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5. Multicriteria analysis – an Example for Prioritization of Investments in Irrigation Infrastructure

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1. Multi Criteria Analysis (MCA)

- There are complex problems in which the OF based only on one factor is not sufficient to take into account all variables affecting the final decision
  - ➢ For example: Investments in rehabilitation of existing water infrastructure when the funds are limited
    - ✓ The question is which system to be selected for rehabilitation
      - – If only money are taken into account, only small systems will be rehabilitated – but they will no produce significant effect on reduction of water use or increasing of profits (or incomes) for the state
      - – If only water use is taken into account, the systems with significant losses may not have significant effect on increasing of profits (or incomes) for the state
- Then the OF can include several parameters or variables of different kind

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1. Multi Criteria Analysis (MCA)

- When the OF includes variables of different kind, then we speak about Multi Criteria Analysis.
  - ➢ One type of water management infrastructure (e.g. Irrigation System) can affect economy and society in different ways.
  - ➢ The following type of OF can be used:

$$Z = \alpha_1 Econ. + \alpha_2 Tech. + \alpha_3 Env + \alpha_4 Soc.$$

where *Econ.* is the variable which takes into account the economic factors;

Tech. is the variable which takes into account Technical factors;

Env. is the variable which takes into account Environmental factors;

Soc. is the variable which takes into account Social factors

α_i are the weighting coefficients (weights) of different factors it should be $\Sigma\alpha_i = 1$

1. Multi Criteria Analysis (MCA)

- Since the variables have different units, a normalization should take place, in order to achieve comparable results
  - ➢ The normalization is done by following formula:

$$Normalized\ \ Variable = \frac{Current - Min}{Max - Min}$$

where *Current* is the value of a given variable, estimated for given value of its driving factors;

Max is the maximum (possible or justified) value of that variable, obtained for the range of variation of the driving factors;

Min is the minimum (possible or justified) value of that variable, obtained for the range of variation of the driving factors;

✓ By this formula 0 corresponds to min value of the variable and 1 corresponds to max value of the variable.

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1. Multi Criteria Analysis (MCA)

- All variables in the OF have to be normalized in such a way so the value 0 to correspond to *min* and value of 1 to *max*.
- By means of the weighting coefficients it is given preference to some of the criteria.
- If the OF is presented by the equation

$$Z = \alpha_1 Econ. + \alpha_2 Tech. + \alpha_3 Env + \alpha_4 Soc.,$$

it is said that a *simple additive weighting* (SAW) is used in multi criteria analysis.

- There are other possible ways the estimate the value of the OF in MCA:

$$Z = \sqrt{\alpha_1 Econ^2 + \alpha_2 Tech^2 + \alpha_3 Env^2 + \alpha_4 Soc^2}$$

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2. Case study

- Reconstruction and modernization (R&M) of irrigation systems (ISs) in Bulgaria
  - Old and deteriorating infrastructure
  - Low efficiency of ISs and lack of adequate water measurement
  - Climate changes
  - Importance of Agriculture
- Funds
  - Rural Development Programme 2014-2020 funds
  - EU Economic Recovery Plan
- Tool for prioritization of investments for R&M – Multi Criteria Analysis
- Subject of analysis – 237 Irrigation systems

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2. Case study

- MCA Approach – Criteria Selection and Evaluation
  - ➢ 4 criteria
    - ✓ Technical
    - ✓ Economic
    - ✓ Environmental
    - ✓ Social
  - ➢ Each criteria has several sub-criteria
  - ➢ Values of the 4 criteria are normalized – i.e. set within the range 0-1
  - ➢ Simple Additive Weighting (SAW) is used as MCA of 4 criteria

Result	Method Criterion	Criterion	Method Sub-criteria	Sub-criteria
Ranking of the Irrigation Schemes	Multi-criteria analysis (MCA)	**Technical**	MCA	**Equipped/Constructed Area ratio**
				Irrigation system size
				Water intake type
				IS efficiency
				Automation opportunity
				Reliability
				Safety
				Others
		Economic	B/C Ratio	Specific investment cost for R&M
				Depreciation, operation and maintenance cost
				Electricity expenses
				Net present value
				Payback period
				Potential additional farm income
				Benefit/Cost ratio
				Others
		Environ-mental	MCA	**Water savings potential**
				Water body status
				Land use
				Others*
		Social		Priority within the NRDP 2014-20
				Social acceptability
				Job creation
				Social benefits
				Others

