MANAGEMENT OF FLUVIAL ECOSYSYTEMS (ATHENS PROGRAM)

MULTICRITERIA DECISION ANALYSIS FOR RIVER BASIN MANAGEMENT

CARLOS ROMERO
PROFESSOR. RESEARCH GROUP: ECONOMICS FOR A SUSTAINABLE ENVIRONMENT.TECHNICAL UNIVERSITY OF MADRID
carlos.romero@upm.es
www.ecsen.es

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- **MANAGEMENT OF FLUVIAL ECOSYSTEMS: TWO MAIN FEATURES**
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- MULTIPLICITY OF CRITERIA OF VERY DIFFERENT NATURE UNDERLYING THE MANAGEMENT (RESTORATION) OF THE FLUVIAL ECOSYSTEM
- **-ECOLOGICAL CRITERIA**
- **-ECONOMIC CRITERIA**
- **-SOCIAL CRITERIA**
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- -MULTIPLE STAKEHOLDERS (DECISION MAKERS) (SOCIAL GROUPS) INVOLVED IN THE DECISION MAKING PROCESS.
- -VERY DIFFERENT SOCIAL PERCEPTIONS
- CONSUMERS, ACADEMY, ECOLOGISTS, PRODUCERS,...
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- MULTIPLE CRITERIA$\Rightarrow$ GOAL PROGRAMMING
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- MULTIPLE SOCIAL GROUPS$\Rightarrow$ AGGREGATION OF PREFERENCES
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- MATHEMATICS AS A TOOL$\Rightarrow$ A BASIC KNOWLEDGE OF LINEAR PROGRAMMING

OUTLINE OF THE PRESENTATION

1. A BRIEF REVIEW OF THE LOGIC OF CHOICE

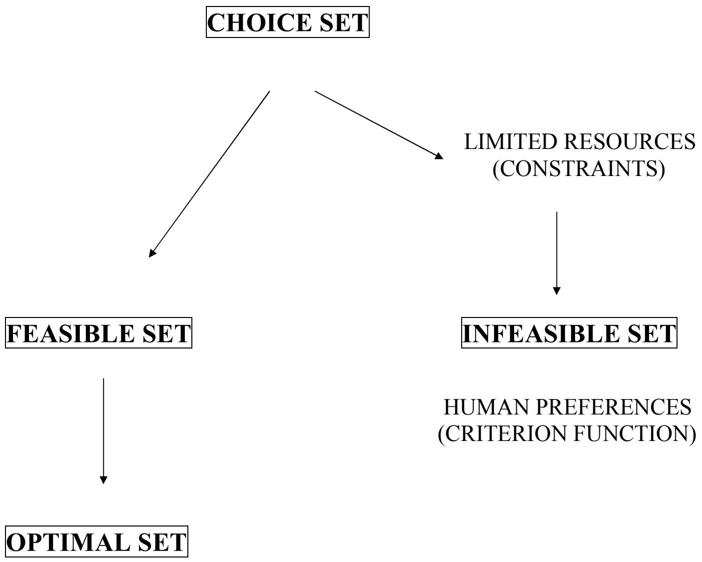
2. BASIC MCDM CONCEPTS
   (ATTRIBUTES, OBJECTIVES, GOALS, CRITERIA)

3. A BASIC GOAL PROGRAMMING MODEL

4. SOME EXTENSIONS

5. CASE STUDY I. THE TAUSTE RIVER

6. CASE STUDY II. IRRIGATED AGRICULTURE IN THE MONEGROS DISTRICT



EXISTENCE OF A SOLUTION

THE EXTREME VALUE THEOREM

CRITERION FUNCTION	**FEASIBLE SET**	**OUTCOME**
CONTINUOUS	COMPACT	LOCAL OPTIMUM
CONCAVE(CONVEX)	COMPACT&CONVEX	GLOBAL OPTIMUM

(WEIERSTRASS THEOREM)

COMPUTATIONAL ISSUES

CRITERION FUNCTION	FEASIBLE SET	APPROACH
CONCAVE(CONVEX)	EQUALITIES	LAGRANGE
CONCAVE(CONVEX)	INEQUALITIES	FOURIER
LINEAR	CONVEX POLYTOPE	DANTZIG
QUADRATIC	CONVEX POLYTOPE	WOLFE
NON-LINEAR	COMPACT	KUHN-TUCKER
POSYNOMIAL	COMPACT	GEOMETRIC PROG

METAHEURISTICS

WHY AN MCDM PARADIGM IN WATER RESOURCES MANAGEMENT?

