Exploratory Spatial Data Analysis

Part V

Multi-criteria decision making

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Contents

- Introduction to multi-criteria decision-making
- Computation-based option evaluation
  - "Ideal Point" method
- Visual option evaluation
  - "Utility symbols"

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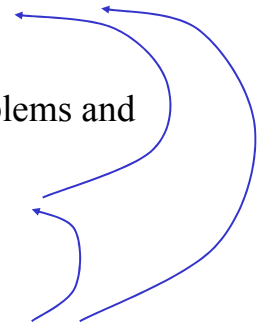
Phases of Decision-making Process

- Intelligence:
  - collect and integrate data;
  - explore the data, identify problems and opportunities
- Design
  - find possible solutions
- Choice
  - analyse and evaluate the options;
  - select the most suitable option or subset



H.A. Simon, *The New Science of Management Decision*

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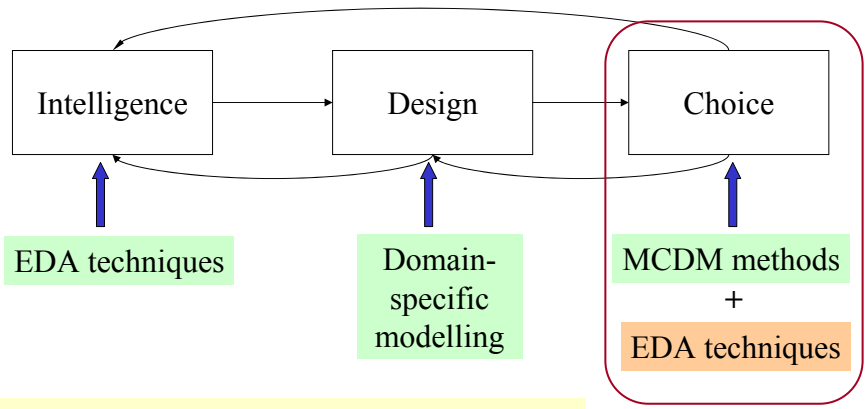
Decision Support Tools



We consider here the choice phase, i.e. assume that the options are already defined (this is often the case in decision-making situations)

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Choice Phase: the Task

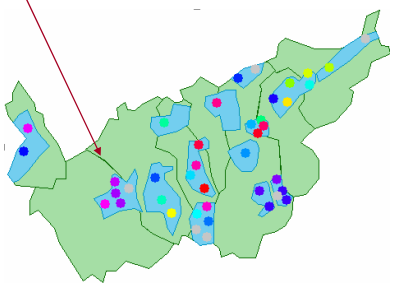
Which option is the most suitable?

	option 1	option 2	…	option k
criterion 1	0.18	1.00	…	0.65
criterion 2	0.87	0.25	…	0.48
…	…	…	…	…
criterion n	0.33	0.42	…	0.81

Multiple criteria

No "ideal" option; the decision has to involve trade-offs

Spatial decision-making: choose from spatially distributed options



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MCDM*: Main Concepts

- Criteria: numeric or ordinal attributes
- Types of criteria:
  - **benefit**: higher values are more suitable
  - **cost**: lower values are more suitable
- Different importance of criteria
  - direct specification: weights or ordering
  - indirect specification: aspiration levels, tolerance intervals, etc.
- Outcome variants
  - evaluation scores or ranking
  - subset of options close to the specified goal (goal approximation)

* Multi-criteria decision-making

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Ideal Point Method

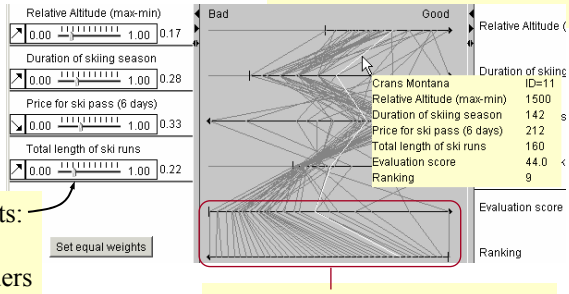
On the basis of option characteristics (in terms of the decision criteria) and criteria weights computes integrated evaluation scores (degrees of "goodness"). The options are then ranked from the best (rank=1) to the worst.

