ETH zürich

How to support decision-making when planning power transmission lines

04/09/2019
Frontiers in Energy Research @Energy Science Center ETH Zurich

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geoinformation engineering ikg eth zurich

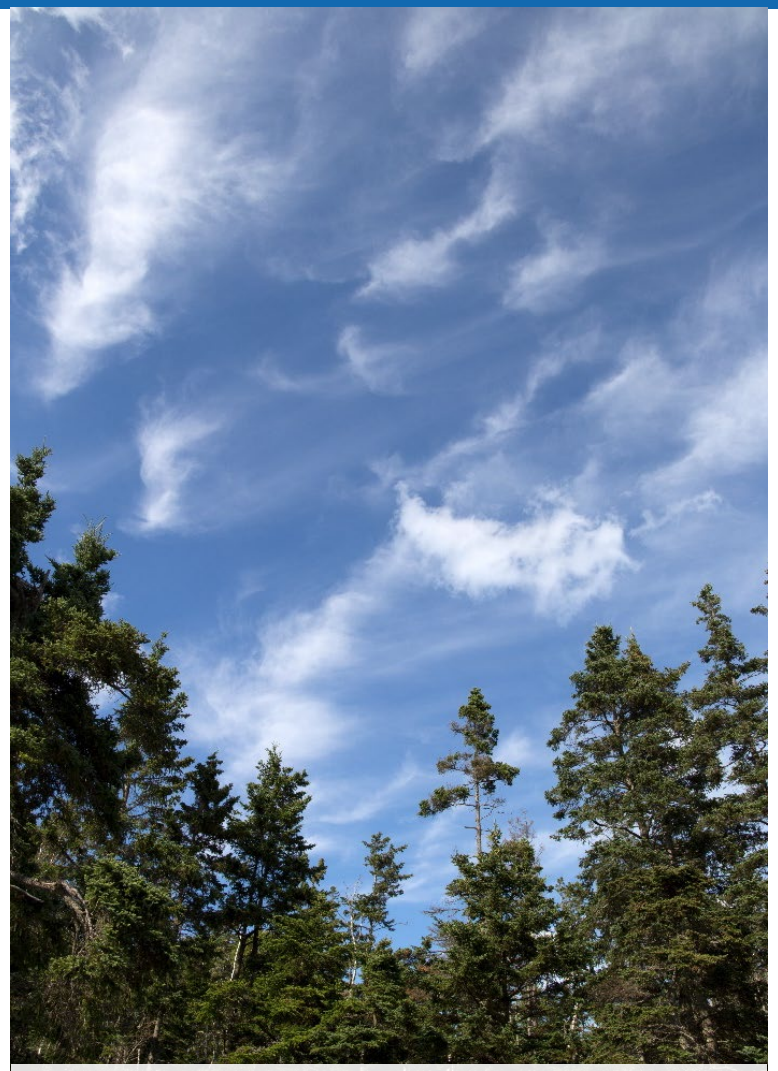
PLUS

3DDSS 3d decision support system

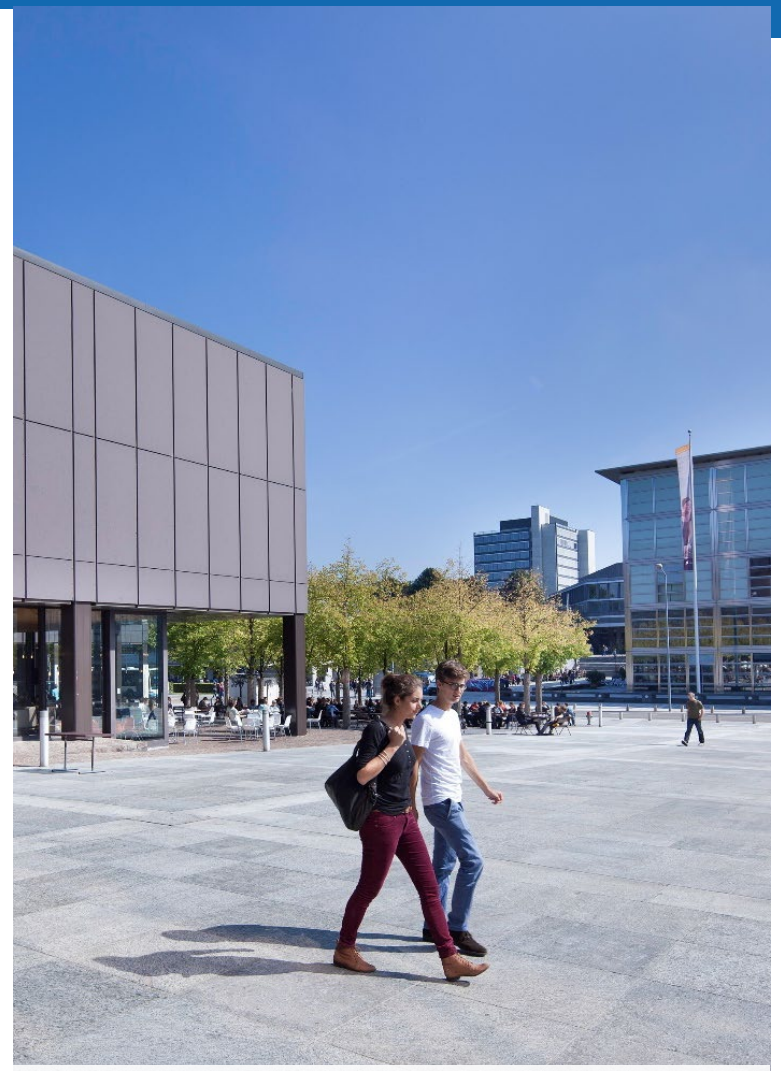

choice


Mettlen
Littau
Luzern
Kriens
Entlebuch
Sarneraatal
Entlebuch
BLN
Engelbergertal
Sarnen
Giswil
Melchtal
Engelberg
Innertkirchen

technical feasibility



environment & landscape

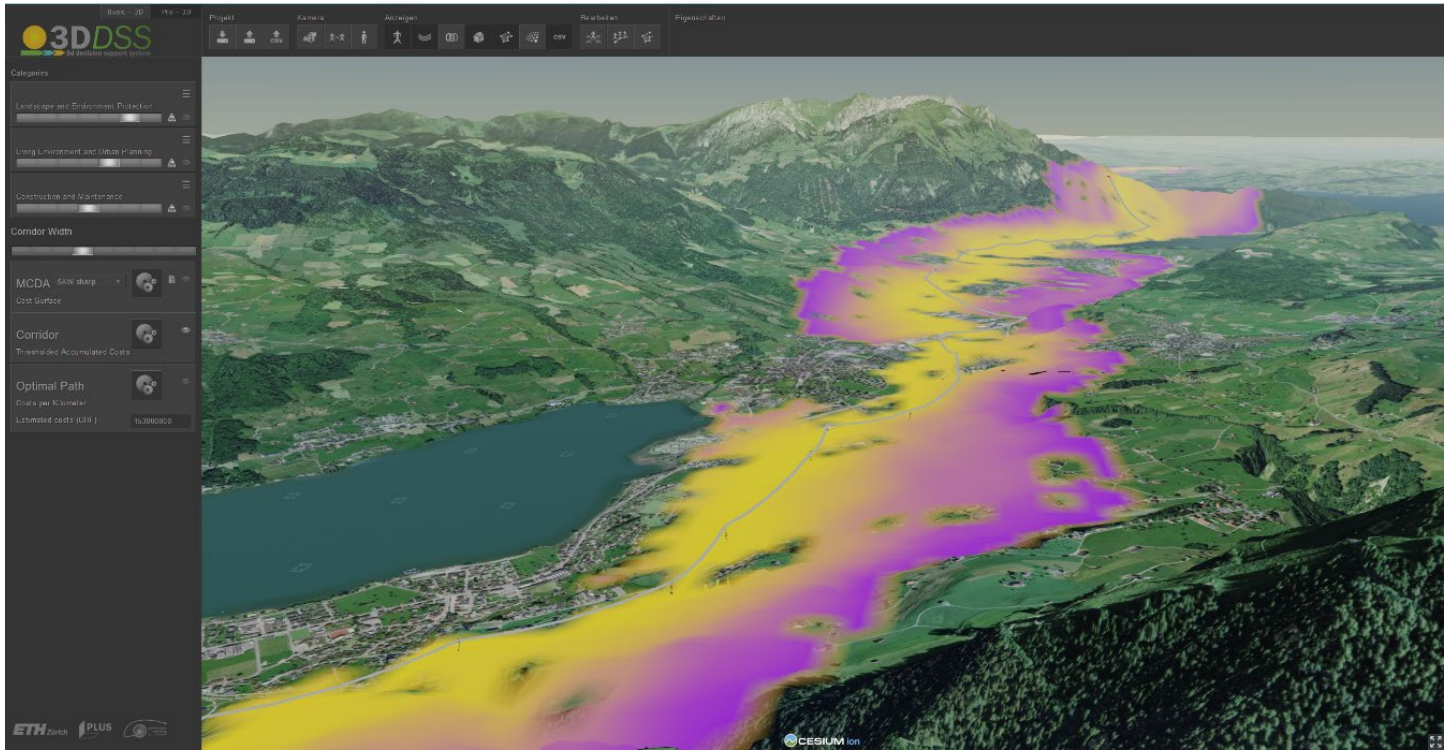


urban planning


Multi-Criteria
Decision Analysis

Content

1. New power transmission lines: a controversial topic
2. The 3D DSS project
3. How our 3D DSS works
4. Recent findings
5. Next steps

