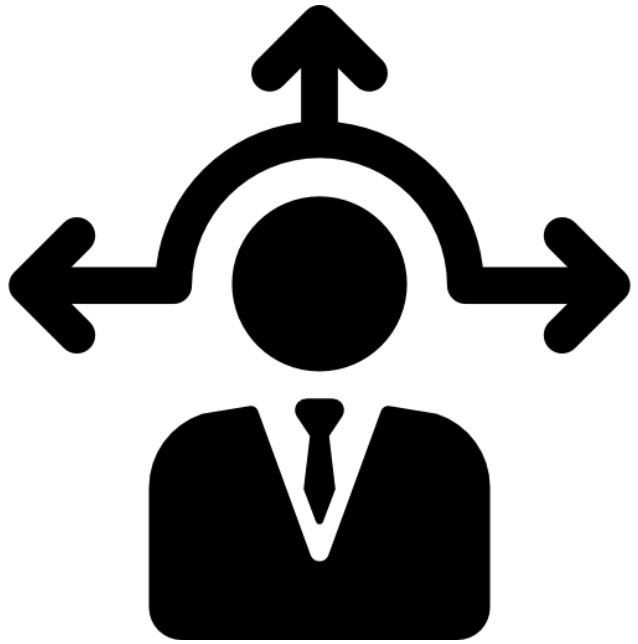
Decision-makers want to decide between few route alternatives, not thousands or millions



Which parameters control the distinguishability of route alternatives?

Which parameters of the decision model can be altered?

resistance	33 x [Lo Hi]
weight	33 x [Lo Hi]
boundary model	A B
MCDA method	A B C
weighting model	A B C
utility function	A B C D

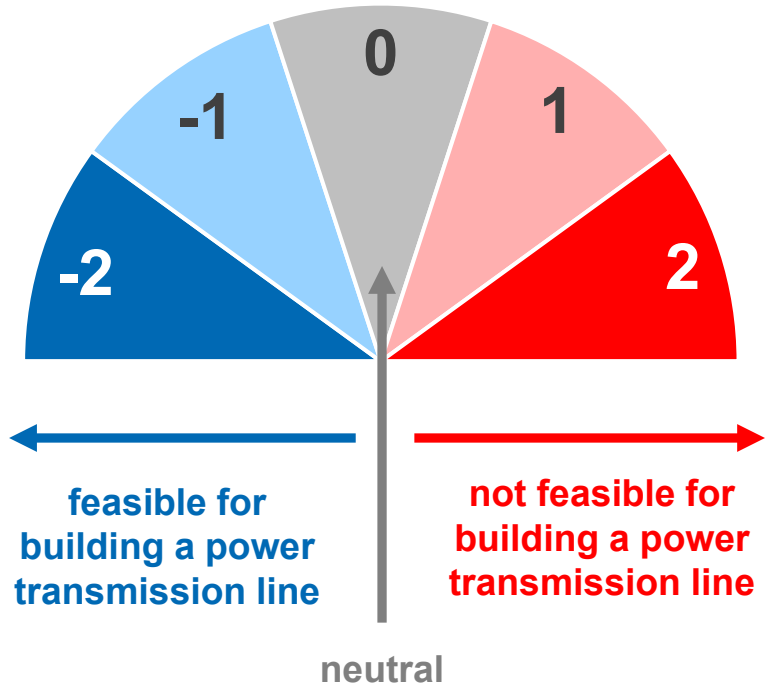


Users can set the following parameters:

1) The desired scenario, based on resistances and weights

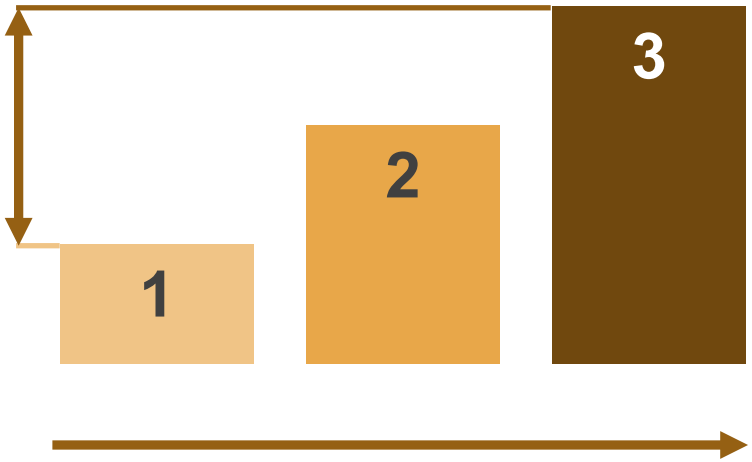
33 x [Lo Hi]

resistance



weight

the higher the weight, the higher the influence of the according factor within its category

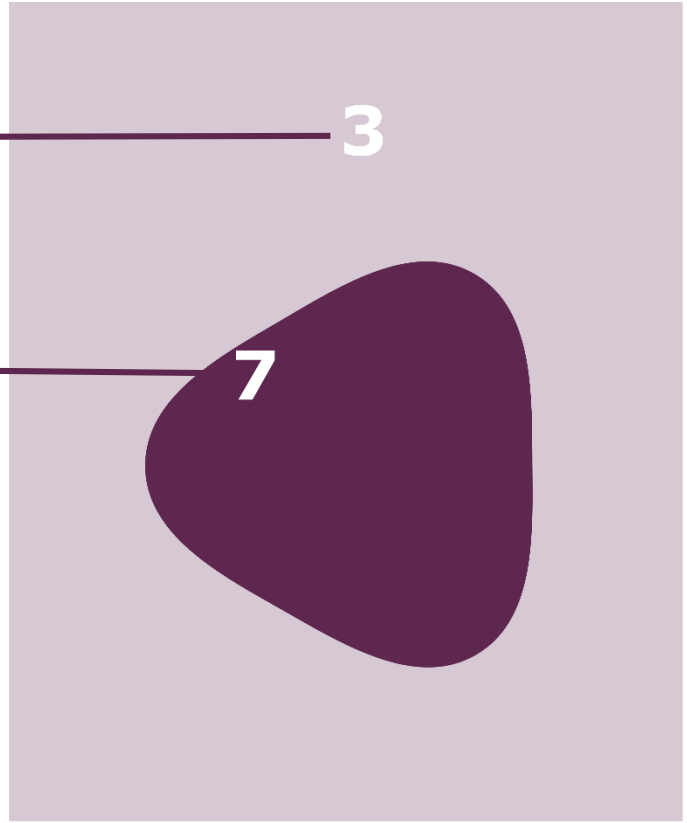


Users can set the following parameters:
2) Which boundary model should be used around areas

