



# Finding the optimal route for new power transmission lines with a 3D Decision Support System

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RGI Webinar

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# Swissgrid – the most important tasks



## Swissgrid...

- ① operates the transmission grid
- ② is responsible for the highest grid level
- ③ maintains the substations and lines
- ④ plans and develops the entire transmission grid
- ⑤ ensures the stability of the grid
- ⑥ works closely together with European transmission grid operators

# Bottlenecks in the transmission grid





# Drivers for grid expansion in Switzerland

## New large power plants

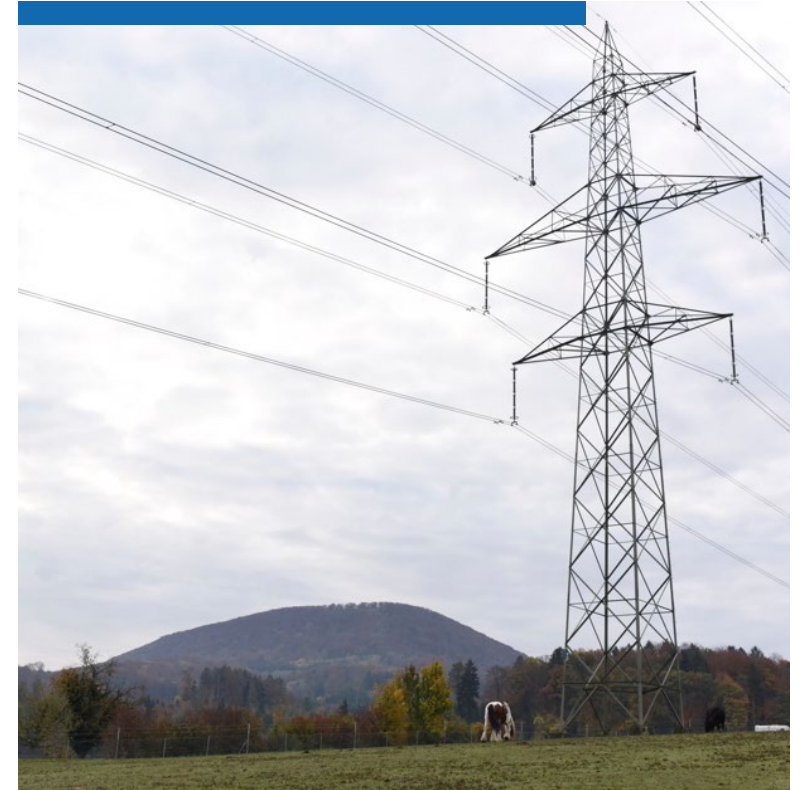
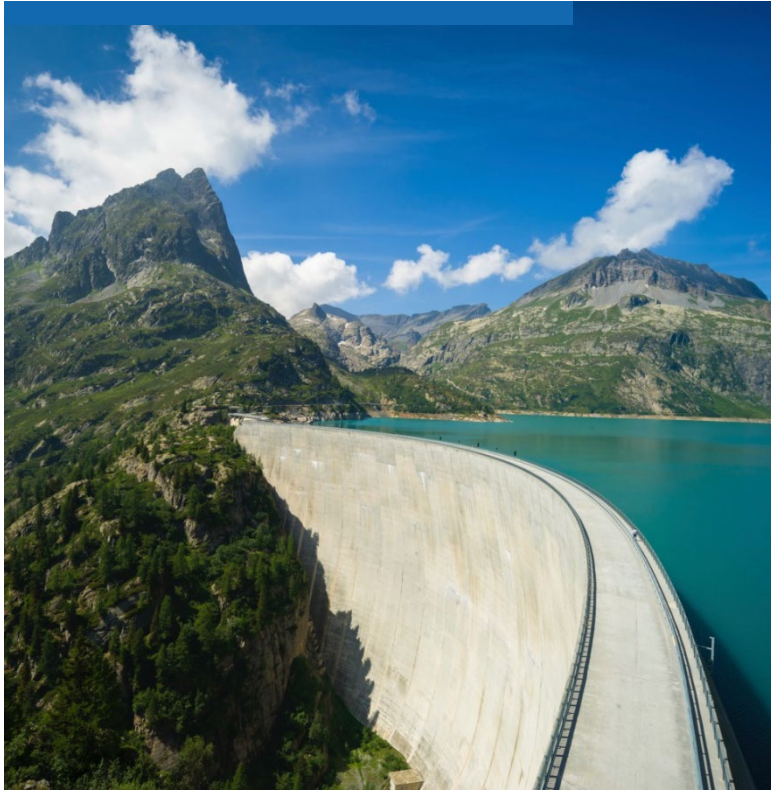
For example, construction of a new pumped storage power plant

## International network

Increasing international energy exchange can lead to grid overload

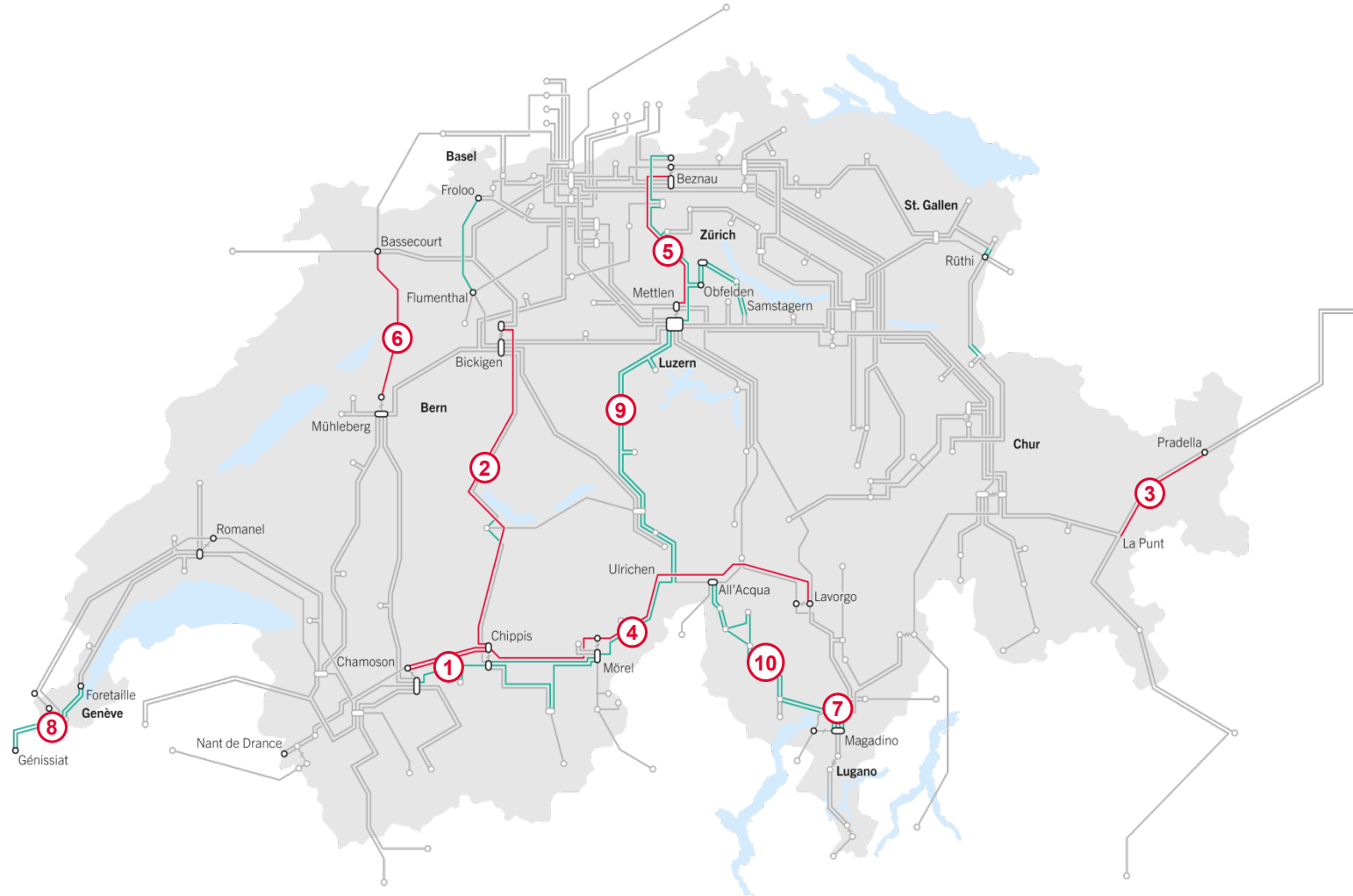
## Supply of downstream grids

New connection requests can lead to congestion





# The grid has to be modernized and expanded



- By 2025, around CHF 2.5 billion will be invested in expanding and maintaining the grid