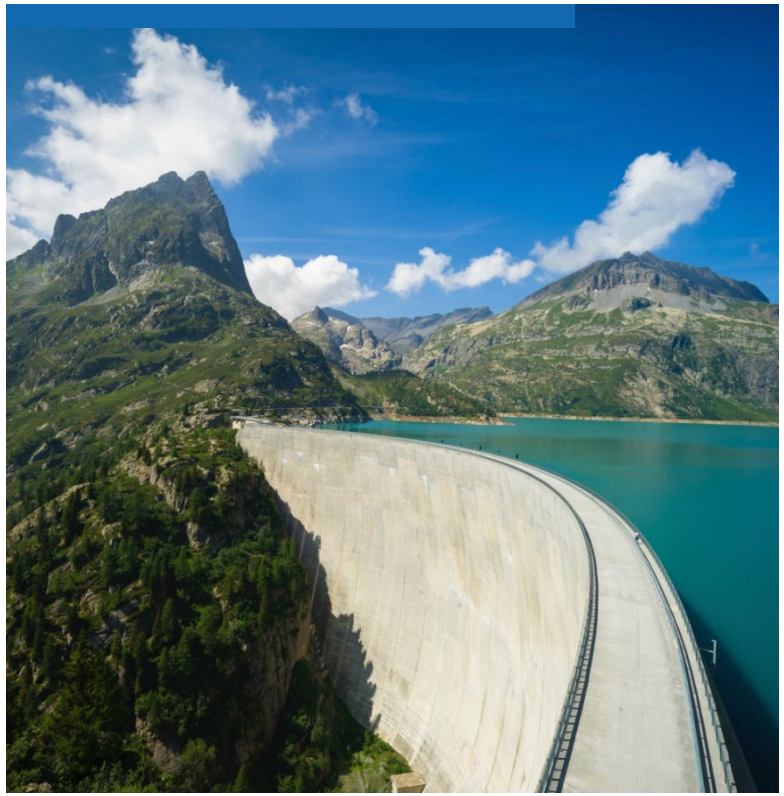


New power transmission lines: a controversial topic

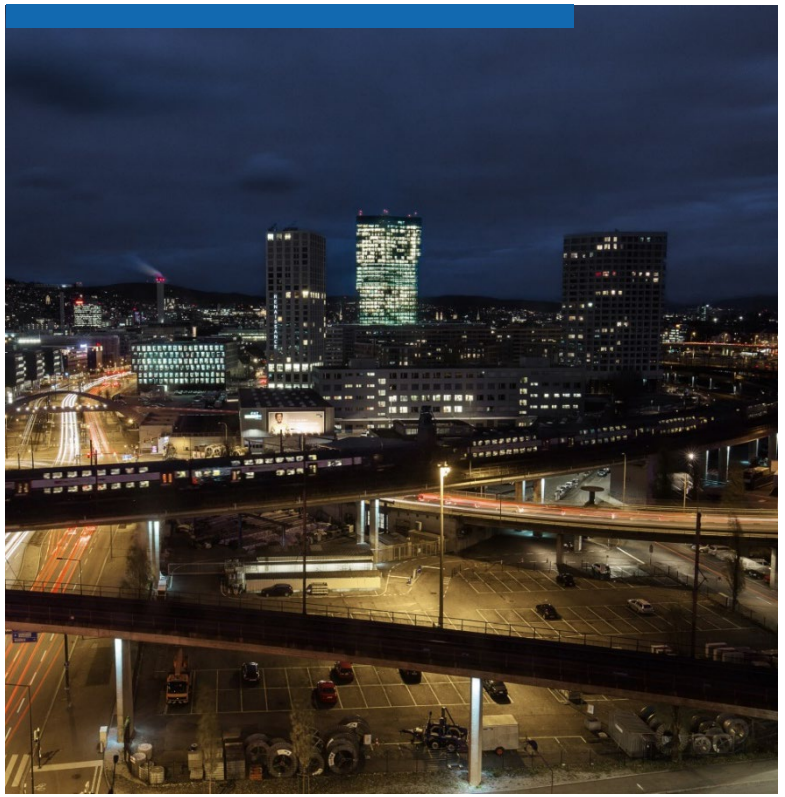
We need electricity for our daily life

Trends in grid expansion due to growth and the energy transition

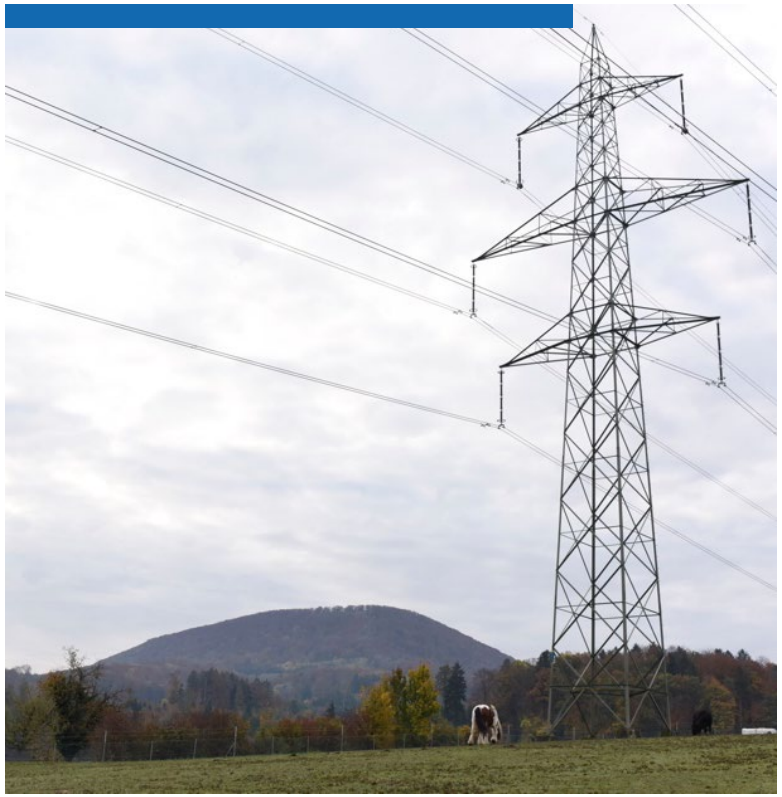
New large power plants



International association



Supply of downstream grids



Delays in grid expansion projects

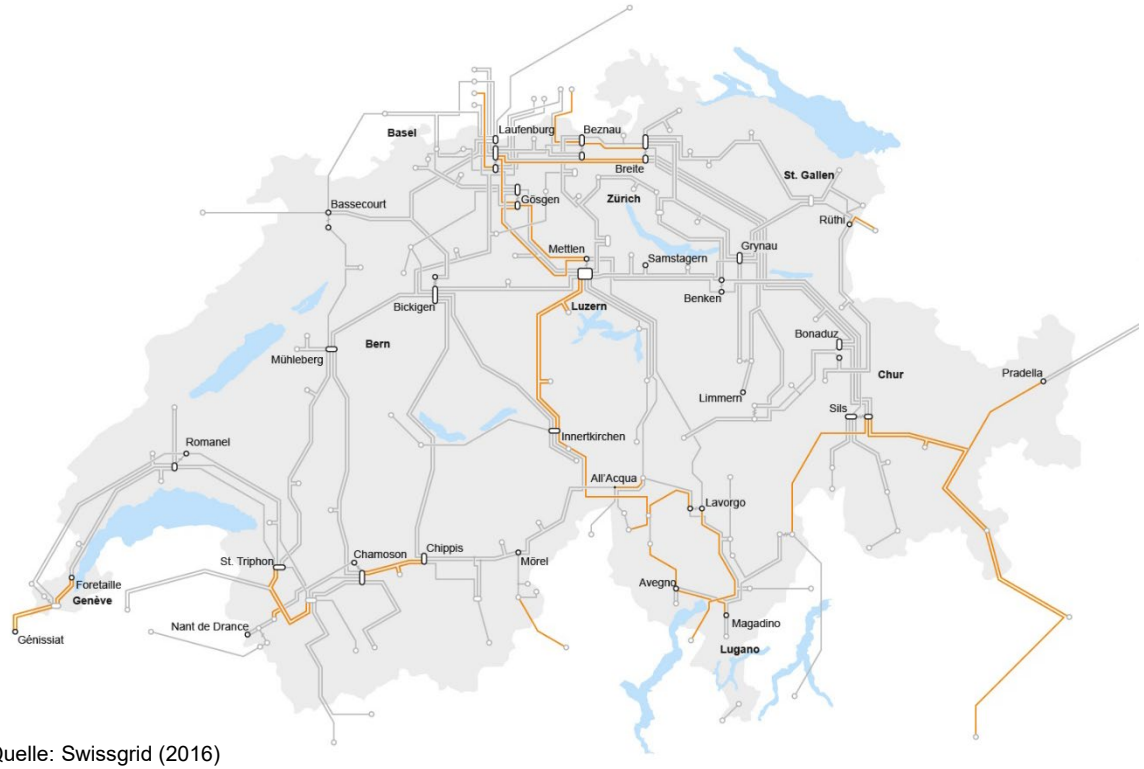
Why?

Affected citizens can object against a new transmission line

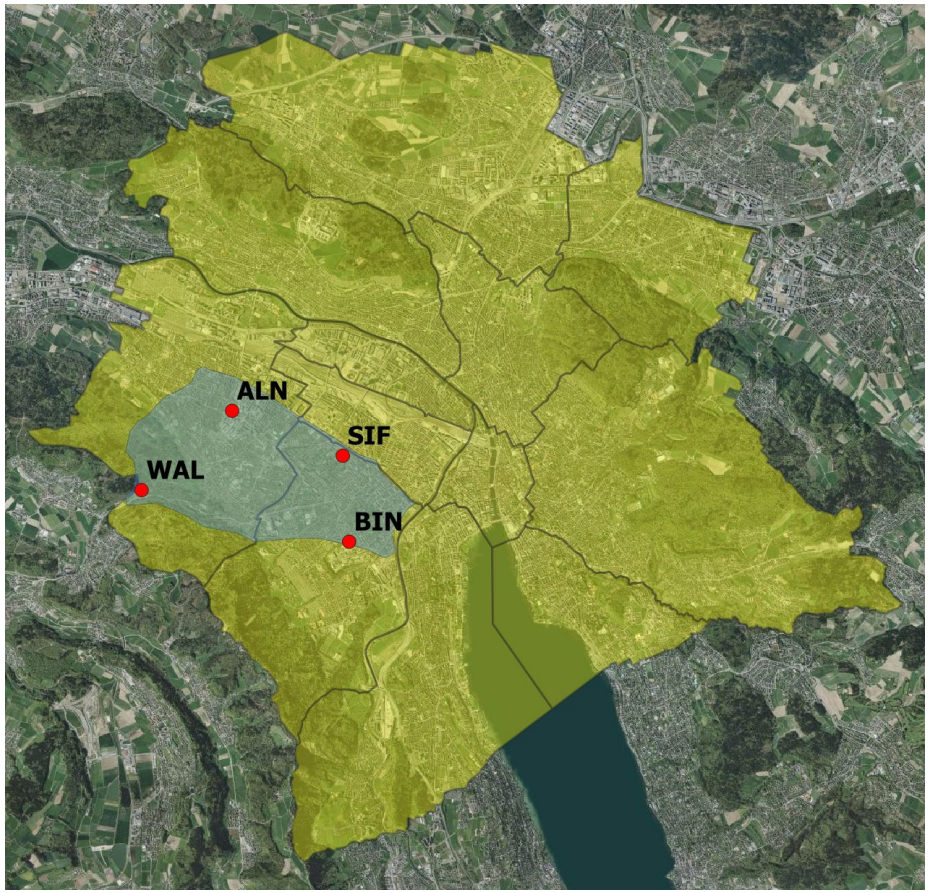
bergrheinfeld-sagt-nein.de (2017)

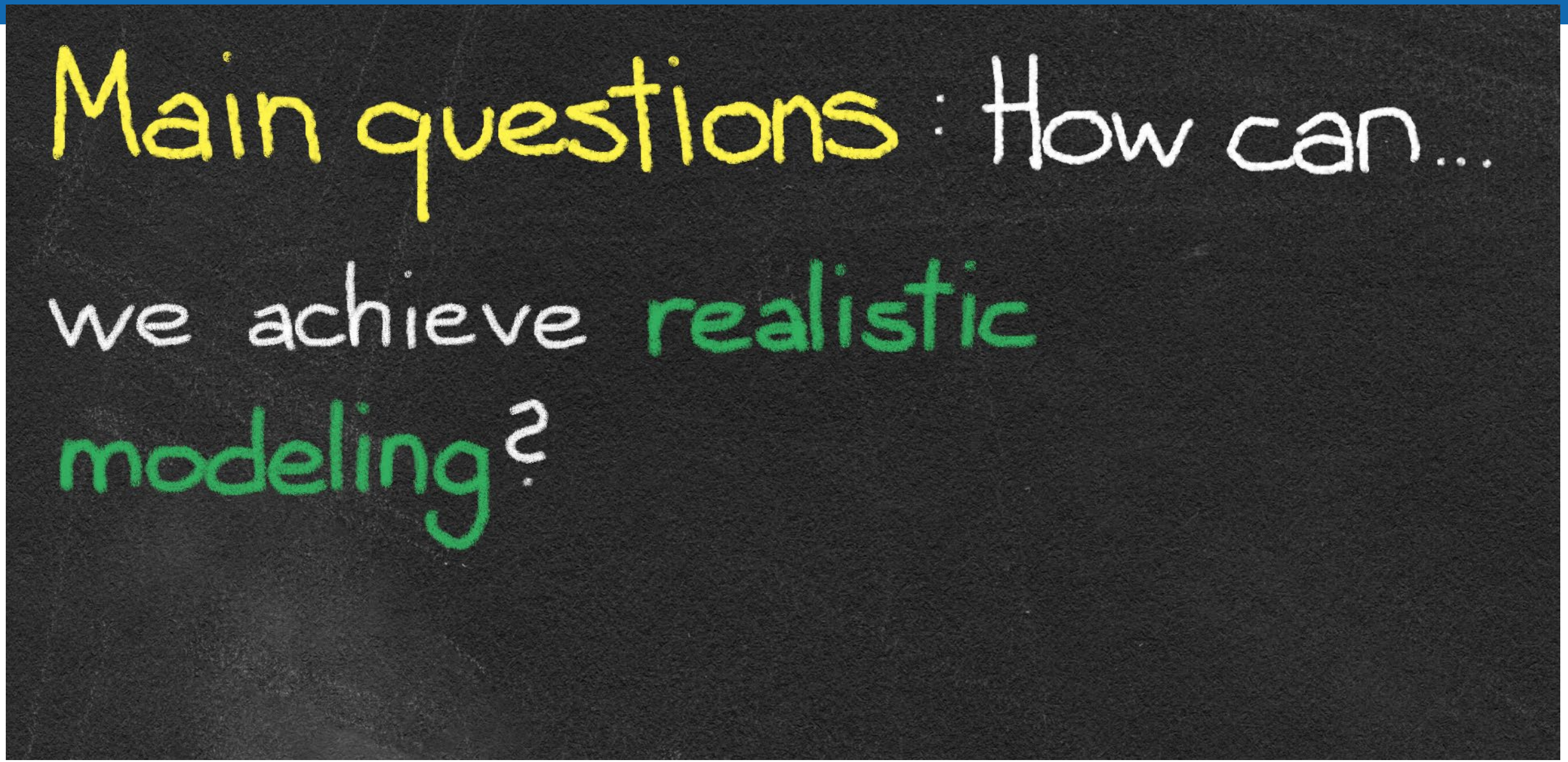
Communicating with affected citizens can help to increase acceptance

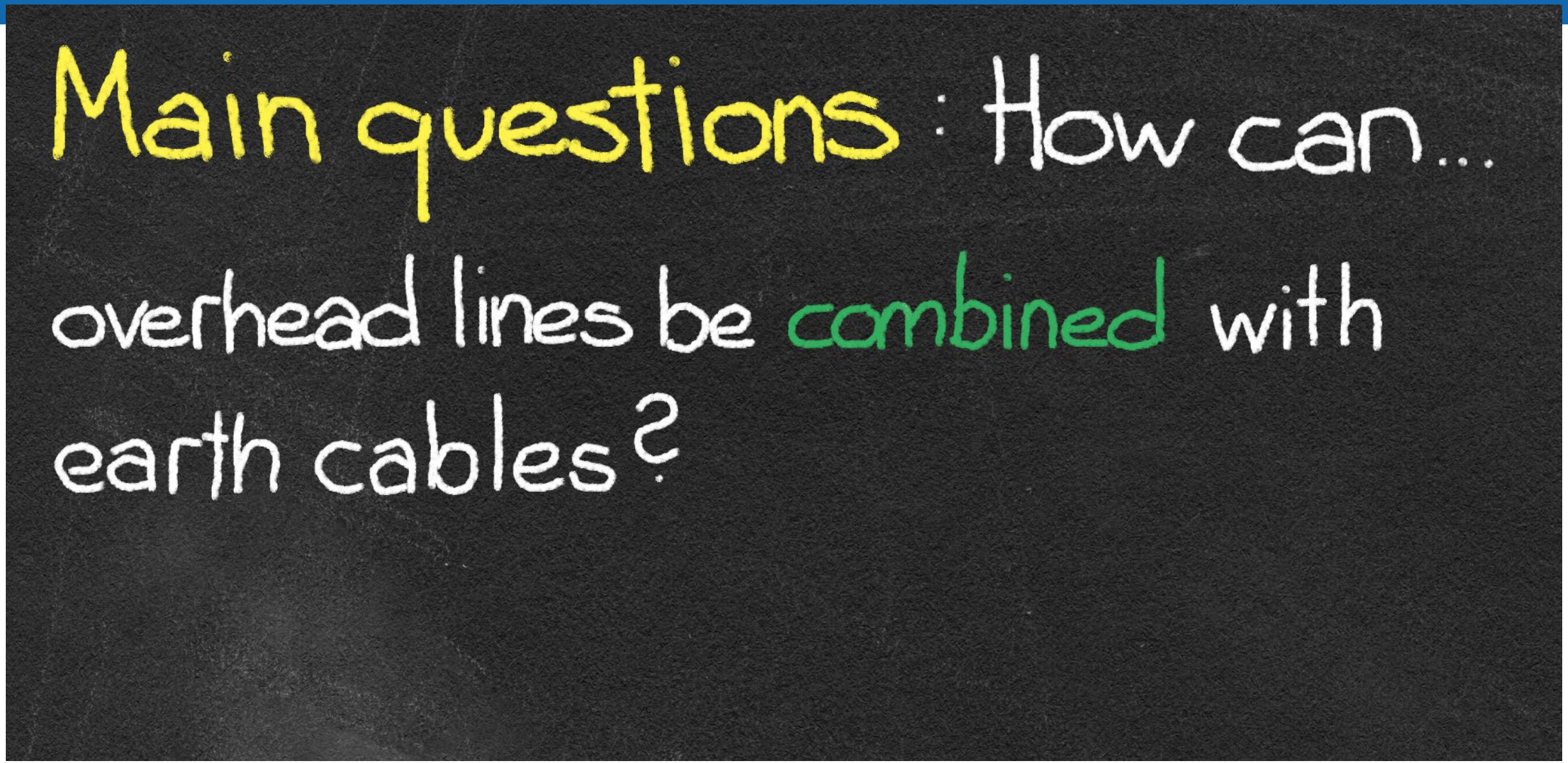
Our study areas: electricity bottlenecks in central Switzerland and Zurich



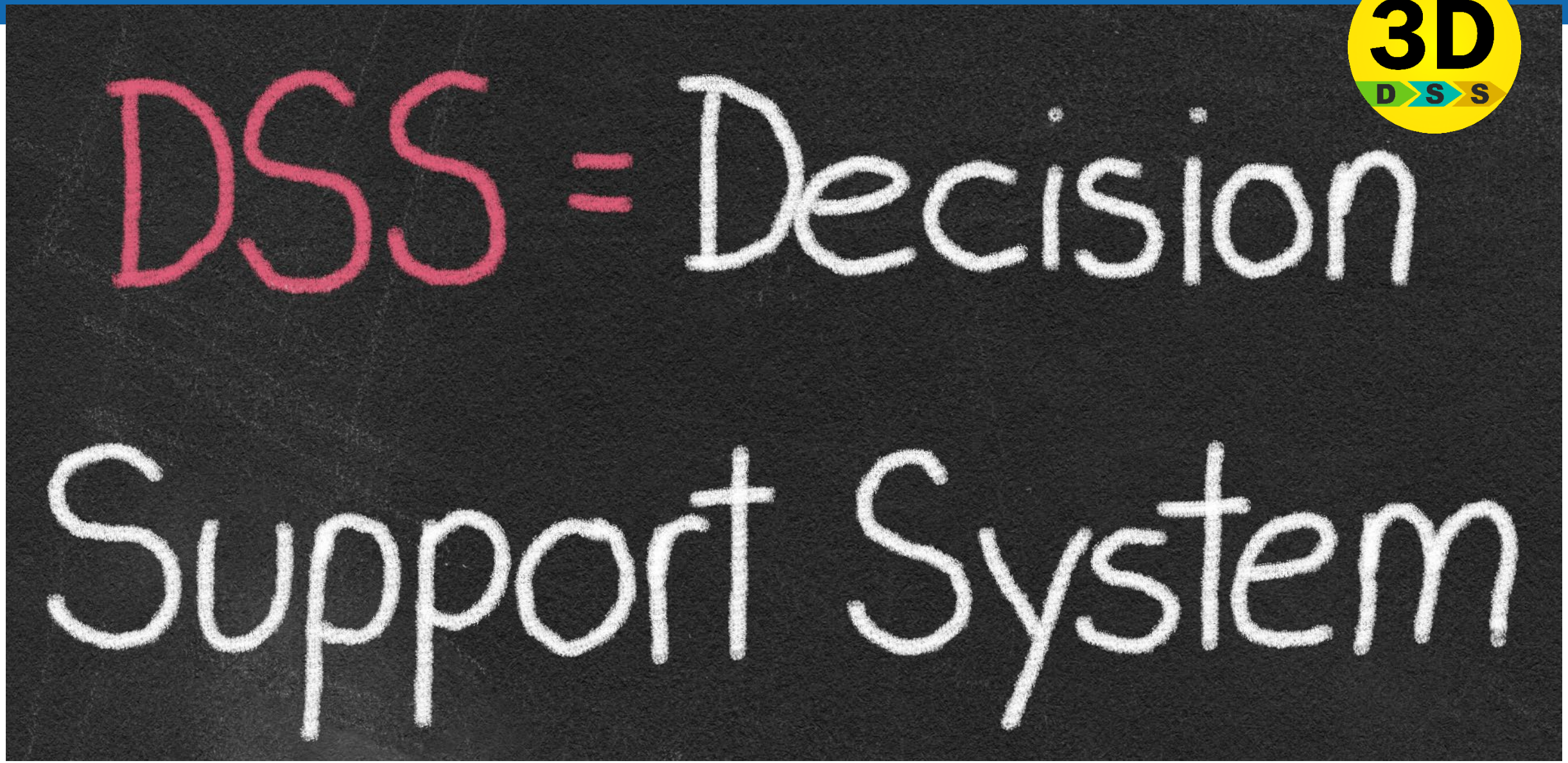
Quelle: Swissgrid (2016)