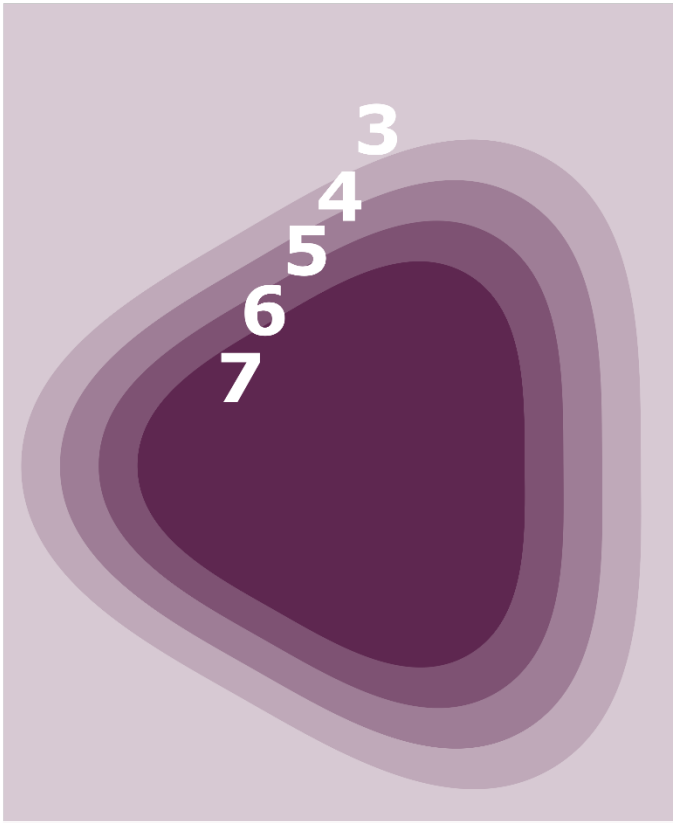
A B

area A with resistance 3

area B with resistance 7



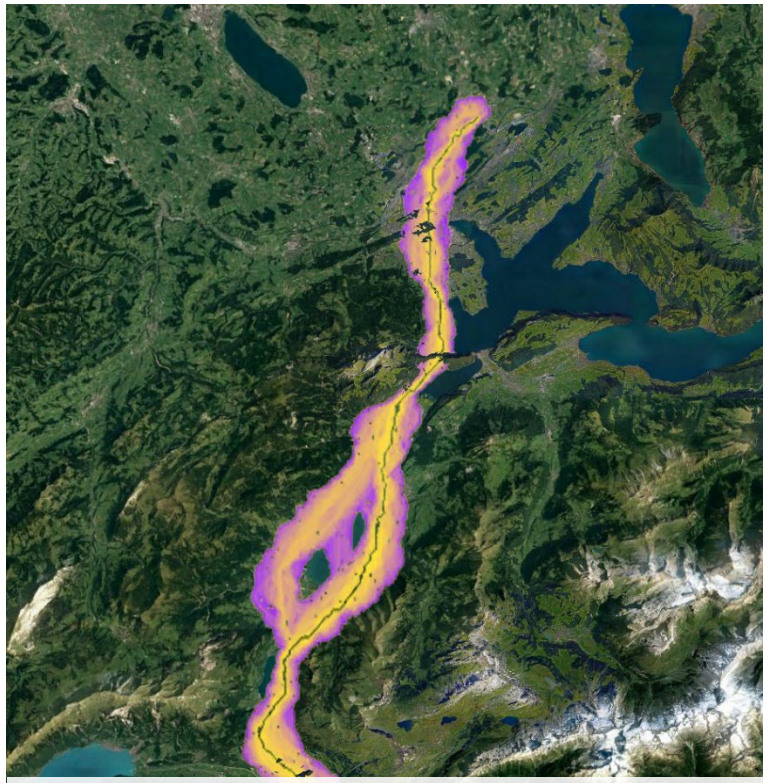
sharp-edged



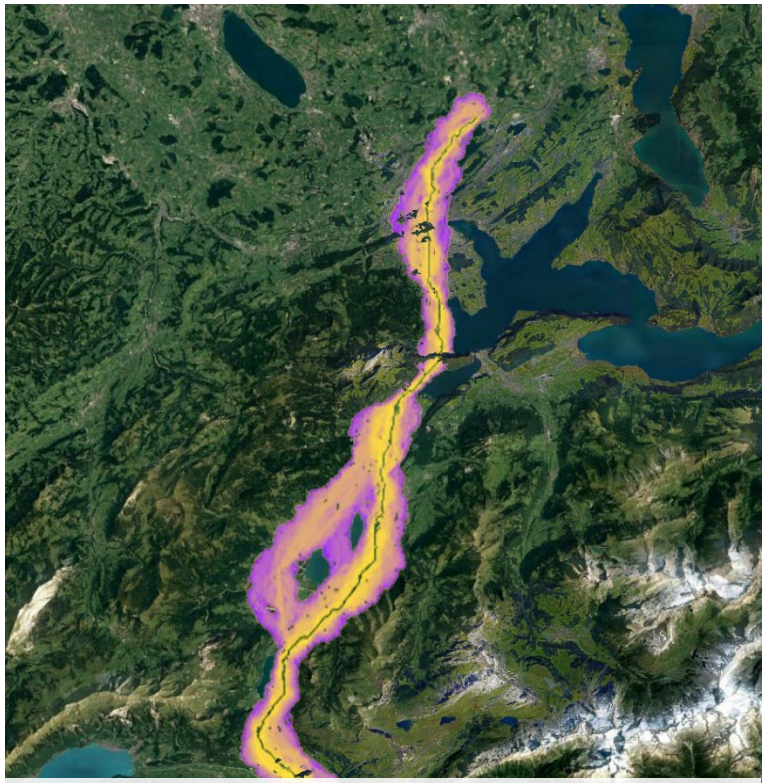
continuous

Users can set the following parameters:
3) Which MCDA method is used to compute the cost surface

