Urban River Basin Enhancement Methods

Tool for assessing potential for rehabilitation
Work Package 6

MULTI-ATTRIBUTE DECISION MAKING MODEL FOR THE GLINSCICA STREAM STUDY SITE

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Summary

As a contribution to the WP5: Tool for assessing potential for rehabilitation, the University of Ljubljana has developed a model for applying a Multi-Attribute Decision Making process. The model can be used as an optional tool to facilitate the control over the application of the assessment process of selected options – alternatives. It is developed on the database template proposed by the WP3 members and adapted by the University of Ljubljana. The MADM model considers the analysis of stakeholders which were identified on the Glinscica study site and their interests, but it can be easily adapted to other study cases.

Contents

1. Introduction

Problems of Multi-Attribute Decision Making (MADM) problems are encountered under various situations where a number of alternatives and actions or candidates need to be chosen based on a set of criteria or attributes (Aouami et al. 2003; Cagno et al., 2001; Hafkam et al., 1993). Advantages of MADM are that it facilitates community-based collaborative decision-making, avoids some of the ethical, theoretical and practical shortcomings of conventional economic approaches, does not require assigning monetary values to ecological services, allows consideration of multiple attributes and is not culturally biased (Prato, 1999).

Comparing the alternatives is the key of making the decision in such cases. Often in planning a river rehabilitation projects, we are faced with making a choice among various options – alternatives. If the only consideration is costs, we can use economic principles to guide our selection. Many times, however, the choice involves both strictly quantitative measures (such as costs) and strictly qualitative measures (aesthetical aspects or even political viability). In such cases we must use a process to approximately “quantify” all measures on a similar, numerical scale, so that we can perform mathematical calculations which assist the decision maker to consider different preferences and interests of all parties involved (stakeholders). Multi-Attribute Decision Making is a numerical process to compare or “score” alternatives on a comparable scale (Ma et al., 1999).

2. Structure of the model

The Glinscica stream MADM model is based and developed on the database which includes hydrological data, data on water quality, water flora and fauna data of the study site. Additionally, main stakeholders were identified together with the range of their interests.

The model consists of four main parts (Appendix 1):

1. ***Interface***. The “Interface” spreadsheet enables the analysis of different combinations of relative importance weights assigned to the main objectives and the numerical and graphical comparison of different alternatives. The combination or the preference of a certain objective expressed by a relative importance factor should be based on the stakeholder agreement.

2. ***MADM-WAM***. The “MADM-WAM” spreadsheet is used for rating the impact of a certain alternative on the attribute. An attribute is by definition a measure (criterion) which enables the assessment of the amount of satisfaction of a certain objective.

3. ***Alternatives***. Alternatives are combinations of certain elements of a rehabilitation scheme. The selection of the elements of the

rehabilitation scheme and the alternatives are made by decision maker. The development of different alternatives (combinations of the elements of rehabilitation scheme) should consider possible budget restrictions which are not included into the model.

4. ***Stakeholders***. The list of main stakeholders together with their interests is included in the model so that the decision maker has an overall picture of the preferences for a certain state of the water body and also possible conflicting interests.

3. Application of the model

The steps for the application of the model are as follows:

1) In agreement with identified stakeholders determine the main objectives that should be considered in choosing the best alternative. These objectives should be reasonably independent. To assure better independence between different main objectives the proper attributes should be assigned.

2) Determine the relative importance of these objectives to each other. A common approach is to select the least important objective and assign it a value of 1. Then for each of the other objectives, ask the question "*How many times more important is this objective than the least important objective*?" The answer will relate to the value assigned, for example, if the selected objective is twice as important as the least important objective, it would receive a value of 2, or if it were equally important it would have a value of 1. It is necessary to limit the maximum value that is assigned to any objective. A maximum value of 3 or 4 is a good choice (Goicoechea et al., 1982). If the maximum value is too large, it has the numerical effect of reducing the problem to a single objective problem. After a relative importance value is obtained for each objective then a normalized importance "weight" for each attribute is obtained by dividing the individual relative importance value by the summation of all the relative importance values. This produces a set of "importance weights" that sum to one.

3) Use a process similar to Step 2) to assign normalized importance weights to defined attributes in spreadsheet "MADM-WAM".