- ① Chamoson – Chippis
- ② Chippis – Bickigen
- ③ Pradella – La Punt
- ④ Chippis – Lavorgo
- ⑤ Beznau – Mettlen
- ⑥ Bassecourt – Mühleberg
- ⑦ Magadino
- ⑧ Génissiat – Foretaille
- ⑨ Mettlen – Ulrichen
- ⑩ All'Acqua – Maggia Valley – Magadino

- existing
- 380 kV
- 220 kV
- Switching substations
- ⊗ Switching substations with transformers



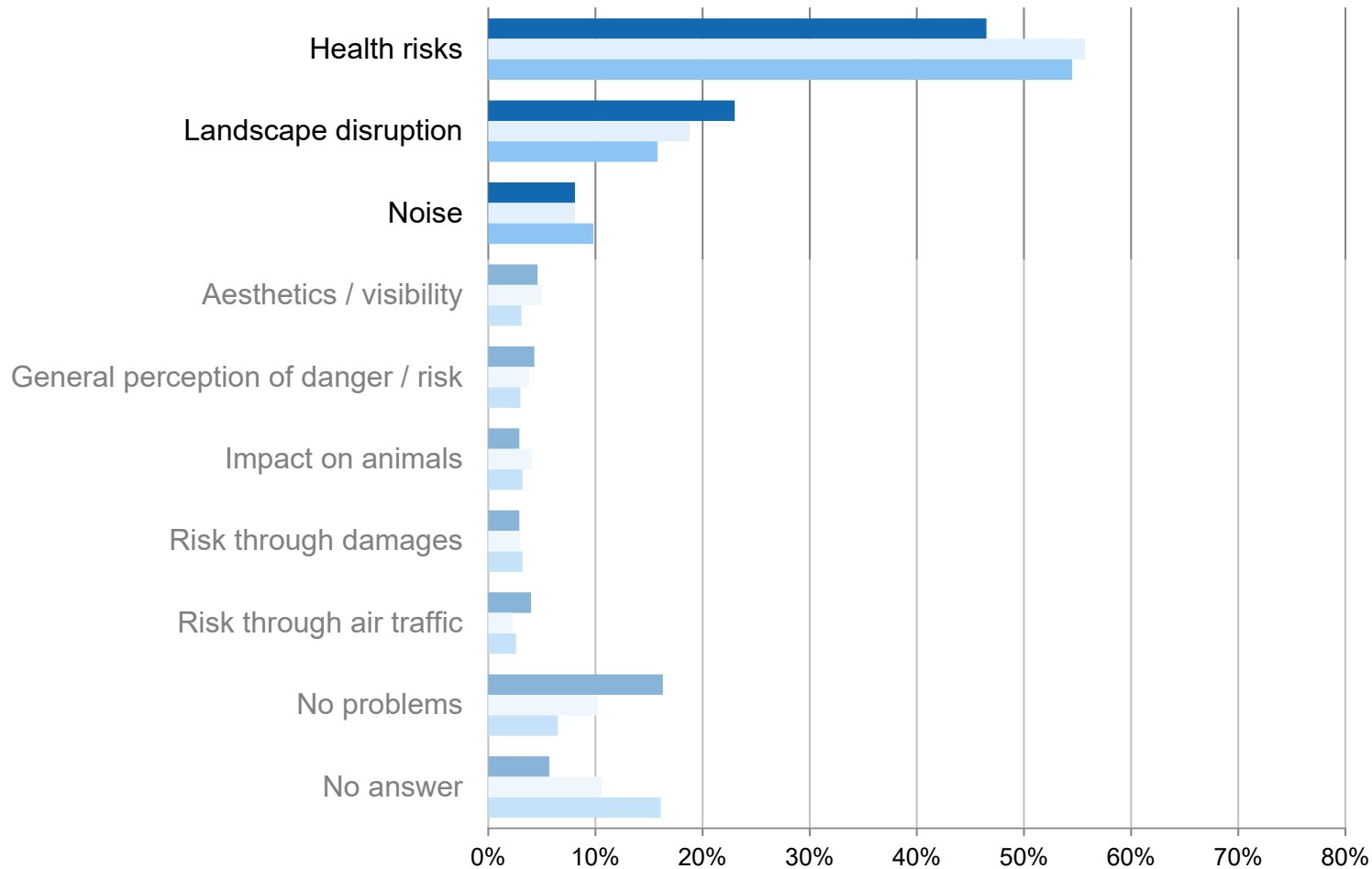


# Delays in power line projects

Why?



# Main problems of overhead lines (OHL)



- Overhead lines (OHL) are perceived as **disturbing**
- Health risks** are clearly the main problem, followed by **landscape disruption** and **noise**

■ OHL visible  
 ■ OHL close to home  
 ■ No OHL close

**What are the main problems of high voltage lines?**

# Main objectives of the project



- Find the solution which has the **highest acceptance** among all stakeholders
- **Multi-criteria decision analysis (MCDA)** allows to take the interests of different stakeholders in the decision process into consideration
- Increase acceptance by realistic **3D visualizations**

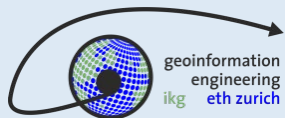


# Project team



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Bundesamt für Energie BFE  
Swiss Federal Office of Energy SFOE



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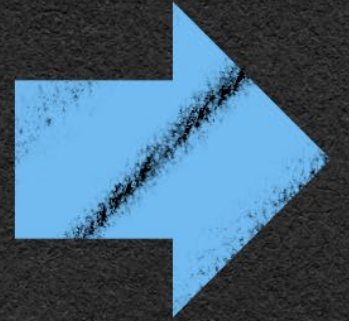
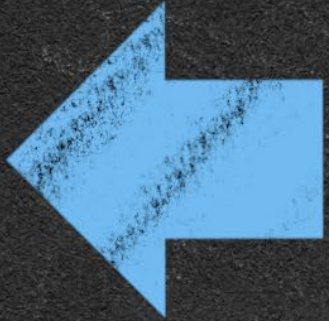
2018–2020:



2014–2017:



choice





How disruptive?

How risky?

How expensive?





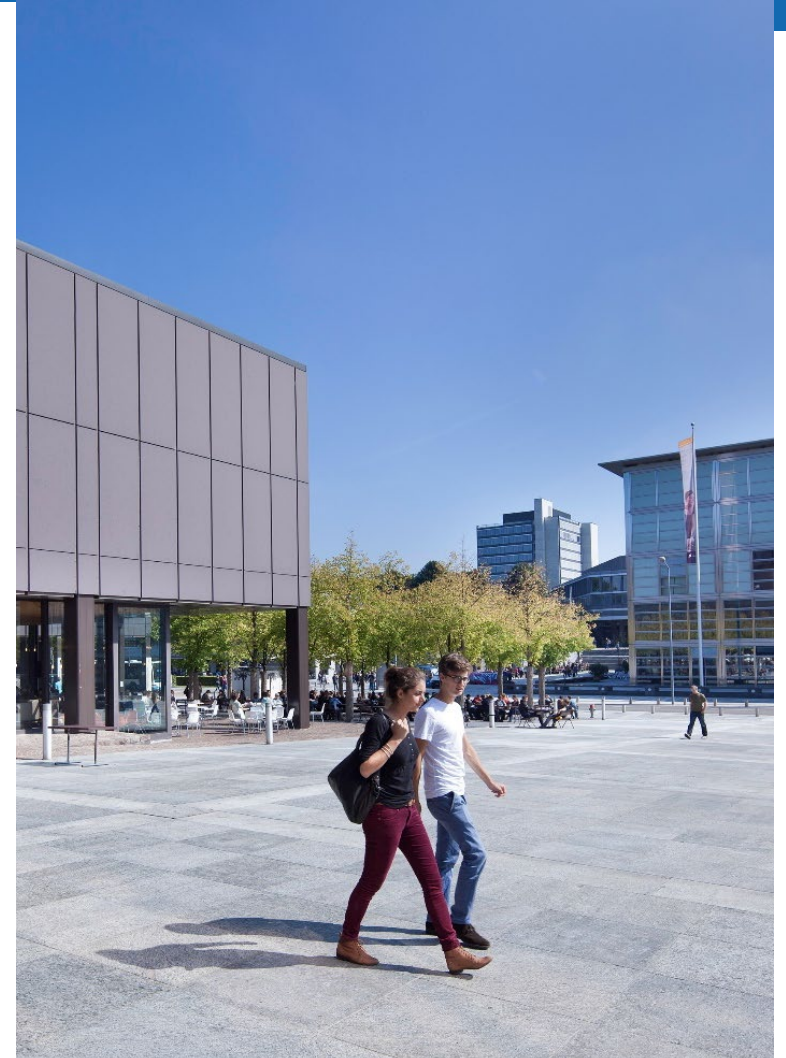




technical feasibility



environment & landscape



urban planning



# Multi-Criteria Decision Analysis

# Main questions



Main questions : How can...