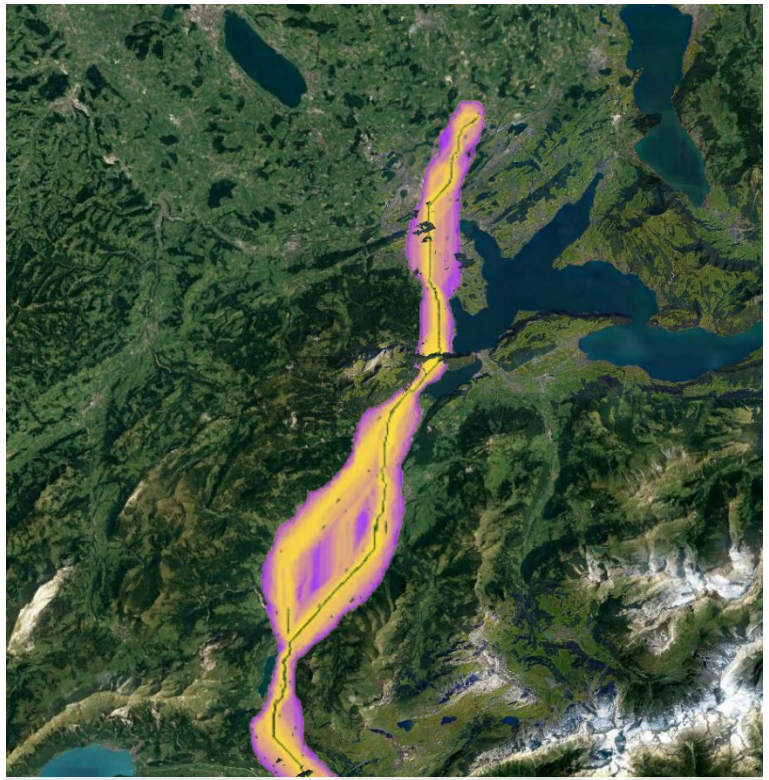
A B C



simple additive weighting SAW
sharp-edged



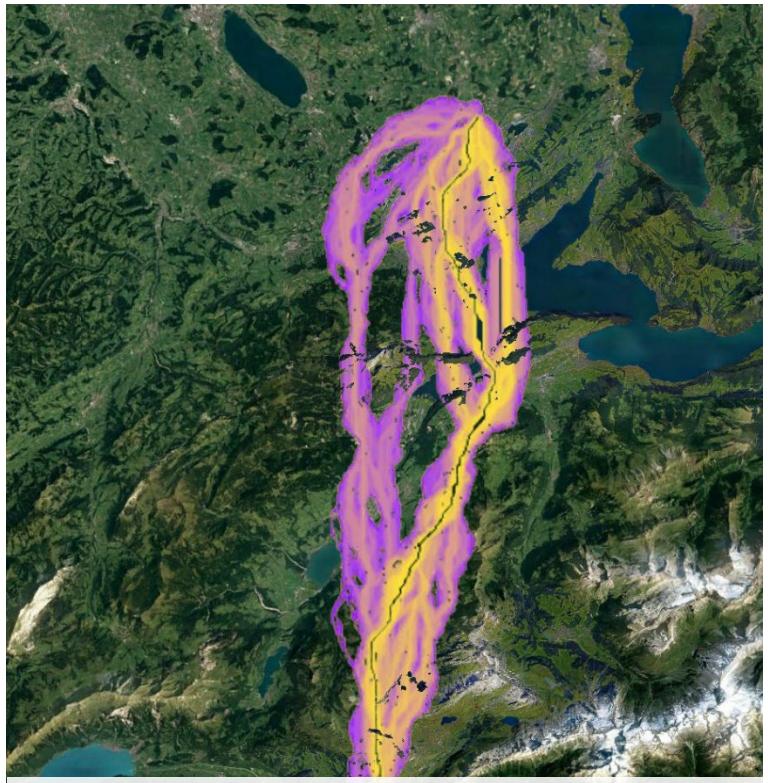
log-corrected SAW
sharp-edged



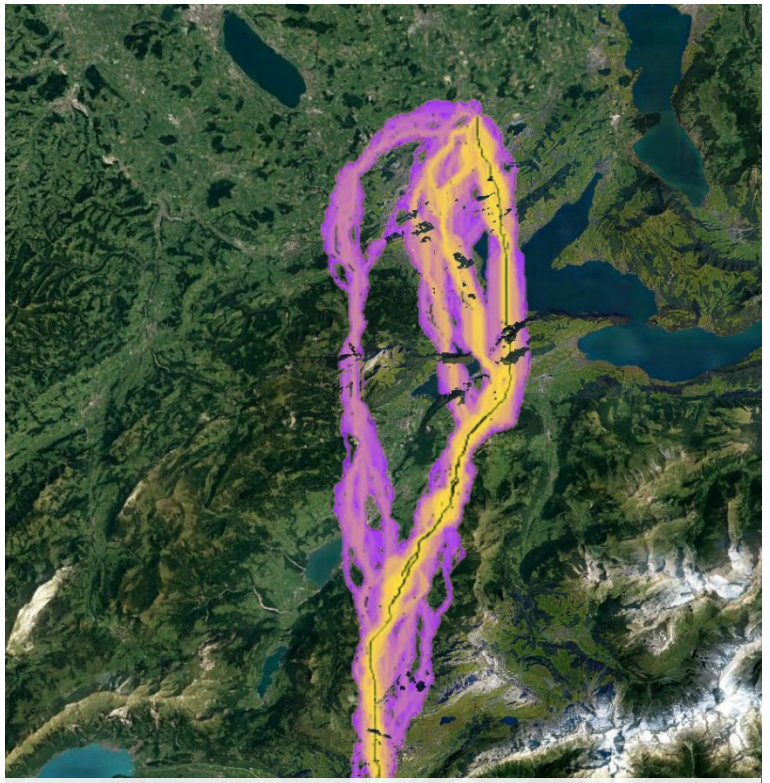
maximum value
sharp-edged

Users can set the following parameters:
3) Which MCDA method is used to compute the cost surface

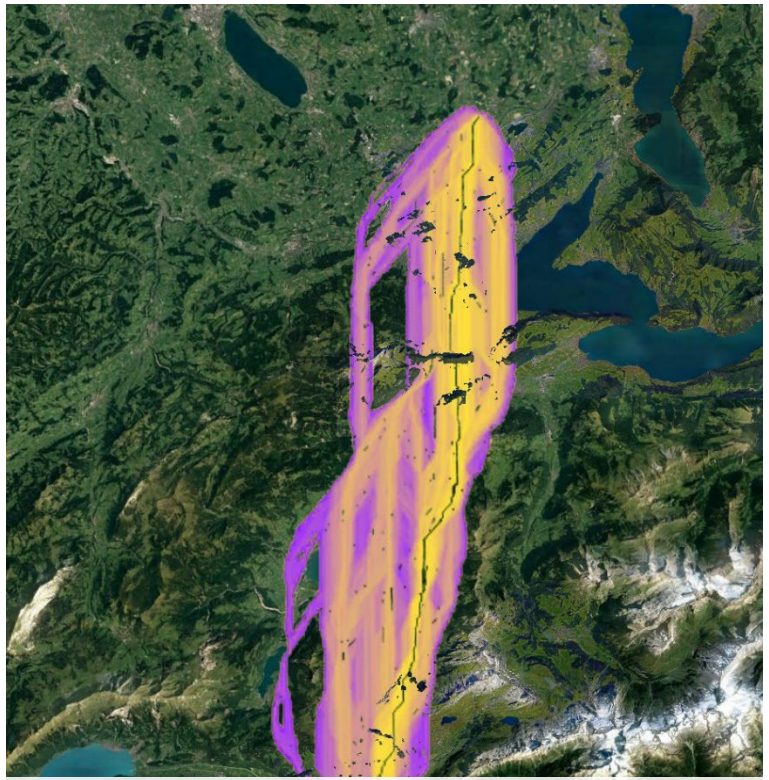
A B C



simple additive weighting SAW
continuous



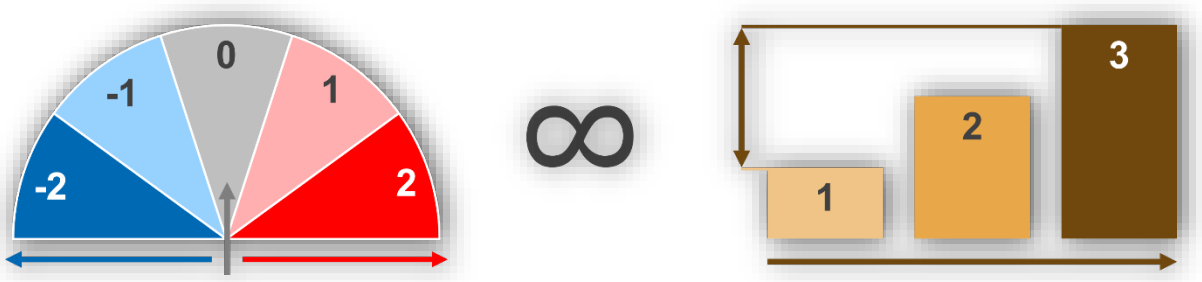
log-corrected SAW
continuous



maximum value
continuous

Users can set the following parameters:
4) The weight's influence on the resistance

