FOREST MANAGEMENT FROM MULTICRITERIA AND GROUP DECISION MAKING VIEW – A METHODOLOGICAL CHALLENGE

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Framework

- For sustainable, multiple use and long term forest management **several alternatives** (scenarios, decisions) are developed

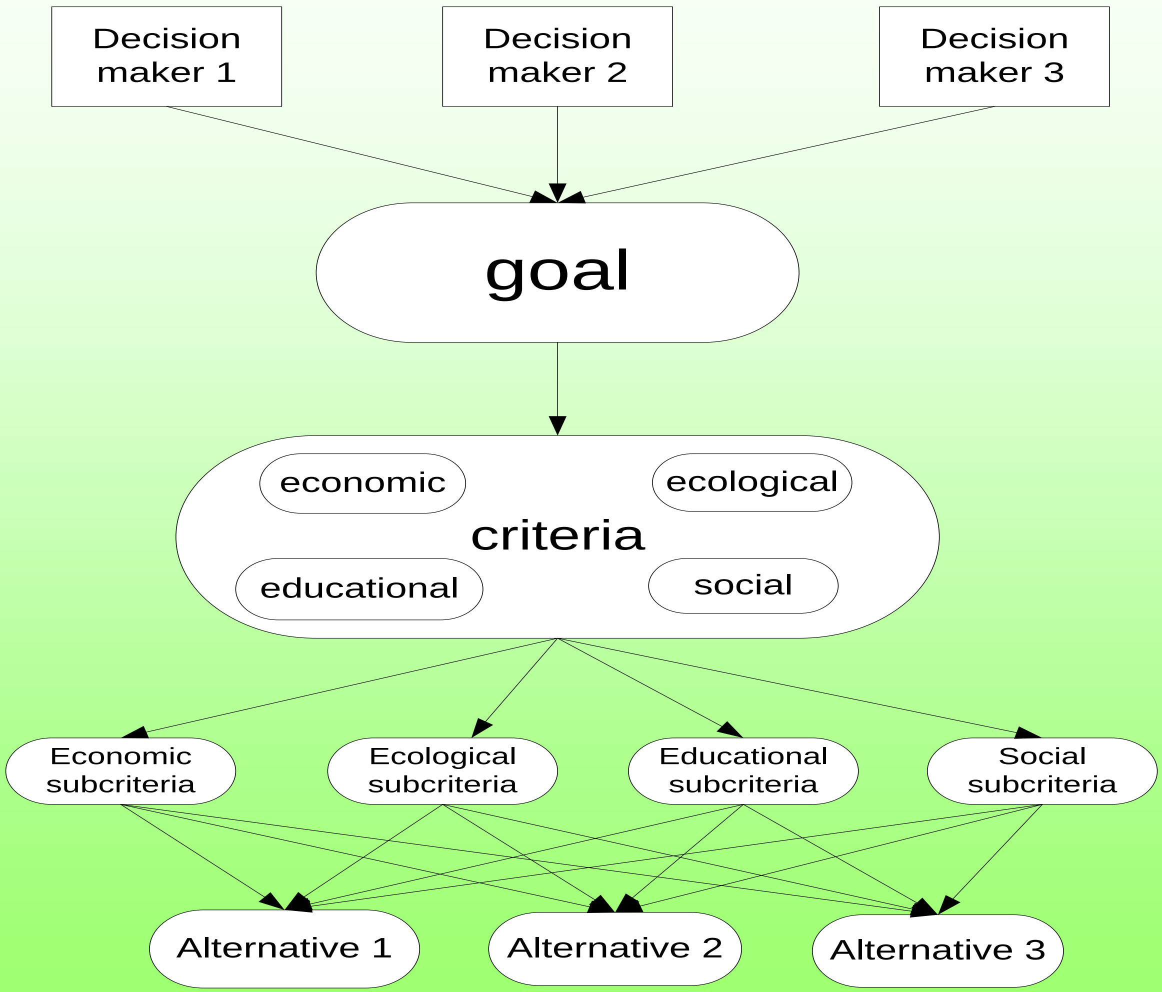
- Each scenario is affected by **several criteria**: economic, ecological, social, educational, etc.