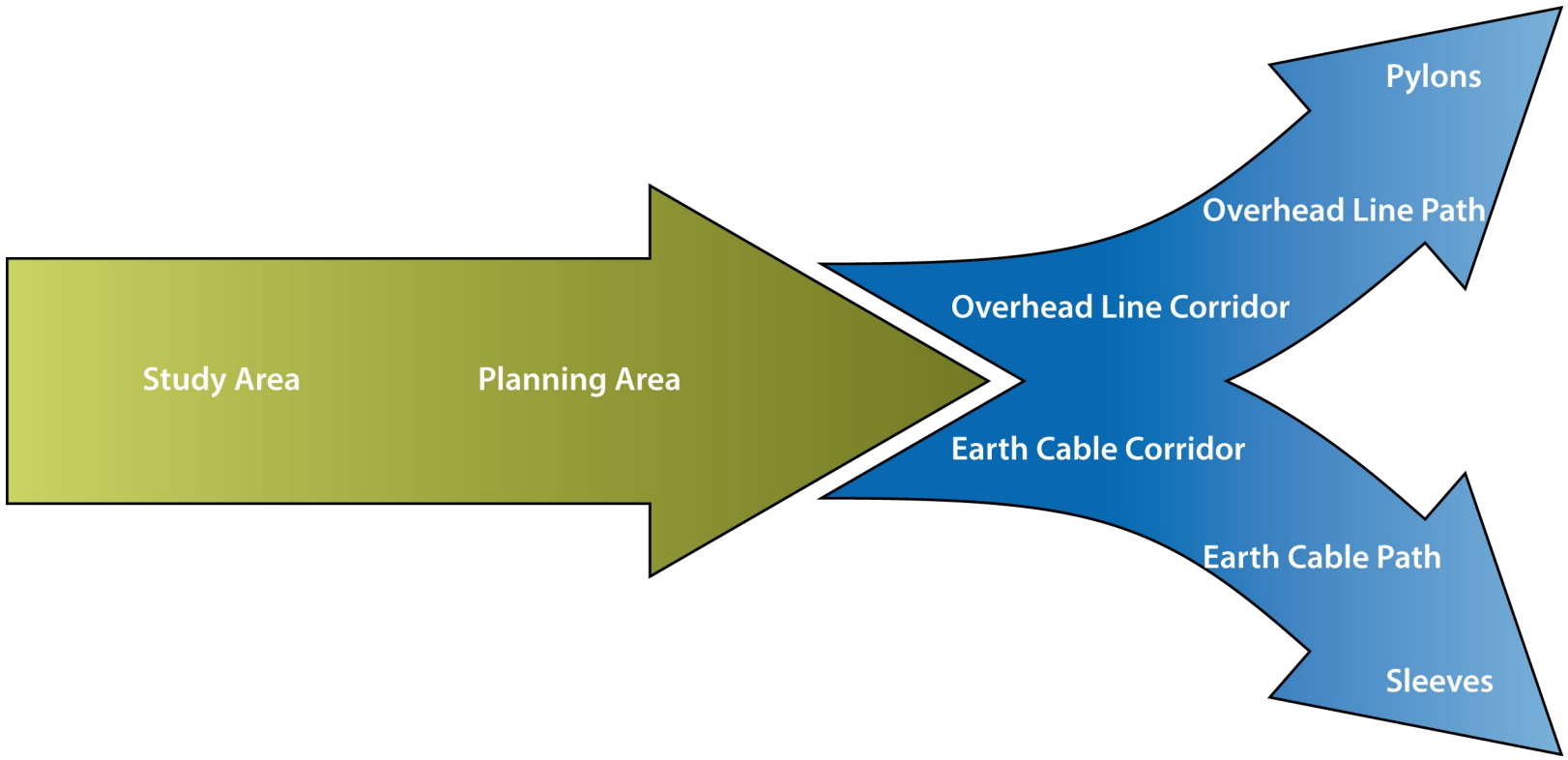

Main questions : How can...
we achieve realistic
modeling ?


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

The 3D DSS project


DSS = Decision
Support System

The 3D DSS project



Acknowledgements

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Confederaziun svizra

Bundesamt für Energie BFE
Swiss Federal Office of Energy SFOE

www.gis.ethz.ch

www.plus.ethz.ch

3ddss.ethz.ch
@3ddss_eth

2018–2020:

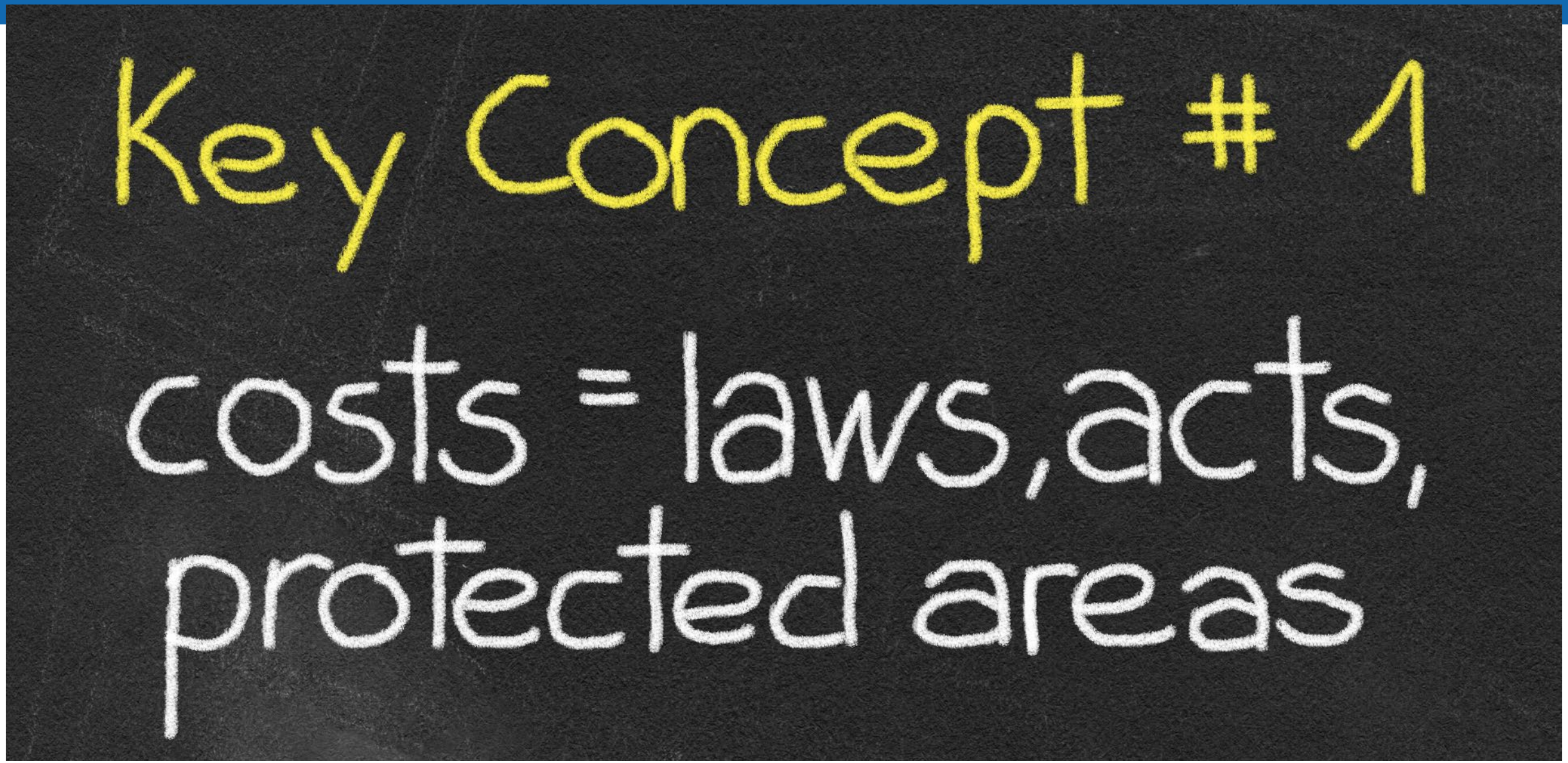
swissgrid

2014–2017:

BKW swissgrid

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


MCDA ∞ 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

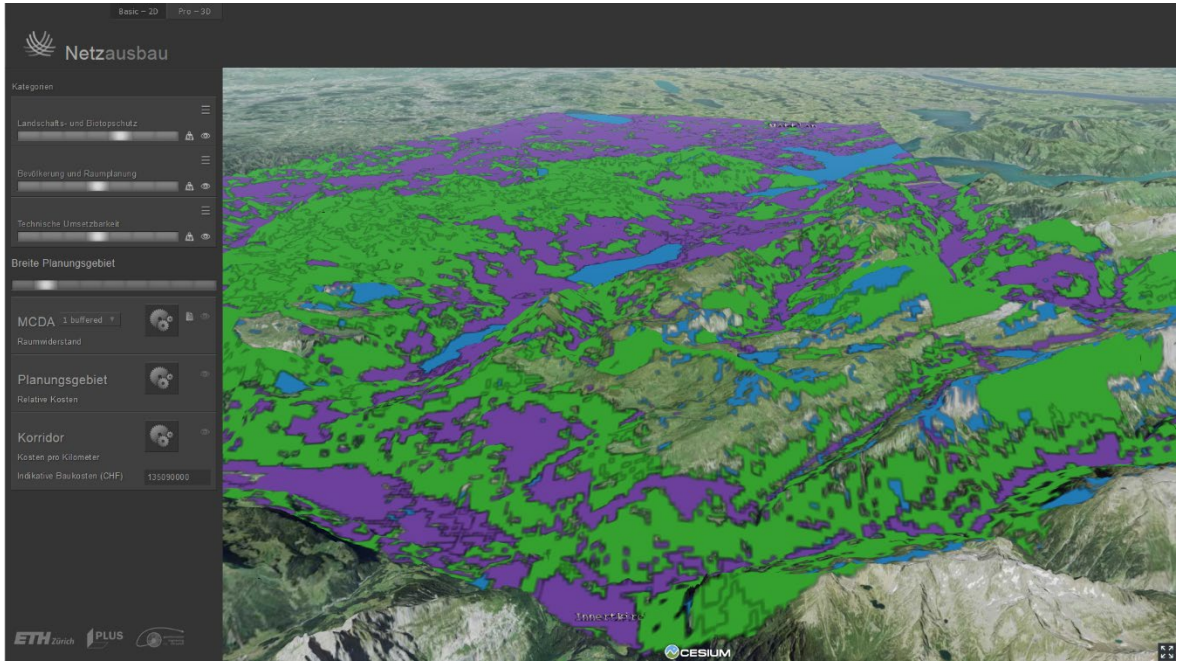
1 *geodata*

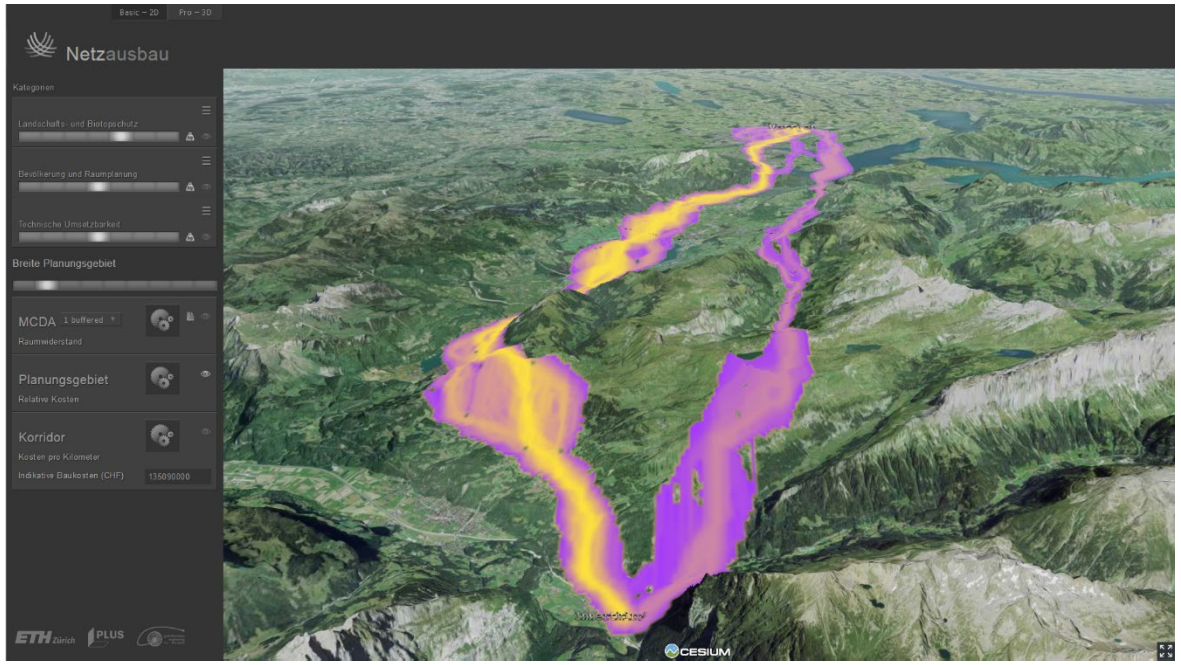
2 *resistance/weight*

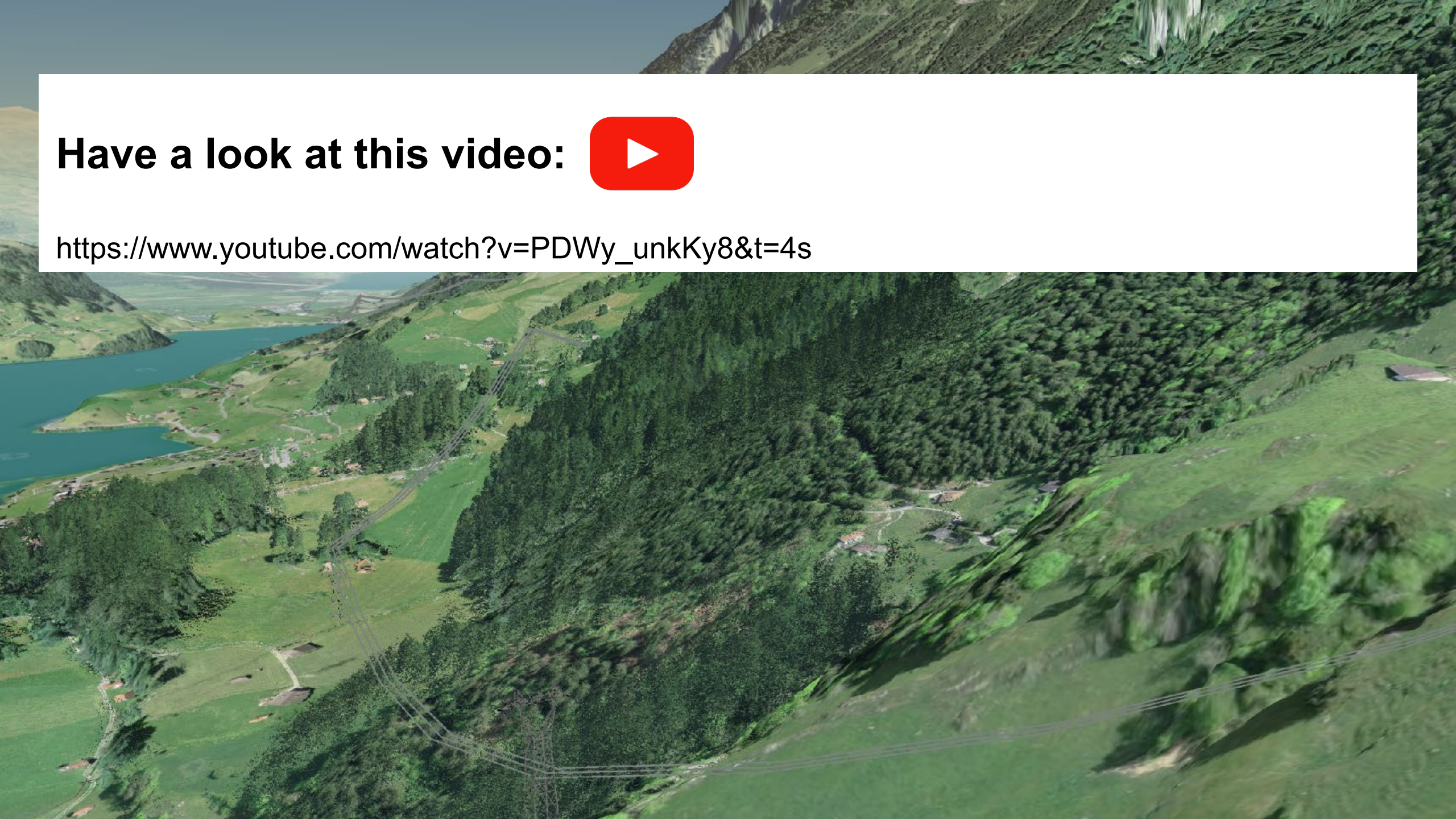
3 *MCDA formula*

4 *optimization*

corridor







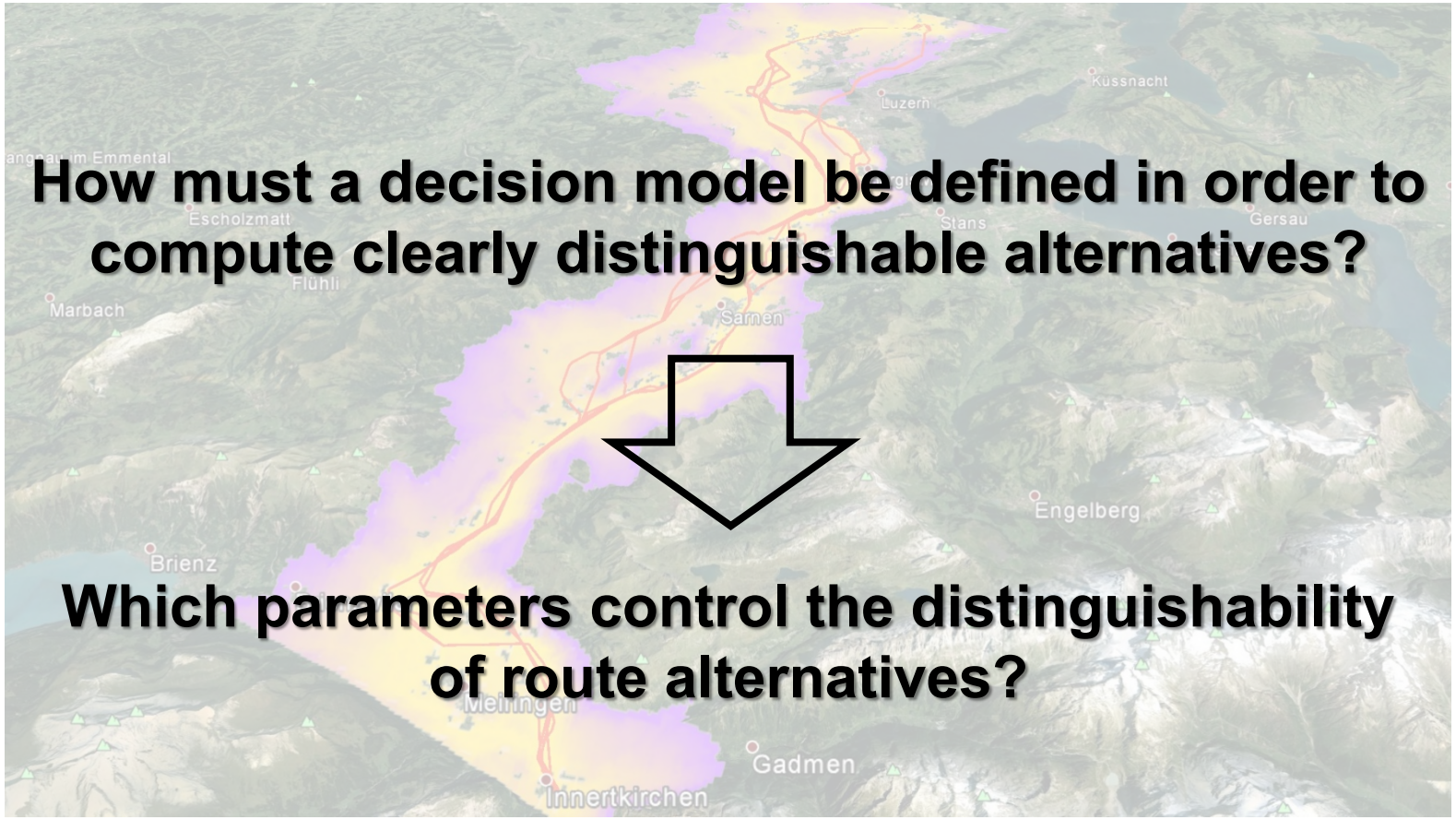
Have a look at this video:

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 ★★★

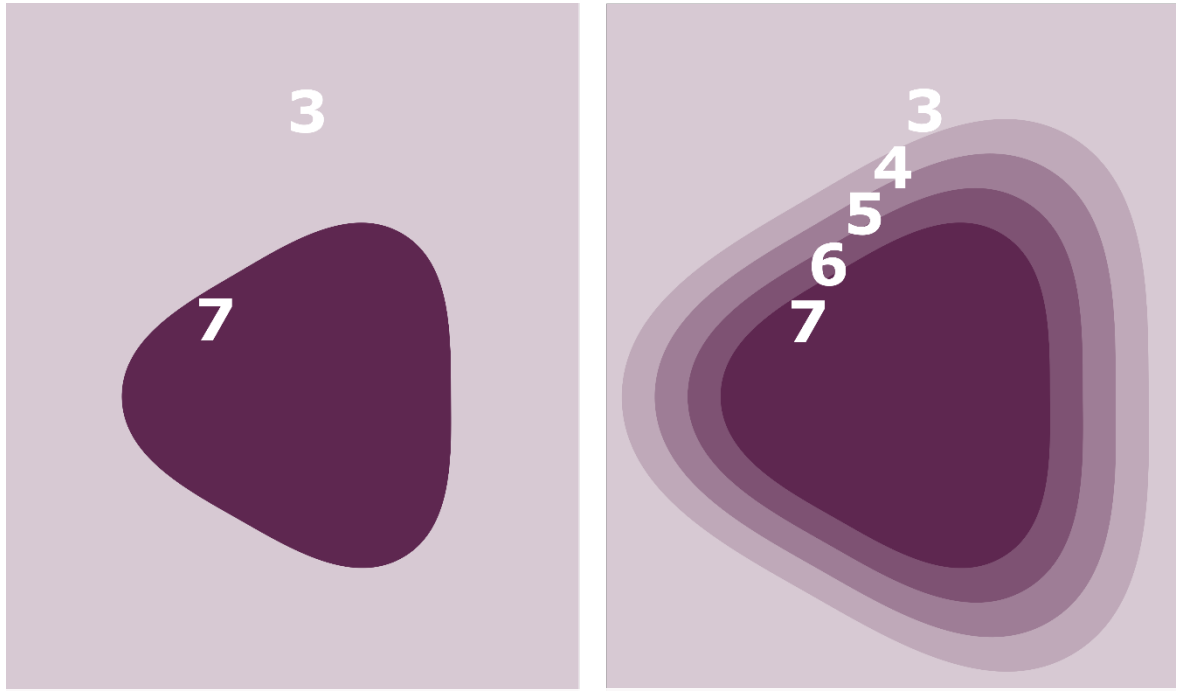
weighting model ★★

utility function ★

interactions

Recent results we use for improving the decision model

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



sharp-edged | continuous

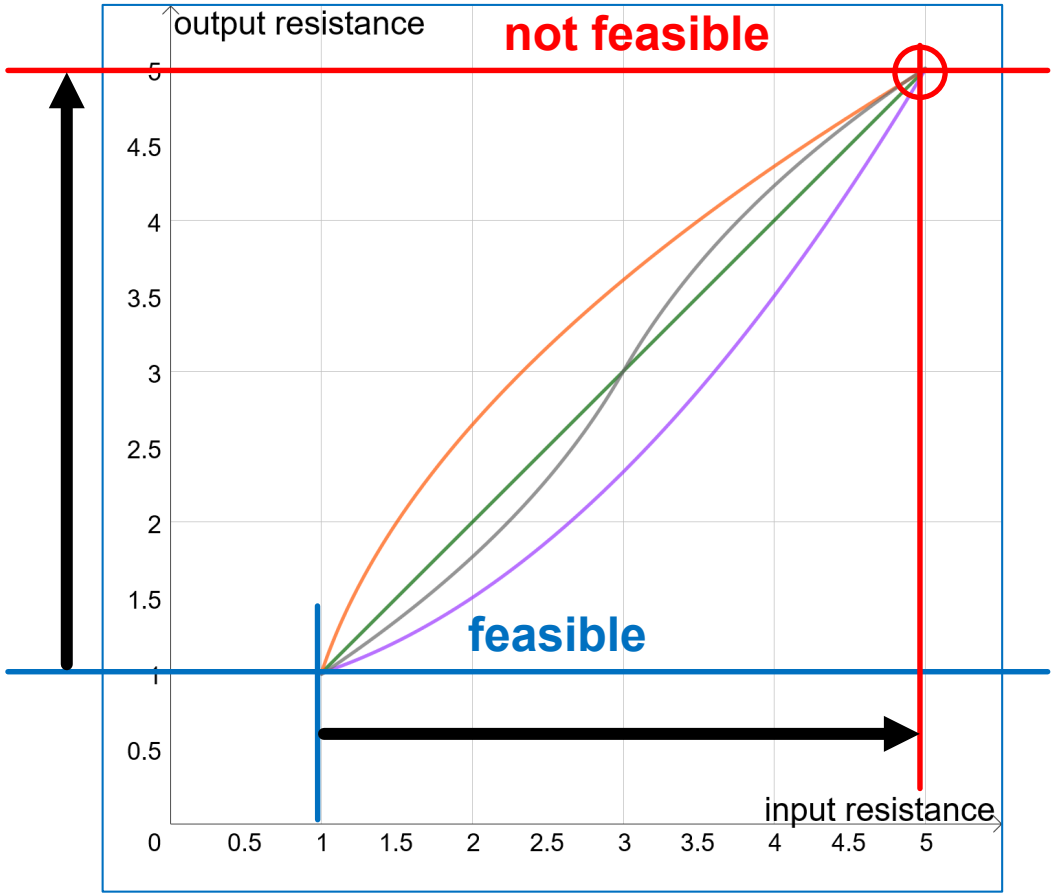
Recent results we use for improving the decision model

- The continuous boundary model achieved best results and reflects real conditions best
- Simple Additive Weighting (= Weighted Linear Combination) 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)




Attributes
vs.
Objectives

Our data model consists of georeferrenced datasets (= criteria)

Categories	Criteria	Objectives
Environmental protection	Protection areas according to game laws	Preserve ecosystems: secondary
Environmental protection	National parks	Preserve landscape: primary
Environmental protection	UNESO World Heritage Site	Preserve landscape: primary
Environmental protection	Geotope	Preserve landscape: secondary
Construction and maintenance	Natural hazard areas	Meet strict legal requirements and minimize risks
Construction and maintenance	Groundwater areas S1 and watercourse corridors	Meet strict legal requirements and minimize risks
Construction and maintenance	Groundwater areas S2	Construct power line despite difficult circumstances and high costs
Construction and maintenance	South facing areas	Construct power line despite difficult circumstances and high costs
Construction and maintenance	Inappropriate relief	Construct power line despite difficult circumstances and high costs
Construction and maintenance	Inappropriate underground material	Construct power line despite difficult circumstances and high costs
Construction and maintenance	Water bodies	Construct power line despite difficult circumstances and high costs
Construction and maintenance	Proximity to wide streets	Construct power line despite difficult circumstances and high costs
Construction and maintenance	Proximity to existing lines	Increase bundling
Construction and maintenance	Proximity to railways	Increase bundling
Urban planning	Infrastructure facilities	Avoid infrastructure facilities
Urban planning	Airports	Avoid infrastructure facilities
Urban planning	Arable land	Preserve landscape: secondary
Urban planning	Areas within noise threshold of 40 dBA	Preserve living space: primary

- Today 33 criteria grouped into 3 categories
- We are working on a new model with 50+ categories to redefine decision-making

- However, we observed that experts focused just on 5–10 criteria
- Nevertheless, experts want to have full control over each criterion and consider them on demand
- However, some criteria **must** be considered by law

Our data model consists of georeferrenced datasets (= criteria)