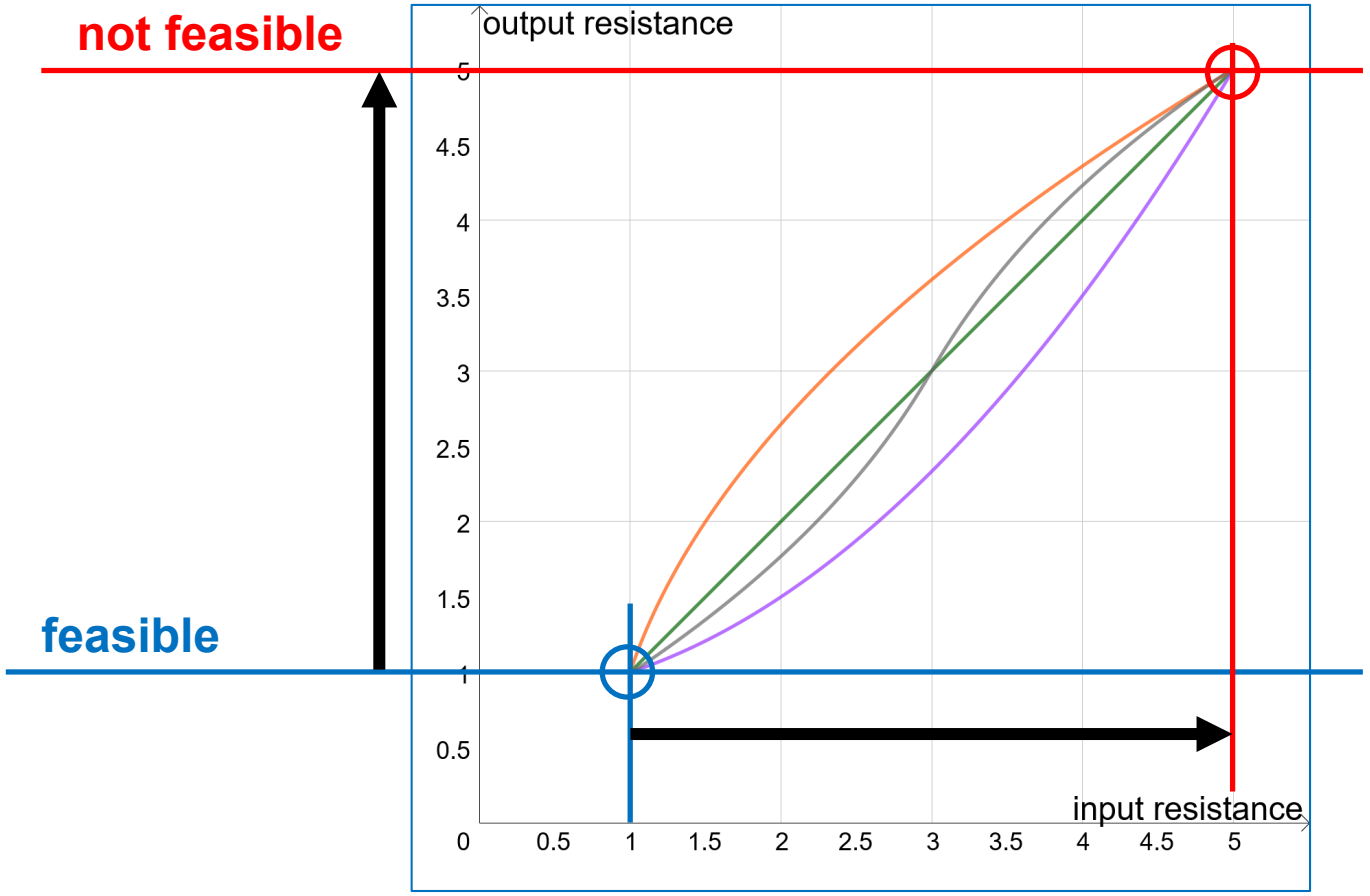
A B C



factor	resistance	weight	corrected resistance
hazard areas	2	1	2.000
lakes and rivers	1	3	1.500
groundwater area (S1)	0	1	0.000
groundwater area (S2)	-1	2	-1.250
unfeasible topography	-2	3	-2.500

Users can set the following parameters:
5) How resistances should be interpreted

A B C D

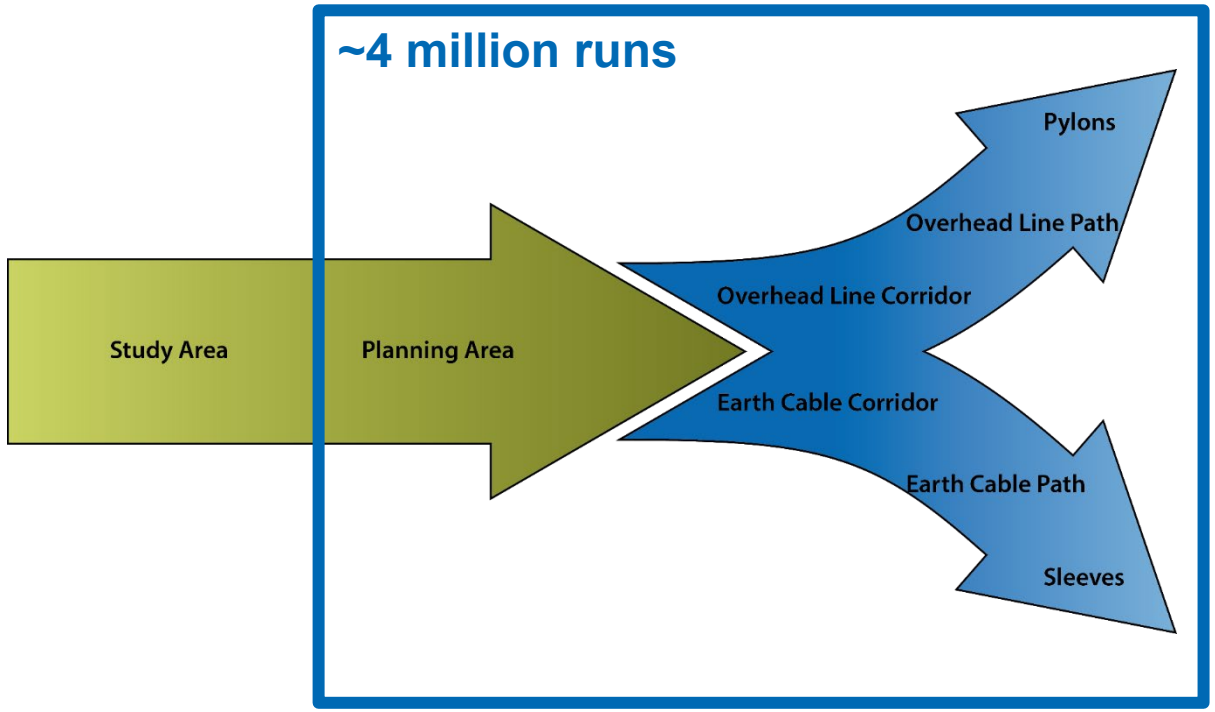


Determining clusters of input parameters that lead to similar results

1) Compute the outputs of all parameter combinations

I N P U T → O U T P U T

resistance	33 x [Lo Hi]
weight	33 x [Lo Hi]
boundary model	A B
MCDA method	A B C
weighting model	A B C
utility function	A B C D