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2. Case study

- MCA Procedure used

1) Determining the weights for MCA

2) Investigate 40 scenarios

3) Make Average ranking for these 40 scenarios

4) Overall ranking – which IS occurs most often in the first 10 in ranking

Main Criteria	**Relative weight within a group**				
	Variants				
	A	***B***	***C***	***D***	***E***
Technical	0,6	0,4	0,3	0,333	0,25
Economic	0,3	0,4	0,6	0,333	0,25
Environmental	0,1	0,2	0,1	0,333	0,5
Technical Sub-criteria	**Variants**				
	1	***2***	***3***	***4***	
E/C Area Ratio	0,167	0,182	0,100	0,125	
IS size	0,167	0,182	0,250	0,250	
WI Type	0,167	0,182	0,200	0,188	
Present IS Efficiency	0,167	0,182	0,250	0,250	
Automation opportunity	0,167	0,182	0,150	0,125	
Reliability	0,167	0,091	0,050	0,063	
Economic Sub-criteria	**Variants**				
	0				
B/C ratio	1				
Environmental Sub-criteria	**Variants**				
	i		***j***		
RPWS	0,5		0,75		
Water body status (WBS)	0,5		0,25		

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2. Case study

- Average Ranking
  - ➢ Three scenarios coincide the most with the average ranking
  - ➢ Scenario B40i - representative
    - ✓ it matches the best with the average ranking.

Sample on MCA results of Scenario B40i:

№	Irrigation Scheme	IS Type	Technical Criteria						Econ. criteria	Environm. criteria		Final Score
			E/C Area	IS size	WI Type	Present effi-ciency	Autom. opp.	Reli-abilty	Norm. B/C Ratio	RPWS normal.	WBS	S
1	Ihtiman IS	Gp	1.00	0.50	1.00	0.61	0.50	0.75	1.00	1.00	0.60	0.84
2	Dobromirtsi IF	Pp	1.00	0.14	1.00	0.81	0.75	0.25	1.00	1.00	0.41	0.80
3	Karaysen IS	C-P2c-S	0.16	0.50	1.00	0.99	0.45	0.07	0.86	1.00	1.00	0.80
4	Petelovo IF	Pp	0.95	0.00	1.00	0.81	1.00	0.25	1.00	1.00	0.41	0.80
5	Bolyarovo IS	C-Pc-P2c	1.00	0.50	1.00	0.56	0.25	0.41	1.00	0.78	0.54	0.79
6	Peshtera IS	C-Gc-Pc	0.53	0.50	0.50	0.64	0.25	0.93	1.00	1.00	0.71	0.78
7	Yastreb IF	Pp	0.71	0.00	1.00	0.81	0.75	0.25	1.00	1.00	0.41	0.78
8	Gorsko slivovo IS	Gc	0.45	0.14	1.00	0.79	0.25	1.00	1.00	1.00	0.47	0.77
9	Vitska IS	C-Gc-Pg-Pp	0.72	1.00	1.00	0.79	0.25	0.58	0.77	1.00	0.47	0.77
10	Polyanovo IF	P1p	1.00	0.14	0.50	0.81	0.75	0.25	1.00	1.00	0.41	0.77

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2. Case study

- Analysis of Investments for the first ten ISs:

№	IS name	Constructed Area, ha	Total Investments, €	IS Type	Score MCA	Score GIS	Number of times in Top 30	R
1	Ihtiman IS	3901.3	7 553 522	Gp	0.84	0.84	40	0.96
2	Dobromirtsi IF	1538.3	1 347 101	Pp	0.80	0.80	40	0.89
3	Karaysen IS	3119.0	4 253 557	C-P2c-S	0.80	0.80	35	0.61
4	Petelovo IF	350.8	159 194	Pp	0.80	0.80	40	0.89
5	Bolyarovo IS	4975.4	5 479 360	C-Pc-P2c	0.79	0.79	40	0.68
6	Peshtera IS	3596.8	4 376 725	C-Gc-Pc	0.78	0.78	40	0.75
7	Yastreb IF	545.9	190 774	Pp	0.78	0.80	40	0.77
8	GorskoslivovoIS.	1180.8	544 567	Gc	0.77	0.76	40	0.76
9	Vitska IS	29200.4	34 679 990	C-Gc-Pg-Pp	0.77	0.80	32	0.54
10	Polyanovo IF	1097.0	534 348	Pp	0.77	0.79	40	0.69
	Total Investments:		59 119 138 €					

- The funds allocated for R&M of IrIs under Rural Development Programme 2014-2020 amount to 54 699 274 €. These funds can be used for R&M of only 10 ISs out of 237, if R&M of the entire ISs are assumed.