4) Select the alternatives to consider. For each alternative, evaluate the performance of that alternative with respect to each objective or its attributes. This performance might be described as a number or it might be a word (such as good or poor). It is advisable that one alternative represents the present condition of the stream or "do nothing scenario". This alternative can be used for comparison with other alternatives and for assessment of the improved conditions which are expected to be achieved by applying the selected alternative.

5) Convert the evaluations of Step 4) to a common numerical score called "rating". A commonly used scale is 1 to 5, where 5 represents the best condition and 1 represents the worst condition. A scale of 5 fits word descriptions such as: Poor(1) Fair(2) OK(3) Good(4) Excellent(5). It is important to make sure than none of the alternatives is completely "dominated" by the others. The results of ranking are summarized in the so called "impact matrix" as shown in spreadsheet "MADM-WAM".

6) The ratings for each alternative are combined into a final score for each alternative. One of the most common MADM methods used to do this is called the ***weighted average method (WAM)***. The score for an alternative is defined as the summation of the products of the normalized weights times the rating for each objective. For example, the overall score for alternative 1 would be computed as:

$$S_1 = \sum_{i=1}^{4} W_i * R_{i,1}$$

Where *i* represents the various criteria. In general then, the score for alternative *j* is found by:

$$S_j = \sum_{i=1}^{4} W_i * R_{i,j}$$

Where *j* = 1, 2, 3

The alternative with the highest score (maximum value of S_j) is the preferred alternative. It is said to have a "rank" of 1. The second highest score is the second preferred alternative (rank 2) and so forth.

4. Conclusion

Multi-Attribute Decision Making models offer effective and quick overview of the impact of the different combinations of relative importance weights on the preference of a certain alternative. While using the model it is easily noticed how the selection of the preferred alternative depends on the combination of the relative importance weights. Thus the resultant objective and attribute weights and rankings of alternatives reflect both the subjective considerations of a decision maker, stakeholders and the objective information of expert. The agreement of the stakeholders on the importance of certain objective is the crucial aspect for the application of the model. Otherwise, if the agreement of the stakeholders on the importance of defined objectives is not reached, the selection of the preferred alternative can be easily manipulated (Appendix 2).

5. References

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Prato, T., (1999). Multiple attribute decision analysis for ecosystem management, Ecosystem Economics, 30, 207-222

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6. Appendices

APPENDIX 1: Components of the model

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.99	3.32	2.40	3.19	3.15
Ranking	5	1	4	2	3

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

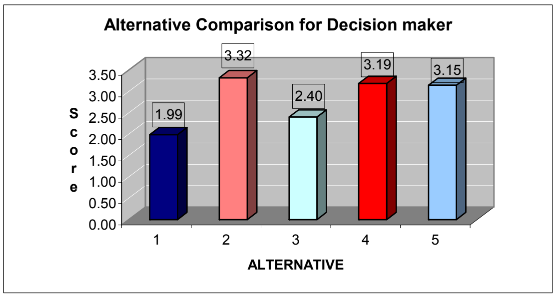

Fig. 6.1.1: The "Interface" spreadsheet.

Weighted Average Method

Objectives	Attributes	Relative Importance Weights	Normalized Weights	Relative Attribute Weights	Normalized Attribute Weights	ALTERNATIVES 1	2	3	4	5
River ecology		2	0.143							
	Ecological status (WFD)			4	0.22	1	1	3	4	2
	Water quality			3	0.17	2	2	3	4	3
	Bio-diversity			3	0.17	2	2	3	4	3
	Species abundance			2	0.11	3	3	4	4	3
	Channel vegetation			2	0.11	1	1	3	4	2
	Bank vegetation			2	0.11	2	2	4	4	2
	Trees			2	0.11	1	1	1	3	1
				18	1.00	1.667	1.667	3	3.889	2.333
Habitats		1	0.071							
	Hydraulic conditions			3	0.19	1	1	5	3	3
	Substrate type and distribution			2	0.13	1	1	4	3	2
	Bank material			2	0.13	1	1	4	4	2
	Bank protection			2	0.13	5	5	3	3	4
	Channel cross section			3	0.19	1	2	3	3	2
	Water abundance			4	0.25	1	1	5	2	3
				16	1.00	1.50	1.69	4.13	2.88	2.69
Flood protection	Flood control standard	4	0.286							
					1.00	2.00	5.00	1.00	4.00	5.00
Recreation		4	0.286							
	Pedestrial access			3	0.38	3	4	4	3	3
	Bicycle access			2	0.25	3	4	3	3	3
	Activity nodes (leisure)			1	0.13	1	3	1	1	1
	Sitting areas			2	0.25	1	4	1	1	1
				8	1.00	2.25	3.88	2.63	2.25	2.25
Urban green space		3	0.214							
	Views to the river			3	0.43	2	2	3	3	2
	Continuity of green space			2	0.29	2	2	3	3	3
	Visual connections			2	0.29	2	2	3	3	3
				7	1.00	2.00	2.00	3.00	3.00	2.57
					Overall	1.988	3.323	2.402	3.189	3.148
		14			*Rank*	*5*	*1*	*4*	*2*	*3*