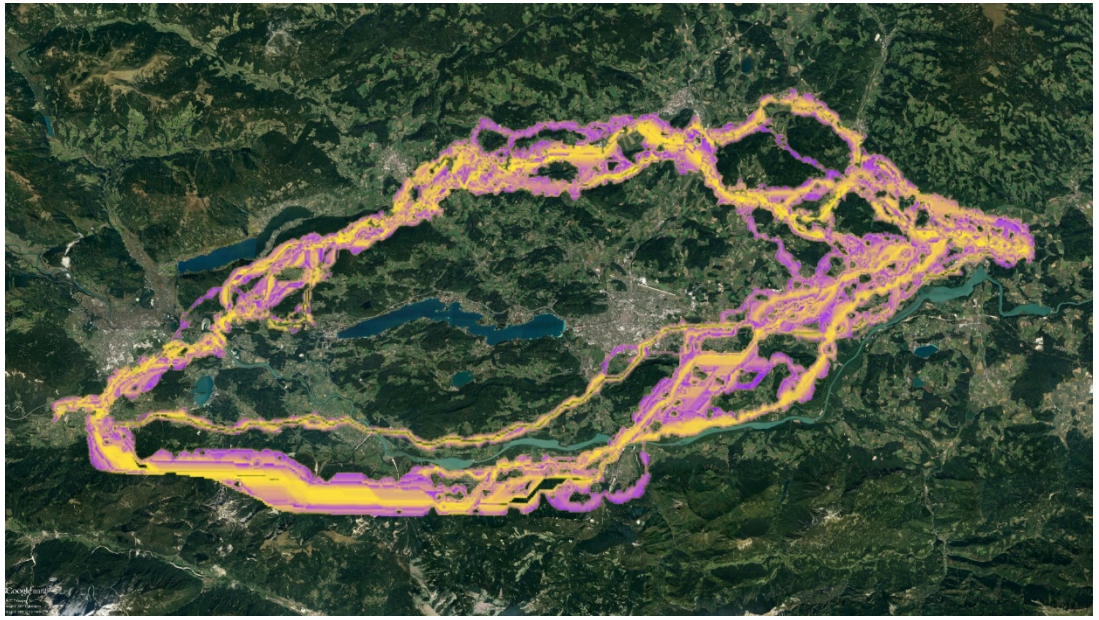


2) Group all results by 72 parameter combinations and average them

G R O U P B Y → AVG → O U T P U T

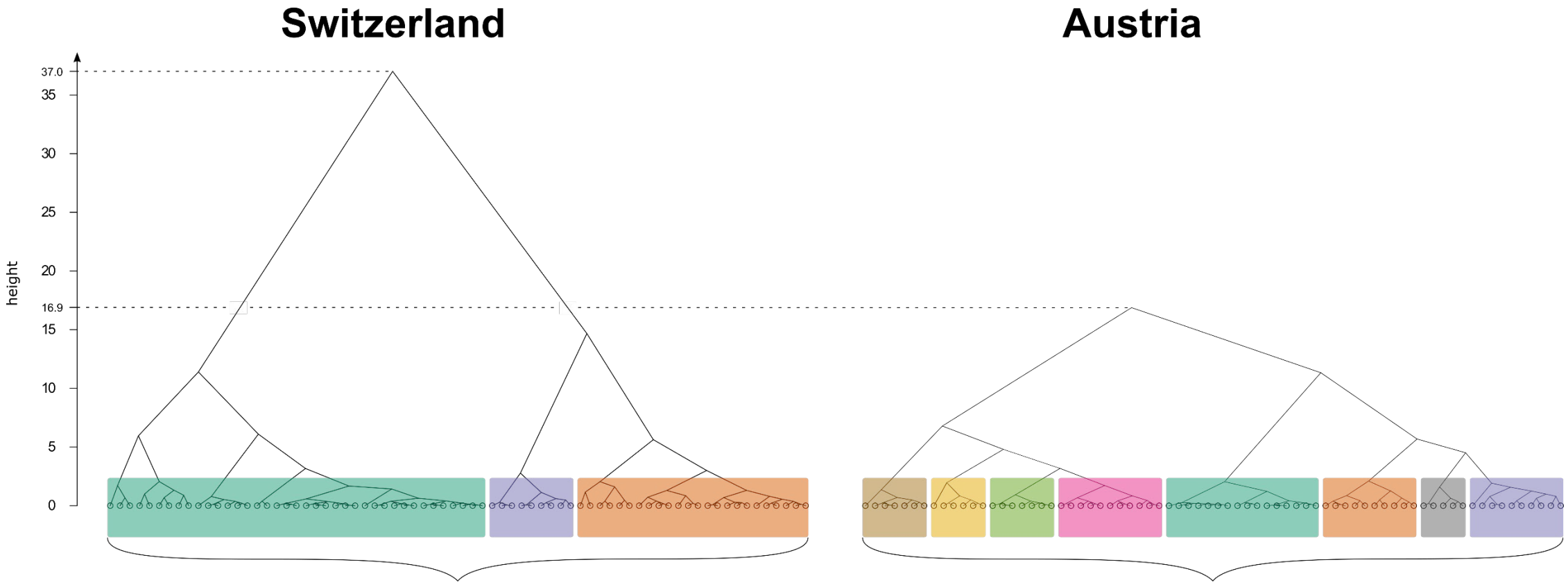
boundary model	A	B		
MCDA method	A	B	C	
weighting model	A	B	C	
utility function	A	B	C	D

72 parameter combinations (2 x 3 x 3 x 4)



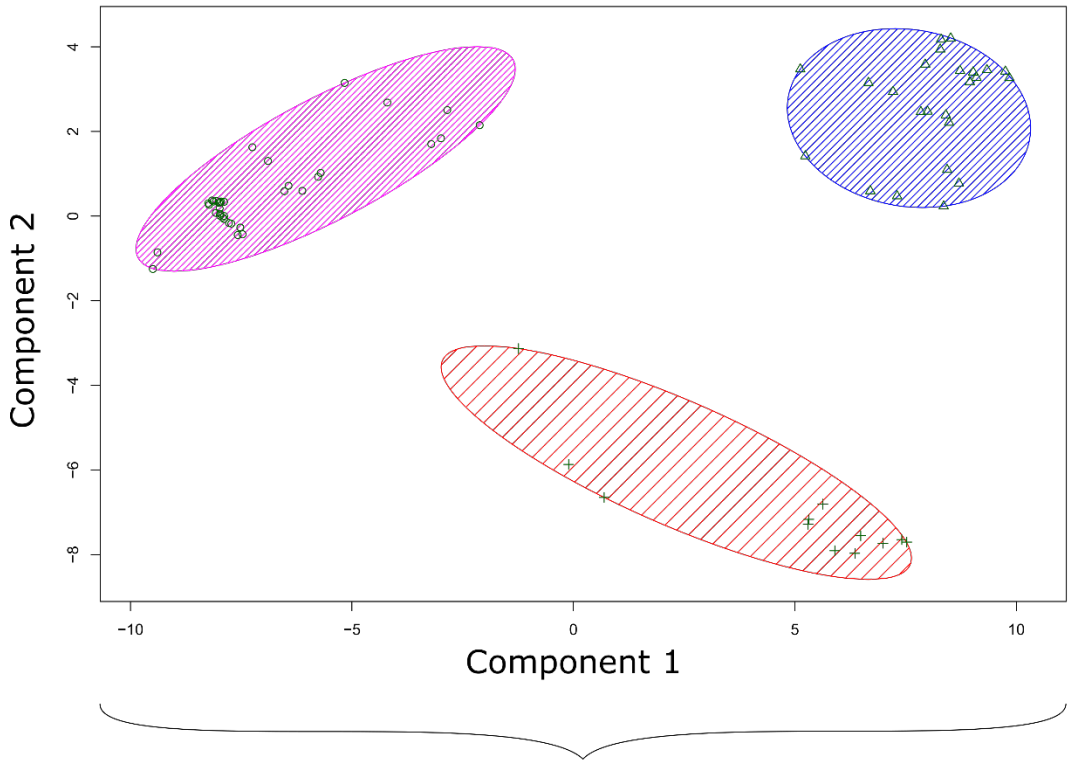
72 averaged study areas (16 visible here)