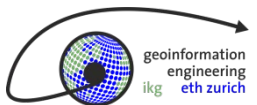
we achieve realistic  
modeling?



Main questions : How can...  
overhead lines be combined with  
earth cables?



# The 3D DSS project





DSS = Decision

Support System



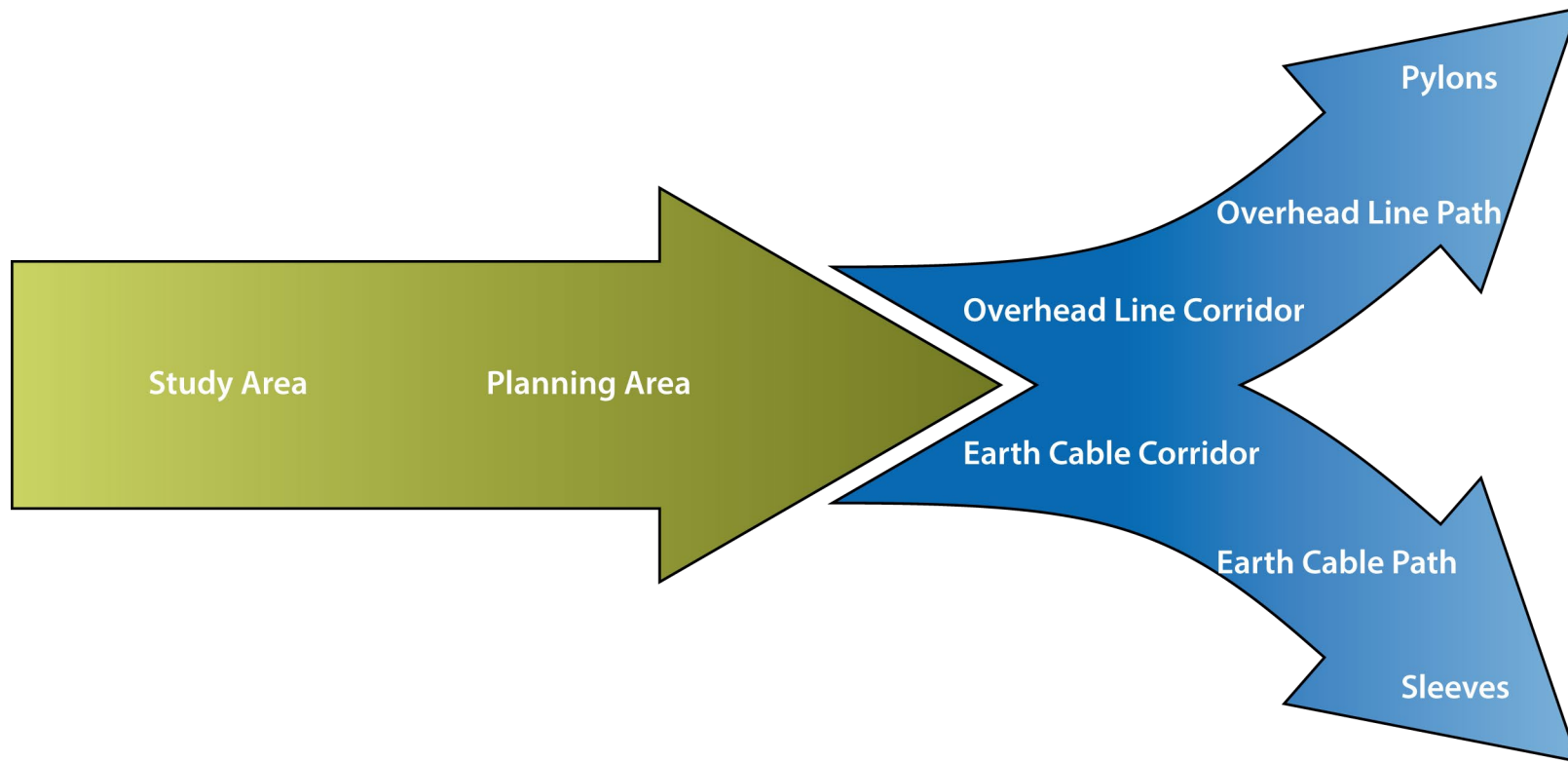


3ddss.ethz.ch



@3ddss\_eth

# The 3D DSS project





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

MCDAA  $\infty$  LCP

Multi-Criteria  
Decision Analysis

Least  
Cost Path



# Key Concept # 1

costs = laws, acts,  