Selected criteria

Option characteristics; good values are on the right

Benefit criteria

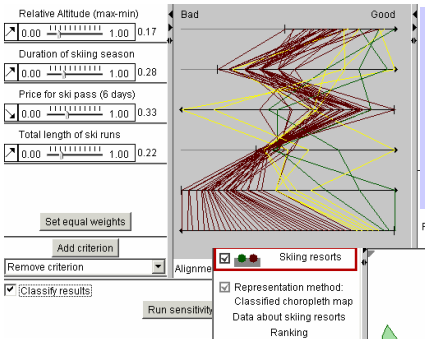
Cost criterion



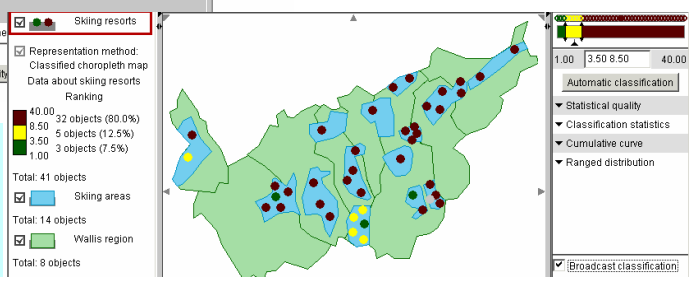
Criteria weights: changed by moving the sliders

Computation results: options' evaluation scores and ranking

Ideal Point Method + Map

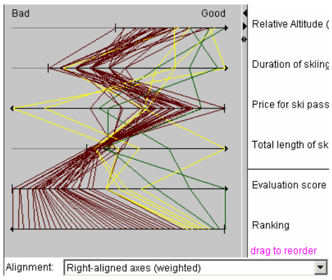


The computation results (either the scores or the ranks) can be visualised on a map. In particular, we can apply classification according to the ranks for dividing the options into "top candidates", "possibly suitable", and "unsuitable"



Here we have divided the options (skiing resorts) into 3 best, 5 good, and the rest.

Ideal Point and Class Propagation



The option classes can be propagated from the map to all other displays. On the parallel coordinate plot, we can compare the characteristics of the top class to those of the other options. We see that our top candidates are far from perfect: their values on some axes are too far from the right (good) pole

identifiers	Relative Altitude (max-min)	Duration of skiing season	Price for ski pass (6 days)	Total length of ski runs	Evaluation score	Ranking
Klein Matterhorn-Schwarzsee	2200	169	146	75	100.0	1
Skipaß 4-Vallees/Mt.-Fort	2509	155	282	386	83.3	2
Saas-Fee	1800	181	270	100	67.5	3
Les Portes du Soleil	1566	116	224	650	60.6	4
Sunnegga-Rothorn	1483	163	218	41	53.8	5
Riffelberg-Stockhorn	1793	155	222	35	50.1	6
Skipaß Zermat-Cervinia	2296	162	354	245	44.2	7
Generalabo Zermatt	2200	184	396	150	44.0	8
Crans Montana	1500	142	212	160	44.0	9
Belalp	1770	135	199	60	37.6	10
Evolene	1330	128	156	45	35.0	11
La Forclaz	500	128	115	6	31.3	12
Arolla	897	128	145	47	30.5	13
Unterbäch/Eischoll	1380	121	163	50	27.6	14
Fiescheralp	1820	128	213	45	24.8	15
Zinal	1225	127	181	70	24.1	16

group by classes Sort by: Ra Ascending TableLens condensed Attribute...

The table view shows us the same information in a different way. The rows are sorted by the ranks. The best options are always at the top of the table. The "table lens" technique paints parts of the table cells proportionally to the numbers in them. This facilitates option and class comparison.