3) Compute Pearson's R of the 72 averaged maps and use PAM to determine clusters



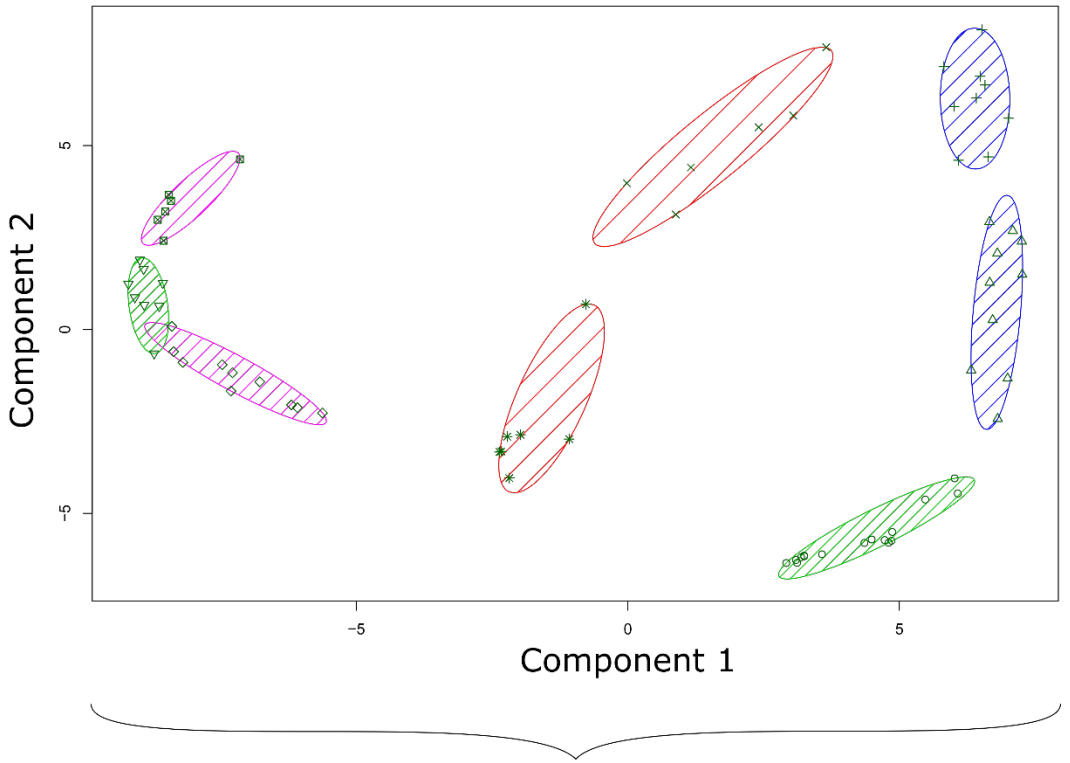
4) Analyze cluster plot

Switzerland



distinct clustering, much variability explained by PCA

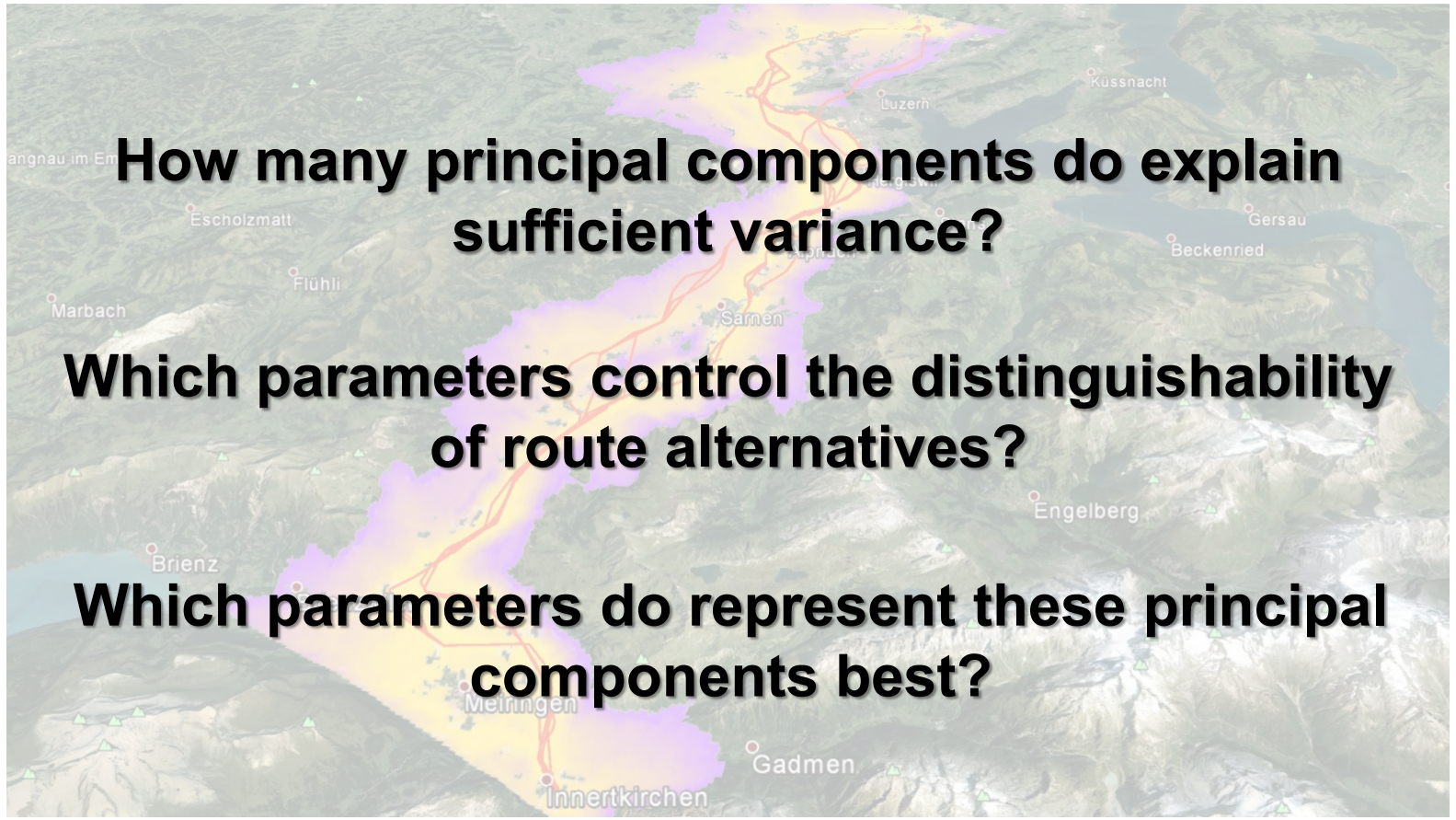
Austria



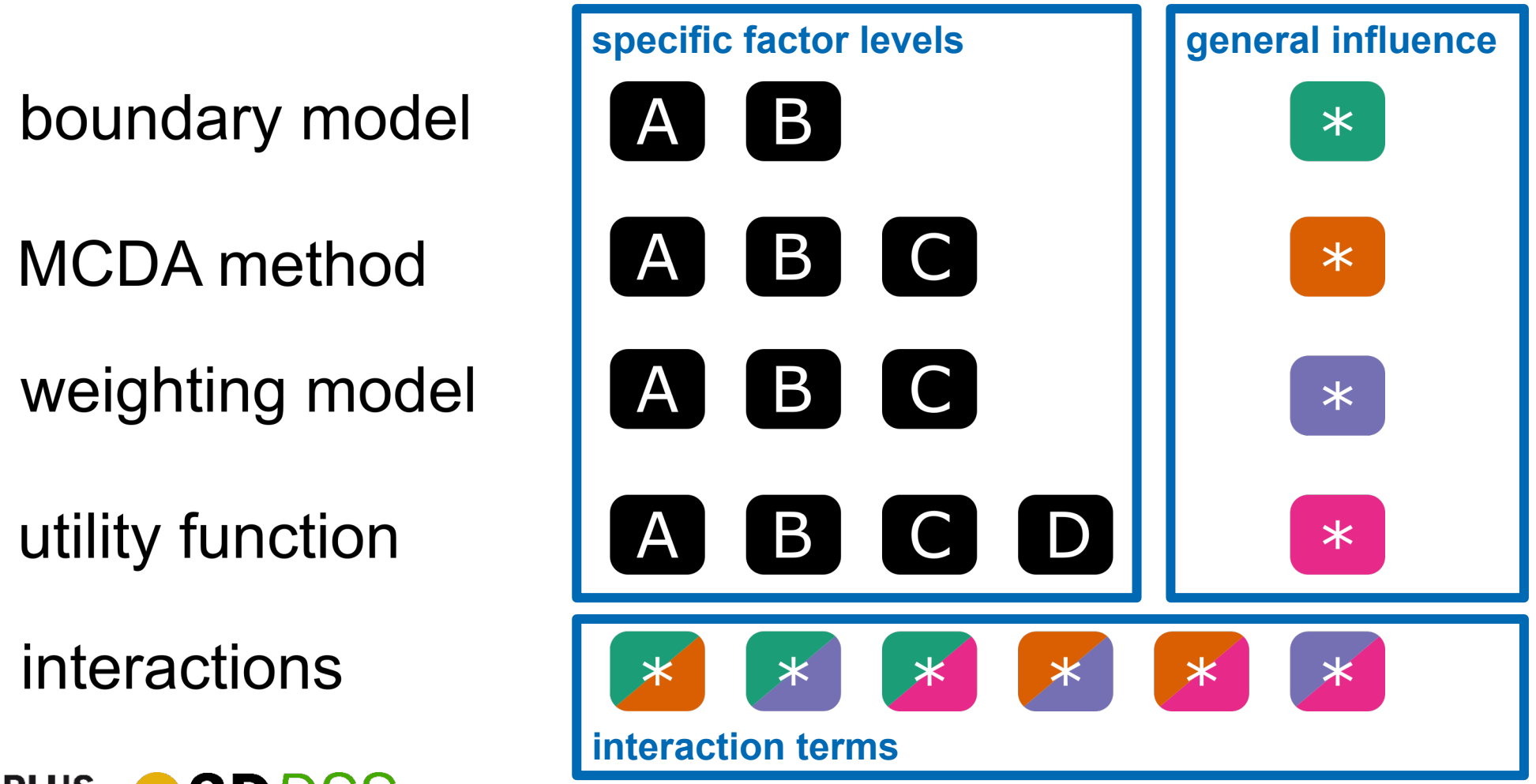
