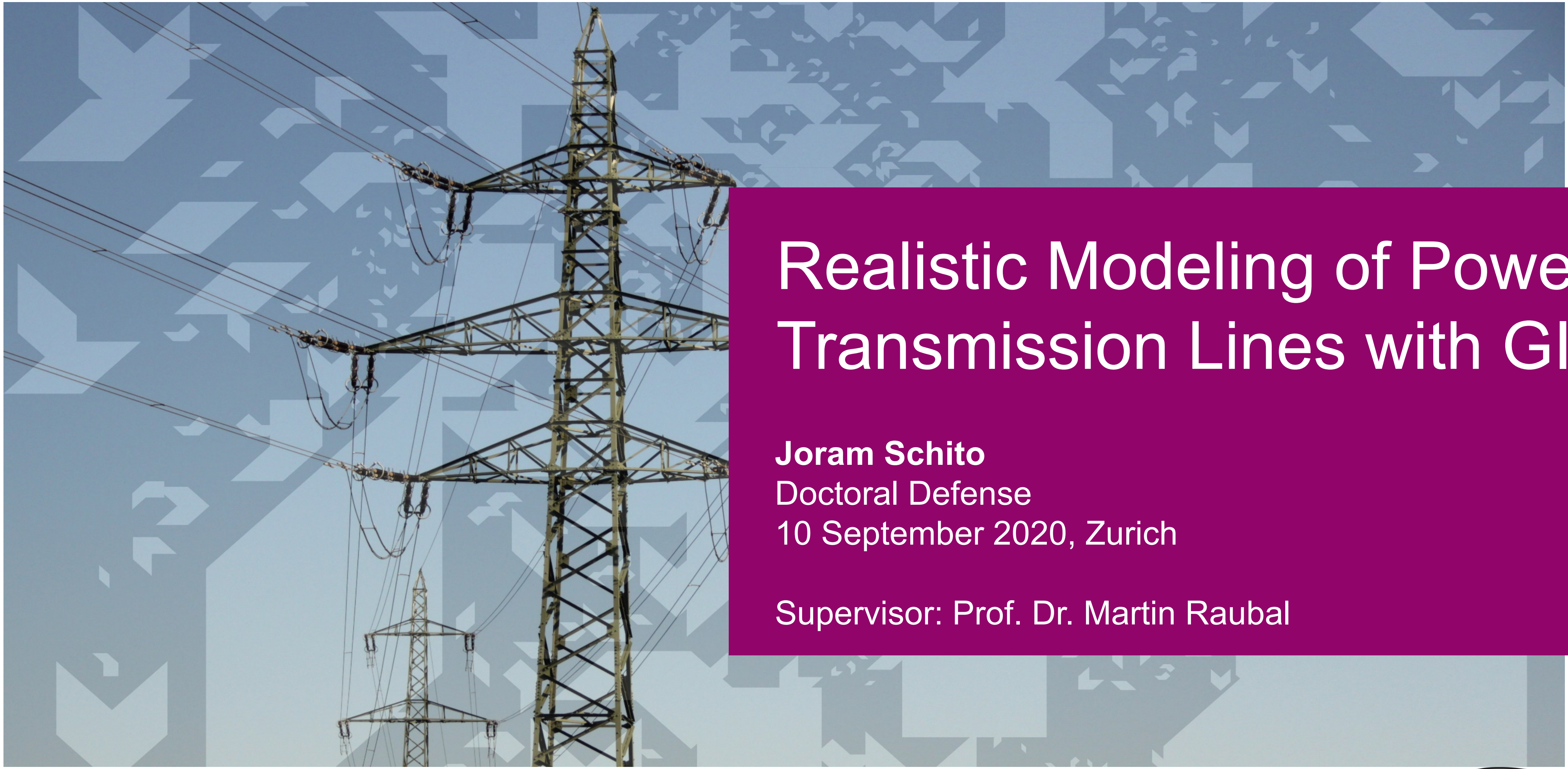
ETH zürich

Institute of Cartography
and Geoinformation



Realistic Modeling of Power Transmission Lines with GIS

Joram Schito

Doctoral Defense

10 September 2020, Zurich

Supervisor: Prof. Dr. Martin Raubal

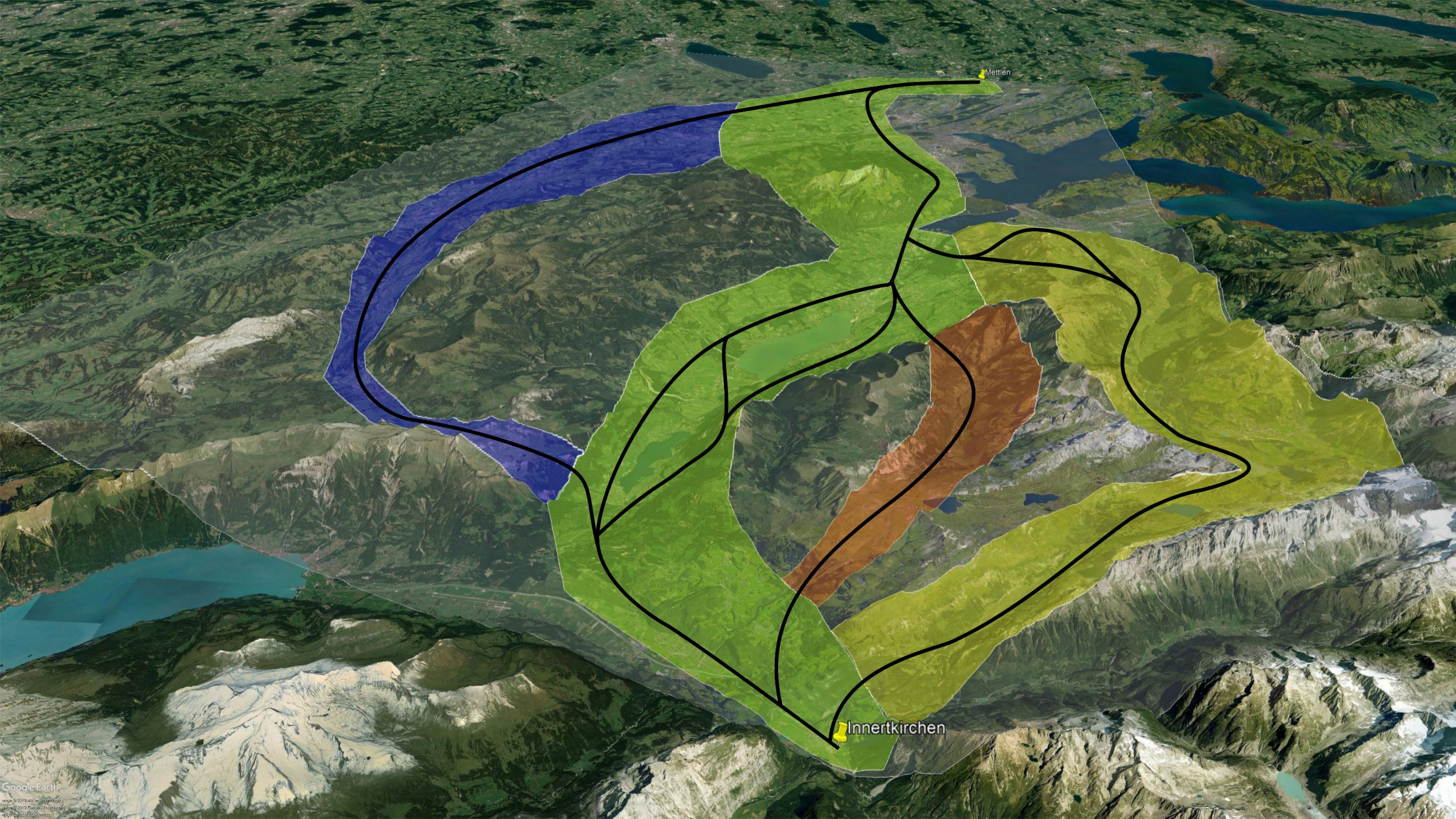
geoinformation engineering
ikg eth zurich

It's all about the choice…

It's all about the choice…


Google Earth


Mettlen
Innertkirchen
Google Earth


Mettlen
Innertkirchen
Google Earth

Agenda

1. Motivation and research questions
2. Description of the 3D DSS
3. Contribution in previous studies
4. Procedure of the current study
5. Results for RQ1
6. Results for RQ2
7. Discussion
8. Conclusion and outlook

1. Motivation and research questions

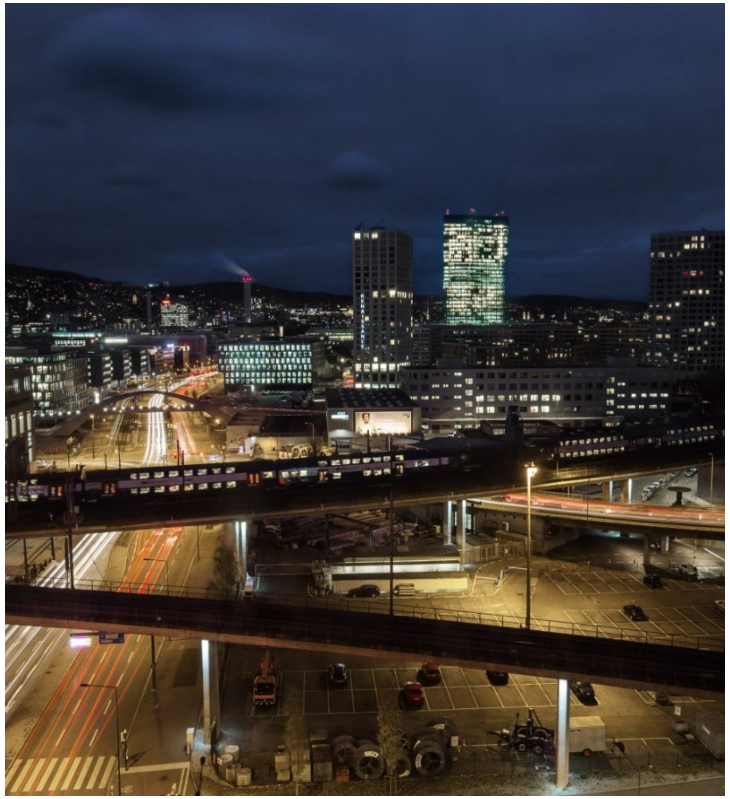
Drivers for grid expansion in Switzerland