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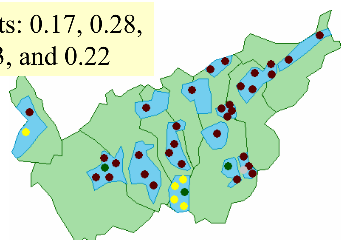
Decision Sensitivity to Weights (1)

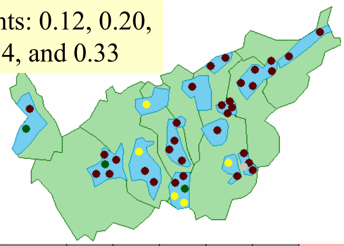
When we change the criteria weights, the Ideal Point re-computes the scores, and the impact can be immediately observed on all displays

Weights: 0.17, 0.28, 0.33, and 0.22



identifiers	Relative Altitude (max-min)	Duration of skiing season	Price for ski pass (6 days)	Total length of ski runs	Evaluation score	Ranking
Klein Matterhorn-Schwarzsee	2200	169	146	75	100.0	1
Skipaß 4-Vallees/Mt.-Fort	2509	155	282	386	83.3	2
Saas-Fee	1800	181	270	100	67.5	3
Les Portes du Soleil	1566	116	224	650	60.6	4
Sunnegga-Rothorn	1483	163	218	41	53.8	5
Riffelberg-Stockhorn	1793	155	222	35	50.1	6
Skipaß Zermat-Cervinia	2296	162	354	245	44.2	7
Generalabo Zermatt	2200	184	396	150	44.0	8
Crans Montana	1500	142	212	160	44.0	9
Belalp	1770	135	199	60	37.6	10
Evolene	1330	128	156	45	35.0	11

Weights: 0.12, 0.20, 0.34, and 0.33



identifiers	Relative Altitude (max-min)	Duration of skiing season	Price for ski pass (6 days)	Total length of ski runs	Evaluation score	Ranking
Les Portes du Soleil	1566	116	224	650	100.0	1
Skipaß 4-Vallees/Mt.-Fort	2509	155	282	386	92.3	2
Klein Matterhorn-Schwarzsee	2200	169	146	75	91.7	3
Saas-Fee	1800	181	270	100	54.6	4
Crans Montana	1500	142	212	160	45.3	5
Sunnegga-Rothorn	1483	163	218	41	43.4	6
Riffelberg-Stockhorn	1793	155	222	35	39.3	7
La Forclaz	500	128	115	6	38.0	8
Evolene	1330	128	156	45	37.7	9
Skipaß Zermat-Cervinia	2296	162	354	245	37.3	10
Arolla	897	128	145	47	35.8	11

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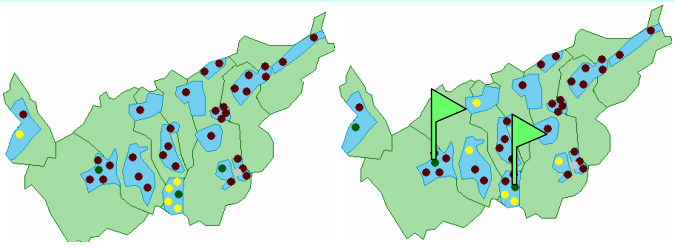
Decision Sensitivity to Weights (2)

The ranks of these two options slightly changed, but they remained among the top 3 candidates. Hence, they are robust and should be preferred to the others.