less distinct clustering, less variability explained by PCA

Determining the effect of the input parameters

Remember our question! …and put it into measurable metrics

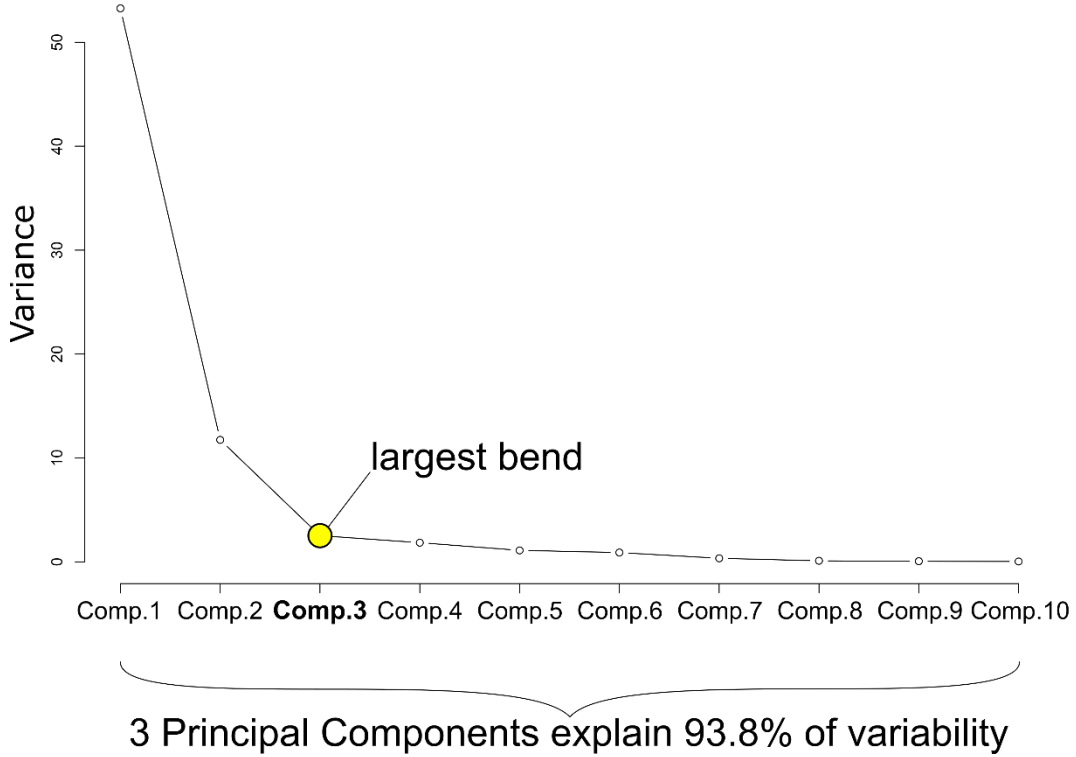


5) Reduce the complexity of the 72 parameter combinations to 22 factor levels used later as regressors in the MANOVA