SEVERAL CRITERIA

a)
MAXIMISATION OF PROFITS (NPV) ⇒ (ECONOMICAL)
MINIMISATION OF BORROWING (WORKING CAPITAL)

b)
MINIMISATION OF WATER CONSUMPTION
MINIMISATION OF "SALT-LOAD" ⇒ (ENVIRONMENTAL)
MINIMISATION OF NITROGEN LEACHATE

c)
MAXIMISATION OF THE LEVEL OF EMPLOYMENT ⇒ (SOCIAL)
MINIMISATION OF SEASONAL LABOUR

2)

* RIGID CONSTRAINTS **VERSUS** FLEXIBLE CONSTRAINTS (GOALS)

* MANY DEMANDING CONSTRAINTS ⟹ NO FEASIBLE SOLUTIONS

SOME BASIC CONCEPTS ON MCDM

ATTRIBUTES ⇒ OBJECTIVES ⇒ ASPIRATION LEVELS

(TARGETS) ⇒ GOALS ⇒ CONSTRAINTS ⇒ CRITERIA

ATTRIBUTES

IT REFERS TO THE DM´S VALUES RELATED TO AN OBJECTIVE REALITY. THESE VALUES CAN BE MEASURED INDEPENTLY FROM DM´S DESIRES AN EXPRESSED AS MATHEMATICAL FUNCTIONS OF THE DECISON VARIABLES.

PROFITS ⇒ $100X_1 + 200X_2$

ENVIRONMENTAL IMPACT ⇒ $X_1 + 1.5X_2$

OBJECTIVES

"DIRECTIONS OF IMPROVEMENT OF THE ATTRIBUTES"

"MORE IS BETTER" ⇒MAXIMISATION PROCESS

"LESS IS BETTER" ⇒MINIMISATION PROCESS

PROFIT⇒ MAX $100X_1 + 200X_2$

ENVIRONMENTAL IMPACT⇒ MIN $X_1 + 1.5X_2$

TARGETS

"IT IS AN ACEPTABLE LEVEL OF ACHIEVEMENT FOR ANY OF THE ATTRIBUTES. THAT IS, REPRESENTS FIGURES FOR WHICH THE DM FEELS SATISFACTORY AND SUFFICIENT ("SATISFICING")

GOALS

"COMBINATION OF AN ATTRIBUTE WITH A TARGET"

PROFITS⇒ $100X_1 + 200X_2 \geq 40{,}000$

ENVIRONMENTAL IMPACT⇒$X_1 + 1.5X_2 \leq 300$

DEVIATION VARIABLES

$100X_1 + 200X_2 + n_1 - p_1 = 40{,}000$

$X_1 + 1.5X_2 + n_2 - p_2 = 300$

UNWANTED DEVIATION VARIABLES

$n_1 \quad p_2$

EXAMPLE

$X_1 = 100; X_2 = 100 \Rightarrow$

$30000 + \mathbf{n_1} - p_1 = 40{,}000 \Rightarrow n_1 = 10{,}000 \quad p_1 = 0$

$250 + n_2 - \mathbf{p_2} = 300 \Rightarrow n_2 = 50 \quad p_2 = 0$

CRITERION

"THIS TERM COMPRISES THE ATTRIBUTES, OBJECTIVES AND GOALS OF A DM RELEVANT TO A PARTICULAR DECISION-MAKING PROBLEM"

MCDM⇒ A PARADIGM FOR ANALYSING DECISION-MAKING PROBLEMS INVOLVING DIFFERENT ATTRIBUTES, OBJECTIVES OR GOALS

GOAL PROGRAMMING

"GP IS AN ANALYTICAL FRAMEWORK DESIGNED FOR ANALYSING COMPLEX DECISION-MAKING PROBLEMS. THE DM ATTACHES A TARGET TO EACH RELEVANT ATTRIBUTE. THEREFORE, THE DM WANTS TO MINIMISE IN ONE WAY OR IN ANOTHER THE LACK OF ACHIEVEMENT OF THE CORRESPONDING GOALS; THAT IS, IN THIS WAY A SATISFACTORY AND SUFFICIENT SOLUTION ("SATISFICING") IS SEARCHED FOR.

(IGNIZIO AND ROMERO, 2003)

A BASIC GOAL PROGRAMMING MODEL

$(g_1)\ \ f_1(\mathbf{X}) + n_1 - p_1 = t_1 \qquad \boxed{n_1} \Rightarrow$ unwanted

. . . . . .

$(g_2)\ \ f_2(\mathbf{X}) + n_2 - p_2 = t_2 \qquad \boxed{p_2} \Rightarrow$ unwanted

. . . . . .

$(g_i)\ \ f_i(\mathbf{X}) + n_i - p_i = t_i \qquad \boxed{n_i, p_i} \Rightarrow$ unwanted

. . . . . .