Identifiers	Relative Altitude (max-min)	Duration of skiing season	Price for ski pass (6 days)	Total length of ski runs	Evaluation score	Ranking
Klein Matterhorn-Schwarzsee	2200	180	148	75	100.0	1
Skipaß 4-Vallees/Mt.-Fort	2509	155	220	280	83.7	2
Saas-Fee	1800	181	270	100	67.4	3
Les Portes du Soleil	1566	116	224	650	60.6	4
Sunnegga-Rothorn	1483	163	218	41	53.8	5
Riffelberg-Stockhorn	1793	155	222	35	50.1	6
Skipaß Zermat-Cervinia	2296	162	354	245	44.2	7
Generalabo Zermatt	2200	184	396	150	44.0	8
Crans Montana	1500	142	212	160	45.3	5
Belalp	2770	1	60	1	1	1
Evolene	930	1	15	45	1	1

Identifiers	Relative Altitude (max-min)	Duration of skiing season	Price for ski pass (6 days)	Total length of ski runs	Evaluation score	Ranking
Les Portes du Soleil	1566	116	224	650	100.0	1
Skipaß 4-Vallees/Mt.-Fort	2509	155	220	280	92.3	2
Klein Matterhorn-Schwarzsee	2200	180	148	75	91.3	3
Saas-Fee	1800	181	270	100	54.6	4
Crans Montana	1500	142	212	160	45.3	5
Sunnegga-Rothorn	1483	163	218	41	43.4	6
Riffelberg-Stockhorn	1793	155	222	35	39.3	7
La Forclaz	500	120	115	6	38.0	8
Evolene	930	1	15	45	1	1
Skipaß Zermat-Cervinia	2296	162	354	245	1	1
Arolla	8	1	14	47	1	1

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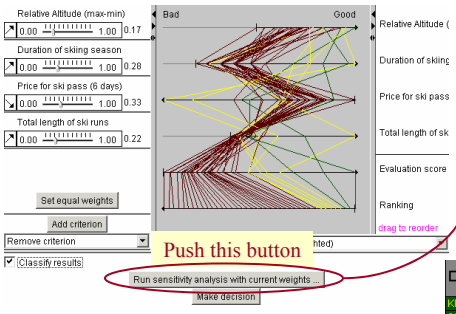
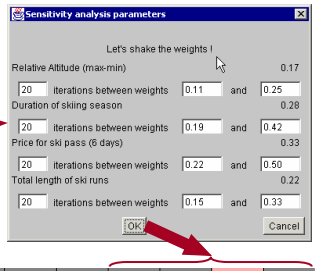
Automated Sensitivity Analysis





Identifiers	Evaluation score	Ranking	Minimum Rank	Maximum Rank	Mean Rank	Rank Variance
Klein Matterhorn-Schwarzsee	100.0	1	1	3	1.0875	0.326
Skipaß 4-Vallees/Mt.-Fort	83.7	2	1	3	1.95	0.314
Saas-Fee	66.4	3	2	4	3.3125	0.686
Les Portes du Soleil	61.0	4	2	9	4.3375	1.542
Sunnegga-Rothorn	54.3	5	4	7	5.0125	0.849
Riffelberg-Stockhorn	50.1	6	5	9	6.4125	0.937
Skipaß Zermat-Cervinia	44.8	8	5	38	9.6	6.767
Generalabo Zermatt	45.1	7	4	39	9.7625	7.342
Crans Montana	[illegible]	[illegible]	[illegible]	3	8.237	1.001
Belalp	37.2	[illegible]	[illegible]	[illegible]	10.011	0.771
Evolene	34.7	[illegible]	[illegible]	[illegible]	10.561	1.23
La Forclaz	[illegible]	[illegible]	[illegible]	[illegible]	12.08[illegible]	2.2[illegible]
Arolla	[illegible]	[illegible]	[illegible]	[illegible]	12.98[illegible]	1.46
Unterbäch/Eischoll	[illegible]	[illegible]	[illegible]	[illegible]	14.[illegible]	1.68
Fiescheralp	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.6[illegible]
Zinal	[illegible]	[illegible]	[illegible]	[illegible]	17.0[illegible]	1.87
Visperterminen	[illegible]	[illegible]	[illegible]	[illegible]	18[illegible]	2.6[illegible]

For the automated sensitivity analysis, we specify the range within which to vary each weight and the number of tests for each weight (the other weights are adjusted proportionally to their current values). The results are the minimum, maximum, and mean rank of each option in all the tests and the variance among the ranks.