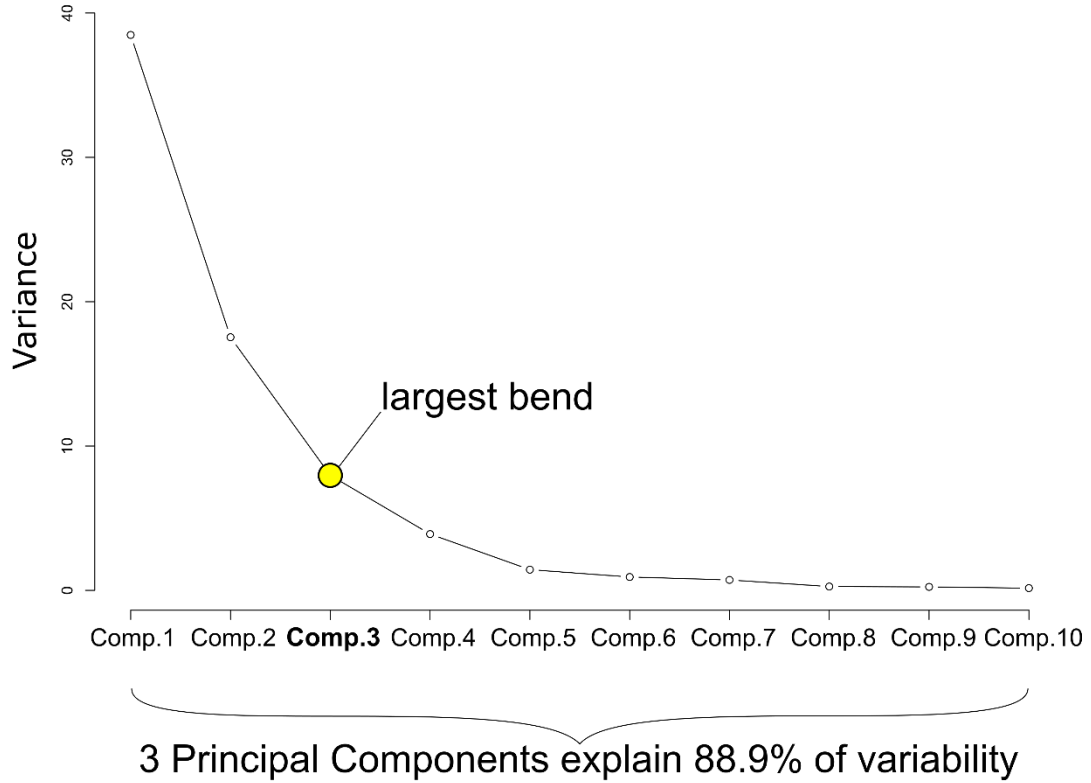


6) Conduct a PCA and determine the number of principal components and their factor loadings used later as explanatory variables in the MANOVA

Switzerland



Austria



7) Run the MANOVA and evaluate the Pillai's traces

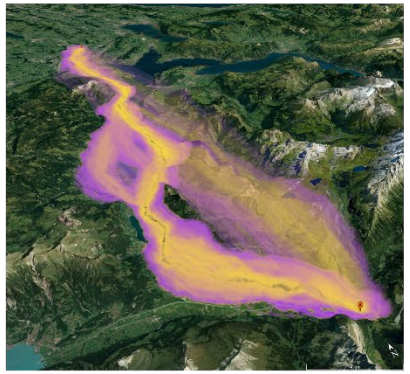
Switzerland			Austria			Averaged Results		
Regressor	Pillai	Sig.	Regressor	Pillai	Sig.	Rank	Regressor	Pillai
β_2	.967	p <.001	β_2	.993	p <.001	1	β_2	.980
β_{13}	.925	p <.001	β_{13}	.985	p <.001	2	β_{13}	.955
β_3	.915	p <.001	β_3	.977	p <.001	3	β_3	.946
β_5	.825	p <.001	β_5	.962	p <.001	4	β_5	.894
β_{10}	.716	p <.001	β_{12}	.929	p <.001	5	β_6	.817
β_6	.712	p <.001	β_1	.924	p <.001	6	β_{10}	.810
β_1	.676	p <.001	β_6	.921	p <.001	7	β_1	.800
β_{12}	.662	p <.001	β_{10}	.904	p <.001	8	β_{12}	.795
β_{14}	.494	p <.001	β_{14}	.825	p <.001	9	β_{14}	.660
β_7	.484	p <.001	β_9	.746	p <.001	10	β_9	.497
β_8	.263	p <.001	β_7	.470	p <.001	11	β_7	.477
β_9	.247	p <.01	β_{11}	.425	p <.001	12	β_{11}	.282
β_{11}	.140	p <.05	β_{15}	.220	p <.01	13	β_8	.223
			β_8	.182	p <.05	14	β_{15}	.220

Conclusions

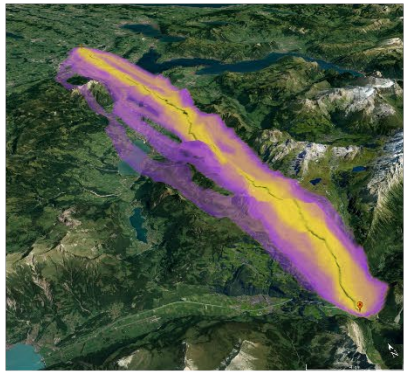
Comparison between both study regions

Switzerland

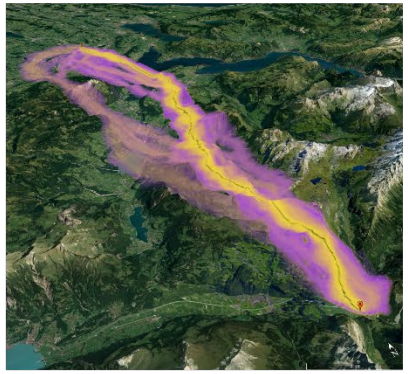
Cluster 1



Cluster 2



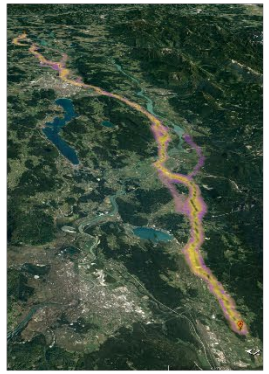
Cluster 3



Suitability

Austria

Cluster 1

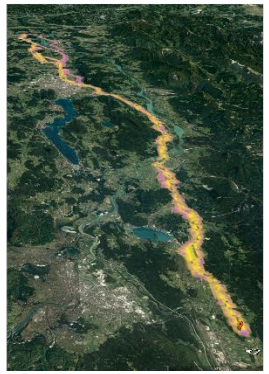


Cluster 2

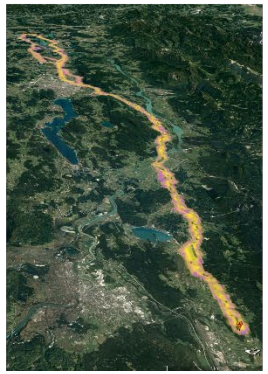
Cluster 3

Cluster 4

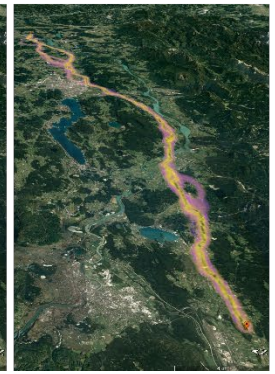
Cluster 5



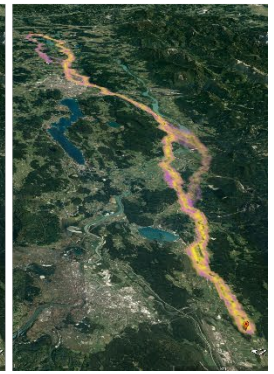
Cluster 6



Cluster 7



Cluster 8



Which parameters matter most?

Concerns!!!

boundary model ★★★★

MCDA method ★★★

weighting model ★★

utility function ★

interactions

How the results help to simplify the decision model

- Reduce complexity
- Helps stakeholders and decision-makers to discuss and negotiate about the essential factors
- Interesting: The conservative MCDA method **Simple Additive Weighting** achieved best results! So its advantages should be clearly communicated.

How the results help to improve the decision model

- Different assessments should lead to distinct alternatives
- Increase the effect of factors that do only slightly explain variability by multiplying the weight (w) with the inverse of the Pillai's trace (p_i).

$$\forall\, x \geq 0 \rightarrow h_{1,i}\left(w_i, p_i\right) = \frac{\sqrt[7]{w_i}}{i \cdot p_i}$$

$$\forall\, x < 0 \rightarrow h_{1,i}\left(w_i, p_i\right) = \frac{1}{\sqrt{w_i} \cdot i \cdot p_i}$$

Future Work

Future work

- Implement a solution to model earth cables.
- Investigate the effects of the decision model on flat regions.
- Investigate, whether different approaches from game theory or linear optimization lead to more realistic results.
- Investigate the effect of the proposed normalization formula.

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