Rating Scale:	Excellent	5
	Good	4
	OK	3
	Fair	2
	Poor	1

Fig. 6.1.2: The "MADM-WAM" spreadsheet.

	Elements of rehabilitation scheme	*ALTERNATIVES*				
		1	2	3	4	5
1	Removal of concrete paving on channel bottom and banks.			x	x	
2	Introduction of structural elements in the channel (pools, riffles, stone weirs).			x		
3	In channel works to provide meandering appearance.			x		x
4	Widening of the channel cross section.		x		x	
5	Arrangement of the two-stage cross section.				x	x
6	Arrangement of levees on both banks.		x			x
7	Arrangement of dry retention areas.		x		x	x
8	Arrangement of hiding places for aquatic fauna.			x		
9	Providing the shading of the channel with high vegetation.				x	
10	Selective cleaning of bank and channel vegetation.			x		x
11	Reconstruction of the storm sewage outflows to the channel.				x	x
12	Provision of footpath along one bank.		x	x		
13	Provision of sitting areas along the channel.		x			
14	Reconstruction of river crossings for pedestrians and cyclists.		x			

Fig. 6.1.3: The “Alternatives” spreadsheet.

Stakeholders	*Interests*
1) Biotechnical Faculty	**Stream as a natural scientific testing ground:** Use of the stream for research and educational purposes
	Ecology: Bio-diversity, Composition and abundance of aquatic flora, Composition and abundance of benthic invertebrate fauna, Composition and abundance of age structure of fish fauna, Channel vegetation, Bank vegetation, Trees, Nature of surrounding catchment
	Aesthetics: Welcoming area
	River- Flood vulnerability; High waters with 5-year return period (12.8 m^3/s) flood left bank and endanger the buildings of the Biological Centre. High waters with 10-year return period (16.5 m^3/s) flood extensive bank areas on both sides of the Glinščica stream.
	Accessibility: River crossings
	Social importance
2) Residents of Municipality of Ljubljana	**Water quality:** Colour, Odour
	Ecology: Nature of surrounding catchment
	Aesthetics: Landscape perception, Natural components
	Social importance: Activities on river front (recreation), Accessibility (river crossings)
3) Fish handling society	**Water quality:** Dissolved oxygen, BOD, pH, Pollutants, Temperature
	Ecology: Abundance and bio-diversity of fish population, River morphology (nursery and hiding places for fish, hydraulic conditions, fish spawning areas), Water abundance (pools), Channel and bank vegetation
4) Municipality of the city of Ljubljana	**Ecology:** Planning of the green system of the city, Development of thematic parks
	Urban development: University center, Development of traffic infrastructure (new railway)
	Aesthetics: Natural components inside the urban area
	Social importance: Activities on river front (recreation, leisure areas), Accessibility (river crossings), Connectivity with suburban areas

Fig. 6.1.4: The “Stakeholders” spreadsheet.

APPENDIX 2: Results based on different combinations of relative importance weights.

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.88	2.85	2.75	3.20	2.97
Ranking	5	3	4	1	2

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

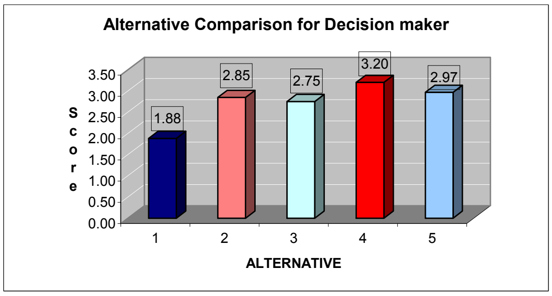

Fig. 6.2.1: Results for the combination of relative importance weights "User".