Good options are those with the lowest ranks and variance

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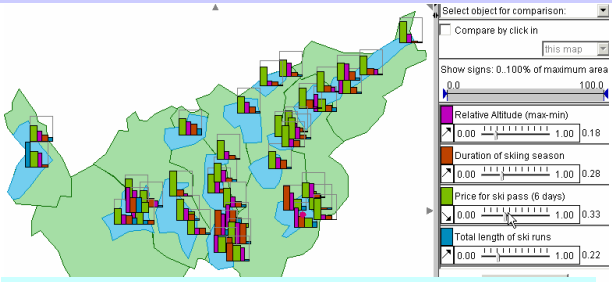
Dynamic Utility Symbols

Support visual analysis and selection of spatial options (no computational "black box" is involved)



Bar heights show the "goodness" of the options according to each individual criterion. Bar widths are proportional to the criteria weights. The total symbol area (or the part of the bounding rectangle covered) represents the overall appropriateness: the bigger, the better. Changing the weights affects the symbol areas.

Very good price, altitude, and season duration, but bad total length of ski runs

Very good altitude, average season duration and total length of ski runs, but rather bad price

Very good total length of ski runs, average price and relative altitude, but very bad season duration

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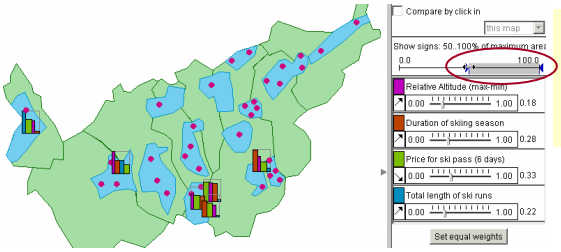
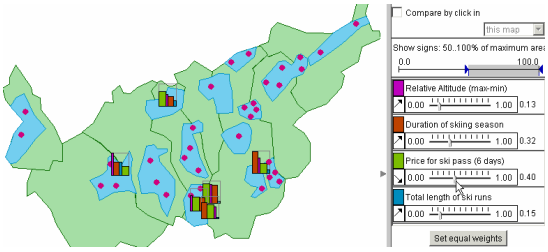
Focusing on the Best Options



This UI element allows us to hide the symbols with small areas and thereby facilitates focusing on the best options



Altering the criteria weights changes the areas. Therefore the set of options in our focus may also change.

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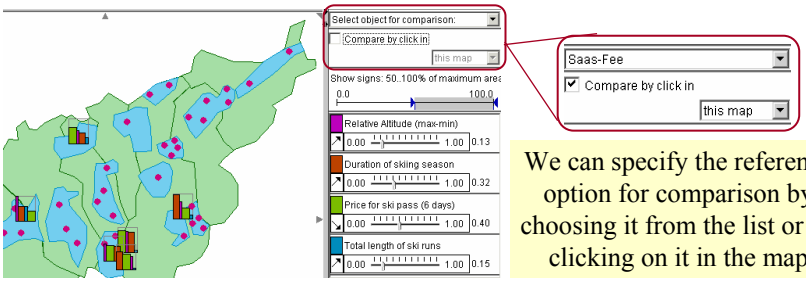
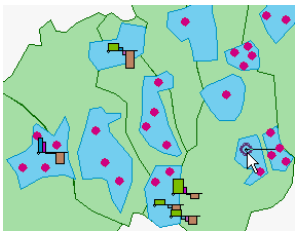
Option Comparison



We can specify the reference option for comparison by choosing it from the list or by clicking on it in the map

For option comparison, the utility bars are transformed: upward oriented bars represent better values than the reference option has, and downward oriented bars correspond to worse values. We can now better see the advantages and drawbacks of each option.



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Summary

This lection was supposed to

- give an introduction to multi-criteria decision making
- demonstrate some decision support methods suitable for site selection
- acquaint with the problem of decision sensitivity
- stress the importance of visualisation for making well-substantiated decisions

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