$(g_q)\ \ f_q(\mathbf{X}) + n_q - p_q = t_q \qquad \boxed{p_q} \Rightarrow$ unwanted

UNWANTED DEVIATION VARIABLES

$\mathbf{n_1, \ p_2, \dots \ ,(n_i, p_i), \dots \ ,p_q}$

ACHIEVEMENT FUNCTION

MIN φ = g(n_1, p_2, ... ,(n_i, p_i),... ,p_q)

SOME EXAMPLES OF ACHIEVEMENT FUNCTION

a) WEIGHTED GOAL PROGRAMMING

MIN $W_1 \frac{n_1}{t_1} + W_2 \frac{p_2}{t_2} + ... W_i \frac{n_i + p_i}{t_i} + ... + W_q \frac{p_q}{t_q}$

b) MINMAX (CHEBYSHEV) GOAL PROGRAMMING

MIN MAX $\left(W_1 \frac{n_1}{t_1}, W_2 \frac{p_2}{t_2}, ..., W_i \frac{n_i + p_i}{t_i}, ..., W_q \frac{p_q}{t_q} \right)$

c) LEXICOGRAPHIC G P, EXTENDED GP, INTERVALAR GP, FUZZY GP, etc

MULTI-OBJECTIVE PROGRAMMING (VECTORIAL OPTIMISATION)

GENERAL SETTING

ALL THE OBJECTIVES DERIVE FROM ATTRUTES "MORE IS BETTER"

X = VECTOR OF DECISION VARIABLES OR MANGEMENT PRACTICES

SET OF OBJECTIVES

f_1 (**X**),.... f_i (**X**),... f_n (**X**)

THERE IS NOT AN OPTIMUM BUT A SET OF EFFICIENT STRATEGIES

CHARACTERISATION OF THE EFFICIENT SET

-Weighting Method

-Constraint Method

-Simplex Multicriteria

PAY-OFF MATRIX

IT IS OBTAINED THROUGH THE INDIVIDUAL OPTIMISATION OF THE OBJECTIVES INVOLVED IN THE DECISION-MAKING PROCESS

USEFULNESS

1. PROVIDES INFORMATION ABOUT THE ACTUAL DEGREE OF CONFLICT AMONG THE RELEVANT OBJECTIVES.

2. PROVIDES POINTS OF REFERENCE

3. PROVIDES THE RANGE OF VARIATION OF THE DIFFERENT OBJECTIVES.

4. CAN BE OBTAINED A "SATISFICING" BEST-COMPROMISE STRATEGY BY THE INDIVIDUAL OPTIMISATION OF ANY OF THE RELEVANT OBJECTIVES?

THE PAY-OFF MATRIX

TABLE 2. PAY-OFF MATRIX FOR THE FOUR CRITERIA CONSIDERED. BOLD CHARACTERS DENOTE IDEAL VALUES AND UNDERLINED FIGURES ANTI-IDEALS.

	Gross Margin (1)	Water Consumption (2)	Nitrogen Consumption (3)	"Wald Maximin" (4)
Gross Margin(€)	**35,297,876**	14,473,166	18,329,564	33,938,524
Water Consumption(m^3)	274,968,992	**91,563,360**	181,772,960	260,518,128
Nitrogen Consumption(Kg)	8,086,172	3,924,144	**2,652,397**	7,564,090
"Wald Maximin" (€)	28,714,312	9,225,586	15,365,626	**29,921,370**

A COMPROMISE PROGRAMMING MODEL

BASIC IDEA

a) CASE "MORE IS BETTER"

$f_i(\mathbf{X}) + n_i - p_i = t^*_i \Rightarrow p_i = 0 \Rightarrow n_i = t^*_i - f_i(\mathbf{X})$

b) **CASE "LESS IS BETTER"**

$f_i(\mathbf{X}) + n_i - p_i = t^*_i \Rightarrow n_i = 0 \Rightarrow p_i = f_i(\mathbf{X}) - t^*_i$

A GENERAL CP MODEL ("MORE IS BETTER")

$$MIN \quad L_p = \left[\sum_{i=1}^{q} w_i^p \left(\frac{t_i^* - f_i(x)}{t_i^* - t_{i*}} \right)^p \right]^{1/p}$$

SUBJECT TO: $\mathbf{X} \in \mathbf{F}$

CONCLUDING REMARKS

a) WATER RESOURCES MANAGEMENT REQUIRES NOWADAYS THE USE OF SOPHISTICATED (BUT EASY) MCDM TECHNIQUES

b) MULTI-CRITERIA OPTIMISATION TECHNIQUES BASED UPON THE MINIMISATION OF DISTANCE FUNCTIONS (GP, CP) SEEMS ESPECIALLY SUITABLE

c) THE COMPLEXITY OF MANY WATER RESOUCES MANAGEMENT PROBLEMS IS CURRENTLY INCREASING, DUE TO THE MANNER IN WHICH DIFFERENT STAKEHOLDERS PERCEIVE THE RELATIVE IMPORTANCE OF THESE CRITERIA⇒**GROUP DECISION MAKING**

MCDM+GDM

THANK YOU VERY MUCH FOR YOUR ATTENTION

COMMENTS, QUESTIONS, QUERIES, CRITICISMS, ...,

ARE VERY WELCOME