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



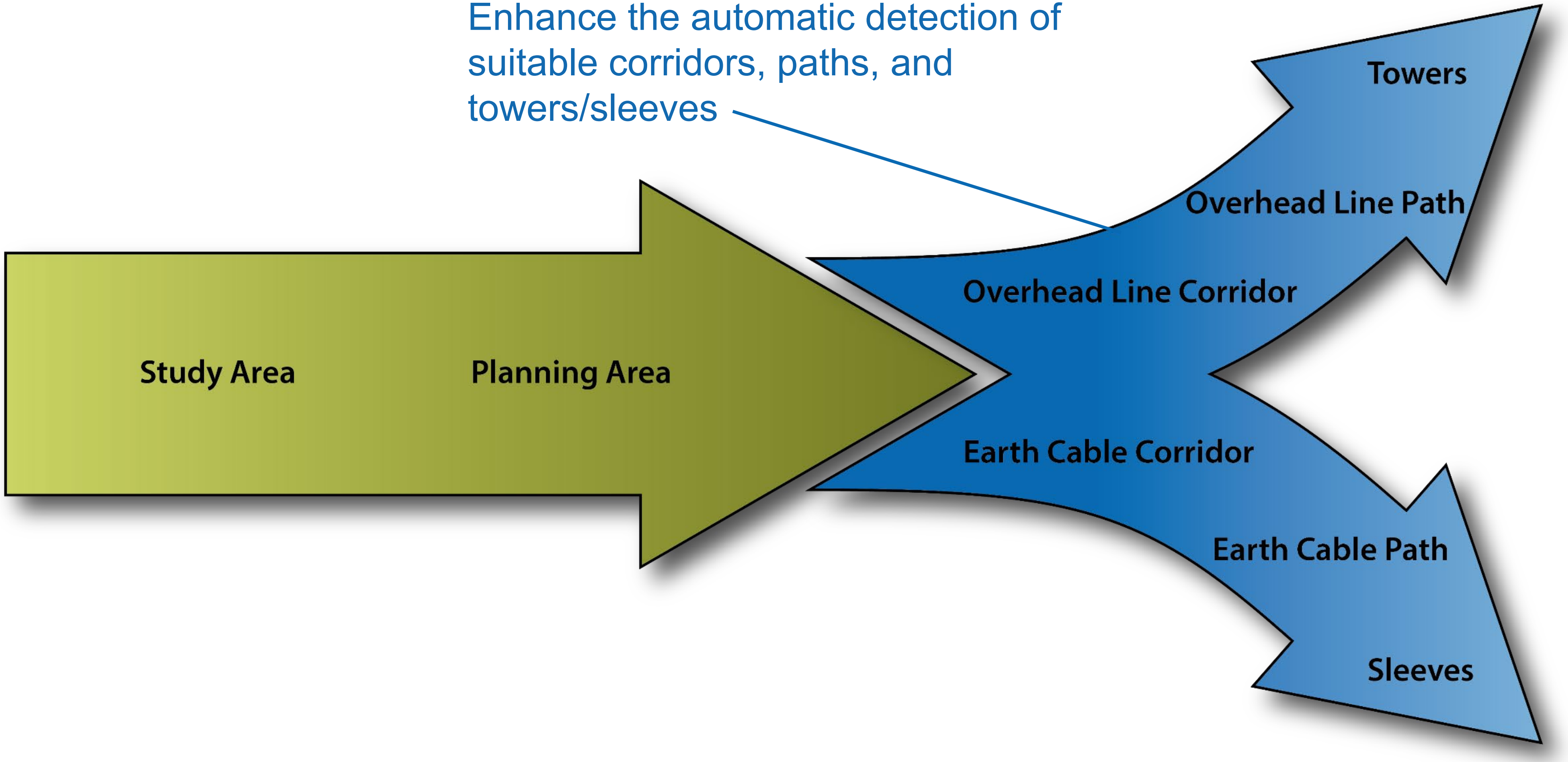
Supply of downstream grids

New connection requests can lead to congestion

Images: Swissgrid

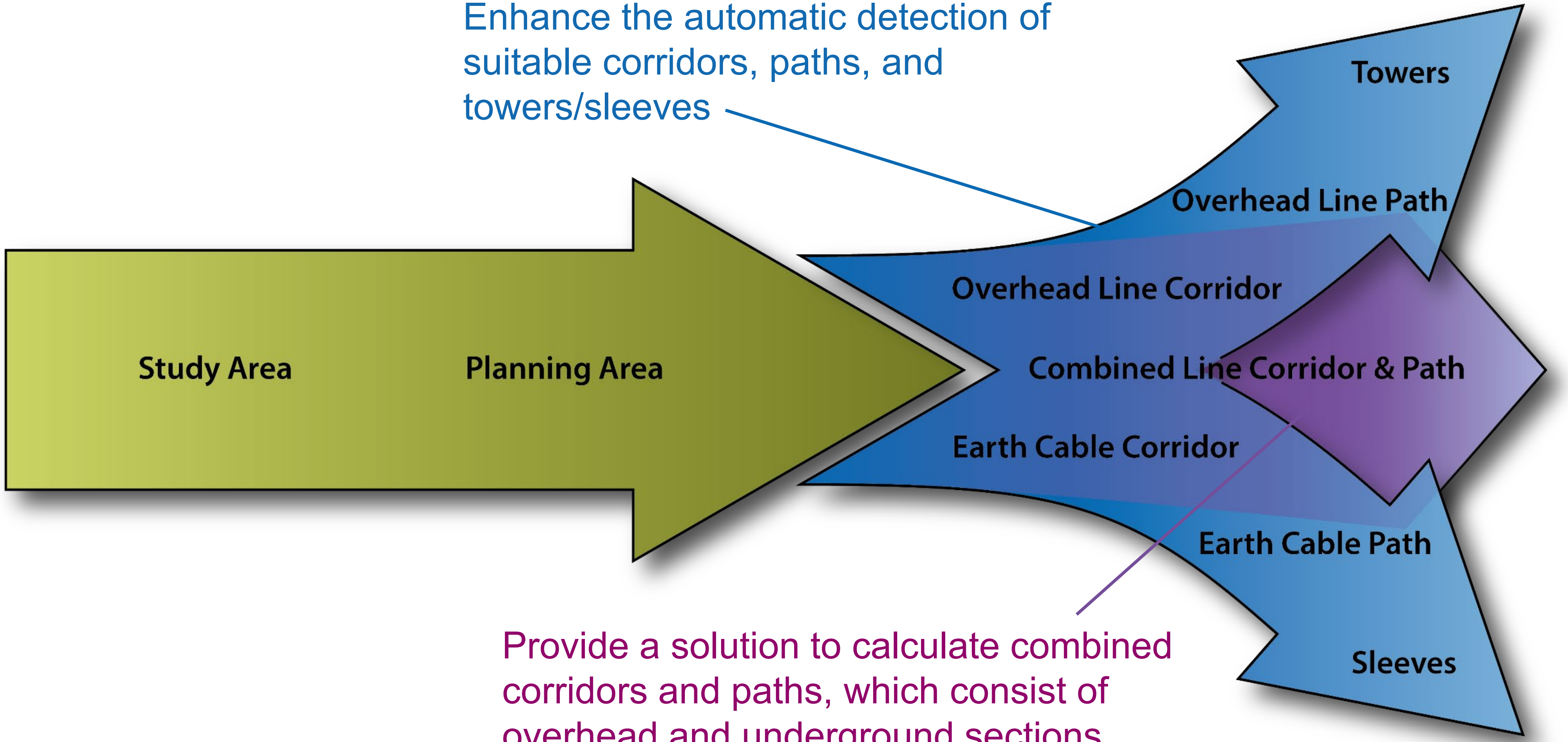
A stepwise planning procedure for power transmission lines

Enhance the automatic detection of suitable corridors, paths, and towers/sleeves



A stepwise planning procedure for power transmission lines

Enhance the automatic detection of suitable corridors, paths, and towers/sleeves

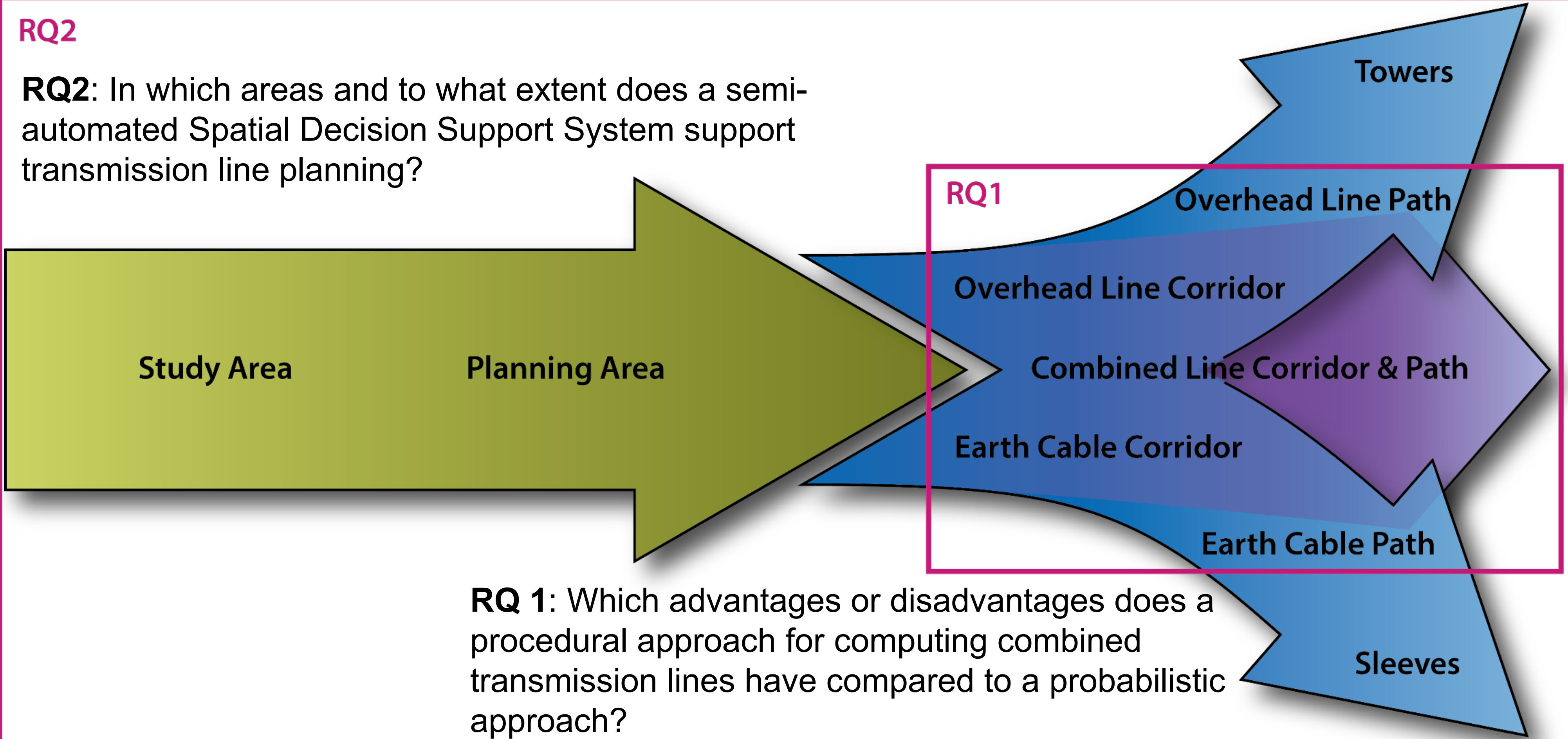


Provide a solution to calculate combined corridors and paths, which consist of overhead and underground sections

A stepwise planning procedure for power transmission lines

RQ2

RQ2: In which areas and to what extent does a semi-automated Spatial Decision Support System support transmission line planning?

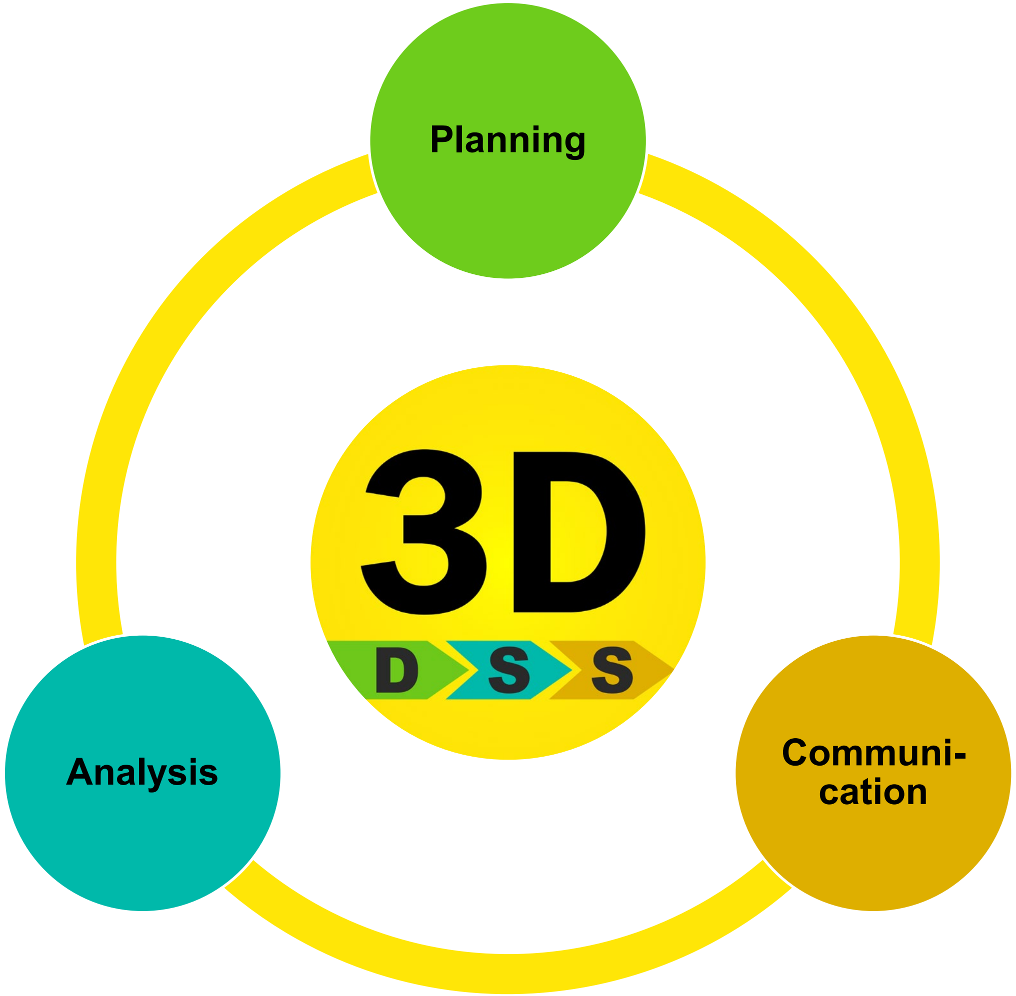


RQ 1: Which advantages or disadvantages does a procedural approach for computing combined transmission lines have compared to a probabilistic approach?