protected areas

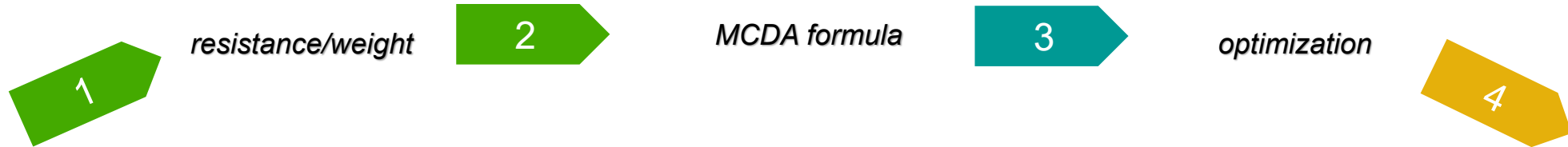


# Key Concept # 2

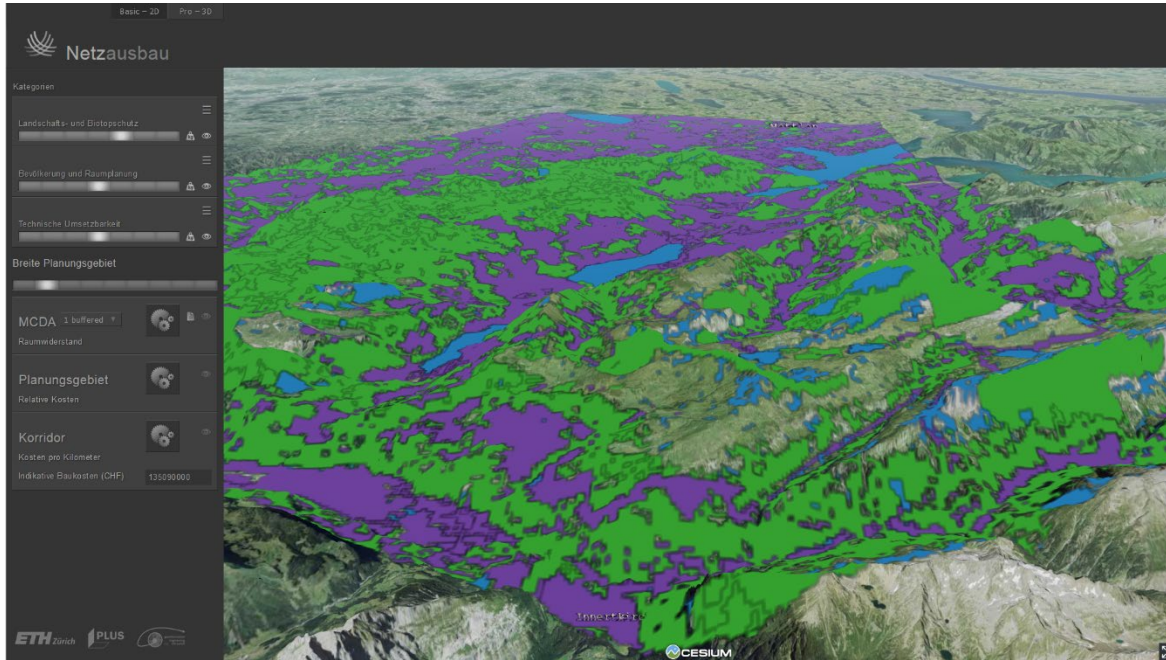
low costs =  
high suitability



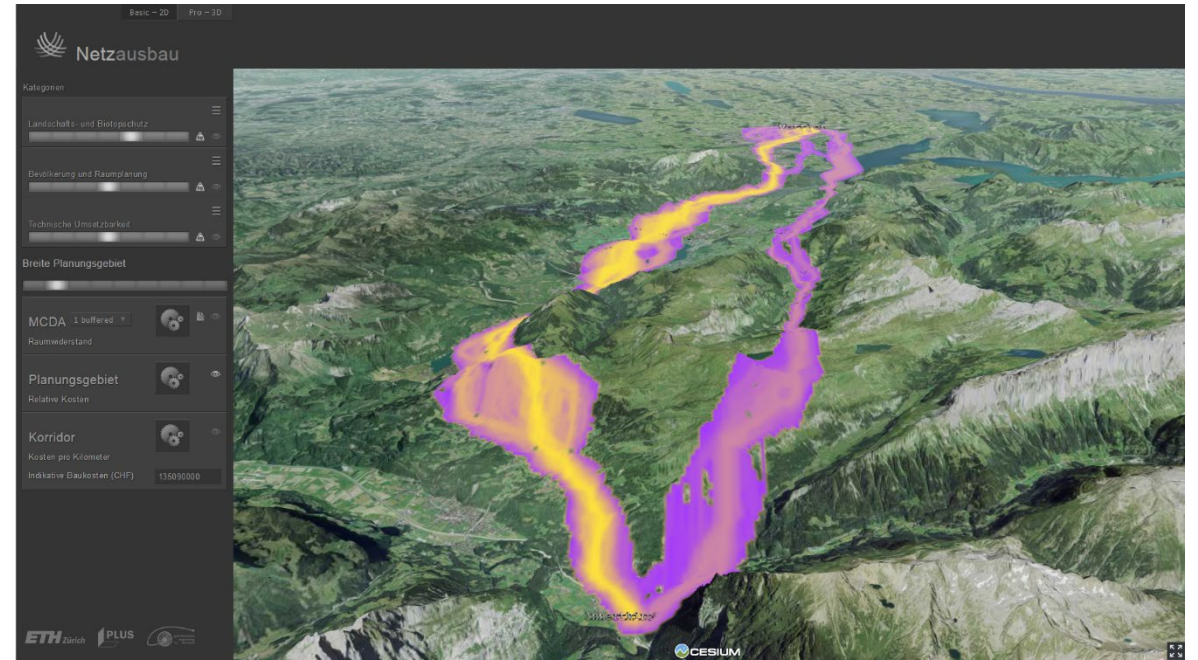
# How the most feasible corridor is calculated



geodata



corridor

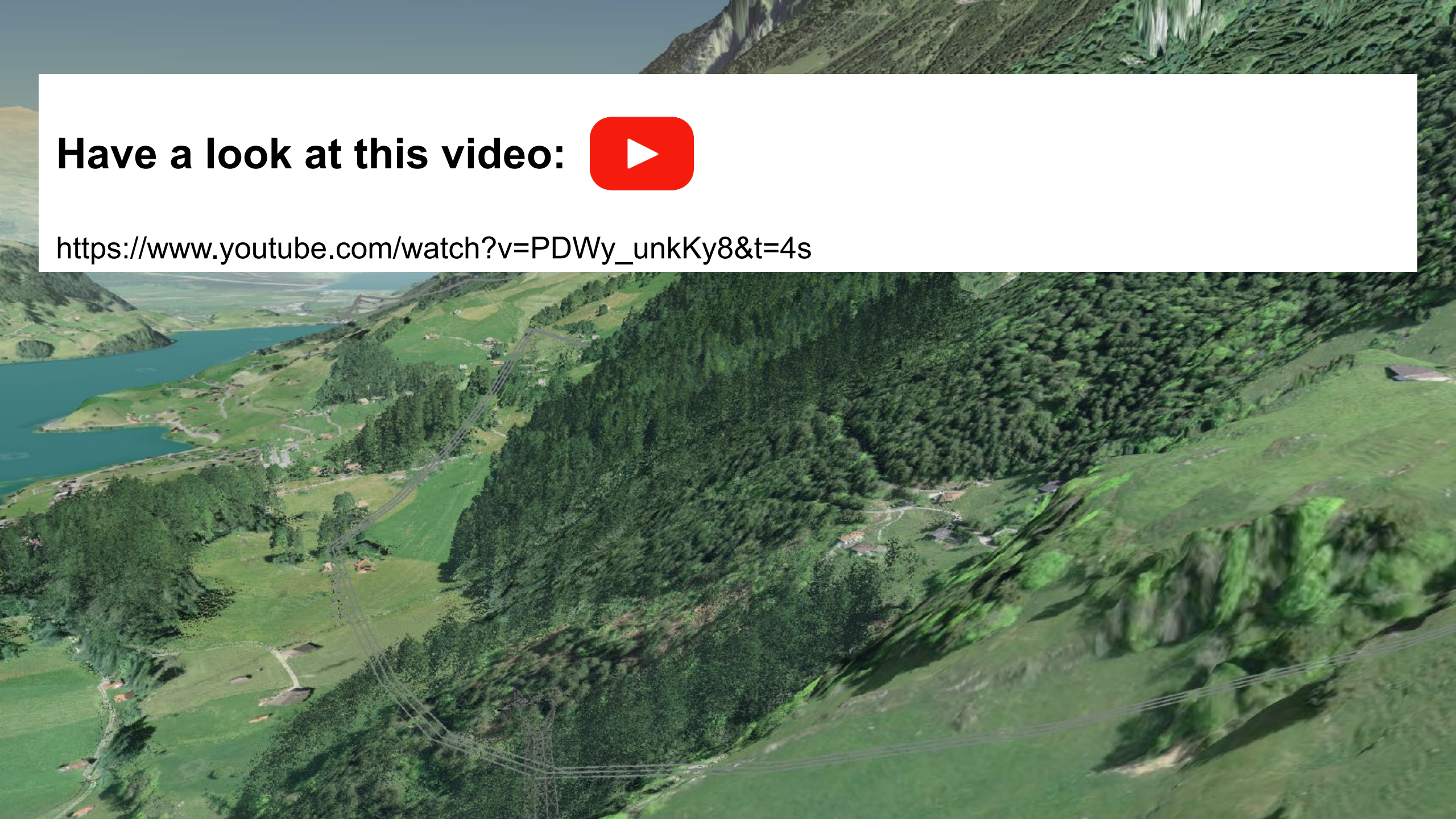




**Have a look at this video:**

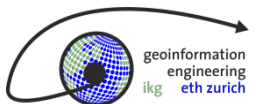


[https://www.youtube.com/watch?v=PDWy\\_unkKy8&t=4s](https://www.youtube.com/watch?v=PDWy_unkKy8&t=4s)