- **Several decision makers** (different social groups) identify and assess the forest management alternatives

Decision making approach to forest management

- Forest management problem formulation
- Forest data and literature
- Defining the management goal
- Defining the forest management alternatives
- Deciding criteria and indicators (sub-criteria, attributes)
- Defining decision groups and their preferences for criteria and indicators
- Evaluating the criteria and indicators
- Weights assignment by the support of the appropriate methodological tool

Hierarchical structure of the problem



Forest management

- The **alternatives (decisions)** in forest management are **affected** by multiple criteria and several attributes (sub-criteria):

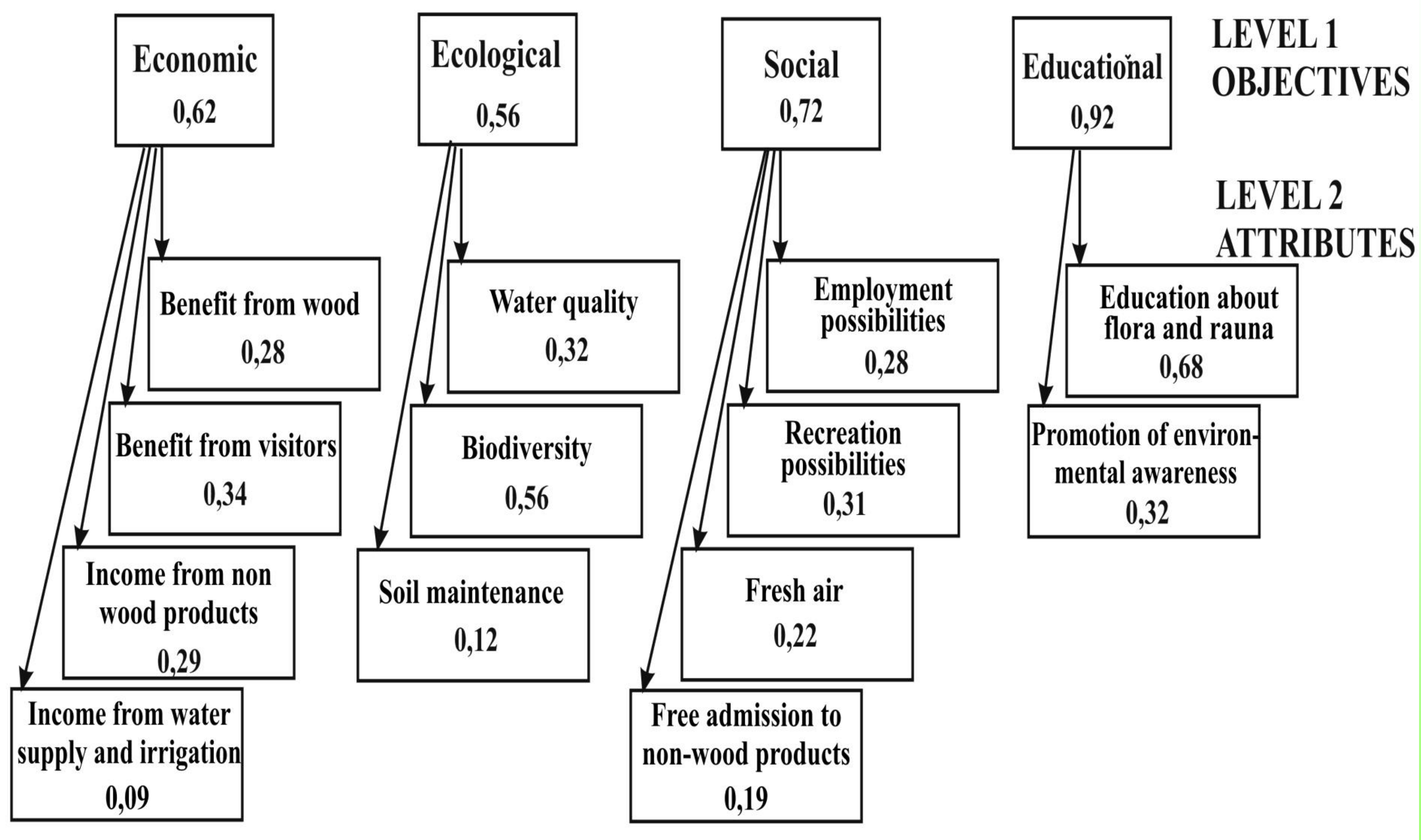
Criteria **Sub-criteria**

Economic timber production, hunting, increase of local income, job opportunities, sustainable economic development of the area, silvicultural treatments, taxes and other fixed costs, change of market prices