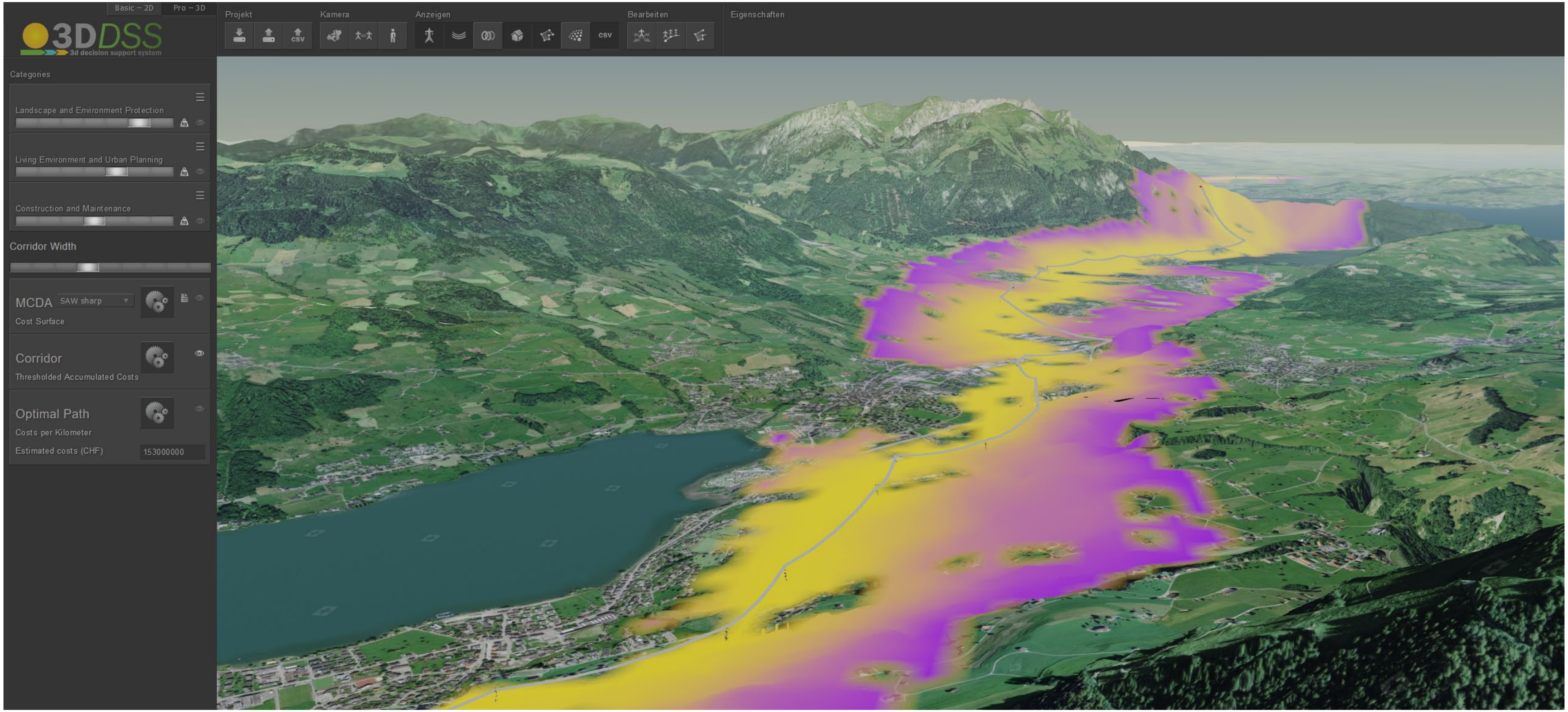
2. Description of the 3DDSS

3d decision support system

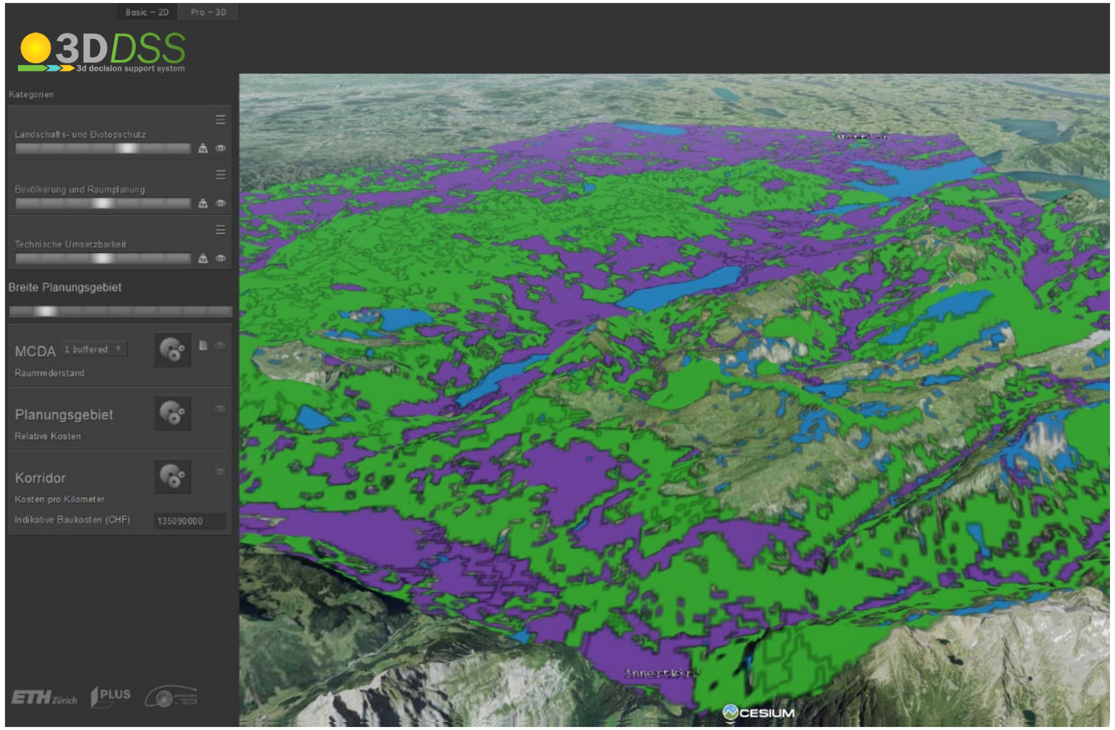
The 3D DSS's function domains

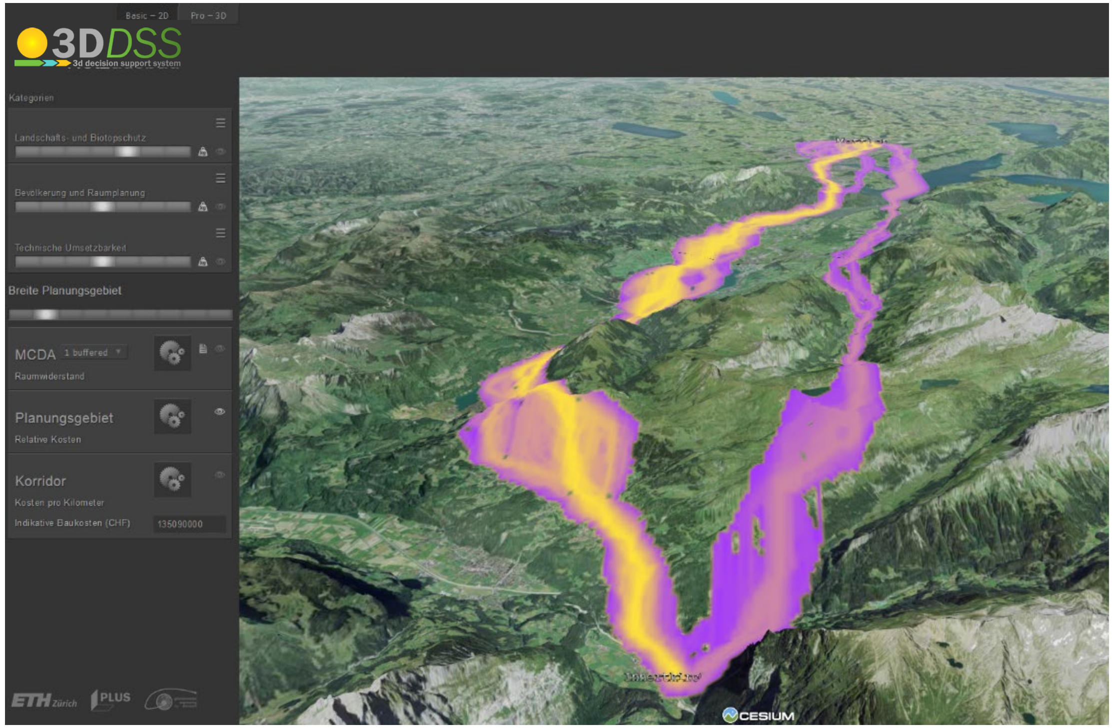


The 3D DSS's graphical user interface



How the optimal corridor is calculated



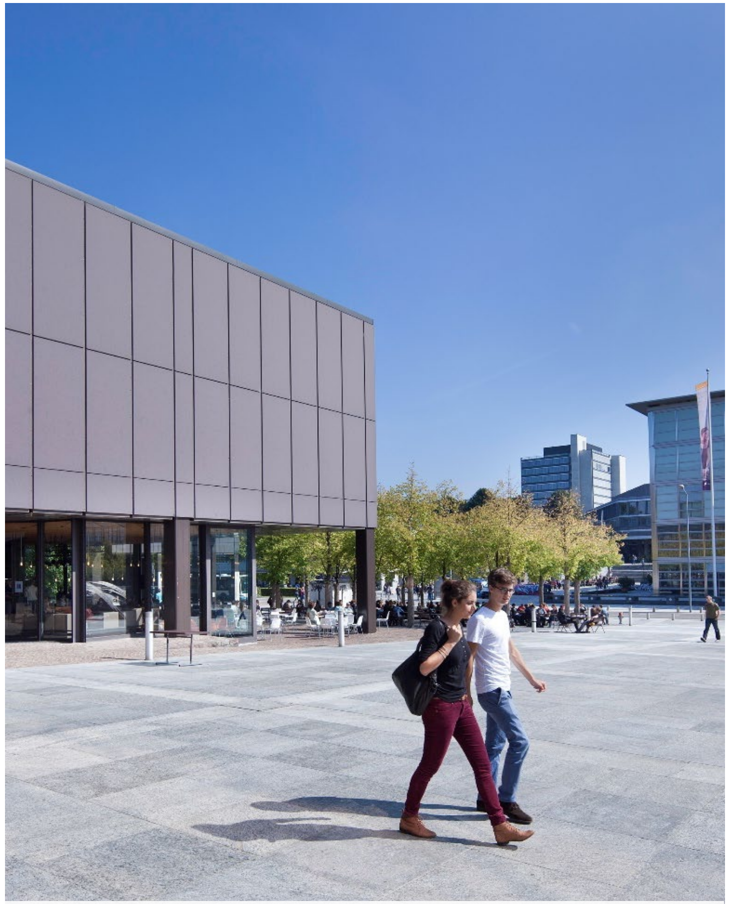


1. Analyze and weight the spatial criteria. Each layer corresponds to one criterion.
2. Compute a cost surface by applying a weighted linear combination and the decision rules.
3. Apply Dijkstra’s algorithm to compute an accumulated cost map.
4. Narrow the corridor by defining an upper cost limit.

The decision model considers various criteria from these three main categories

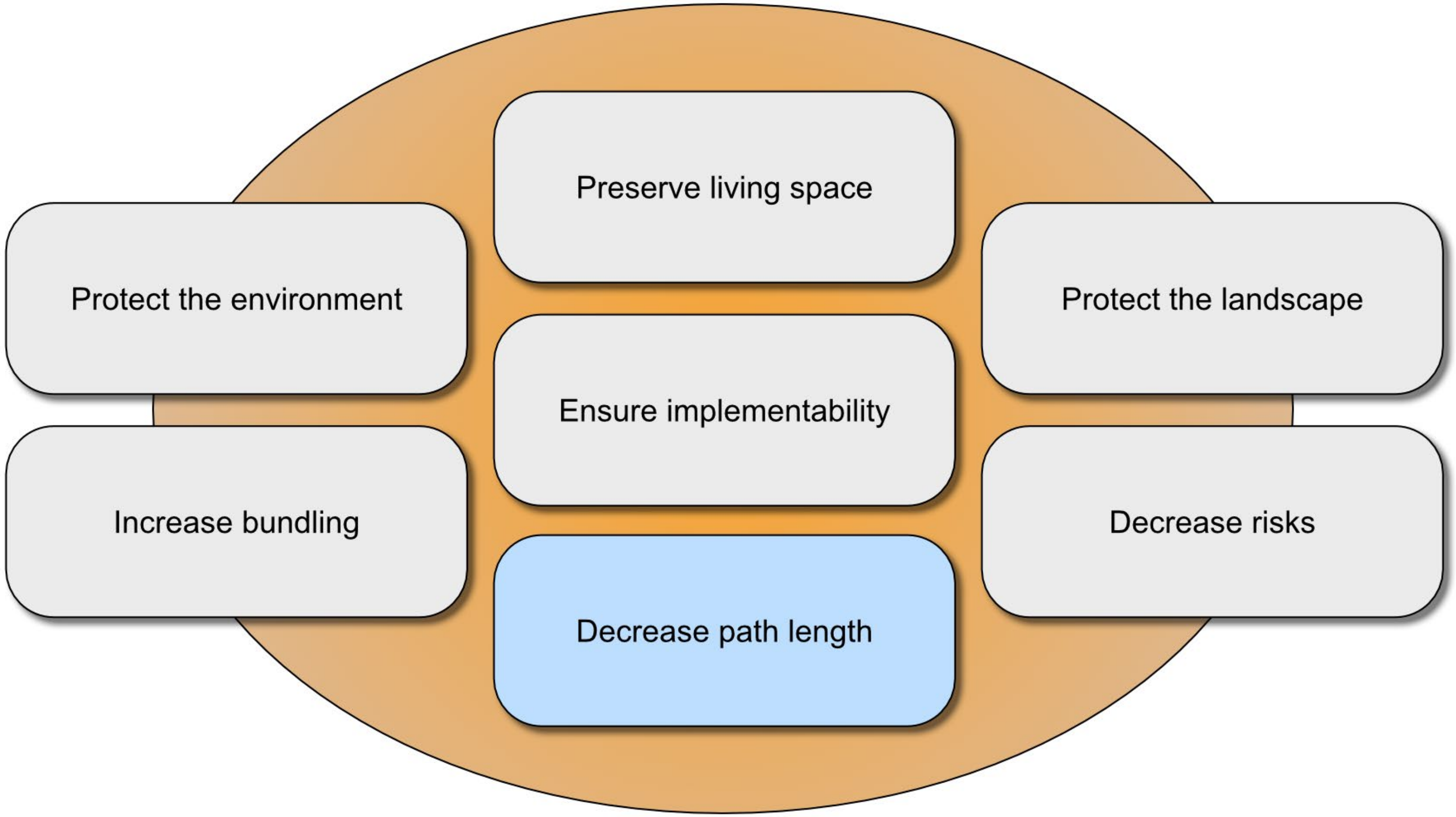
technical feasibility

environment & landscape

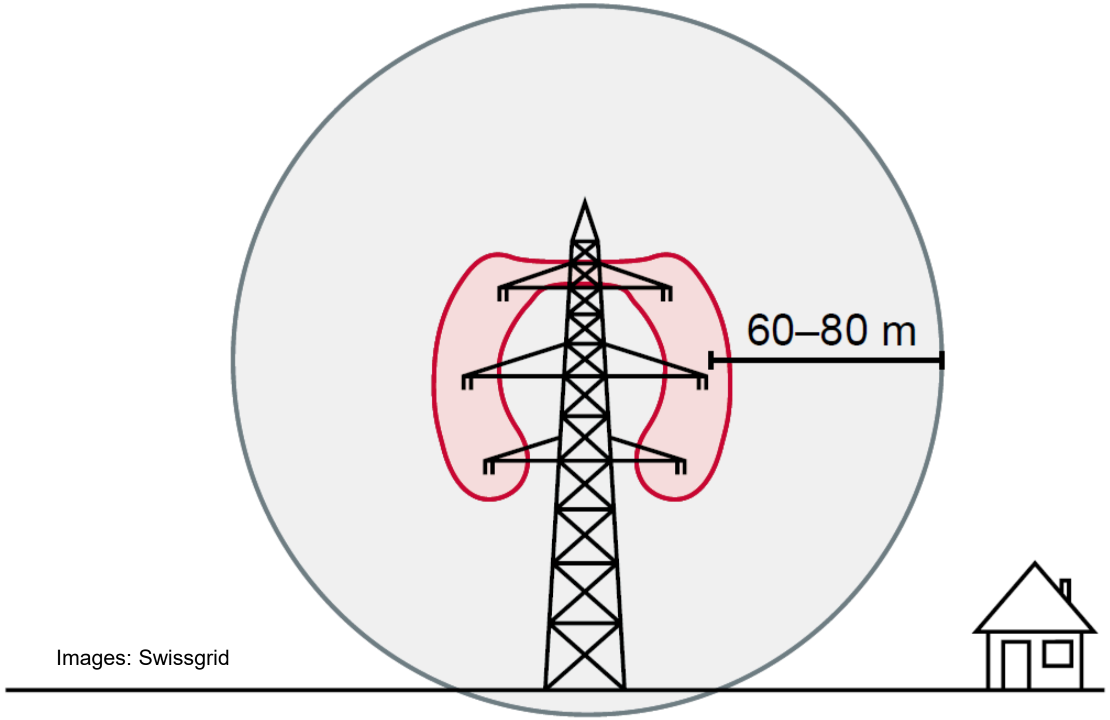


urban planning

The criteria are associated with the objectives. The stakeholders weight the objectives based on their interests.