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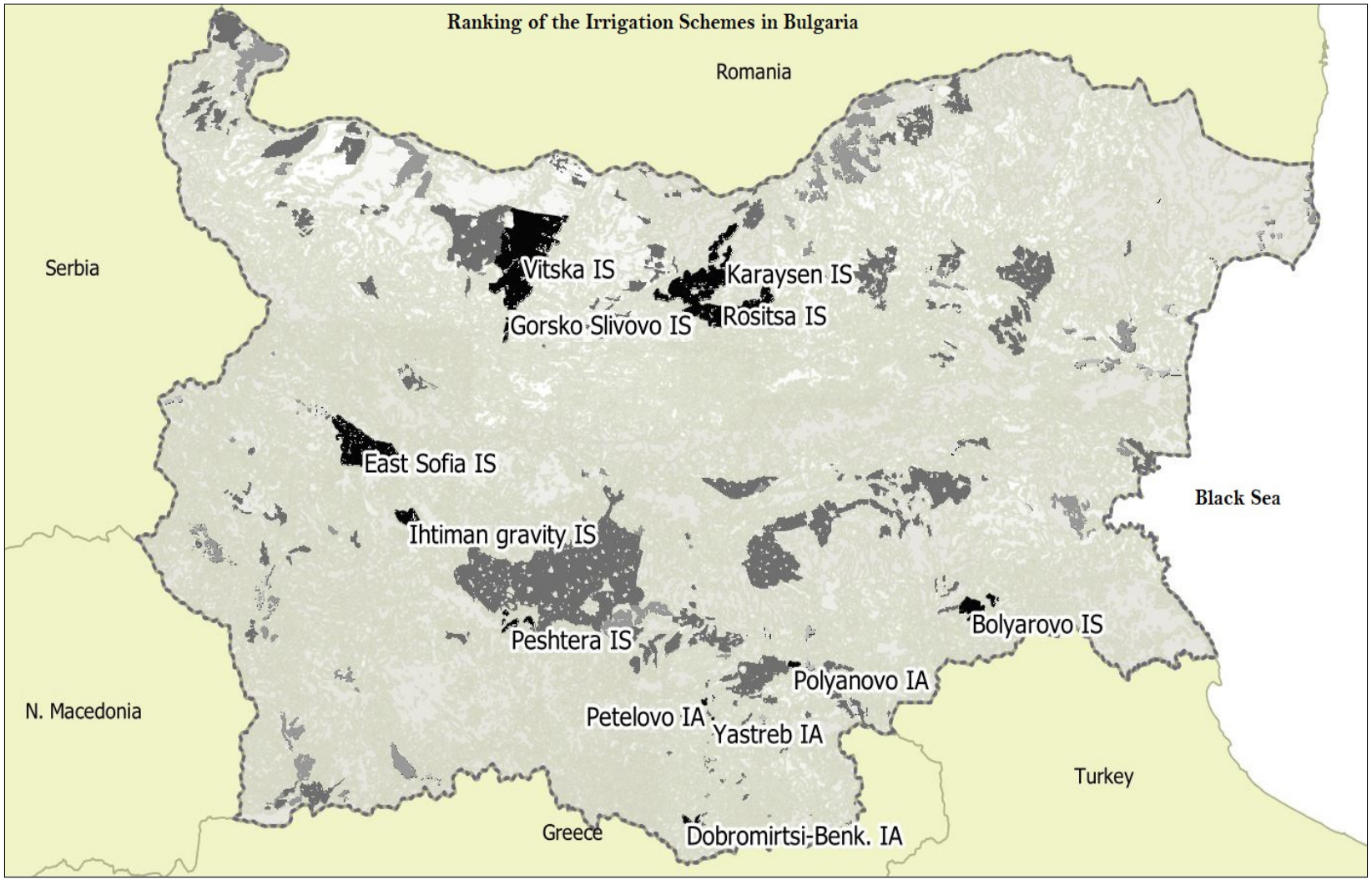
- GIS overlay analyses result



- Bad (<0,17)
- Satisfactory (0,17÷0,34)
- Good (0,34÷0,51)
- Very good (0,51÷0,76)
- Excellent (>0,76).

The ISs in "Excellent" group are shown in dark grey

2. Case study

- **Conclusions**
  - This MCA approach can be used both in government and private sector assessments.
  - The three criteria - *technical*, *economic* and *environmental*, with their sub-criteria, make possible objective ranking of the ISs.
  - MCA with only major criteria - sensible and not recommended.
  - MCA method minimizes the subjectivity factor in evaluation
  - In all 40 scenarios, Ihtiman IS always ranks first.
  - The GIS overlay analysis - similar results to SAW MCA method.
  - Small ISs (constructed area less than 2,500 ha) are ranked with high scores, despite the low weight, given to IS Size sub-criteria.
  - This MCA approach allows for future analyses on the basis of sub-systems.