Ecological increase and conservation of biodiversity, forest health, increase of quality and quantity of water, improvement of fauna and flora, prevention of flood danger, prevention of soil erosion, climate changes, reforestation with autochthonic species, global carbon cycle

Social free access to nontimber products, recreation, source of wealth for local population, free entrance, employment possibilities

Educational forest learning trails, preservation of natural heritage, guided tours


Economic
0,62
Ecological
0,56
Social
0,72
Educational
0,92
LEVEL 1
OBJECTIVES
LEVEL 2
ATTRIBUTES
Benefit from wood
0,28
Benefit from visitors
0,34
Income from non wood products
0,29
Income from water supply and irrigation
0,09
Water quality
0,32
Biodiversity
0,56
Soil maintenance
0,12
Employment possibilities
0,28
Recreation possibilities
0,31
Fresh air
0,22
Free admission to non-wood products
0,19
Education about flora and rauna
0,68
Promotion of environ-mental awareness
0,32

Multiple criteria group decision making

- Forest management decisions are made under a multiple decision maker context.
- Many stakeholders, owners, forest managers, ecologists, and public participate in forest resource use and conservation; they promote communication between the interest groups
- The decision maker gathers the information about the values, attitudes and beliefs of the interest groups.

Multiple-criteria and group decision making models – a theoretical approach

- **Multiple-criteria models** (MCM) and methods imply a process of assigning values to alternatives that are evaluated along multiple-criteria.
- MCM deal with the selection of the best alternative based on conflicting objectives.
- MCM vary across decision making problems (GP, MAUT, SMART, ELECTRE, AHP, ANP,.....).
- The problems present a challenge for developing new multiple-criteria methodologies.

- MCM problems can be single-decision maker problems or group decision problems (GDP).
- GDP techniques provide a framework to represent the decision groups into a single model and are searching for group valuation of alternatives:
  - compromise
  - voting
  - consensus
  - aggregating methods
    - the aggregation of individual priorities
    - the aggregation of individual judgments

AHP and group methods

- According to hierarchical structure of a FM problem we are favoring AHP.
- AHP is rated very high compared with other MCM regarding applicability, validity of outcomes, structure, etc. (Peniwati, 2007)
- AHP, with its modified form ANP, was developed by Saaty in 1980, first for one decision maker.
- Eigenvector method: $Aw = \lambda_{max.} w$