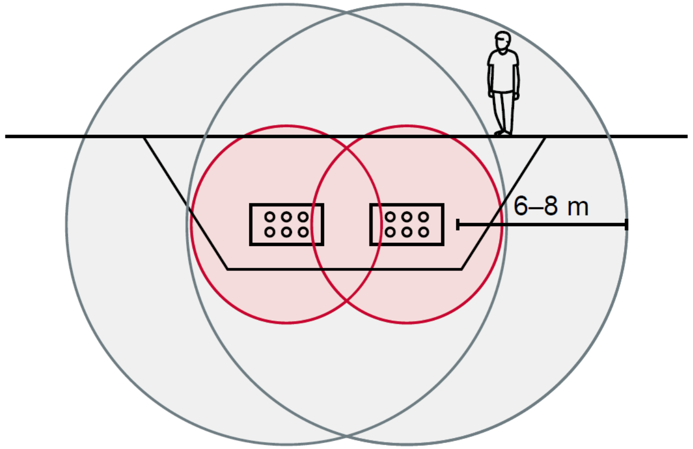


Different transmission technologies require different decision rules

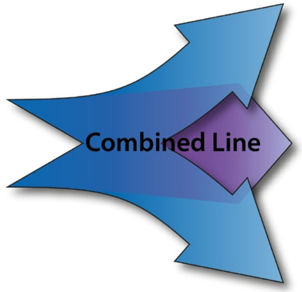


Images: Swissgrid

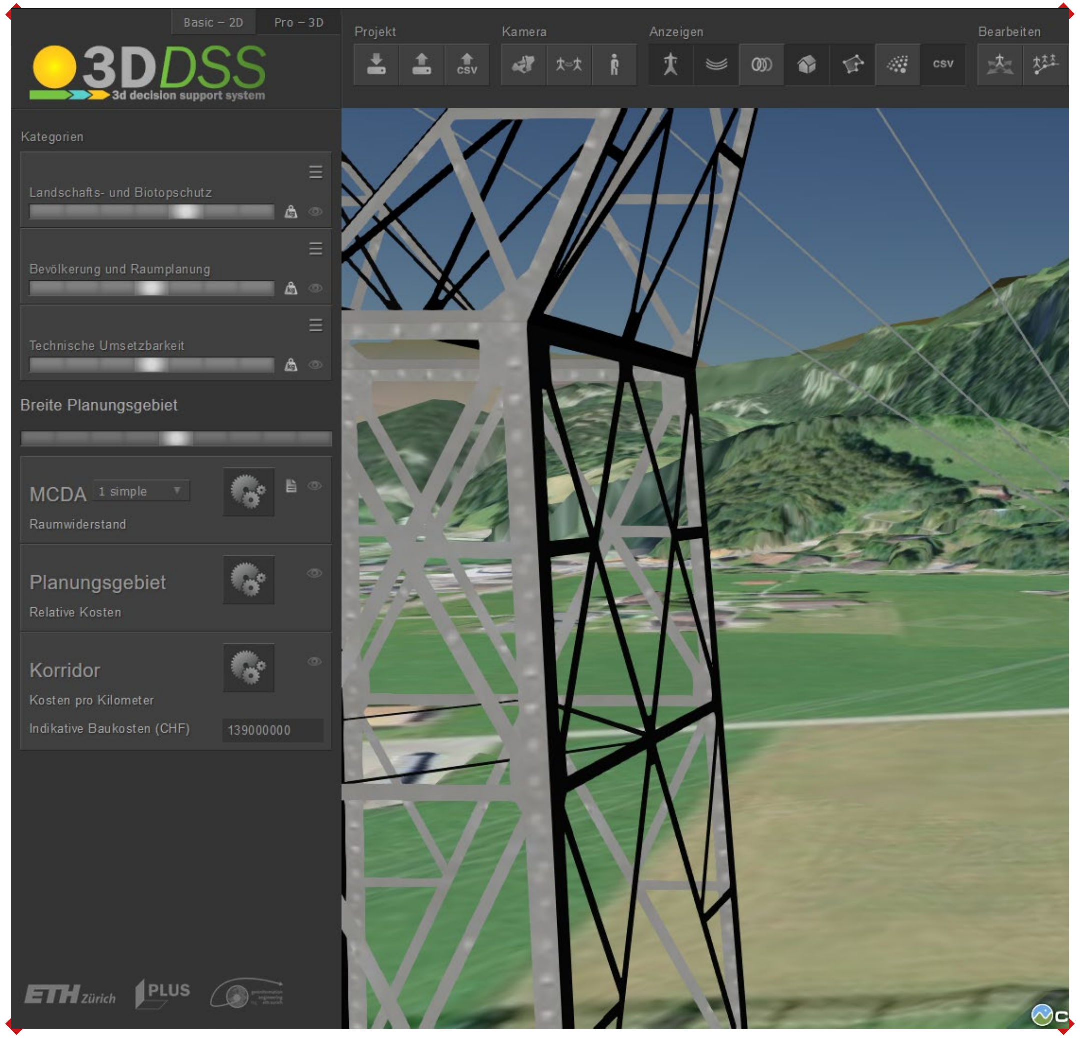
Despite the different decision rules, how can a model be built that combines sections of both transmission technologies with each other?



RQ1

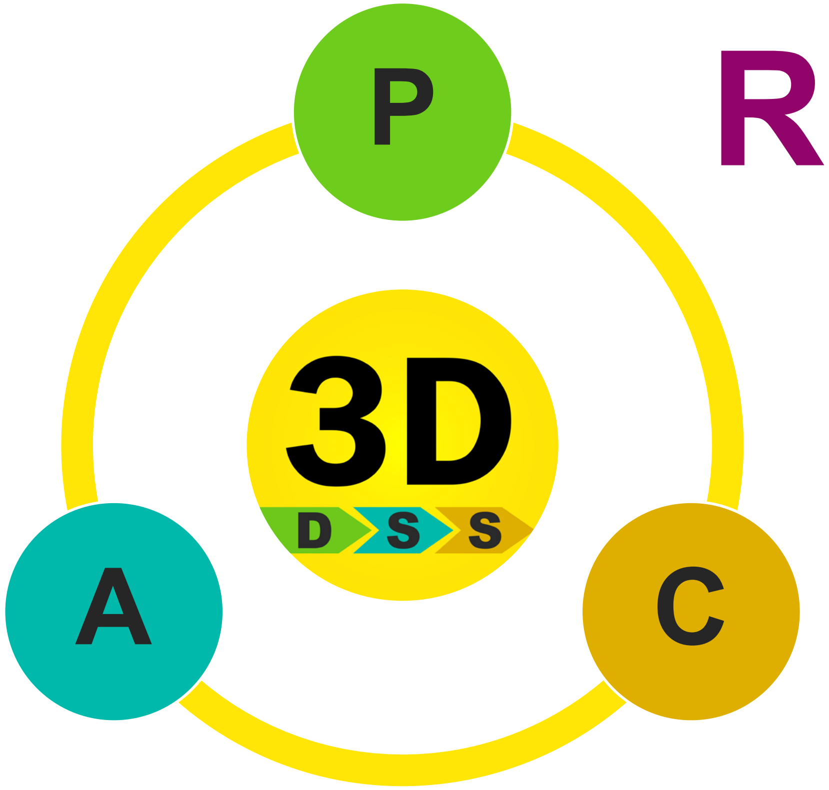


What is the potential of a Spatial Decision Support System regarding realistic transmission line planning?



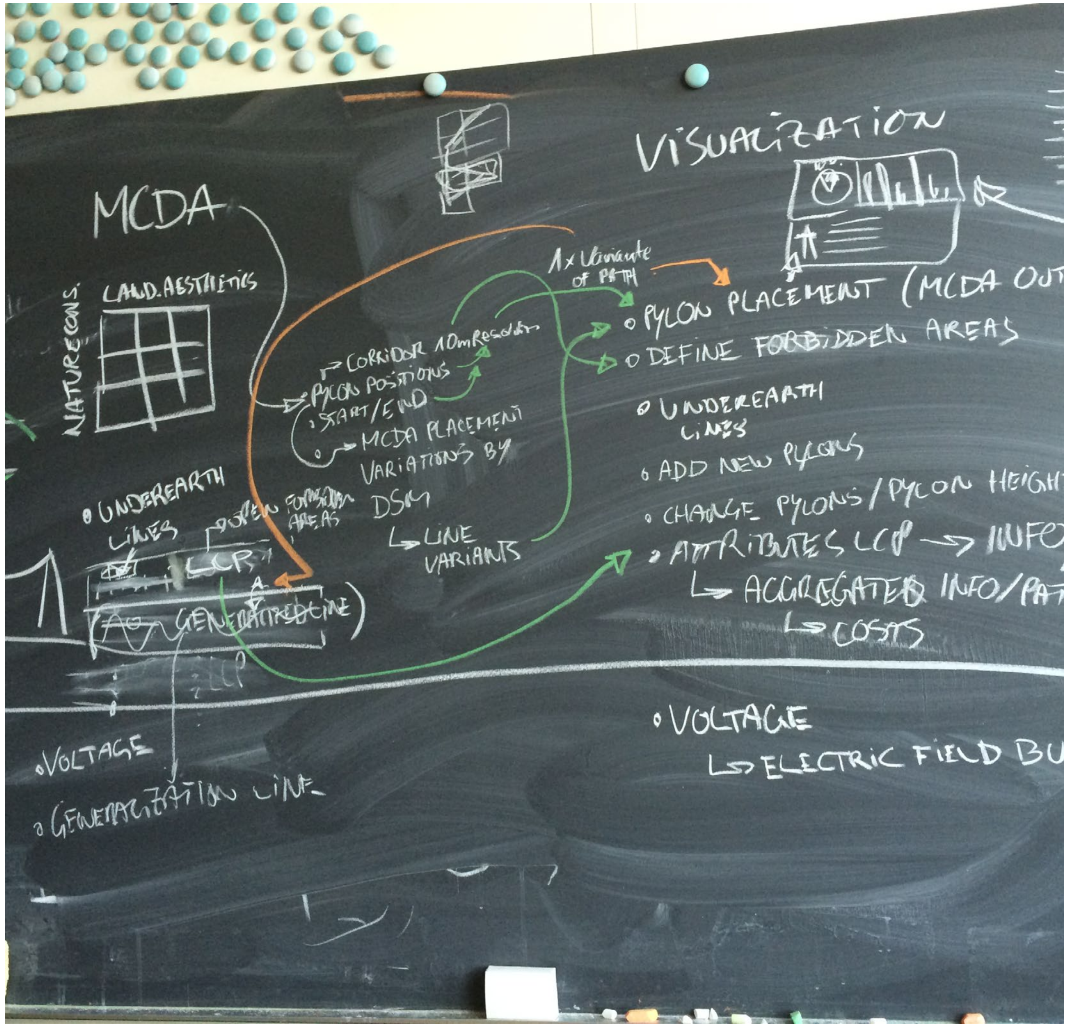
To what extent can a semi-automated approach support the planning, analysis, and communication of new transmission lines?