## Current results and work

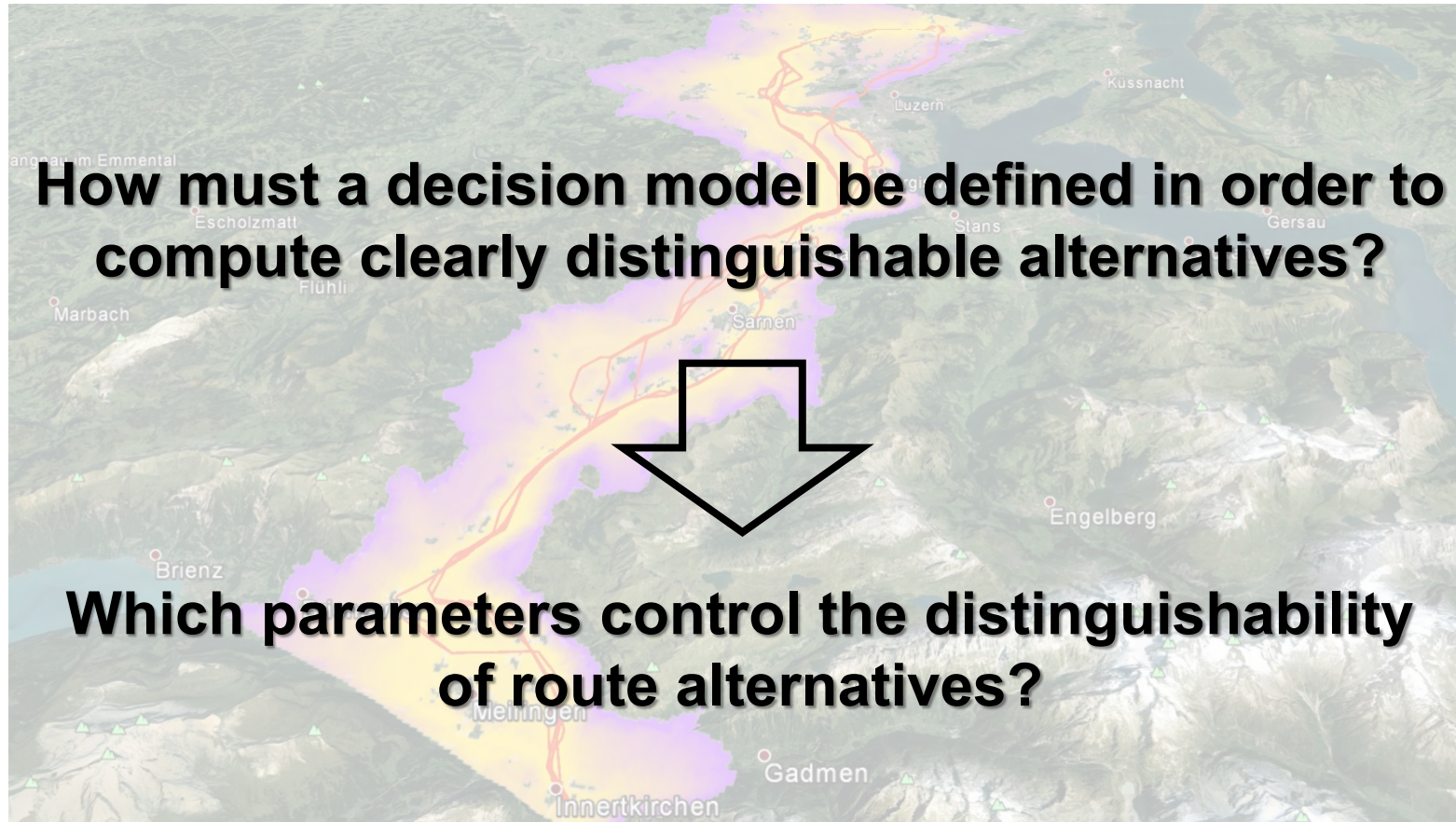


# The decision model





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



# Which parameters matter most?

## Concerns!!!

boundary model



MCDA method



weighting model



utility function



interactions





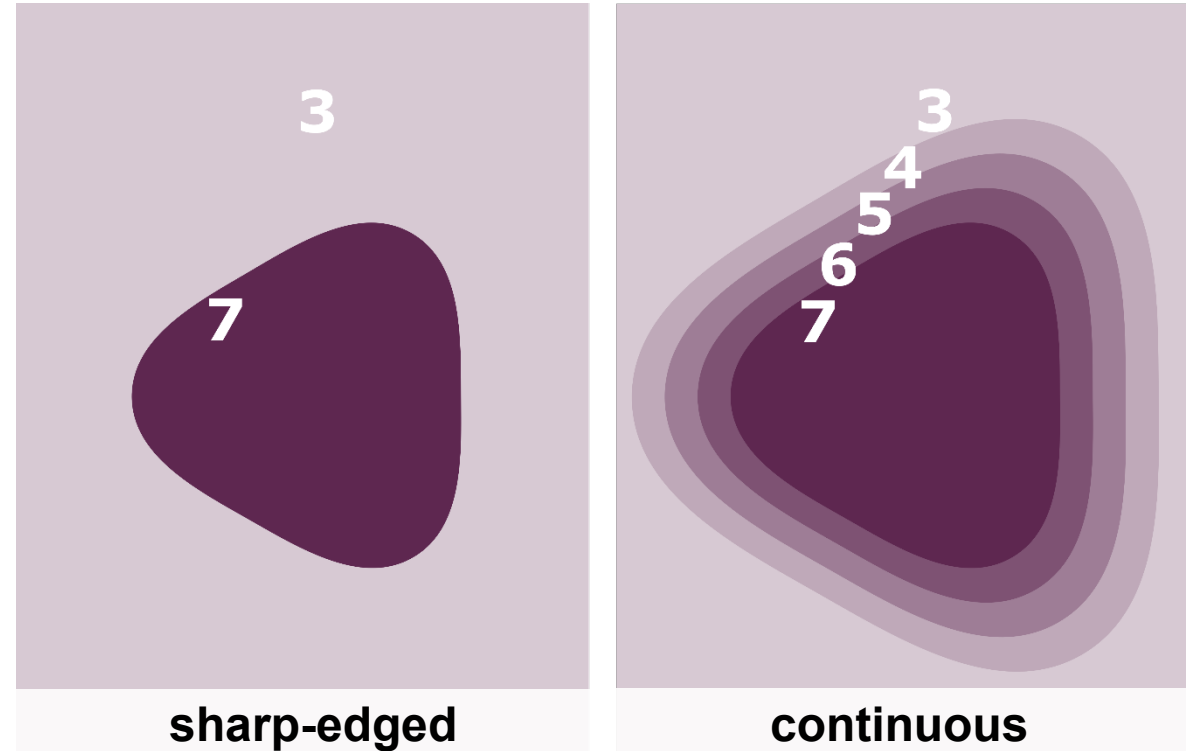
Key Result #1

our world is

CONTINUOUS!

# Recent results we use for improving the decision model

- The continuous boundary model achieved best results and reflects real conditions best





Key Result #2

KISS



keep it short and simple!



# Recent results we use for improving the decision model

- The continuous boundary model achieved best results and reflects real conditions best
- Simple Additive Weighting achieved best results and is easy to understand



Simple Additive Weighting

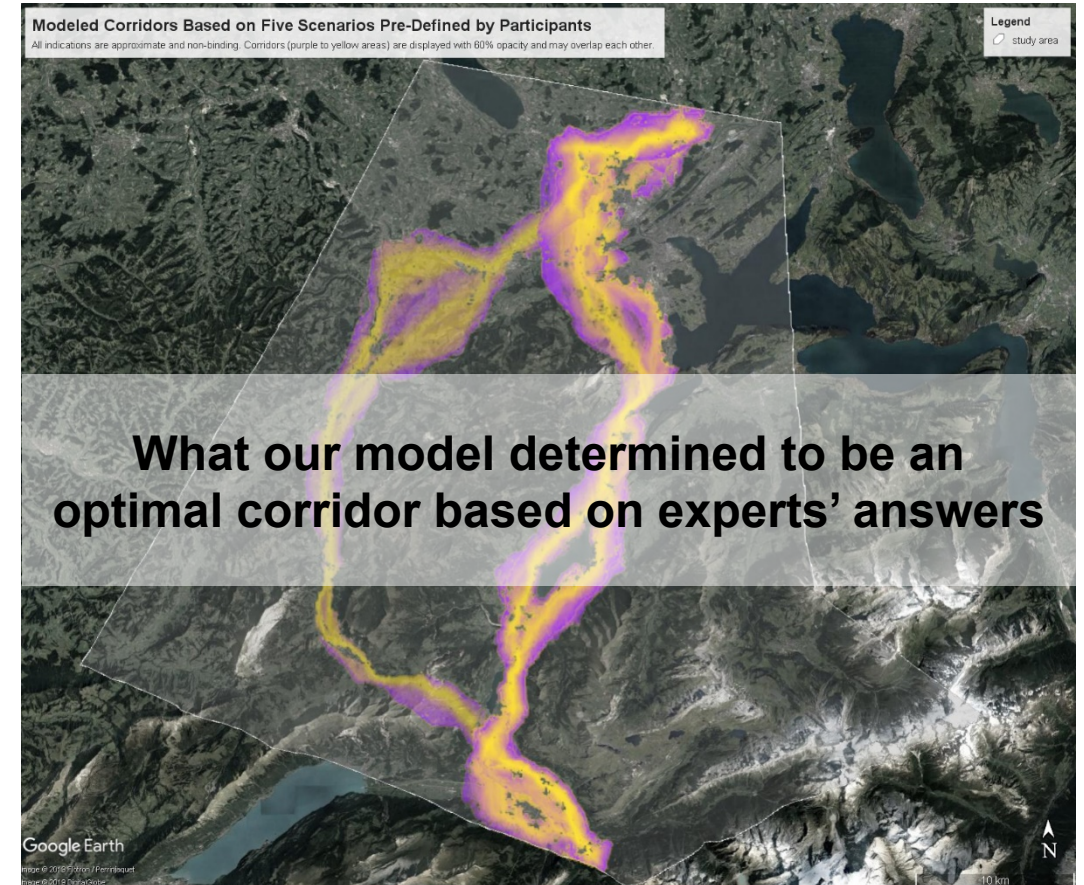
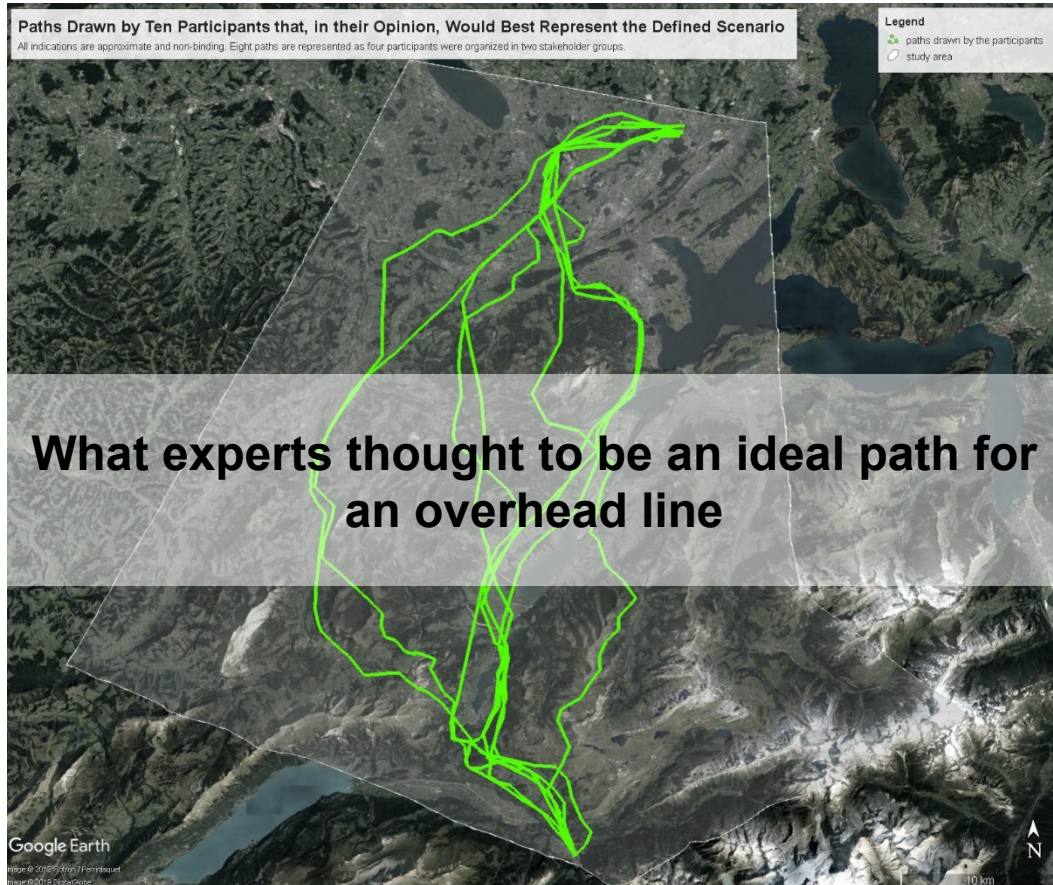
# Recent results we use for improving the decision model