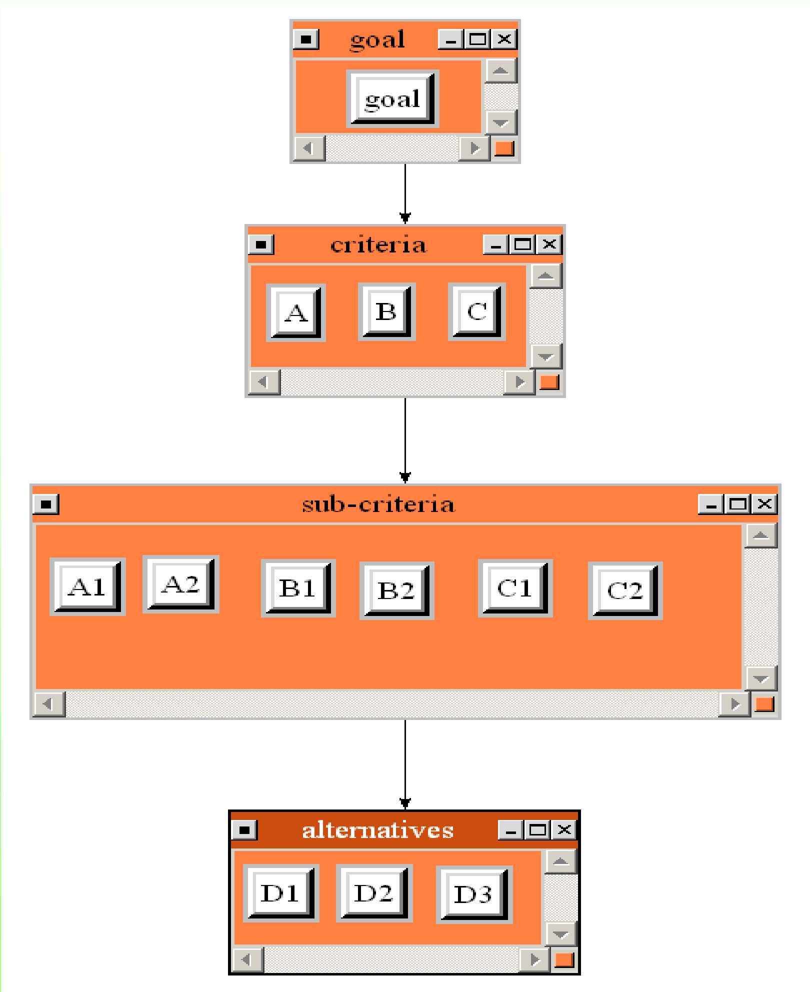
Comparison matrices of three decision makers for economic, ecological, educational and social criteria and their priority vectors

$$A = \begin{bmatrix} 1 & 3 & 2 & \frac{1}{2} \\ \frac{1}{3} & 1 & \frac{1}{5} & \frac{1}{5} \\ \frac{1}{2} & 5 & 1 & 1 \\ 2 & 5 & 1 & 1 \end{bmatrix} \quad w_A = \begin{bmatrix} 0.2897 \\ 0.0698 \\ 0.2688 \\ 0.3718 \end{bmatrix}$$

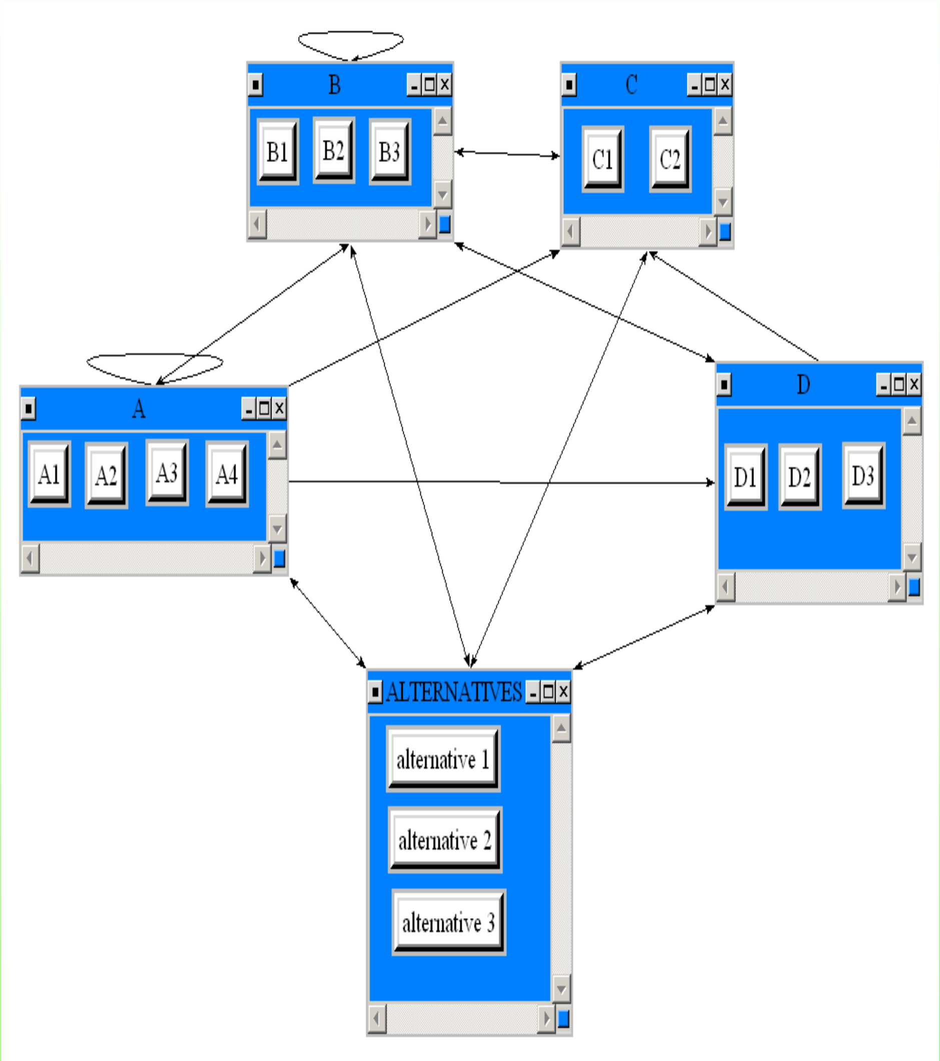
$$C = \begin{bmatrix} 1 & \frac{1}{2} & 4 & 1 \\ 2 & 1 & 6 & 5 \\ \frac{1}{4} & \frac{1}{6} & 1 & \frac{1}{5} \\ 1 & \frac{1}{5} & 5 & 1 \end{bmatrix} \quad w_C = \begin{bmatrix} 0.2149 \\ 0.5384 \\ 0.0568 \\ 0.1899 \end{bmatrix}$$