New focus

Categories	Criteria	Objectives
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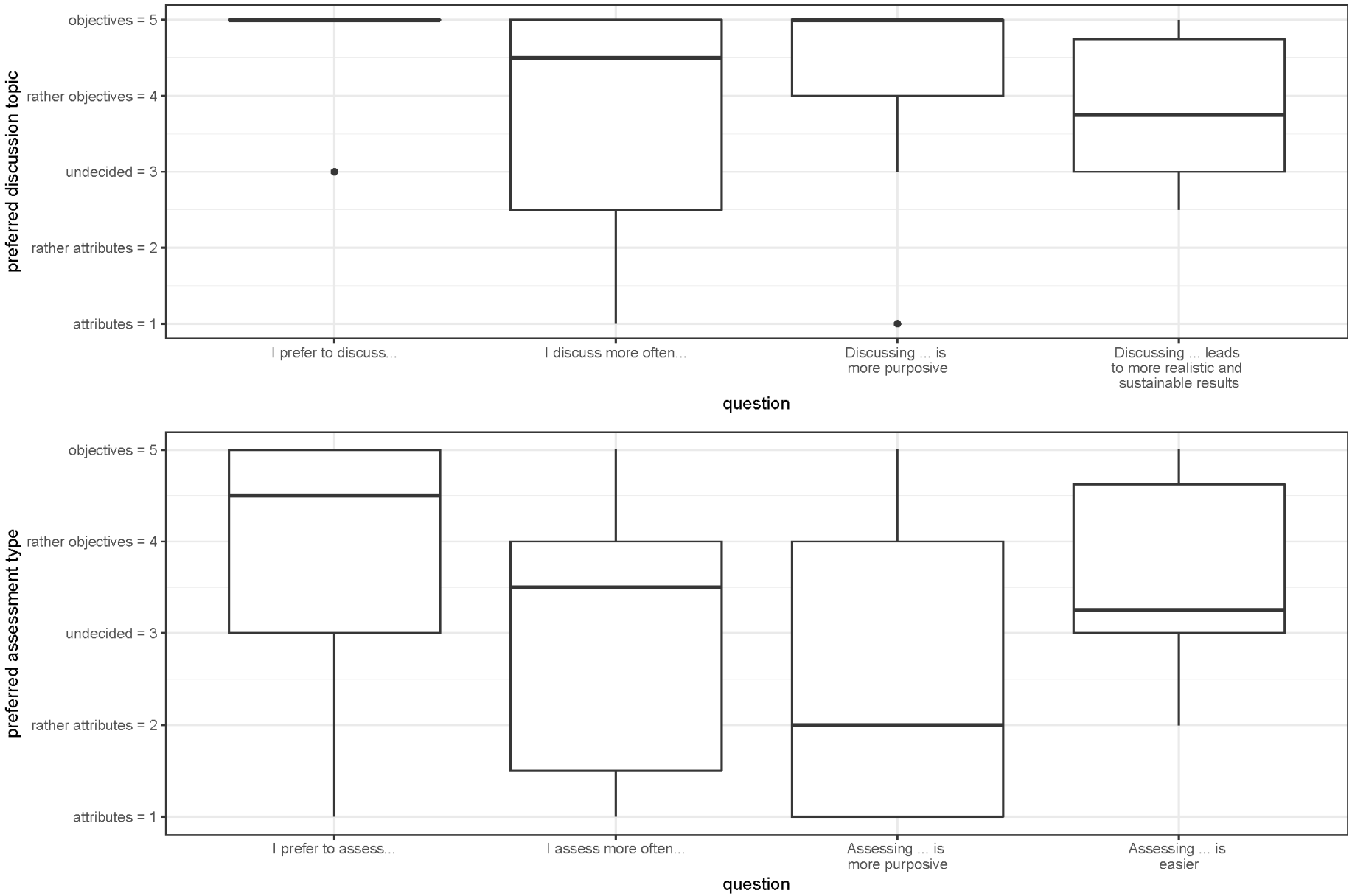
Ω

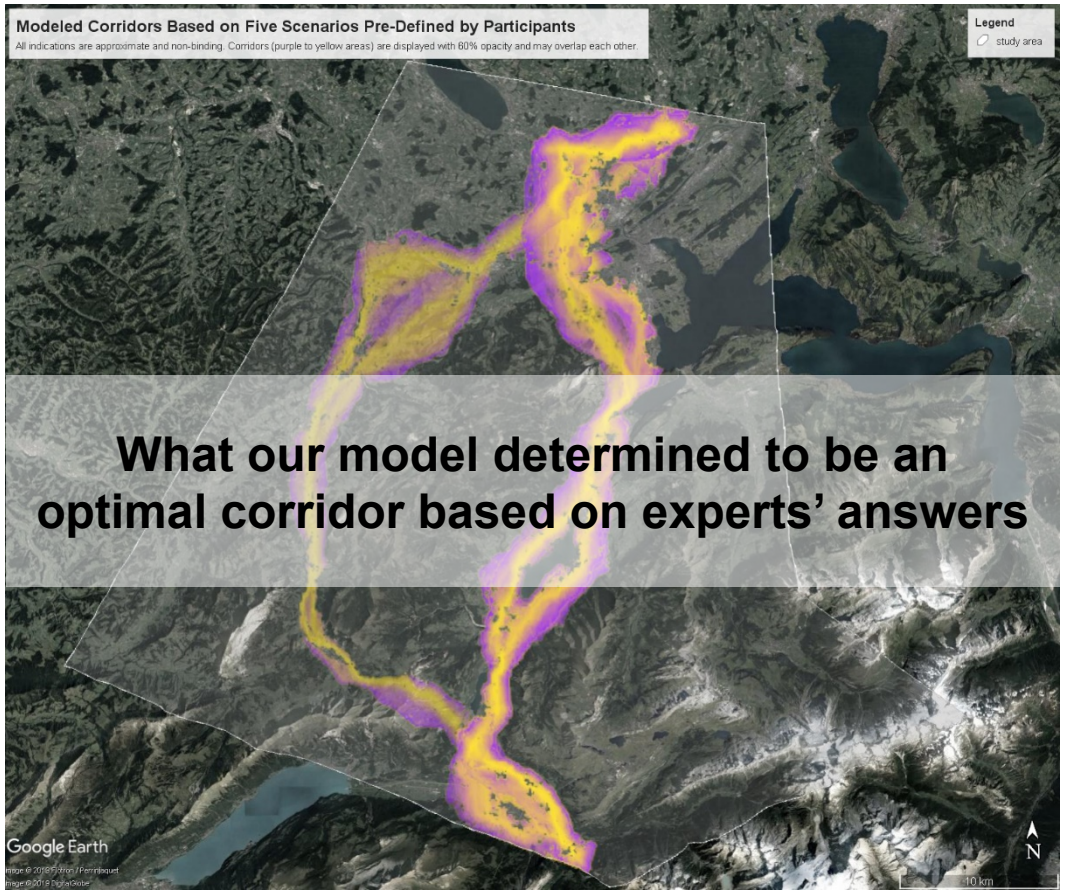
- Each factor is assigned a main objective.
- This main objective is fulfilled the more the corresponding areas are avoided.
- Alternatives can be compared based on the achievement of a specific objective.
- **We want to determine the most suitable alternative based on spatial (linear) optimization**

Differences of discussing and assessing attributes or objectives

n = 10 participants

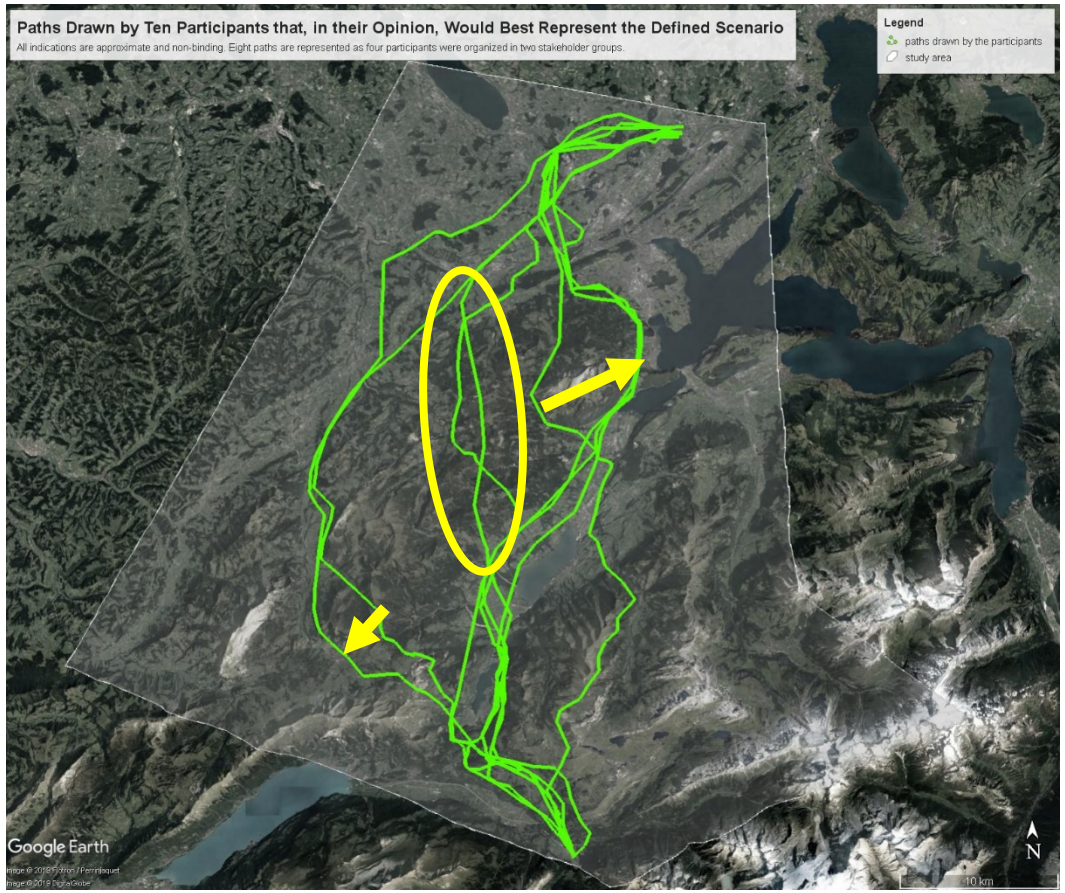


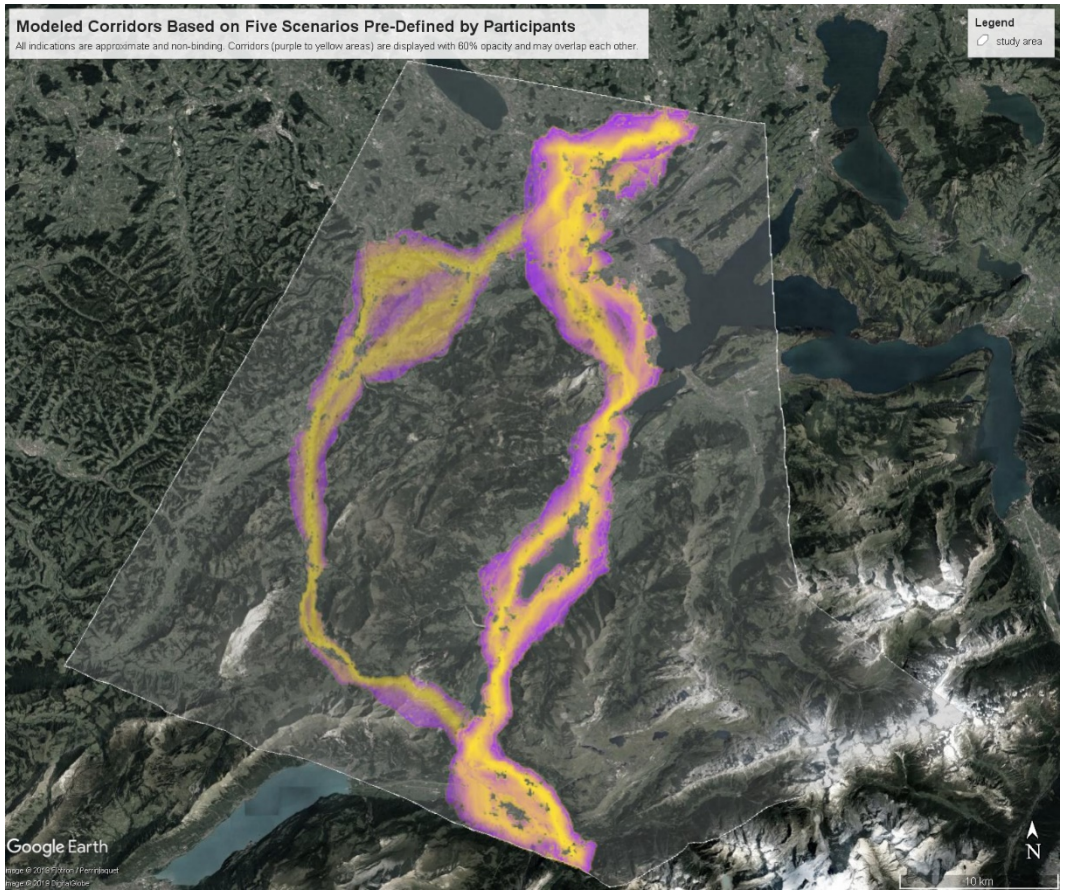
Study conducted with 10 planning experts (2019)



Study conducted with 10 planning experts (2019)

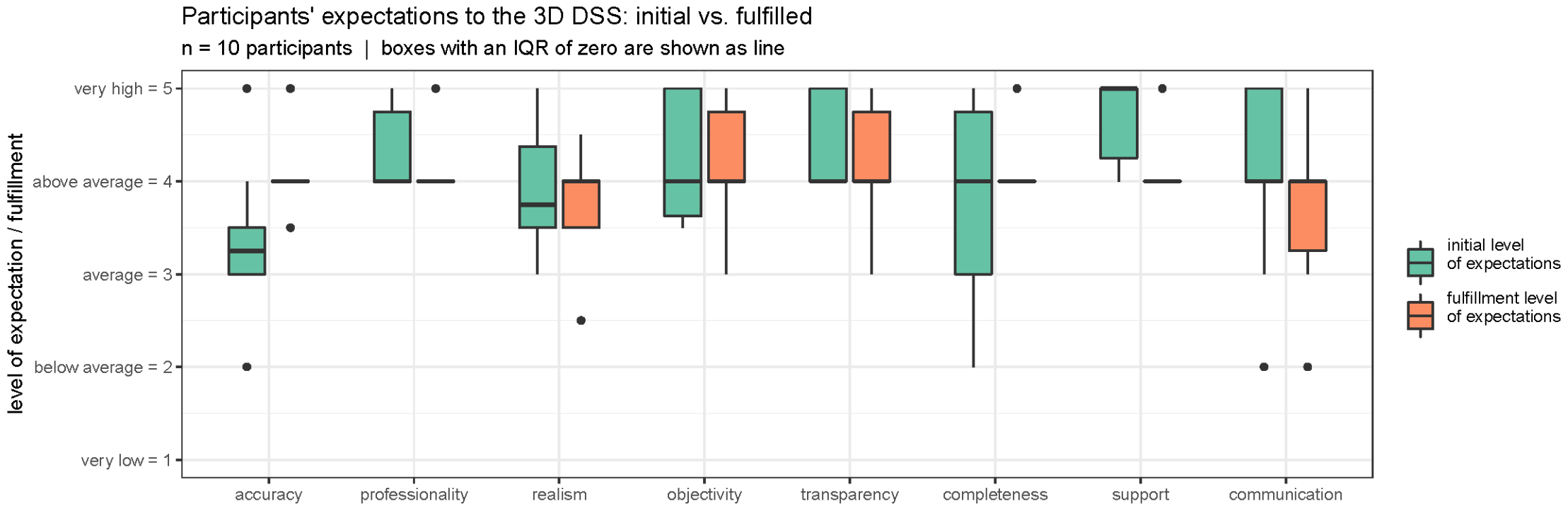
Experts agreed reconsidering critical sections of proposed lines





Study conducted with 10 planning experts (2019)