- The continuous boundary model achieved best results and reflects real conditions best
- Simple Additive Weighting achieved best results and is easy to understand
- The utility function with linear increase achieved best results (perhaps because users expect linearity)





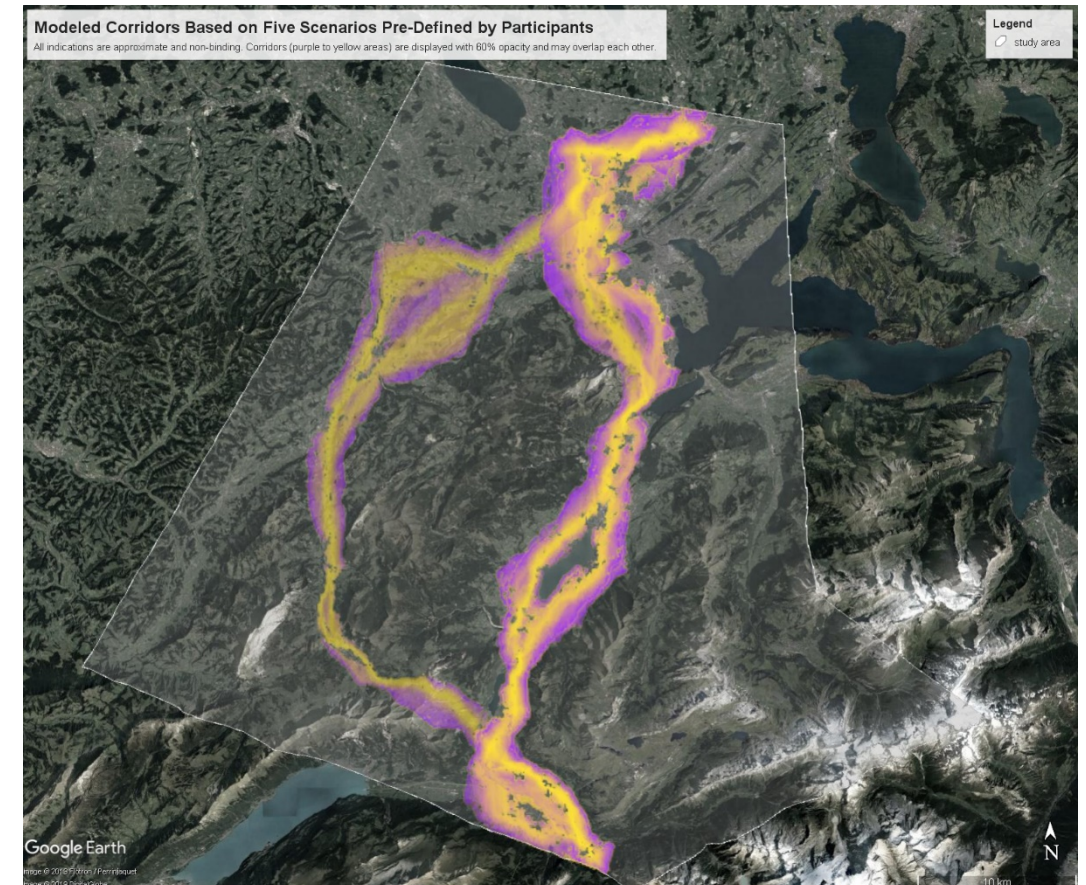
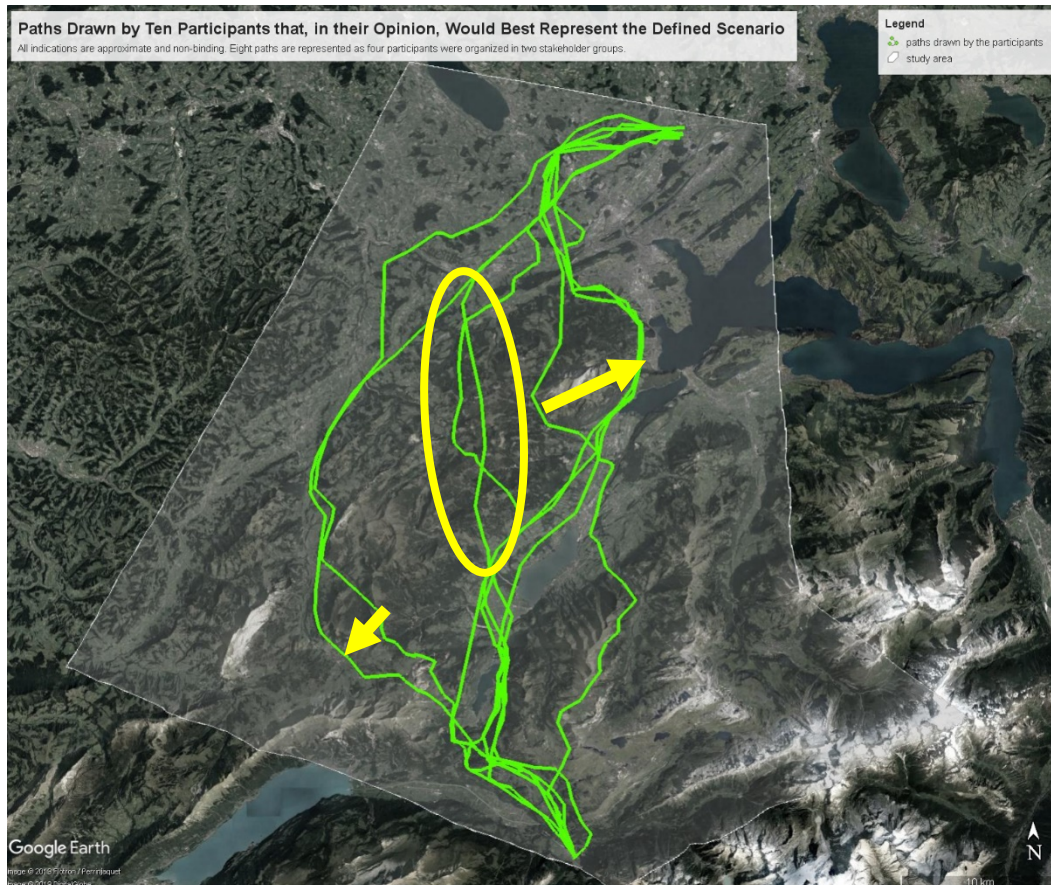
# Study conducted with 10 planning experts (2019)