$$B = \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} & 1 \\ 2 & 1 & 3 & 3 \\ 2 & \frac{1}{3} & 1 & 3 \\ 1 & \frac{1}{3} & \frac{1}{3} & 1 \end{bmatrix} \quad w_B = \begin{bmatrix} 0.1529 \\ 0.4611 \\ 0.2620 \\ 0.1241 \end{bmatrix}$$

Super-Decisions; AHP



Super-Decisions; ANP



New multiple criteria group approaches

- Weighted geometric mean method - WGMM (Saaty, 1980, Aczel and Saaty, 1983))
- Aggregation of individual preference structures (Escobar and Moreno-Jimenez, 2007)
- Taguchi's loss function (Cho and Cho, 2008)
- Goal programming (Bryson and Joseph, 1999)
- Fuzzy preference programming (Mikhailov, 2004)
- Weighted least squares group method (Sun and Greenberg, 2006)
- DEA group method (Wang and Chin, 2009)
- Weighted geometric mean method within DEA – WGMDEA (Grošelj, Zadnik Stirn, 2009)

Weighted geometric mean method - WGMM (Saaty)

In the group decision making there are *m* decision makers with nxn comparison matrices $A^{(k)}=(a_{ij}^{(k)})$, $k=1,...,m$. The importance of *k*-th decision maker's opinion is denoted by α_k. In the WGMM, their group opinion is presented by the weighted geometric mean complex judgment

matrix $A^{WGM} = (a_{ij}^{WGM})_{n \times n}$

where $a_{ij}^{WGM} = \prod_{k=1}^{m} \left(a_{ij}^{(k)}\right)^{\alpha_k}$

The group priority vector from A^{WGM} is then derived by the eigenvector method.

Weighted least squares group method (Sun and Greenberg)

min $$f(w) = \sum_{k=1}^{m} \alpha_k \sum_{j=1}^{n} \sum_{i=1}^{n} \left\| a_{ij}^{(k)} w_j - w_i \right\|_2$$

$$= \sum_{k=1}^{m} \sum_{j=1}^{n} \sum_{i=1}^{n} \alpha_k \left(a_{ij}^{(k)} w_j - w_i \right)^2,$$

subject to $$\sum_{i=1}^{n} w_i = 1,$$

$$w_i > 0, \quad i=1,\ldots,n$$

The solution of the weighted least squares group method

Let $\tilde{A} = (\tilde{a}_{ij})_{n\times n}$, $\tilde{a}_{ij} = \sum_{k=1}^{m} \alpha_k a_{ij}^{(k)}$,

$\hat{a}_{ij} = \sum_{k=1}^{m} \alpha_k \left((a_{ij}^{(k)})^2 + 1 \right)$, $\eta_j = \sum_{i=1}^{n} \hat{a}_{ij}$ and $\Lambda = diag(\eta_1, \eta_2, \ldots, \eta_n)$.