Our 3D DSS fulfills experts' expectations well



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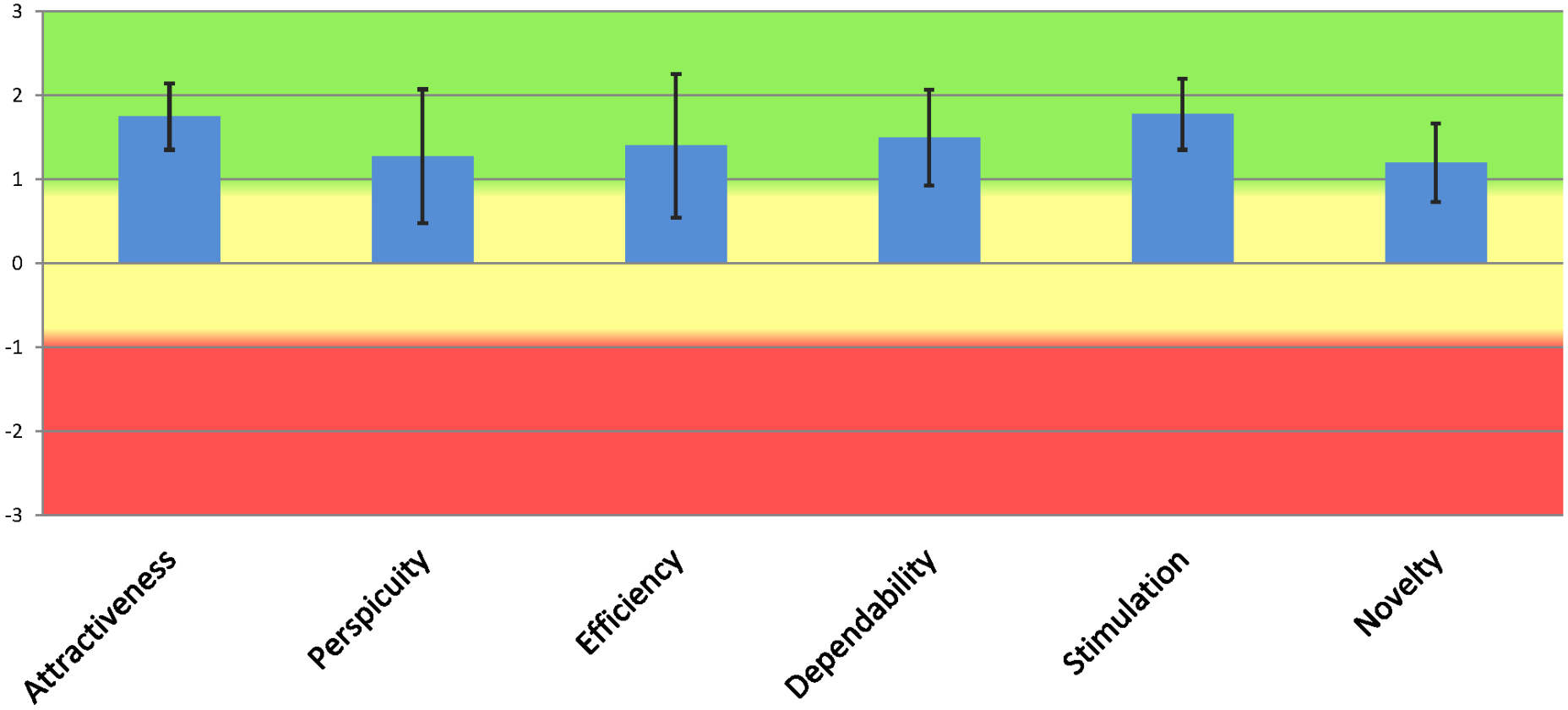
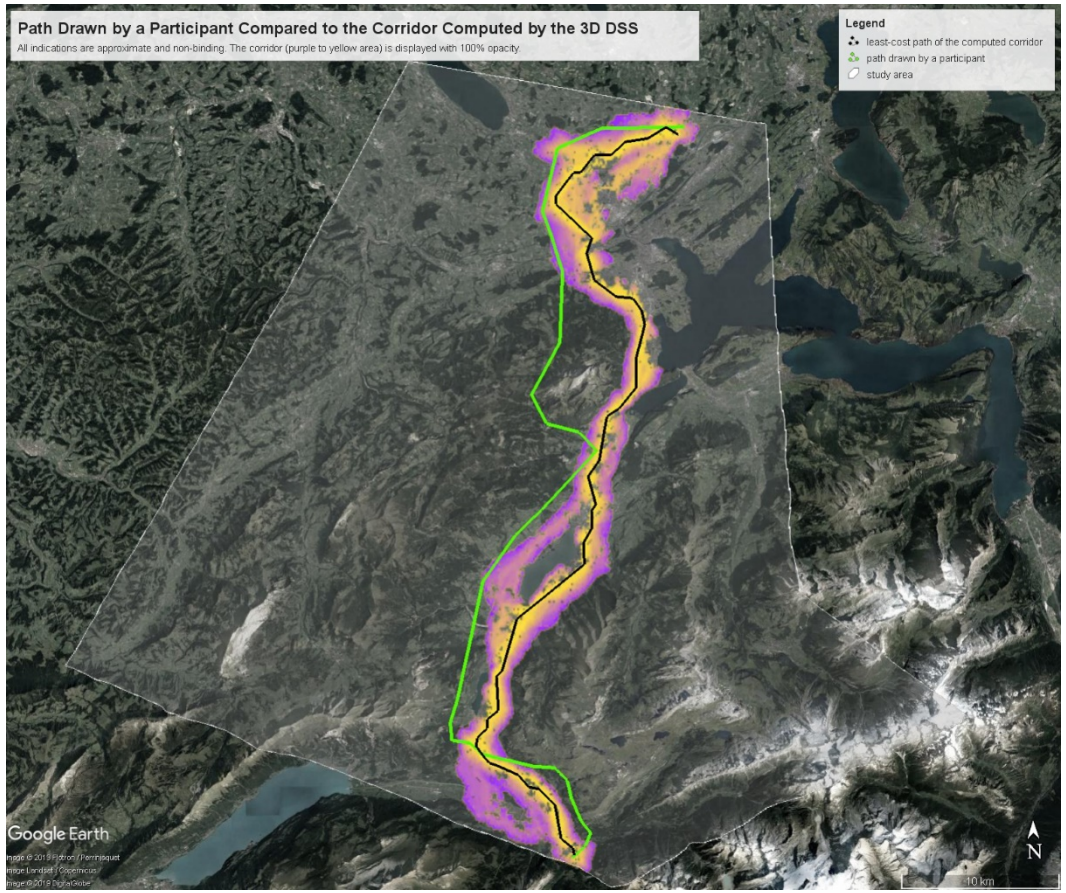
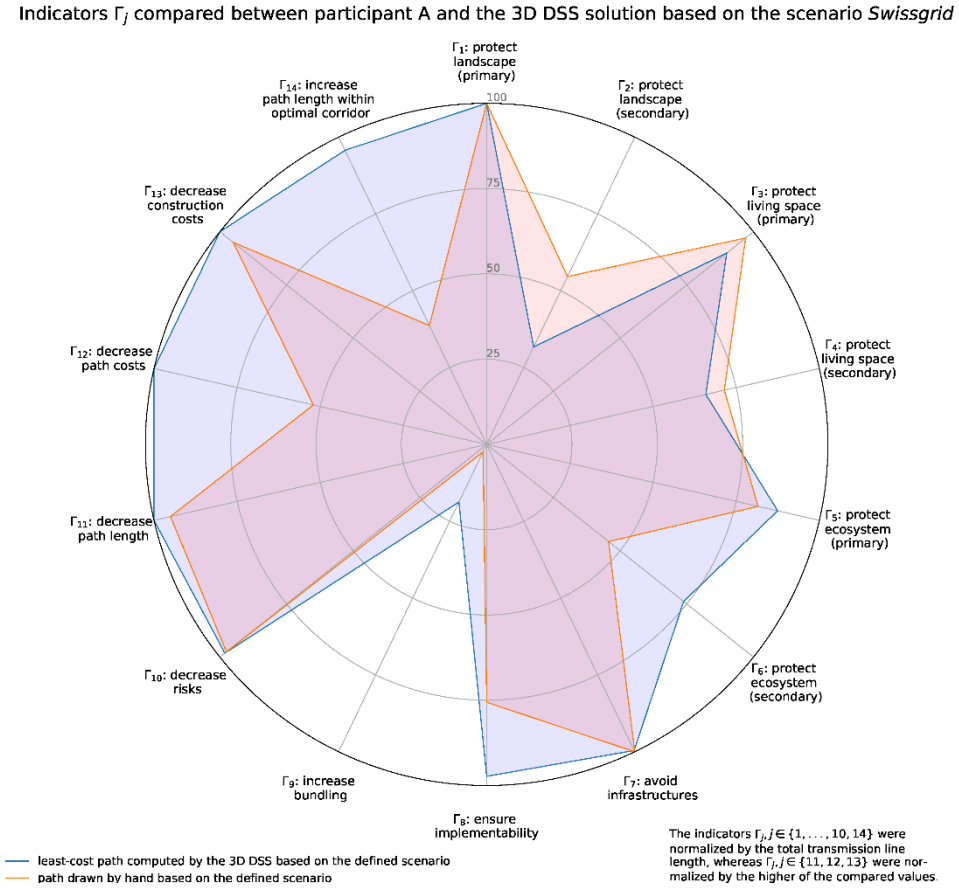


User Experience Questionnaire

Study conducted with 10 planning experts (2019)

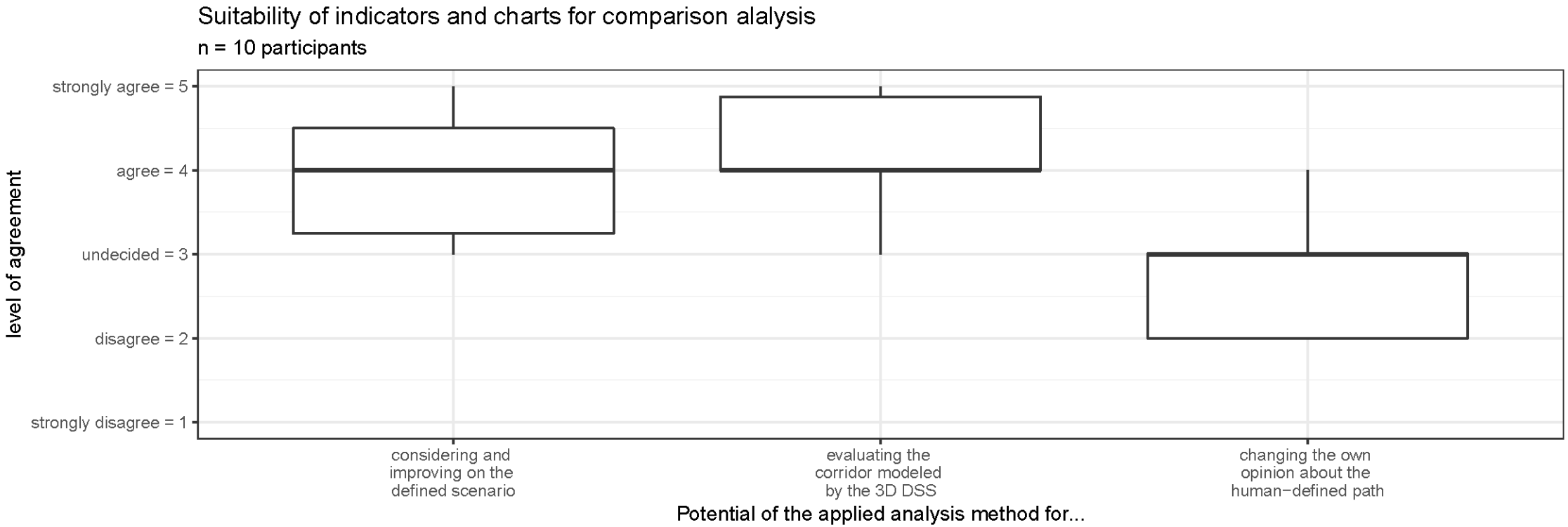
Graphical outputs that support decision-making





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?

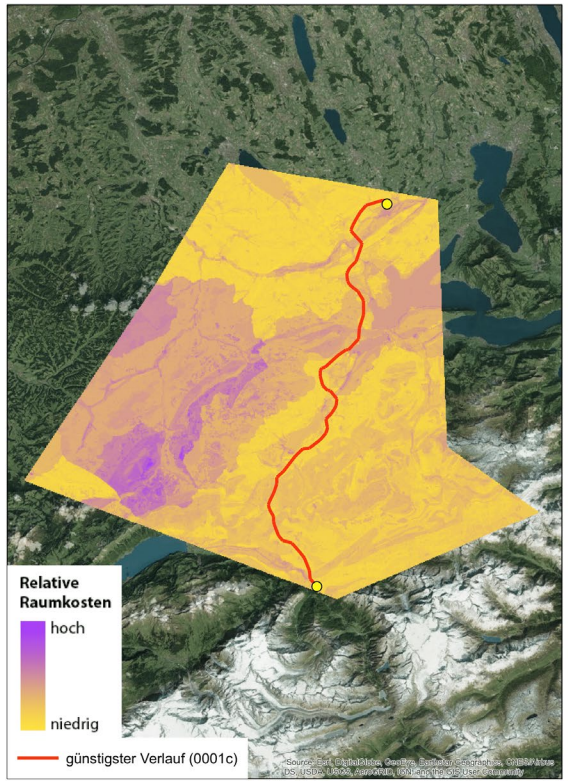
Compute a combined corridor (earth cable + overhead line)