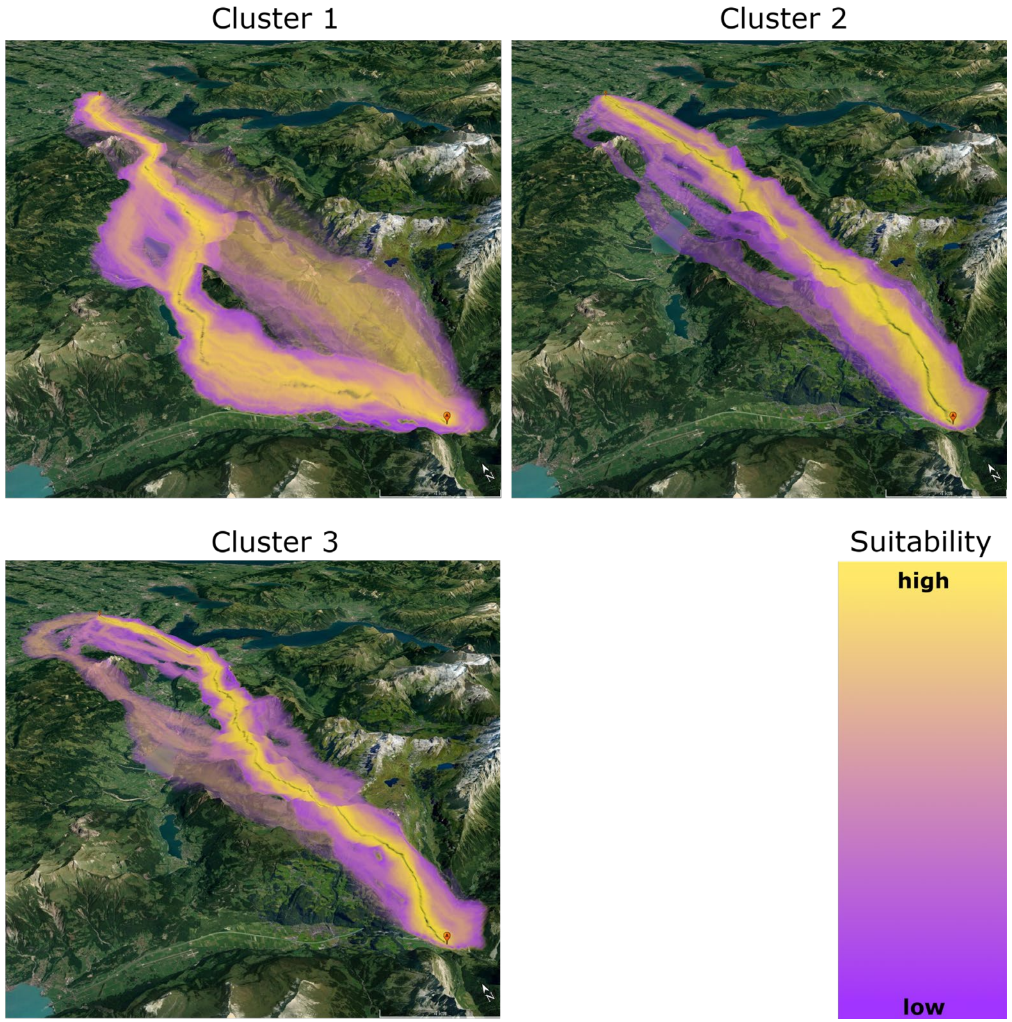
RQ2



3. Contribution in previous studies

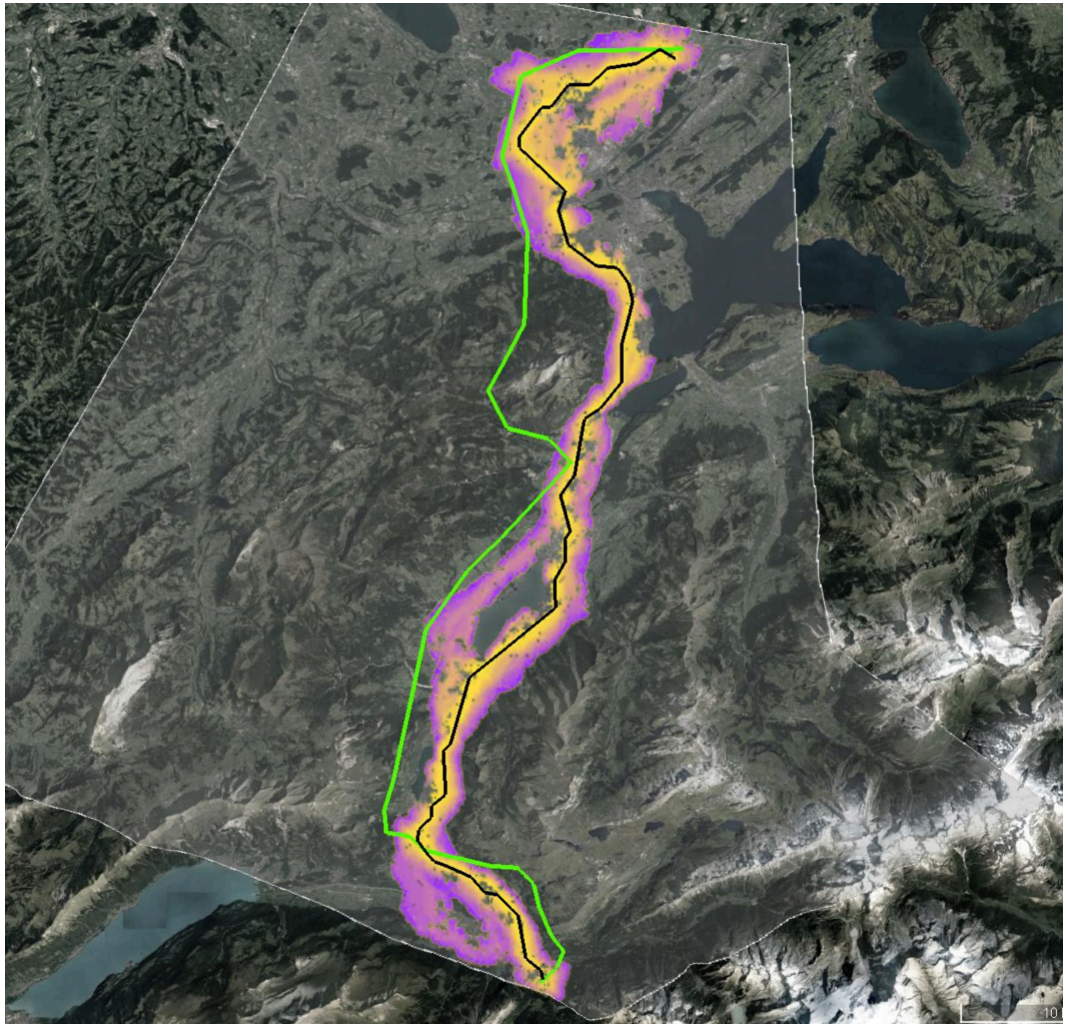
2018: Which parameters of the decision model contribute most to the spatial variability of the resulting corridors and paths?

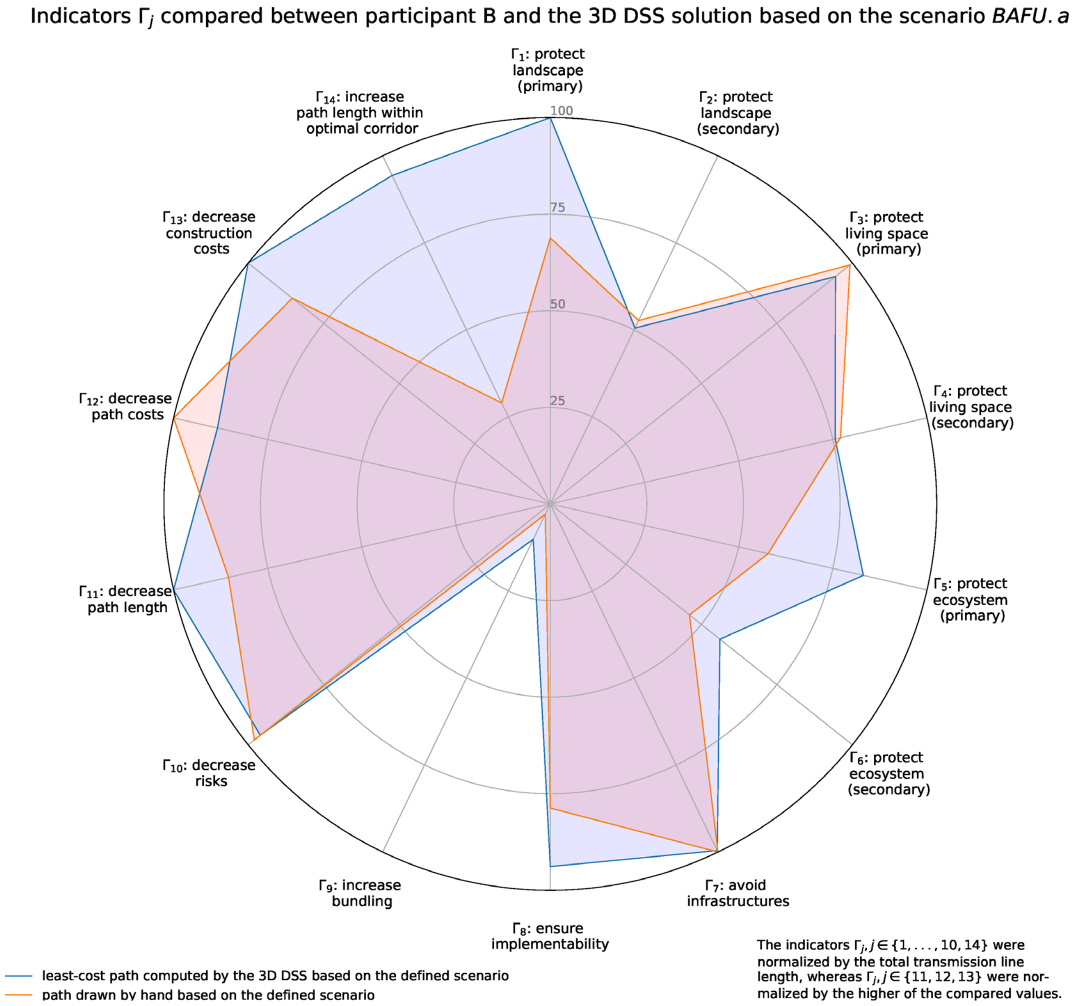




Schito et al. (2018)

2019: We allowed experts to draw a line they think would fulfill their objectives best. Charts supported the evaluation of their proposition.





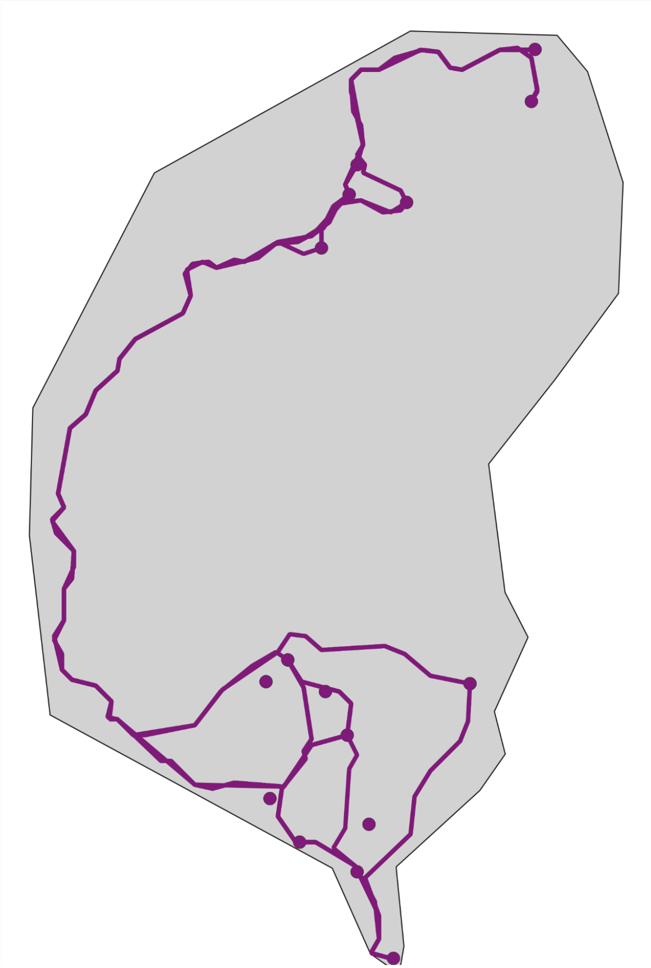
Schito et al. (2019)

2020: We developed an approach that determines Pareto optimal path alternatives based on a network graph

all abstract paths

dominant abstract paths

dominant geographic paths

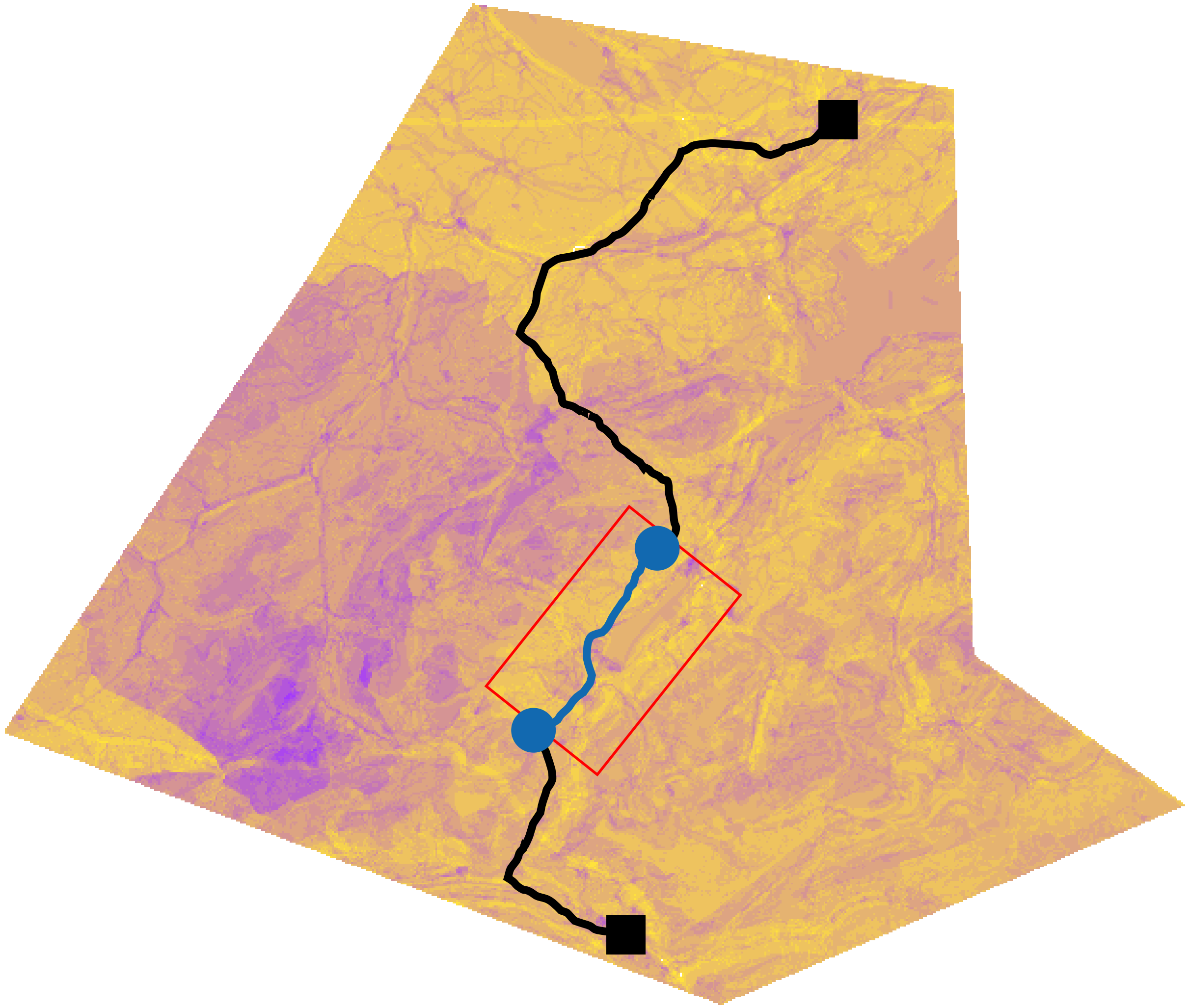


Schito et al. (2020)