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.80	2.89	2.62	3.49	3.25
Ranking	5	3	4	1	2

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

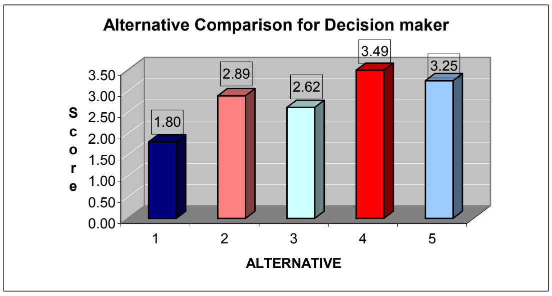

Fig. 6.2.1: Results for the combination of relative importance weights "G1".

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.99	3.32	2.40	3.19	3.15
Ranking	5	1	4	2	3

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

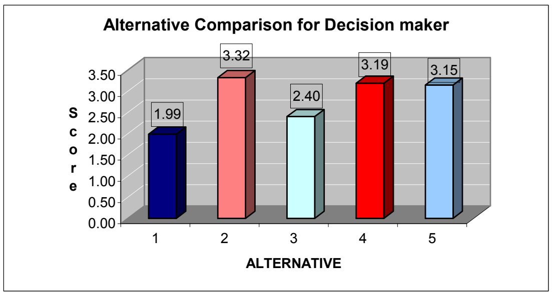

Fig. 6.2.1: Results for the combination of relative importance weights "G2".

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.74	2.19	3.18	3.28	2.71
Ranking	5	4	2	1	3

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

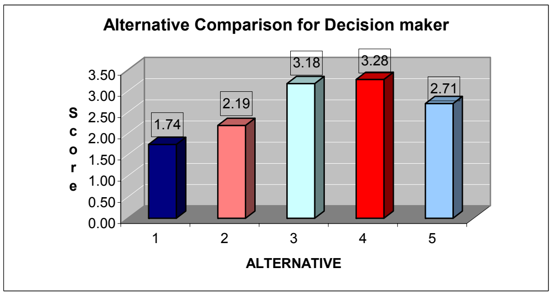

Fig. 6.2.1: Results for the combination of relative importance weights "G3".

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.93	3.65	2.09	3.50	3.73
Ranking	5	2	4	3	1

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

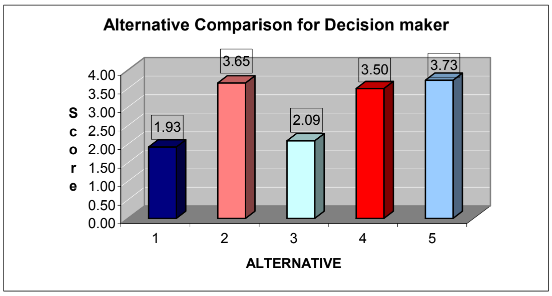

Fig. 6.2.1: Results for the combination of relative importance weights "G4".

Glinscica MADM Example

Results

Alternative	1	2	3	4	5
Score	1.94	2.77	2.90	2.96	2.65
Ranking	5	3	2	1	4

Relative importance weights

Objectives	User	G1	G2	G3	G4	G5
River ecology	1	4	2	4	1	2
Habitats	1	3	1	4	1	2
Flood protection	1	4	4	1	4	1
Recreation	1	1	4	1	1	4
Urban green space	1	1	3	2	1	3

Relative importance weights:	Least important objective:	1
	Max importance value:	4

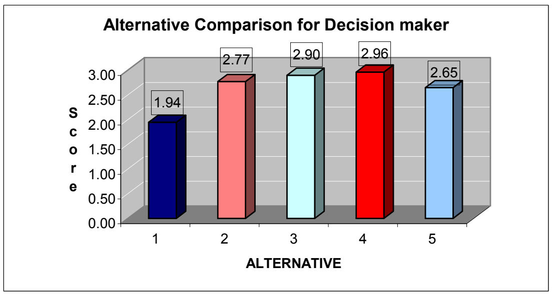

Fig. 6.2.1: Results for the combination of relative importance weights "G5".