Classical approach

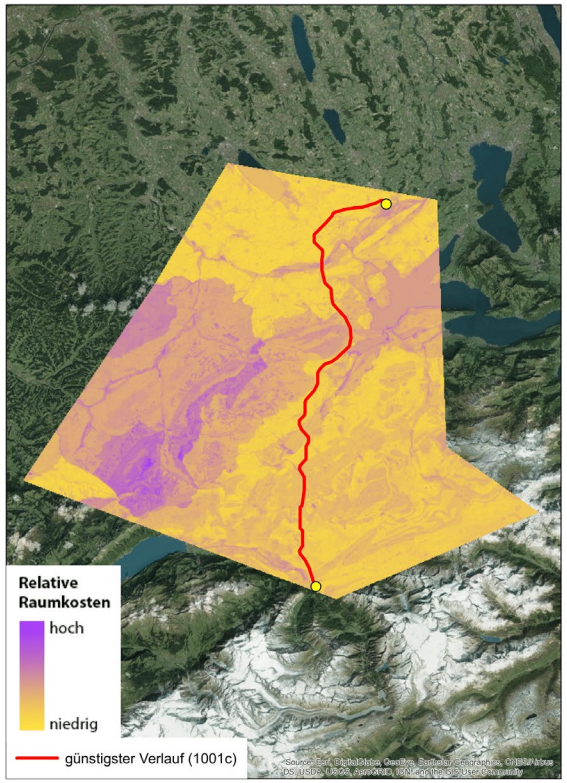
- One decision model for computing an earth cable and one for an overhead line
- Users set the resistances for both decision models
- Two cost surfaces are computed
- The cost surfaces are weighted with

$$w_{EC} + w_{OH} = 1$$

w_{EC}



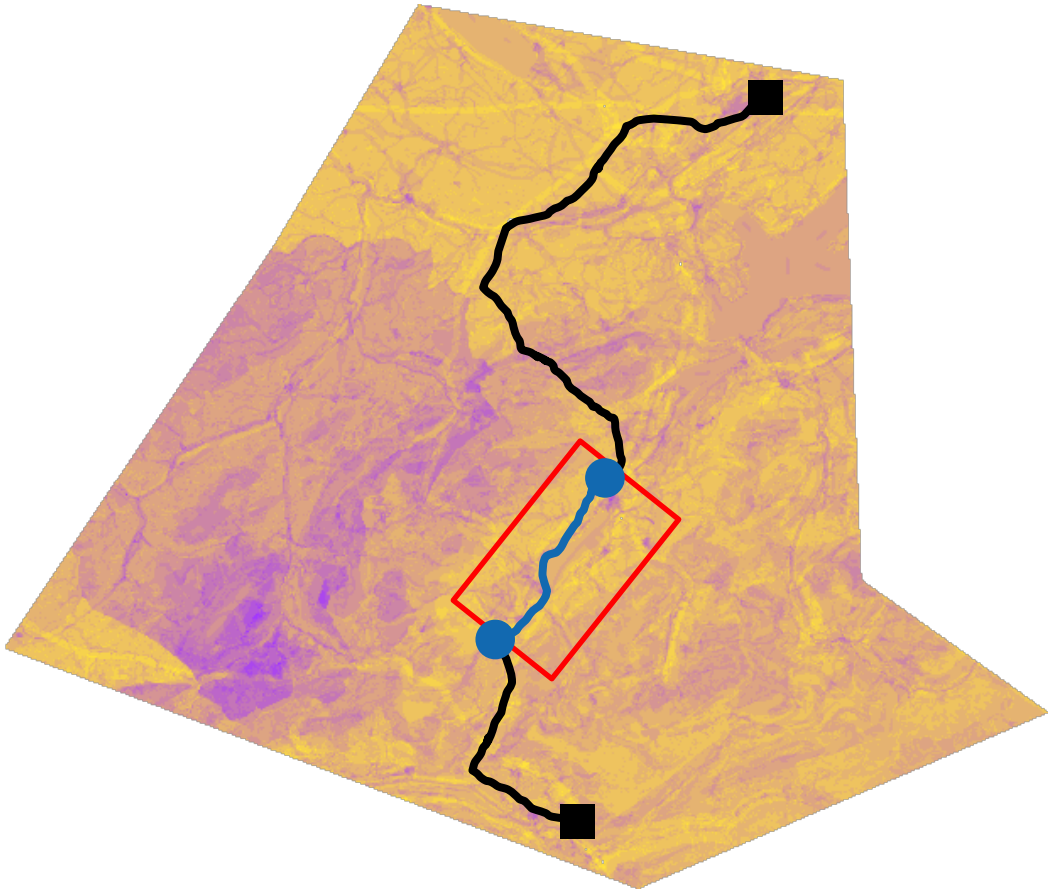
$w_{OH} = 1 - w_{EC}$



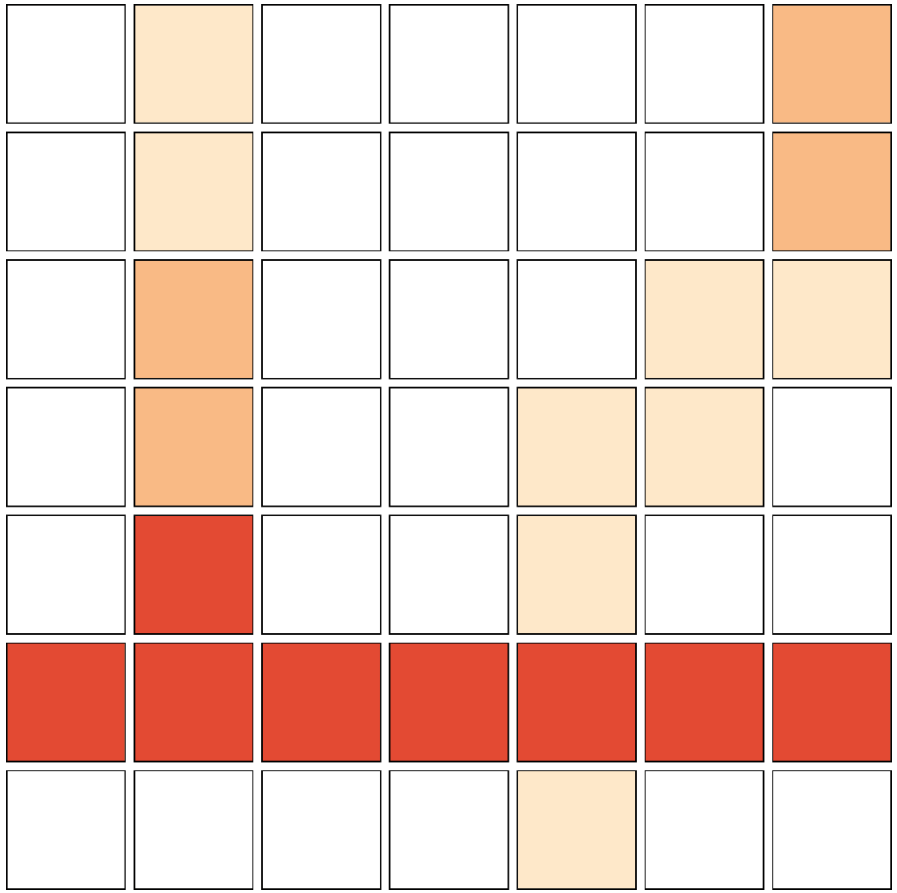
Compute a combined corridor (earth cable + overhead line)

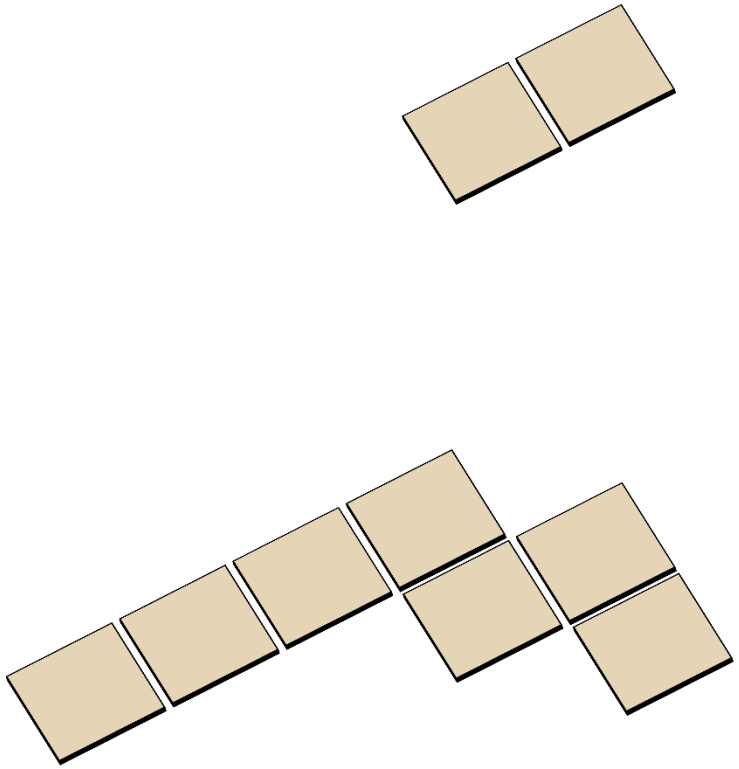
Novel approach

- 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.



How the data model could be defined for different depths





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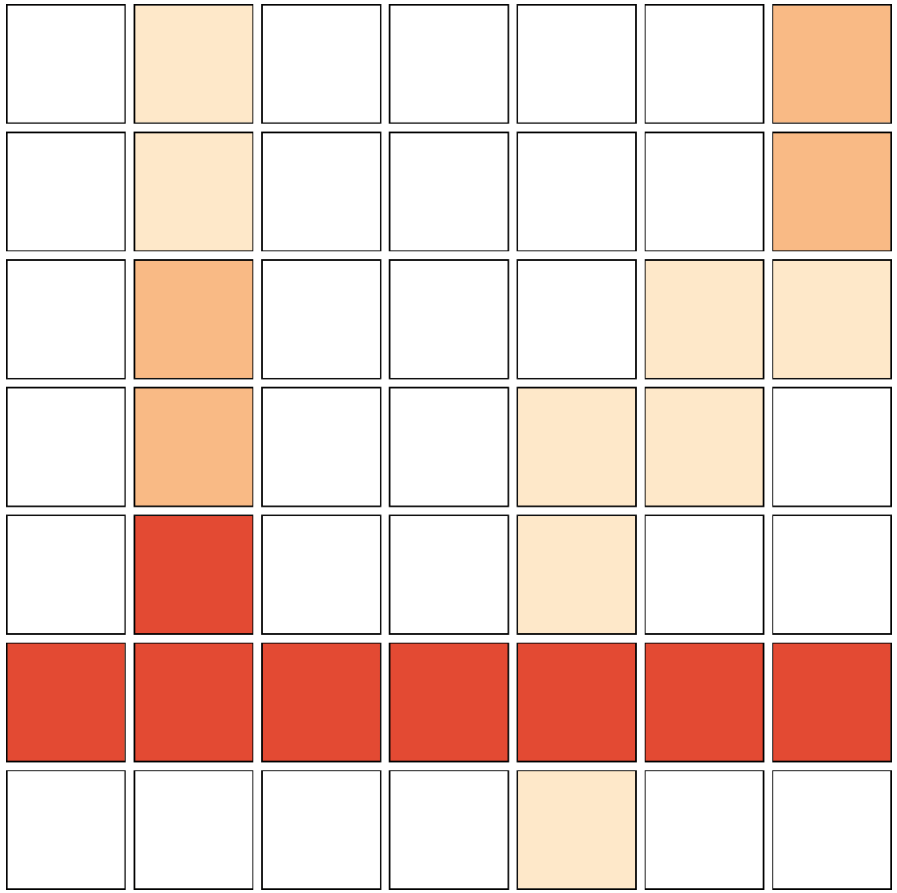

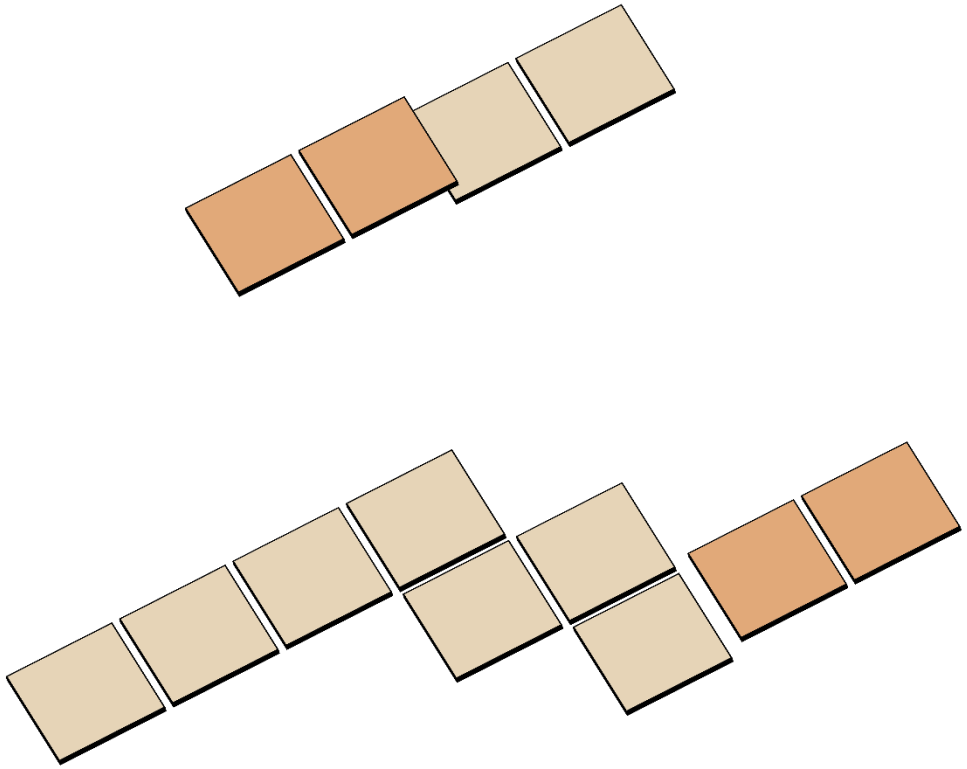

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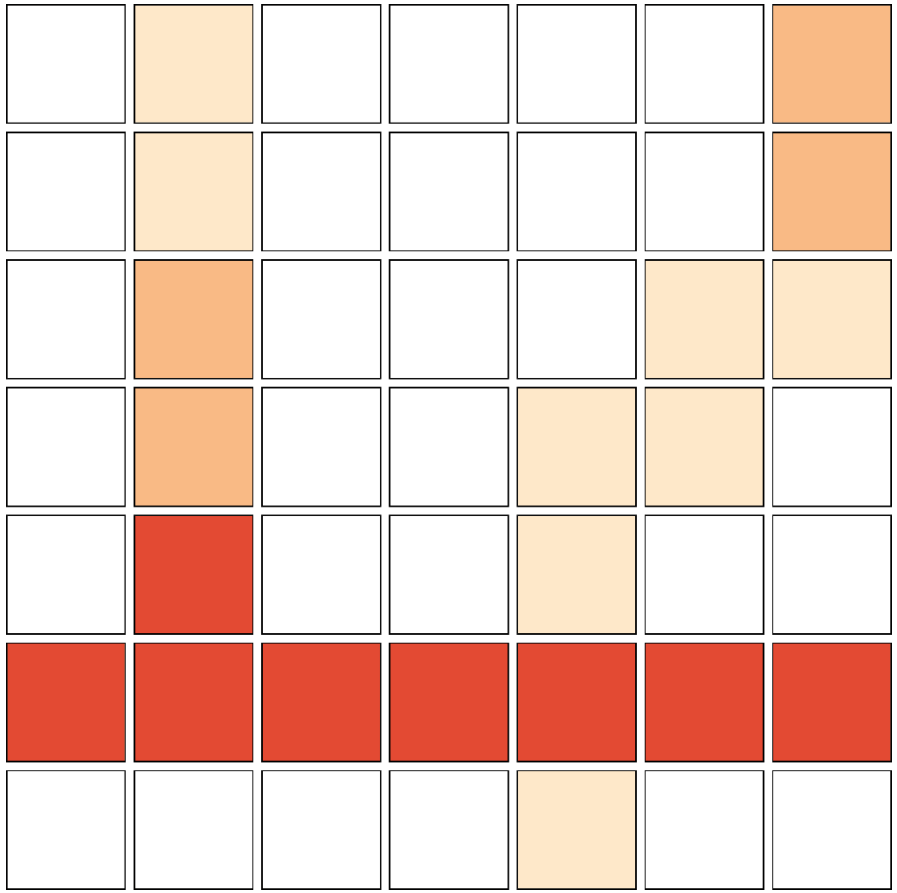