4. Procedure of the current study

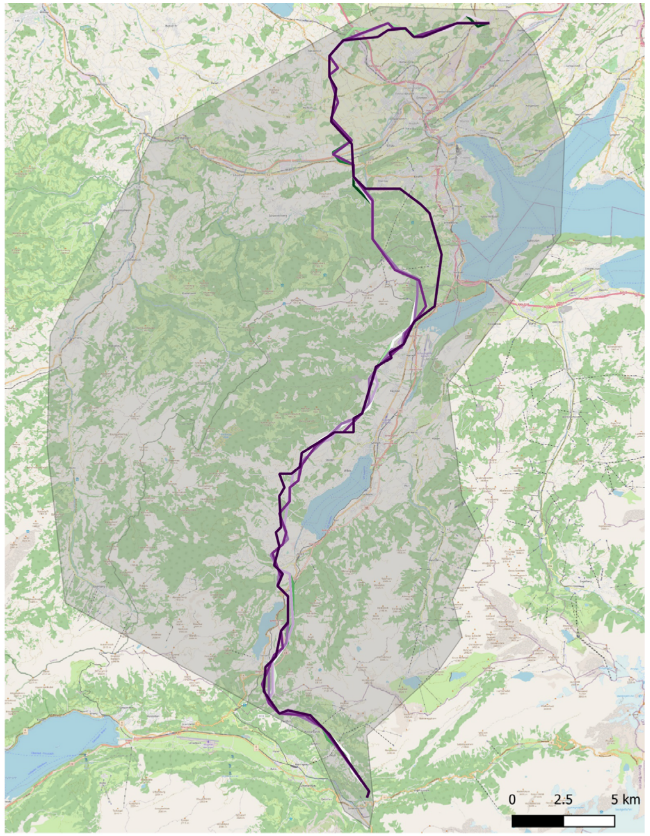
Assume that overhead lines are the regular case. Earth cables are preferred only if a significant advantage can be proven.

How the procedural approach works

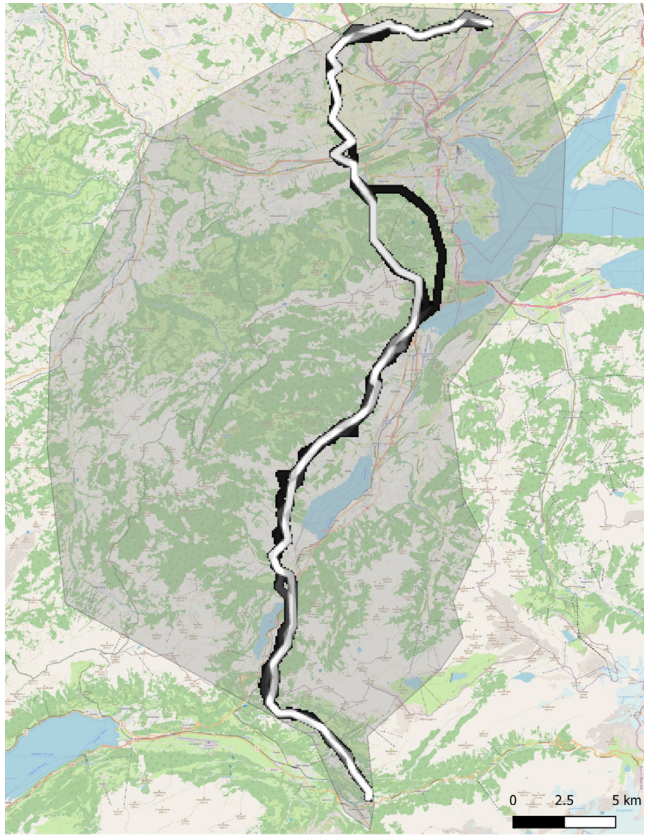


1. Determine areas in which an earth cable would be more suitable than an overhead line.
2. At the borders of these areas, determine appropriate places for a transition building.
3. Compute the optimal earth cable path between the two transition buildings.
4. Connect the transition buildings with the start and end point by an overhead line.

How the probabilistic approach works



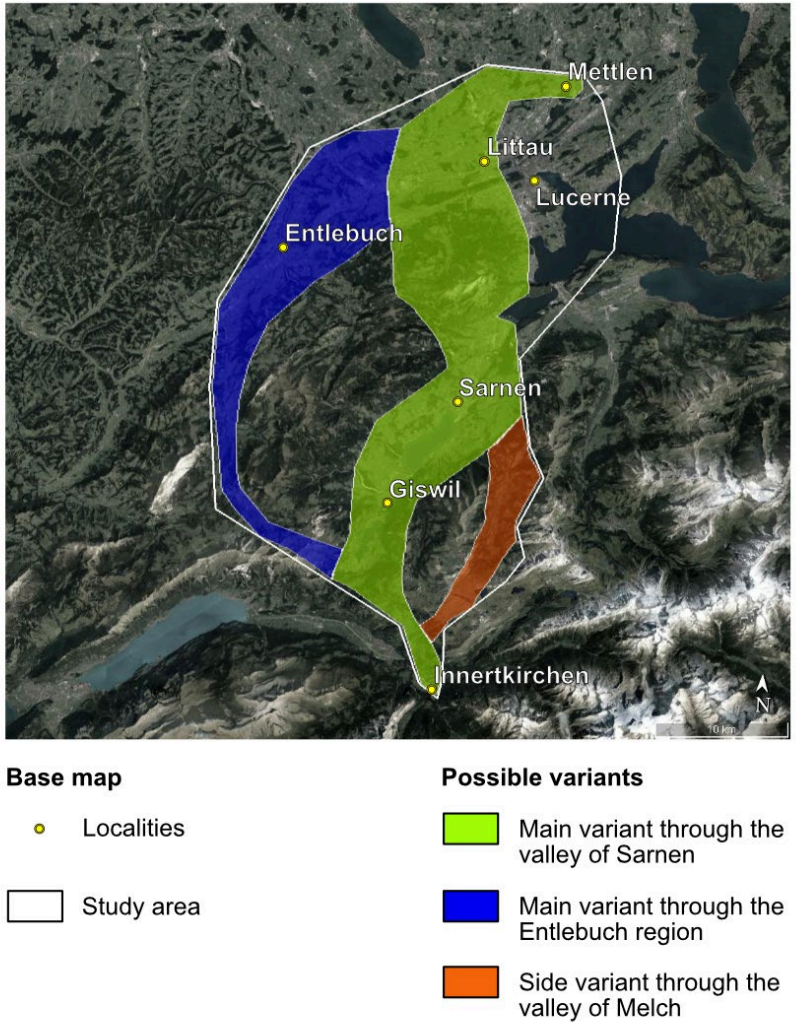
- LCP0% overhead | 100% underground
- LCP10% overhead | 90% underground
- LCP20% overhead | 80% underground
- LCP30% overhead | 70% underground
- LCP40% overhead | 60% underground
- LCP50% overhead | 50% underground
- LCP60% overhead | 40% underground
- LCP70% overhead | 30% underground
- LCP80% overhead | 20% underground
- LCP90% overhead | 10% underground
- LCP100% overhead | 0% underground
- study area Innertkirchen–Mettlen



kernel density estimation on 11 least cost paths
- 1 path
- 11 overlapping paths
- study area Innertkirchen–Mettlen

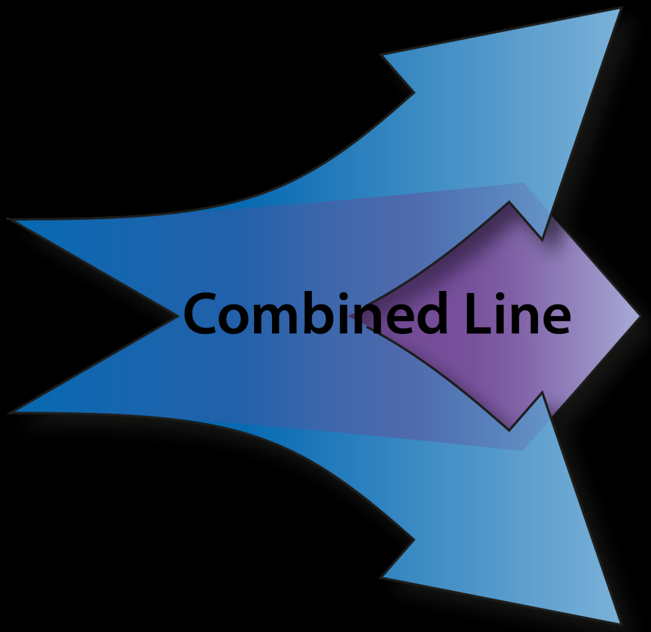
1. Assume different decision models for each transmission technology.
2. Build two cost surface for the two pure cases:
   - 100% overhead
   - 100% underground
3. Linearly combine both cost surface in steps of 10% with each other.
4. Determine the least cost paths.
5. Conduct a kernel density estimation to determine the probability of each area of being suitable for constructing a transmission line.

Study area and study design

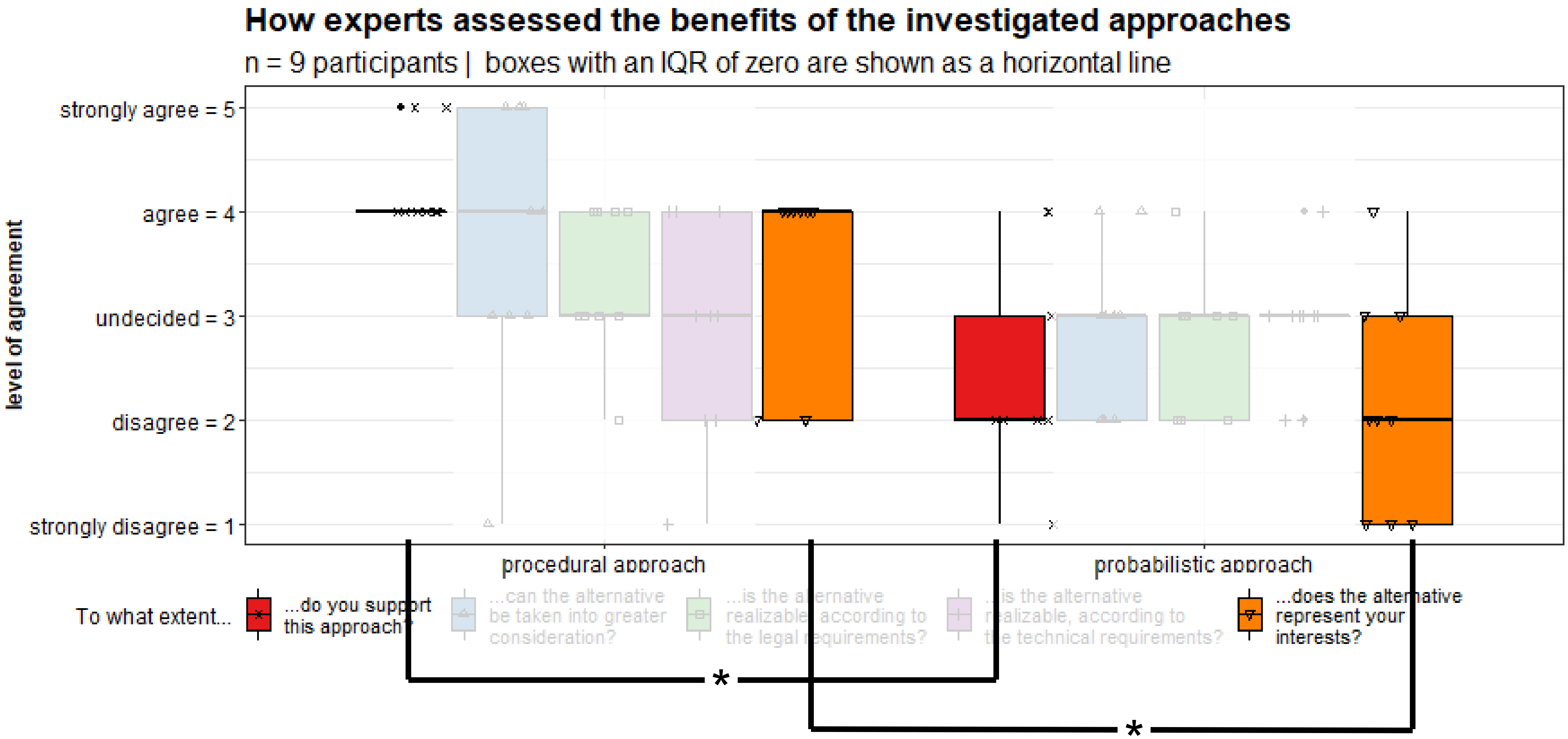


- Expert study with 9 participants
  - 1 female, 8 males
  - 4 working as transmission line planners, 5 working for approving authorities
  - confident with the study area
- Phase 1: Preparation and weight elicitation
  - Obtain the weights for each objective
- Phase 2: Main study
  - RQ1: Both approaches were directly compared by answering a questionnaire (repeated-measures design)
  - RQ2: Semi-automated approach assessed by a questionnaire and by expert interviews

