Tutorial

Multi-Criteria Decision Analysis

Multi-Criteria Decision Analysis, or MCDA, is a decision making tool that helps in simplifying complex decision-making which may involve many stakeholders/decision-makers, and to assess the diversity of possible outcomes.

In general, a Multi Criteria Analysis seeks to identify the alternatives or options that are to be investigated and decided upon, based on a finite set of evaluation criteria by which to rank a finite number of decision options and to aggregate preferences. The final outcome is a preferred option or set of options that is based upon a priorities and preferences decided by the stakeholders/decision-makers.

The following steps are carried out by the decision-makers in a Multi Criteria Analysis:

- To formulate problem
- Identify the feasible alternatives or preferred outcomes
- Identify the criteria by which to judge these outcomes
- Apply appropriate weights on each of the criteria which represents the preferences.

The Analytic Hierarchy Process, one of the more widely used multi criteria methods, is used in SEFEA.

The Analytic Hierarchy Process

AHP is MCDA method of analyzing decisions based upon a hierarchy of components of the decision, known as the Analytic Hierarchy Process (AHP). AHP method which can be used by the decision maker to calculate the priority weights for criteria using simple decision matrix.

The AHP is based upon the construction of a series of 'pair-wise comparison' matrices which compare criteria to one another. The

comparison of criteria is based upon decision that is defined based on expert's judgments.
This is done to estimate a ranking or weighting of each of the criteria that describes the importance of each of these criteria in contributing to the overall objective.

Steps in SEFEA
Step 1. Select class of analysis

Class of analysis is based upon following classes:

- Priority based
- Distance based
- Attribute based
- Cluster based

Step 2. Select variables

See the details on data notes

Step 3. Matrix calculation
A pair wise comparison of n criteria (C1… Cn) to reflect the importance or weighting of each criterion in influencing the overall goal, involves building an n by n matrix (M) which shows the comparison of the criteria in the left-hand side column with respect to each criterion in the top row.

Step A. Developing a hierarchical structure with a goal at the top level, the attributes/criteria at the second level and the alternatives at the third level.

Example

Create a comparison matrix using AHP tool
For our suitability model, assume we use three criteria

Distance to train stations
Distance to high density areas
Distance to roads

Distance-based selection to convert land

Attribute or Criteria	**Distance to train stations**	**Distance to high density areas**	**Distance to roads**
Convert land (High)	8	6	10
Convert land (Medium)	6	NA	6
Convert land (Low)	4	10	2

In the above example each criterion to convert land has their own value of distance to train stations, distance to high density areas, distance to roads.

Step B) Determine the relative importance of different attributes or criteria with respect to the goal.

Having the above example, how important is the distance to train station if we highly prioritize land conversion. Or what is the importance of distance to high density areas if we highly prioritize land conversion.
This pair-wise comparison matrix is created with the help of scale of relative importance. Here is the scale of relative importance.

Comparisons using selected intensities

1 = equal preference
3 = prefer
6 = strongly prefer

For each paired choice below, tick the box to indicate which criteria is more important (or equal) for ranking

Criteria	**Strongly prefer**	**prefer**	**Equal**	**Prefer**	**strongly prefer**	**Criteria**
Distance to train stations						Distance to train stations
Distance to high density areas						Distance to high density areas
Distance to roads						Distance to roads

For example, finding suitable residential locations we find that:
Distance to train stations is preferred over distance to high density areas
Distance to train stations is strongly preferred over distance to roads
Distance to high density areas is preferred over distance to roads

Step C
The length of pairwise matrix is equivalent to the number of criteria
Pair-wise comparison matrix. After making the diagonal values = 1, Fill in upper right corner of the matrix.
The diagonal values (cells) will be one always.

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	1	3	6
Distance to high density areas		1	3
Distance to roads			1

Step D Fill in matrix with reciprocal values. These values are calculated in AHP tool. Here is the example of calculated values using excel.

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	1	3	6
Distance to high density areas	1/3	1	3
Distance to roads	1/6	1/3	1

Step E
Sum columns

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	1	3	6
Distance to high density areas	1/3	1	3
Distance to roads	1/6	1/3	1
	1.50	**4.33**	**10.00**

***Step F*. Normalized pairwise matrix**
Normalize the matrix by dividing each value with it's corresponding column sum.

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	1	3	6
Distance to high density areas	1/3	1	3
Distance to roads	1/6	1/3	1
	1.50	**4.33**	**10.00**

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	.666	.692	.600
Distance to high density areas	.222	.230	.300
Distance to roads	.111	.076	.100

Step G. The average of the rows, will be the weights for the criteria

Criterion	Distance to train stations	Elev	Asp
Distance to train stations	.666	.692	.600
Elev	.222	.230	.300
Asp	.111	.076	.100

(.666+.692+.600) / 3 = 0.653 Visibility

(.222+.230+.300) / 3 = 0.251 Elevation

(.111+.076+.100) / 3 = 0.096 Aspect

Sum to 1

Step H. Check for consistency in comparisons by first computing a consistency vector

Criterion	Distance to train stations	Distance to high density areas	Distance to roads
Distance to train stations	1	3	6
Distance to high density areas	.333	1	3
Distance to roads	.166	.333	1

Original matrix from 4.b

0.653 Distance to train stations

0.251 Distance to high density areas

0.096 Distance to roads

Weights from 4.c

Distance to train stations	(0.653)(1) + (0.251)(3) + (0.096)(6) = 1.982
Distance to high density areas	(0.653)(.333) + (0.251)(1) + (0.096)(3) = 0.756
Distance to roads	(0.653)(.166) + (0.251)(.333) + (0.096)(1) = 0.2878

Distance to train stations	1.982 / 0.653 = 3.035
Distance to high density areas	0.756 / 0.251 = 3.011
Distance to roads	0.287 / 0.096 = 2.989

New consistency vector

Step I

Now that we have the consistency vector, we need to compute two more terms, lambda (λ) and the consistency index (CI)

λ = the average of the consistency vector from step H.

$$= (3.305 + 3.011 + 2.989) / 3$$

$$= 3.018$$

Step J.

Compute the consistency index which provides a measure from consistency. CI is the index of the consistency of judgements across all pairwise comparisons.

CI = (λ – N) / (N- 1)

N = number of criteria

CI = (3. 018 – 3) / (3 -1)

= 0.009

Step K. With the consistency index (CI) the random index (RI) table is used to compute the consistency ratio (CR).

CR = CI / RI

= 0.009 / 0.58
= 0.015

Number of criteria	RI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

Step 8. Interpretation of the consistency ration (CR)
If CR < 0.100 then
there is consistency in responses

In our example, since the CR is 0.086 which is < 0.100 then we can use the weights from step G!

0.653 Distance to train stations

0.251 Distance to high density areas

0.096 Distance to roads

Next Steps

There are two things incorporated in SEFEA an AHP setup and multiplication of weights from AHP with criteria layers (gis layers) and combing them.

Weighted sum tool from ArcGIS is integrated in SEFEA