Inverse Weighting Approach for GIS-MCDA

Current MCDA and MCDM in GIS

- GIS MCDA overly relies on 'expert' driven weighting schemes: AHP, WLC, OWA (Malczewski, 1999; Jankowski, 1995; Malczewski & Rinner, 2015).

- Standard approaches can often be arbitrary, subjective, and spatially implicit. They cannot be supported by observed decisions, making them normative rather than descriptive. (Malczewski & Jankowski, 2020).

- Numerous authors call for more systematic approaches to validating/deriving weights to improve sensitivity analysis and transparency. (Malczewski, 2006; Ligmann-Zielinska and Jankowski, 2008; Malczewski and Jankowski, 2020).

- Inverse weighting methods do exist within MCDA, but are very seldom applied to GIS applications (Jankowski, 2001; Malczewski & Jankowski 2020).

Inverse MCDA found outside of GIS

- **Inverse methods do exist and have been around for some time:**
  - UTilities Additives Method (UTA) (Jacquet-Lagreze & Siskos, 1982)
    - Various UTA variants (UTA-STAR, UTA-II).
  - Robust Ordinal Regression (ROR) (Greco, Mousseau, & Slowinski, 2008).
  - Inverse Optimization (Ahuja, Orlin, 2001; Heuberger, 2004).

- Approaches can be aggregated into two schools:

1. Preference Disaggregation: UTA, ROR, variants.

2. Inverse Optimization: linear or combinatorial.

Comparison

	Common Approaches	Inverse Approaches
Objective	Assign weights prior to analysis to generate output suitability/ranking.	Weights or utility functions are derived from expected rankings or outcomes.
Role of DM	Expert judgement on what weights should be (normative)	Uses preferences, pre-defining ranks, or known outcomes as input (descriptive)
Examples	AHP, WLC, OWA, Rank-sum	UTA (Utilities Additives), ROR (Robust Ordinal Regression), Direct Rank Minimization
Application to GIS-MCDA	Dominant	Rare, need for is noted.

there needs to be more comparison of the methods, like how they differ

Our Contribution

- Adoption and application of inverse MCDA weighting approaches found outside of GIS to spatial decision making problems.

- We provide a framework for applying rank minimization and/or preference disaggregation to spatial analysis.
  - Given a known 'high fire risk' set of parcels within a region, weights can be derived to make this set rank lowest out of the population.

- Decision makers may be better suited to select 'best' or 'worst' locations rather than weights. Inverse weighting supports this.

- Further, Inverse approaches can be used in conjunction with observed data: i.e. burn scars or structural damage within a region, as a method for improving exploratory analysis.

Ultra Brief Outline

1. Introduce current GIS MCDA weighting techniques. Point out their issues, and the calls that have been made for better exploratory analysis and inverse methods.

2. Discuss Inverse weighting methods outside of GIS. Compare them to weighting methods found in GIS MCDA, and how they can answer the gaps in current literature.

3. Define problem setting: Wildfire mitigation and prioritization, and how exploratory analysis and inverse MCDA is applicable.

4. Apply inverse methods (rank minimization) using expert defined spatial sets to derive weights.

5. Compare application of inverse methods to standard approaches. Demonstrate that an inverse approach can be used to better understand given factors and as an exploratory tool.