5. Results for RQ1



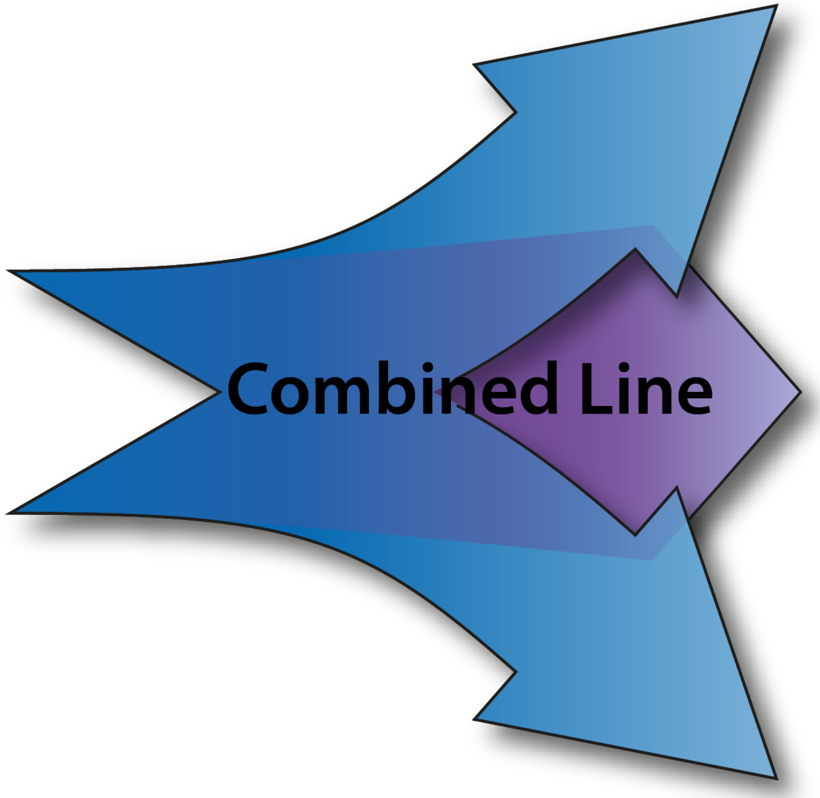
Regarding support and interest representation, the procedural approach performed significantly better than the probabilistic approach (p < .05)



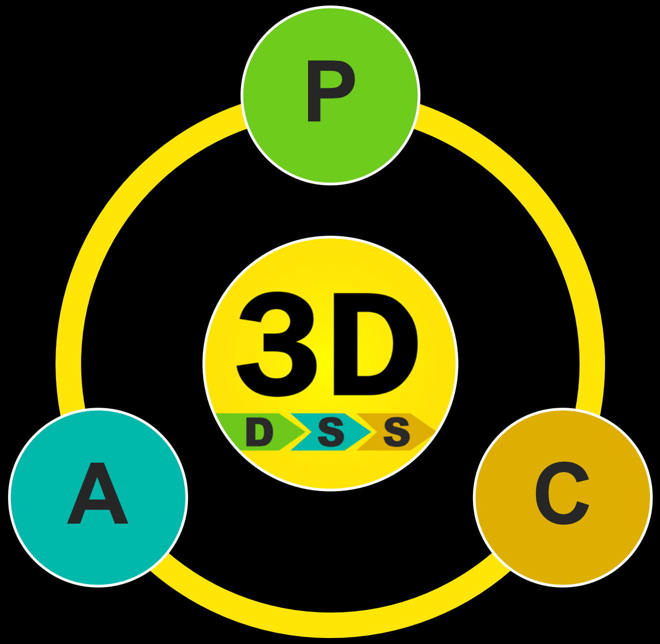
Key findings

- The procedural approach was more supported by the experts and represented their interests more accurately than the probabilistic approach.
- Both approaches yielded similar results concerning the realizability of the calculated corridors and paths.
- Experts assessed the procedural approach to be better suited for determining feasible alternatives.

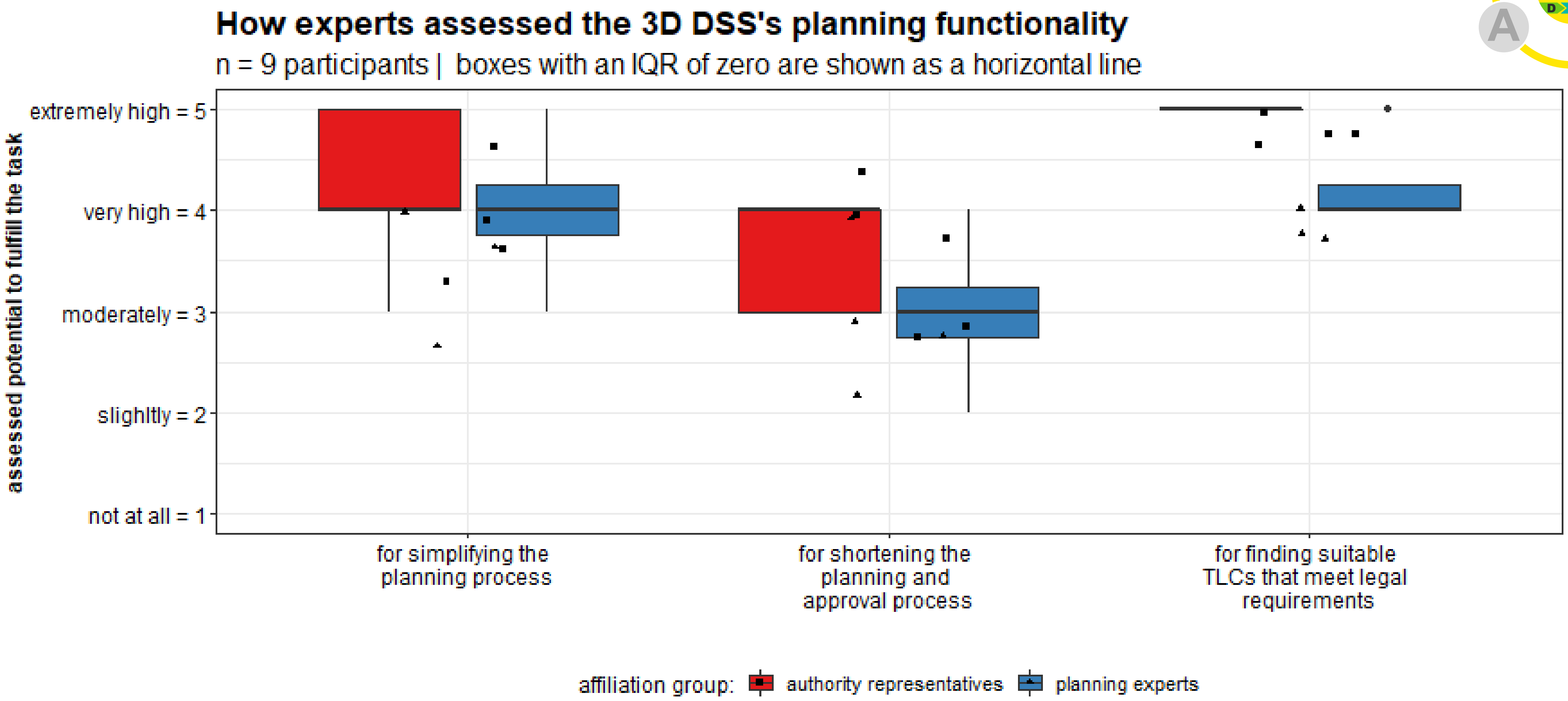
RQ1



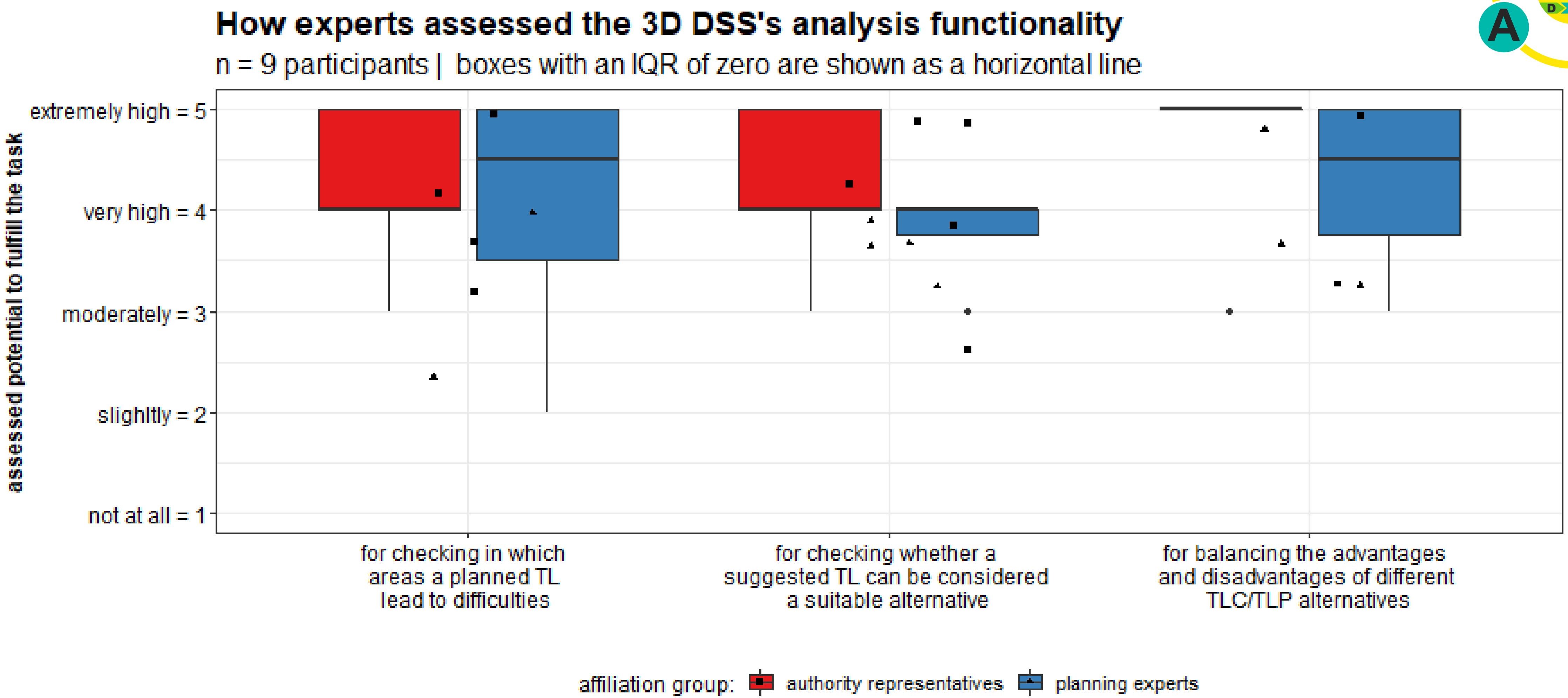
6. Results for RQ2



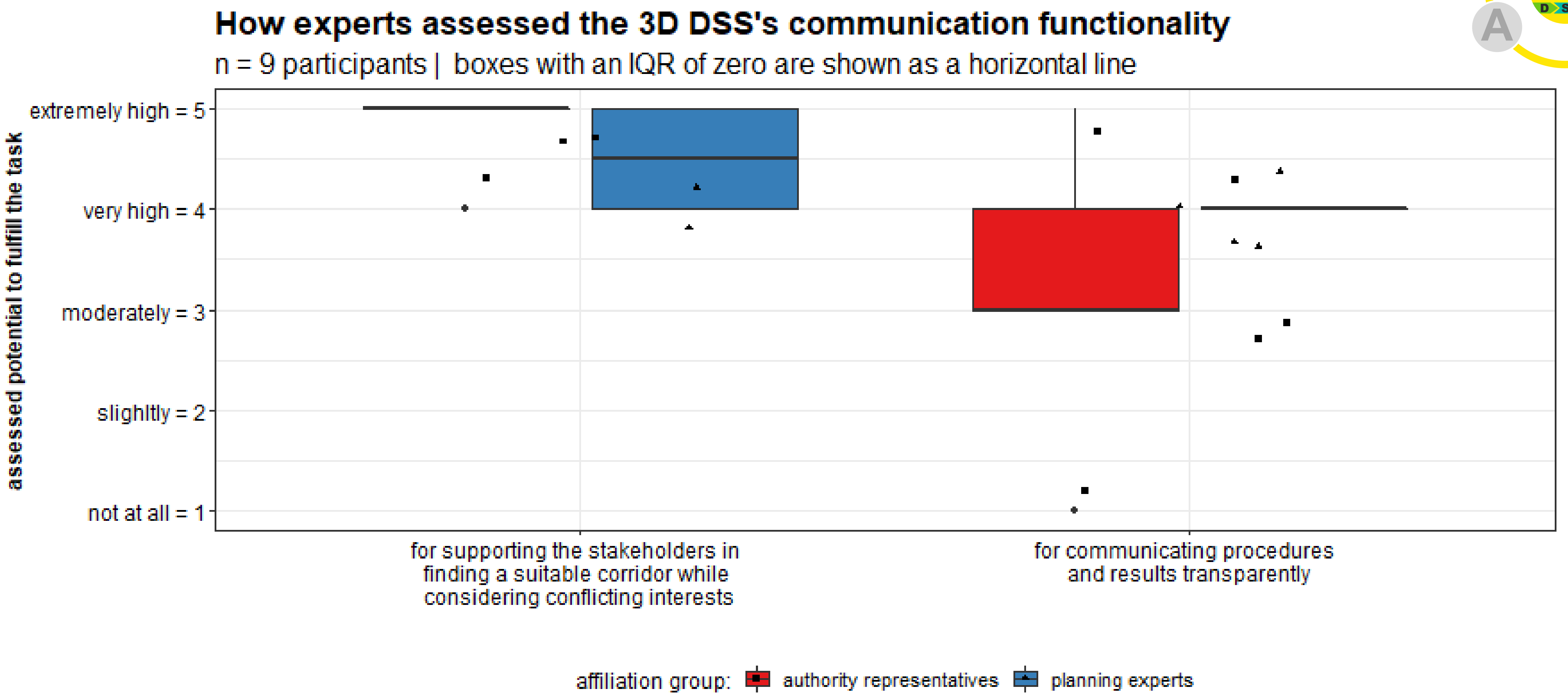
Planning experts assessed the planning functionality more critical than authority representatives