# Study conducted with 10 planning experts (2019)

## Experts agreed reconsidering critical sections of proposed lines

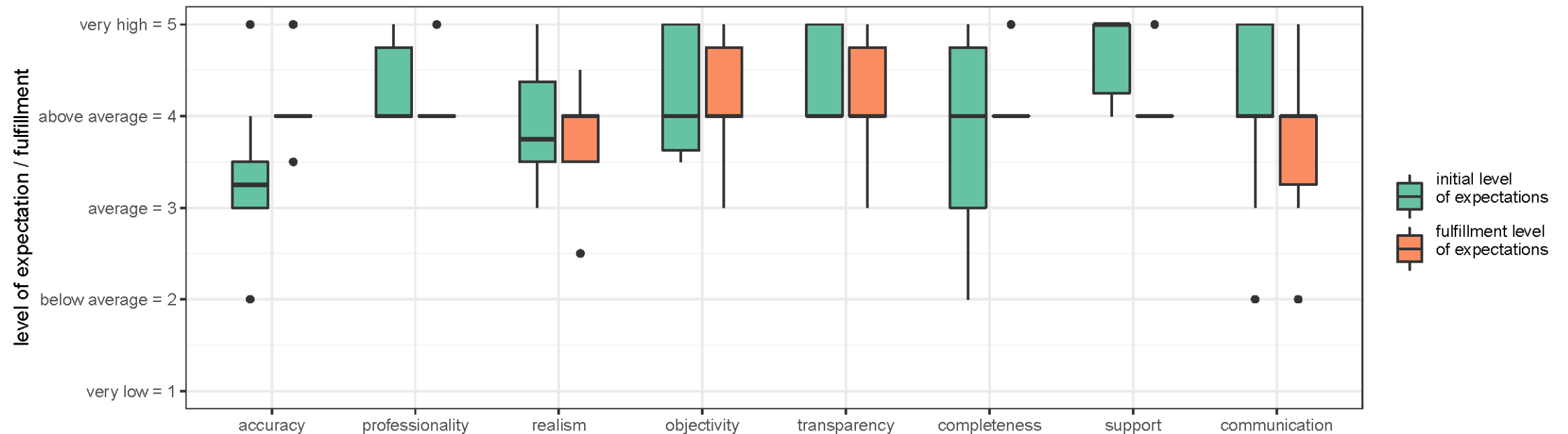




# Study conducted with 10 planning experts (2019)

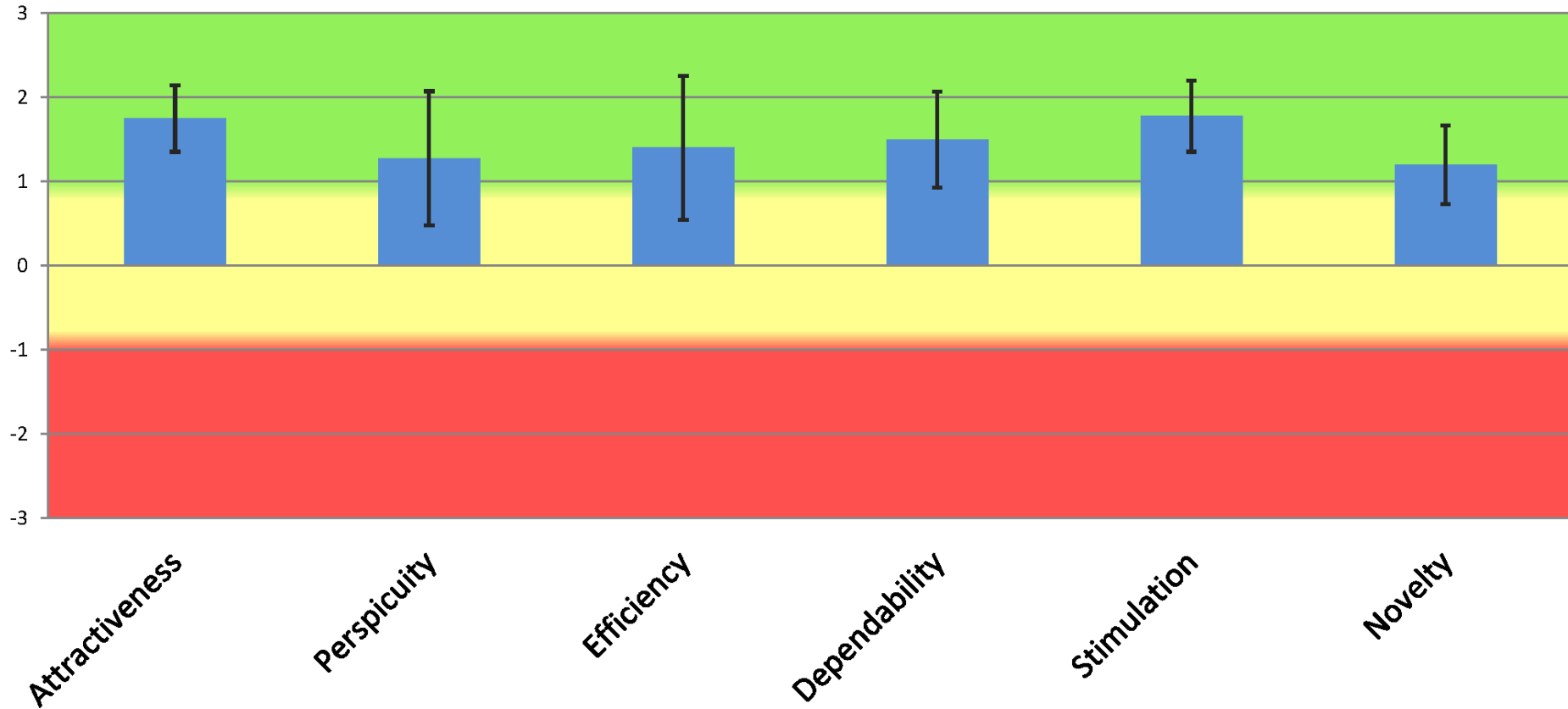
## Our 3D DSS fulfills experts' expectations well

Participants' expectations to the 3D DSS: initial vs. fulfilled  
 n = 10 participants | boxes with an IQR of zero are shown as line