Then the group priority vector is given by $w = C^{-1}\lambda,$

where $C = \tilde{A} + \tilde{A}^T - \Lambda$, $C^{-1} = (\bar{c}_{ij})_{n\times n}$

and $\lambda = \left(\frac{\bar{\lambda}}{2}, \frac{\bar{\lambda}}{2}, \ldots, \frac{\bar{\lambda}}{2} \right)^T$, $\bar{\lambda} = 2 / \left(\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{c}_{ij} \right)$.

DEA group method (Wang and Chin)

n criteria, *m* decision makers with comparison matrices $A^{(k)} = (a_{ij}^{(k)})_{n \times n}$, *k=1,…,m,* $\sum_{k=1}^{m} \alpha_k = 1$

LP model:

max $$w_0 = \sum_{j=1}^{n} \left(\sum_{k=1}^{m} \alpha_k a_{0j}^{(k)} \right) x_j,$$

subject to $$\sum_{j=1}^{n} \left(\sum_{k=1}^{m} \sum_{i=1}^{n} \alpha_k a_{ij}^{(k)} \right) x_j = 1,$$

$$\sum_{j=1}^{n} \left(\sum_{k=1}^{m} \alpha_k a_{ij}^{(k)} \right) x_j \geq n x_i, \quad i = 1, \ldots, n$$

$$x_j \geq 0, \quad j = 1, \ldots, n$$

WGMDEA (Grošelj, Zadnik Stirn)

It uses the weighted geometric mean that keeps the reciprocal property.

LP model:

max $$w_0 = \sum_{j=1}^{n} \left(\prod_{k=1}^{m} \left(a_{0j}^{(k)} \right)^{\alpha_k} \right) x_j$$

subject to: $$\sum_{j=1}^{n} \left(\sum_{i=1}^{n} \prod_{k=1}^{m} \left(a_{ij}^{(k)} \right)^{\alpha_k} \right) x_j = 1$$

The numerical example:

$$A = \begin{bmatrix} 1 & 3 & 2 & \frac{1}{2} \\ \frac{1}{3} & 1 & \frac{1}{5} & \frac{1}{5} \\ \frac{1}{2} & 5 & 1 & 1 \\ 2 & 5 & 1 & 1 \end{bmatrix} \quad B = \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} & 1 \\ 2 & 1 & 3 & 3 \\ 2 & \frac{1}{3} & 1 & 3 \\ 1 & \frac{1}{3} & \frac{1}{3} & 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & \frac{1}{2} & 4 & 1 \\ 2 & 1 & 6 & 5 \\ \frac{1}{4} & \frac{1}{6} & 1 & \frac{1}{5} \\ 1 & \frac{1}{5} & 5 & 1 \end{bmatrix}$$

$$CR_A = 0.0824 \quad CR_B = 0.0656 \quad CR_C = 0.0728$$

$$\alpha_A = 0.5 \quad \alpha_B = 0.25 \quad \alpha_C = 0.25$$

Results

	WGMM	Rank	WLSGM	Rank	Group DEA	Rank	WGMDEA	Rank
economic	0.2741	2	0.3970	1	0.2150	4	0.2724	2
ecological	0.2214	3	0.1583	4	0.2788	1	0.2253	3
educational	0.2153	4	0.1726	3	0.2409	3	0.2259	4
social	0.2892	1	0.2721	2	0.2653	2	0.2764	1

- The example given here as well as others (Grošelj, Zadnik Stirn, 2009-EJOR, CEJOR) show the differences in results.
- Some methods have drawbacks (violation of reciprocal property, etc.)
- WGMM and WGMDEA give similar results.
- The advantage of WGMDEA is LP (WGMM uses eigenvector procedure).

Conclusions

- In the presentation the central concern of solving a sophisticated FM problem is an integrated approach to MCDA methodologies.
- We discussed the idea of drawing together different MCDA methodologies to provide a meta-solution to multi-criteria and group FM problem
- Such considerations lead to the research needs in the area of MCDA.

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