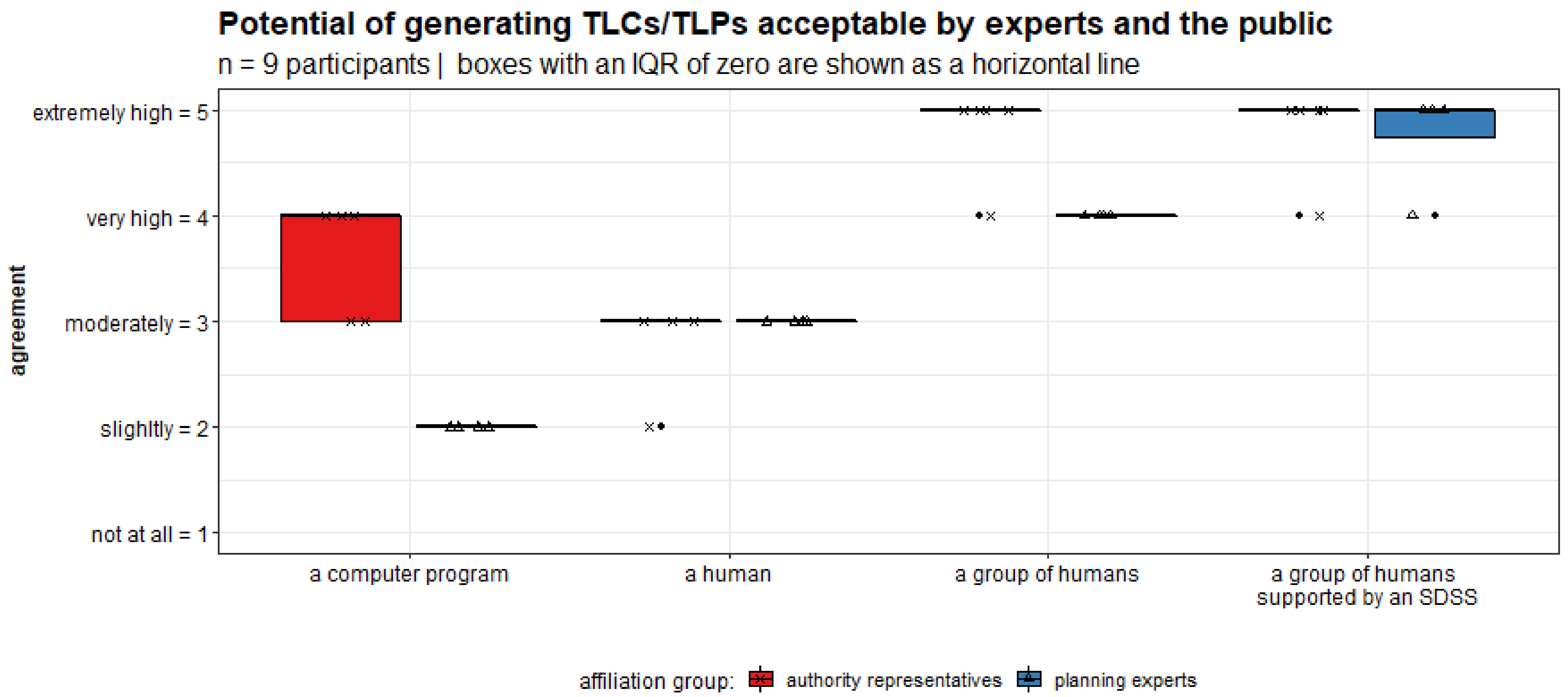
Both groups assessed the potential of supporting the analysis very high



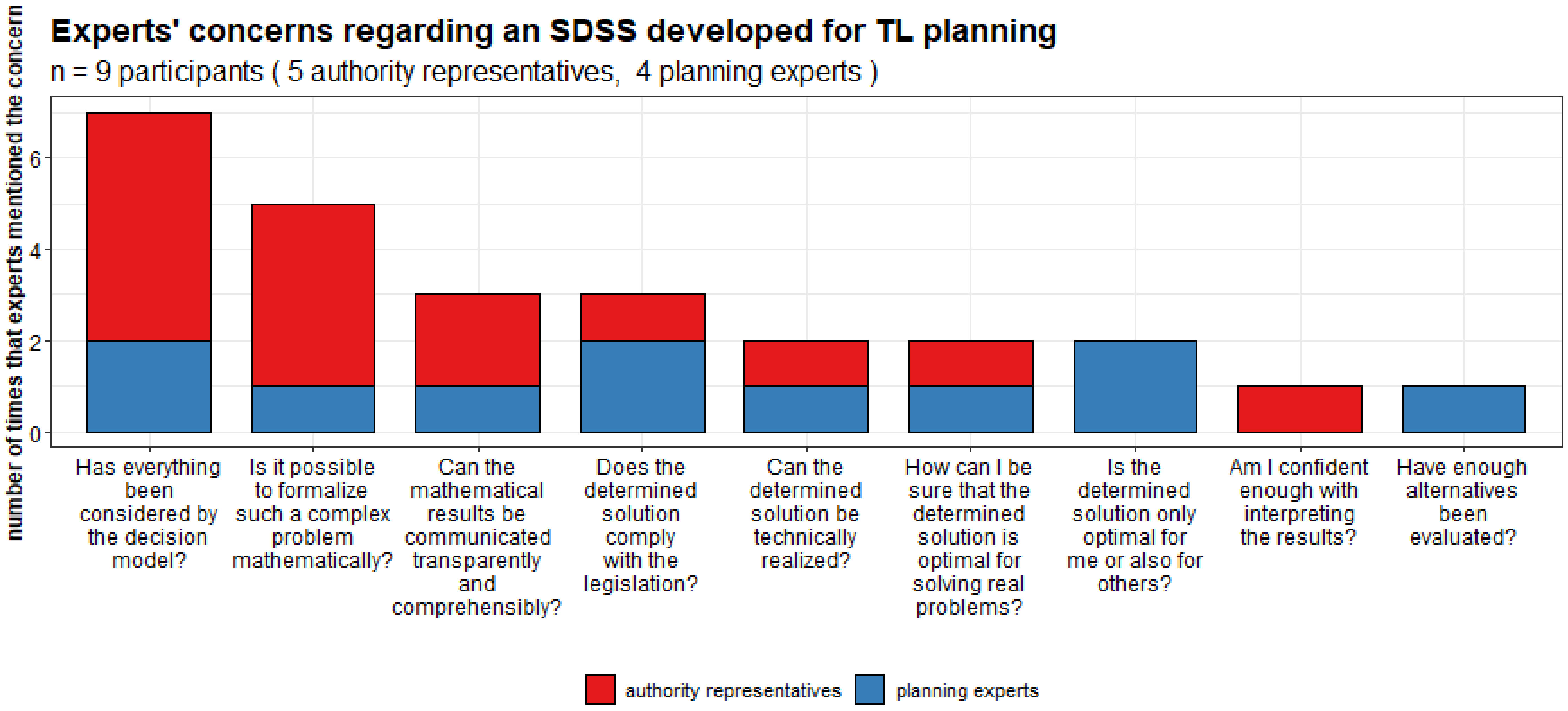
The 3D DSS's ability to support discussions was assessed higher than the potential of communicating procedures and results transparently



Who do experts rely on when deciding about transmission line paths?



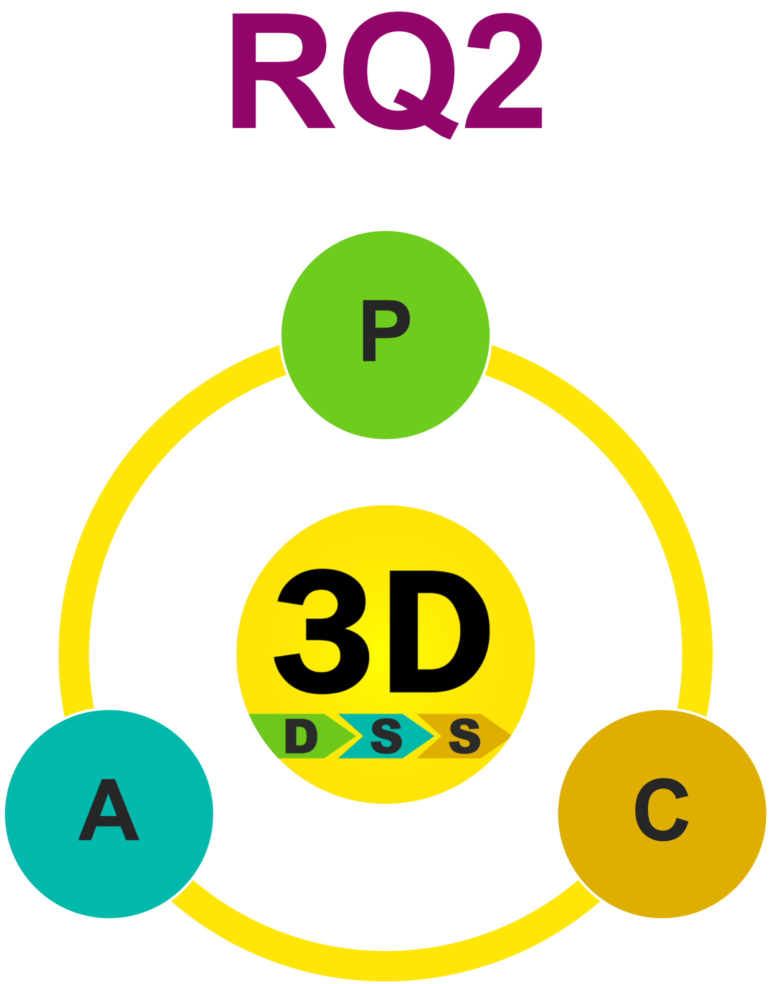
Is a mathematical approach as reliable as humans?



Key findings

- A Spatial Decision Support System can:
  - simplify the planning process
  - find suitable corridors that meet legal requirements
  - support the analysis of different alternatives by determining Pareto optimal solutions
  - support the discussion among different stakeholders with conflicting interests

- Experts were mainly concerned about the question, whether or not a mathematical approach can be as reliable as humans.



7. Discussion

To what extent can a Spatial Decision Support System support transmission line planning?

- The 3D DSS has a high potential to be used in real transmission line planning as it supports planning, analysis, and communication.
- The semi-automated approach helps to save time when calculating and evaluating suitable corridors and paths.
- It supports stakeholders in agreeing on a suitable alternative.

To what extent can the results be considered realistic?

- The experts agreed that the 3D DSS determines feasible corridor alternatives.
- The procedural approach was favored since it simulates a real planning process.
- Even though more different hotspots could have been detected, the experts agreed that the identified area for laying a cable is significant.

Can a Spatial Decision Support System foster democratization and user participation?

- Participation and democratization can be fostered by a Spatial Decision Support System.
- However, it must be defined in advance how the feedback should be used in the decision-making process.
- Thus, the applied methods must be communicated simply and clearly.

Can a Spatial Decision Support System replace humans?

- No, and this is not the purpose of a Spatial Decision Support System.
- The time gained by making use of a semi-automated approach can be used to conduct more profound analyses.
- A Spatial Decision Support System can support the mediation among stakeholders with conflicting interests.

8. Conclusion and outlook

Conclusion and outlook

- The 3D DSS project investigated a wide range of methods, how transmission line planning can be automated.
- The developed 3D DSS supports the planning, analysis, and communication of new transmission lines.
- Planners, stakeholders, and decision-makers can benefit from its analytical approach, making the planning process more inclusive.
- Open questions:
  - How can the modelling of earth cables be enhanced?
  - By which concepts can the applied procedures be communicated more clearly?

Publications

- Schito, Joram (2017). “Modeling and optimizing transmission lines with GIS and Multi-Criteria Decision Analysis”. In: *it – Information Technology*. Thematic Issue: Recent Trends in Energy Informatics Research / Guest Editors: Sebastian Lehnhoff, Astrid Nieße. 59.1, pp. 1–9. DOI: 10.1515/itit-2016-0057.
- Veronesi, Fabio, Joram Schito, Stefano Grassi, and Martin Raubal (2017). “Automatic selection of weights for GIS-based multicriteria decision analysis: site selection of transmission towers as a case study”. In: *Applied Geography* 83, pp. 78–85.
- Schito, Joram, Ulrike Wissen Hayek, and Martin Raubal (2018). “Enhanced multi criteria decision analysis for planning power transmission lines”. In: *Proceedings 10th International Conference on Geographic Information Science (GIScience 2018)*. 10th International Conference on Geographic Information Science (GIScience 2018). Ed. by Stephan Winter, Amy Griffin, and Monika Sester. Vol. 114. Melbourne (Australia): LIPICS. ISBN: 978-3-95977-083-5. DOI: 10.4230/LIPIcs.GIScience. 2018.15.
- Schito, Joram, Joshu Jullier, and Martin Raubal (2019). “A framework for integrating stakeholder preferences when deciding on power transmission line corridors”. In: *EURO Journal on Decision Processes* 7.3, pp. 159–195. DOI: 10.1007/s40070-019-00100-w.
- Schito, Joram, Daniele Moncecchi, and Martin Raubal (2020). “Determining transmission line path alternatives using a valley-finding algorithm”. In: *Manuscript submitted for publication*. *Under review in Computers, Environment and Urban Systems.*

ETH zürich

Joram Schito
Doctoral student
jschito@ethz.ch

ETH Zurich
Institute of Cartography and Geoinformation
HIL G 23.1
Stefano-Franscini-Platz 5
8093 Zurich, Switzerland

www.gis.ethz.ch
3ddss.ethz.ch