# Study conducted with 10 planning experts (2019)

## Our 3D DSS fulfills experts' expectations well

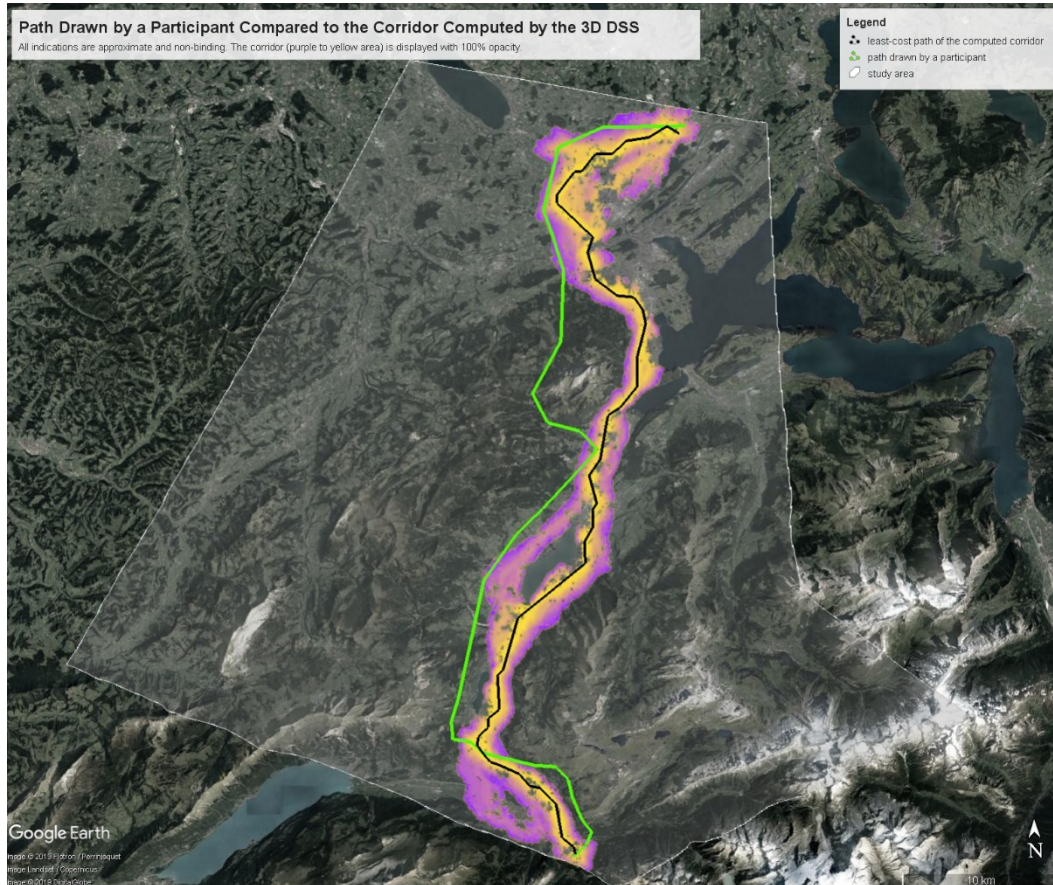


User Experience Questionnaire

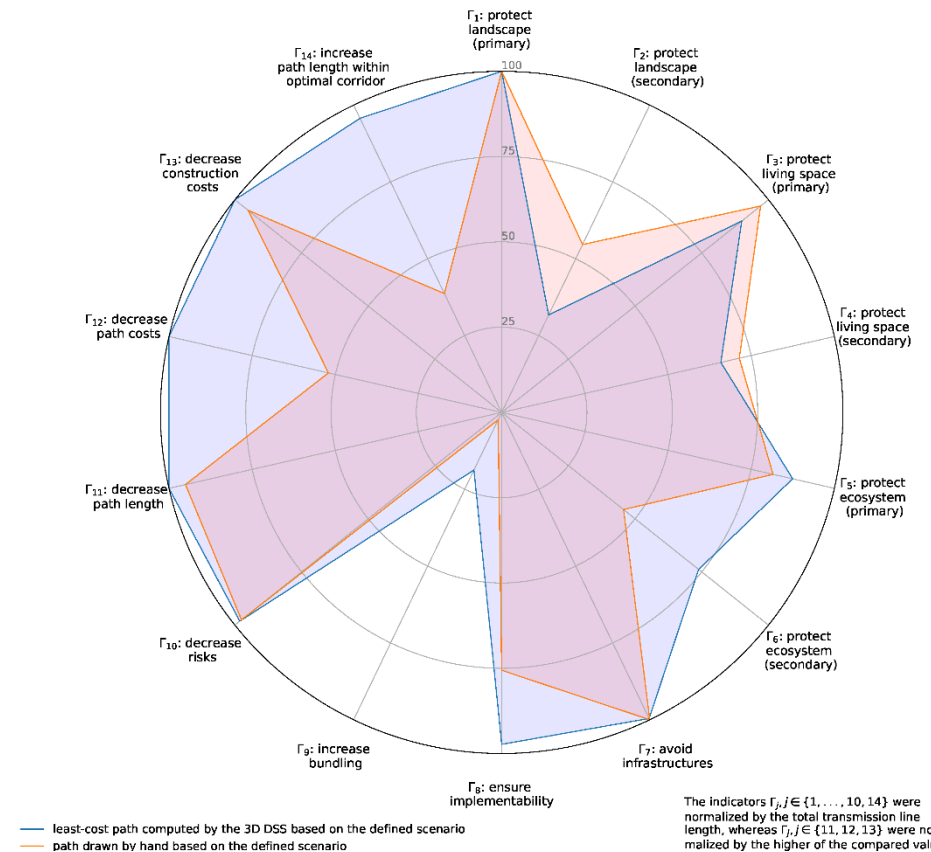


# Study conducted with 10 planning experts (2019)

## Graphical outputs that support decision-making

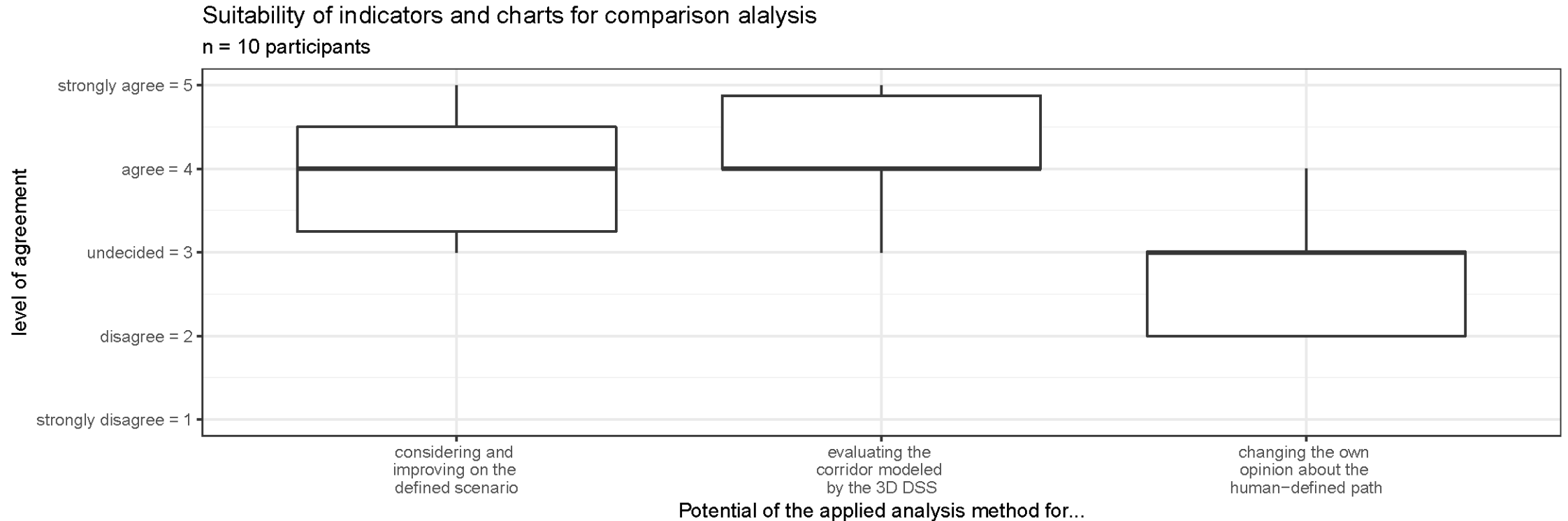


Indicators  $\Gamma_j$  compared between participant A and the 3D DSS solution based on the scenario *Swissgrid*



# Study conducted with 10 planning experts (2019)

## Graphical outputs are helpful, however, their effect is limited





Next steps

combine overhead lines  
with earth cables





# Areas of high resistance: Where are they located?



Firmendb.de





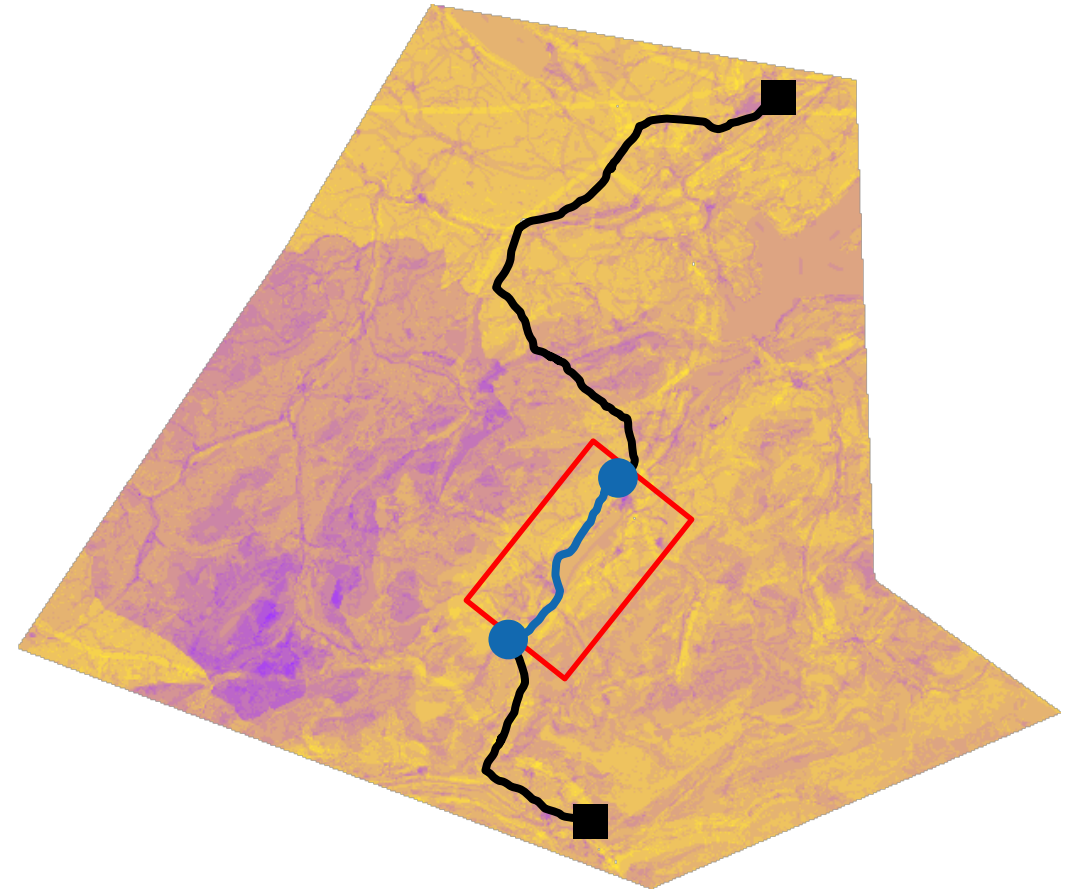
# Main question: Where should transition structures be built?



# Compute a combined corridor (earth cable + overhead line)

## Novel approach

- Determine areas of a high stress level in which an earth cable would be relieving.
- At the borders of these areas, determine appropriate places for a transition building.
- Compute the optimal earth cable path between the two transition buildings.
- Between the transition buildings and the start and end point, compute an overhead line.





# Impressum

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