ETH zürich

Planning Earth Cables with GIS

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1 Motivation

Overhead lines have been considered as the dominant way to transmit electric power, having although significant defects related to the negative visual impact, the development constraints and the social resistance.

The underground approach called earth cabling, is a stable and modern solution that can minimize impacts and promote the local environment.

Since the complexity of earth cable planning is high due to the numerous influence criteria and legal restrictions, a decision model is necessary.

2 Method overview

Study area: between Mettlen and Innertkirchen in central Switzerland. It constitutes a section of the Mettlen to Ulrichen project of Swissgrid.

Evaluation criteria: identified based on literature reviews and techical guides.

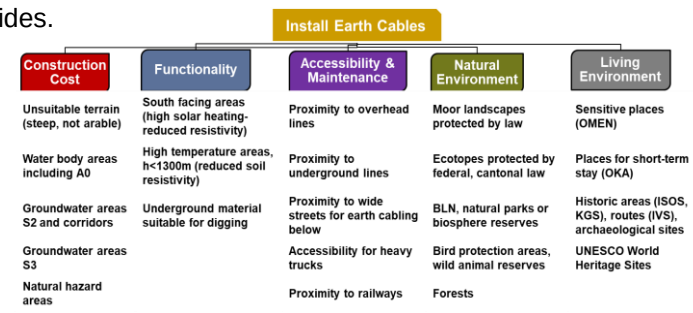

Figure 1. The identified evaluation criteria for earth cable planning.

Influence modeling: in collaboration with grid experts. The importance of the criteria was assessed through questionnaires by making pairwise comparisons and by direct rating.

Multi-criteria Decision Analysis: a novel MCDA method called Analytic Hierarchy Process was applied to derive the weights of the criteria.

Result aggregation techniques: *Aggregation of Individual Priorities (1)* and *Aggregation of Individual Judgements (2)*.

$$w_i^{(g)} = \sum_{k=1}^{m} a_k \, w_i^{(k)}, \quad i = 1, \dots, n \qquad (1)$$

$$a_{ij}^{(g)} = \prod_{k=1}^{m} \left(a_{ij}^{(k)}\right)^{a_k} \qquad (2)$$

Model development: In ArcGIS ModelBuilder environment by applying:
- Raster reclassification.
- Cost surface development based on the influence criteria.
- Least Cost Path (LCP) and Least Cost Corridor analysis (Dijkstra).

3 Results

Questionnaire: 10 out of 16 experts assessed the identified evaluation criteria as a complete approach.

Model development: two scenarios adopted presenting rational results.
- balanced economic and environmental development (intermediate).
- use of hard constraints to avoid the unsuitable areas.

Sensitivity analysis: two additional scenarios. No significant changes.
- one economic, directed to reduce construction costs.
- one environmental, directed to reduce environmental impact.

4 Evaluation and discussion

Evaluation method: the AHP compared to the direct rating method.

- **Weight values comparison:** generally similar. Smoothly distributed over all criteria in direct rating. Some higher values presented in AHP.
- **LCP comparison:** Slightly different LCPs due to the different weights.

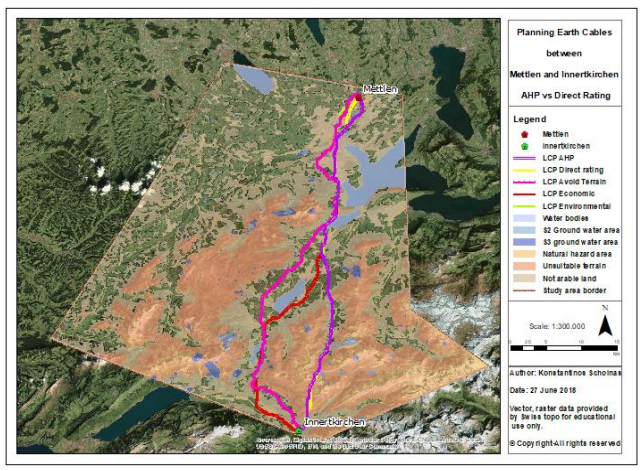

Figure 3. LCPs direct rating (yellow), AHP (purple), constraint (magenta), sensitivity (red, green).

- **Statistical analysis:** tests were applied for 5% significance level.
  - **Shapiro-Wilk:** weight samples are not normally distributed ($p<0.05$).
  - **Wilcoxon signed rank:** more participants needed for 0.9 power.
  - **Kruskal-Wallis:** No significant influence among priorities and criteria or criteria category. Not enough evidence to reject influence among priorities and aggregation technique ($p=0.49>0.05$). Rational since priorities are affected by the selected aggregation technique.

5 Conclusion

Both MCDA methods indicated similar results. Slight differences in the LCPs exist due to the different weighting of the existing criteria. The AHP seems to have the potential to become the dominant method. However, for a secure conclusion both quantitative and qualitative information is necessary as below:

- Objective reclassification of the rasters and accurate interpretation of the LCPs upon accurate and updated mapping of the area.
- Careful selection of the participants upon knowledge, experience and management level, so as to apply weighted aggregation techniques.
- Sufficient number of participants according to statistical testing.

6 References

[1] Mu, E., Pereyra-Rojas, M. (2017): Practical Decision Making - An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions v2. Springer, 2017.
[2] Ossadnik, W., Schinke, S., Kaspar, R.H (2015): Group Aggregation Techniques for Analytic Hierarchy Process and Analytic Network Process: A Comparative Analysis.
[3] Rendigs, S. (2016): Transformation des Schweizer Stromübertragungsnetzes: Herausforderungen und Aufgaben für die Raumplanung, Doctoral Dissertation, ETH Zurich.

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