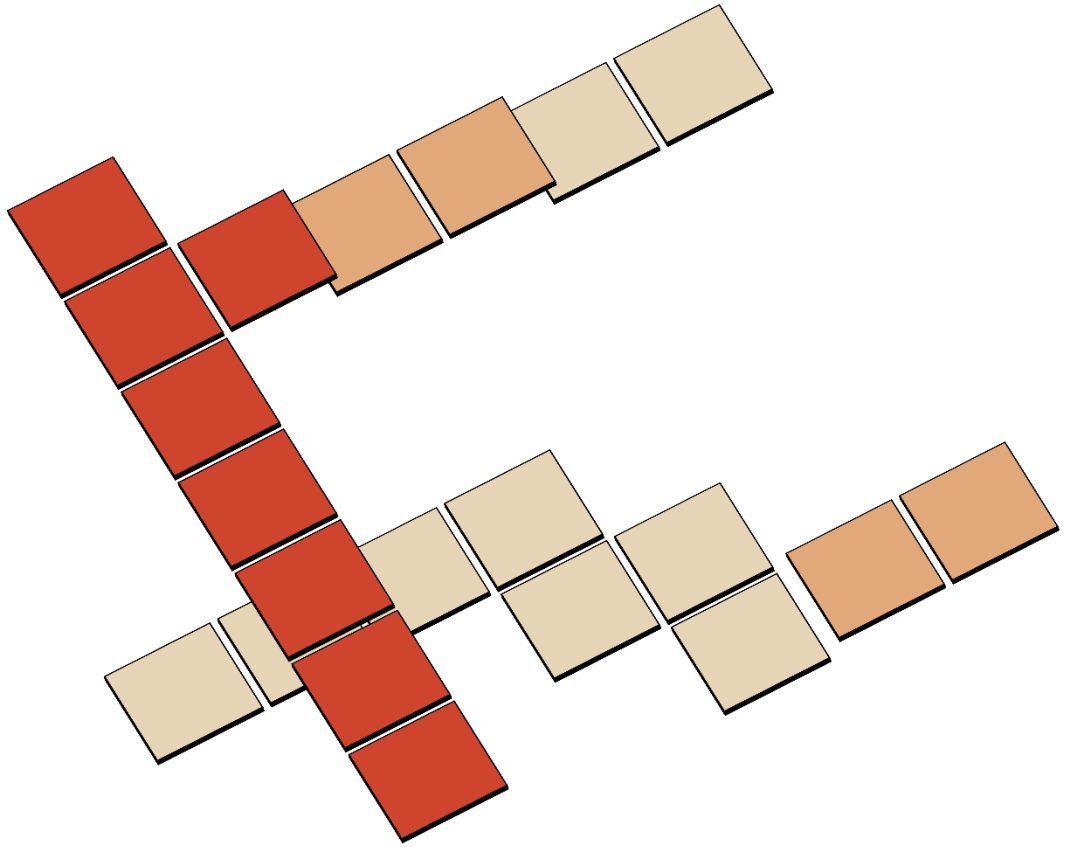

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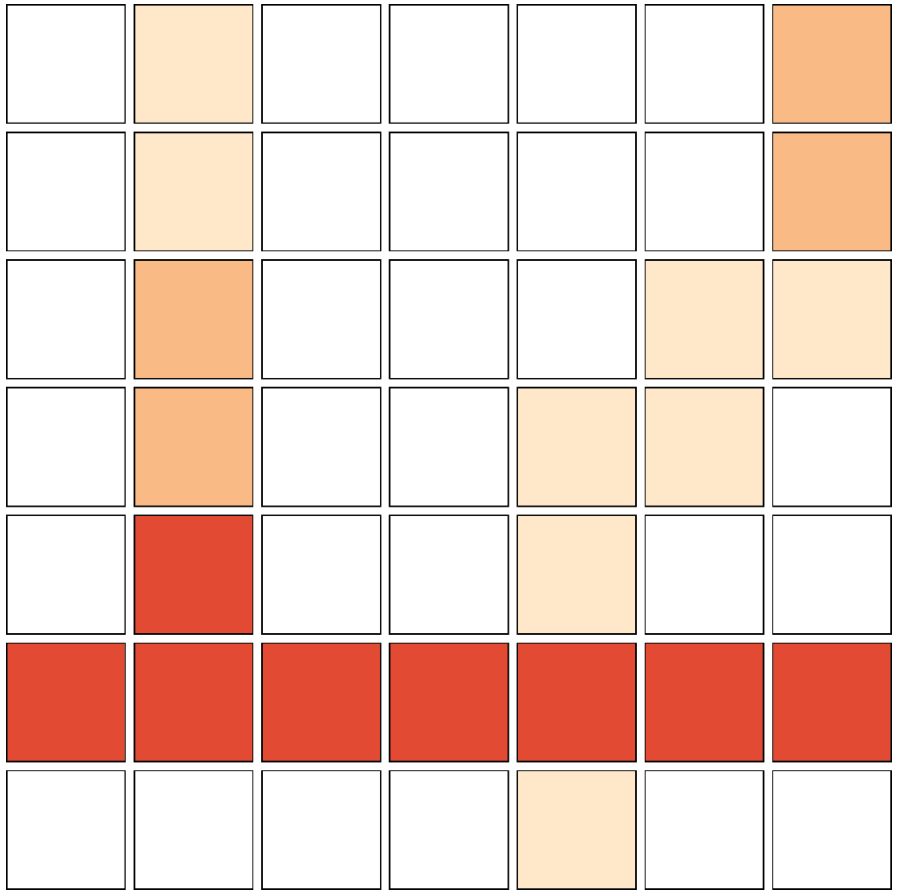
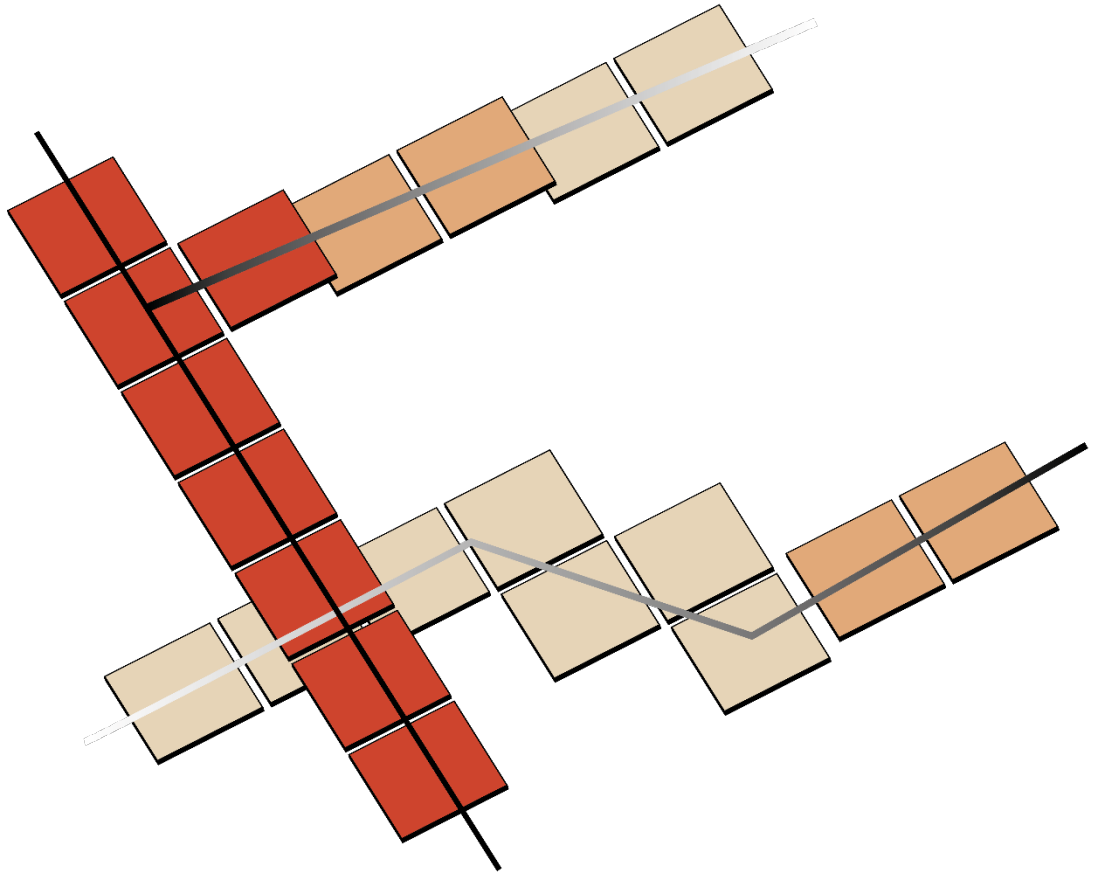


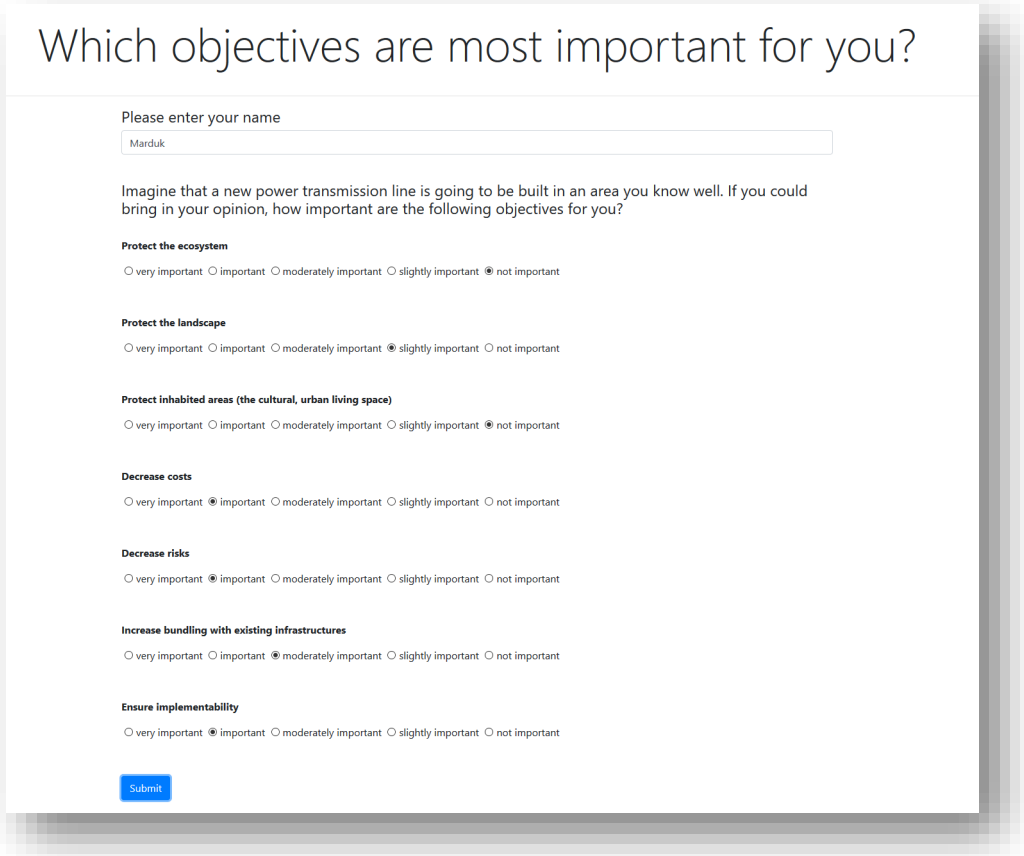


Next steps

allow group

decision-making

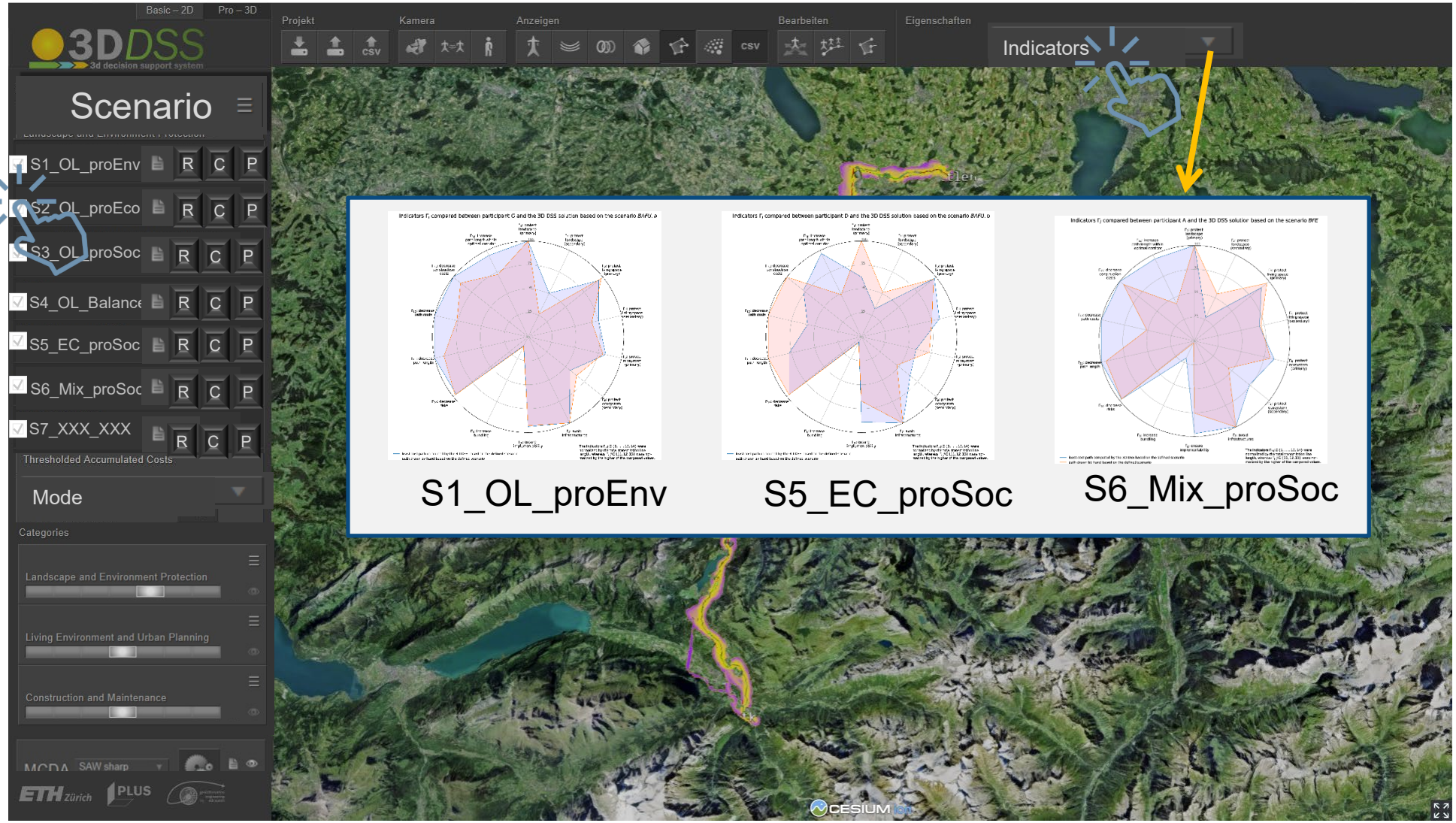
In your opinion, which objectives are most important when planning power transmission lines?



- Please, fill out the form on

survey.joramschito.ch

- A similar approach allows considering other aggregation models, as e.g., PROMETHEE or the Analytical Hierarchy Process.
- This might require different elicitation methods.


Basic – 2D
Pro – 3D
3DDSS
3d decision support system
Projekt
Kamera
Anzeigen
Bearbeiten
Eigenschaften
Indicators
Scenario
S1_OL_proEnv
S2_OL_proEco
S3_OL_proSoc
S4_OL_Balance
S5_EC_proSoc
S6_Mix_proSoc
S7_XXX_XXX
R C P
Thresholded Accumulated Costs
Mode
Categories
Landscape and Environment Protection
Living Environment and Urban Planning
Construction and Maintenance
MCDA
SAW sharp
ETH zürich
PLUS
S1_OL_proEnv
S5_EC_proSoc
S6_Mix_proSoc
CESIUM

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