KAE/ST1
Selected Topics in Management

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Software Support for Managerial Decision-Making

Intended topics of the course

- **Decision making**
  - under ignorance
  - under risk
  - under uncertainty
  - under certainty
  - also multiple-criteria, multiple experts

- **Methods, assumptions, algorithms, models, theories**

Intended topics of the course

That is e.g.

- Decision matrices
- Decision trees
- Pairwise comparison methods (AHP)
- Partial goals method
- TOPSIS
- Fuzzy (linguistic) modelling
- Zadeh-Bellman optimization

- Linear programming
- Optimization
- Simplex method
- Game theory
- Delphi
- Consensus
- Voting

- DEA, WA, OWA, GM, FES, ...

When is decision support needed anyway?

- **Lack of time** (real time results needed)
- **Too much complexity**
- **Too much information**
- **Insufficient memory/computational skills**
- **Insufficient experience?**

- **Objectivity/excuse** (explanation to external subjects, removal of „human element“)
- **Delegation of responsibility**
- **Confirmation of intuition** (often when higher values are at stake)
- **…**

Please keep in mind!!!

Decision making

$\neq$

Decision support (its outcomes)

Even a very sophisticated decision support model/tool can not be held responsible for the consequences of decisions taken upon its results. PEOPLE MAKE DECISIONS. PEOPLE ARE SUPPOSED TO THINK, not models!

General goals of decision-making models

- **Selection of the best alternative/strategy**
  (which phone to buy, which company to invest in, ...)
- **Ordering of alternatives/strategies**
  (get a list of workers wrt. their performance, list of projects wrt. their appropriatenes for the company)
- **Decision on acceptance/nonacceptance of alternatives**
  (loan decisions in banks, ...)

- **Classification**
  (different from ordering, if the classes are not ordered, still may be useful in economics)

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Absolute or relative?

- **Classification**
  (different from ordering, if the classes are not ordered, still may be useful in economics)

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200?

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR?

- Amount/specificity of information

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR?

- Amount/specificity of information
- Scale chosen

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR fine for speeding?

- Amount/specificity of information
- Scale chosen
- Context (frame)

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR fine for speeding compared to a 500 EUR fine?

- Amount/specificity of information
- Scale chosen
- Context (frame)
- Other alternatives

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR fine for speeding compared to a 5 EUR fine?

- Amount/specificity of information
- Scale chosen
- Context (frame)
- Other alternatives!!!

Relative vs. absolute evaluation

How do we evaluate an alternative wrt. a criterion?

What plays an important role?

How good is 200 EUR fine for speeding compared to a 5 EUR fine?

- Amount/specificity of information
- Scale chosen
- Context (frame)
- Other alternatives!!!

Is it OK that the evaluation (even scale) changes with adding more information and alternatives?

Relative vs. absolute evaluation

- **Relative evaluation**
  - is dependent on the reference framework
  - can change with the addition or removal of **other alternatives**
  - Takes into account **differences**, not absolute values (hence relative)

→**ordering of alternatives**

→**selection of best alternative**

X decision on acceptance of an alternative

Relative vs. absolute evaluation

- **Absolute evaluation**
  - is dependent on the reference framework
  - does not change with addition/removal of alternatives
  - requires more information to be available
  - more interpretation possibilities (degree of goal fulfillment)
  - Requires specific scale/criteria (with definable max and min values or thresholds)

→ordering of alternatives

→selection of best alternative

→decision on acceptance of an alternative

Basic components of decision making models

- **Decision makers (DMs)**
  - rational $P = \{1, \dots, n\}$
  - irrational (nature) $Q = \{1, \dots, m\}$
- **Alternatives (sets of them)**, also called strategies
  - for rational DMs

    X_p is a set of alternatives considered by a DM $p \in P$
  - for irrational DMs

    Y_q is a set of alternatives considered by a DM $q \in Q$
- **Result of the decision making situation** (general)

$$(x_1, \dots, x_n, y_1, \dots, y_m) \in X_1 \times \dots \times X_n \times Y_1 \times \dots \times Y_m$$

Basic components of decision making models

- **Criteria (for rational DMs)**
  - A set of k criteria for a decision maker p: $C_1^p, \dots, C_k^p$
  - (cost, gain, utility, color, ...), usually shared by all DM $C_1, \dots, C_k$
- **Weights of criteria**
  - A set of k weights of criteria for a decision maker p: $w_1^p, \dots, w_k^p$
- **Objective function of DM_p**

$M_p\colon \mathrm{X}_1 \times \cdots \times X_n \times Y_1 \times \cdots \times Y_m \ \rightarrow R$ *(scalar)* ***or some scale element***

or

$$\boldsymbol{M}_p\colon \mathrm{X}_1 \times \cdots \times X_n \times Y_1 \times \cdots \times Y_m \ \rightarrow R^r \text{ (vector)}$$

Basic components of decision making models

- **Context**
- ***Culture***
- ***Time***
- ***Situation***
- ***Purpose***
- ***REPETITION?***
- **…**

Correctness / validity / appropriateness / quality of the models – ***HOW TO ASSESS IT?***

Decision makers

- **Rational**

  "Base their decisions on reasonable assessment of the situation, try to achieve a given goal." (usually gain or utility maximization is supposed)

  - ***Is selecting an alternative randomly rational, if you DECIDE to do so?***

- ***Irrational = nature***

  "The outcomes/alternatives are "chosen" randomly."

  - **Either probabilities (probability density functions, distributions) are known or not.**
  - **Unpredictable to some extent.**
  - **There is no purpose, no goal nor motivation guiding the selection of alternatives.**
  - **Not necessarily human.**

Decision makers

At least one rational DM is assumed in a decision making situation

- Bounded rationality (see eg. Herbert Simon) – rationality restricted to available information
- Near optimality (sufficient improvement) vs. maximization/minimization
- Freedom to choose
- Additional limitations may appear
- Counterintuitivness

Decision makers

It is important to know:

!whether other DMs are rational!

!if so in what sense!

!if not, what can be expected / observed / found out!

Completness of information (see more in game theory)

Completness of information concerning DMs

- Decision making under **CERTAINTY**
  - Everything is known (complete information in the pure sense – no uncertainty) – nonstochastic = deterministic
- Decision making under **UNCERTAINTY (IMPRECISION)**
  - The evaluations or weights of criteria (even probabilities of states of world) cannot be determined precisely or are provided in linguistic terms
- Decision making under **RISK (STOCHASTIC)**
  - The evaluations depend on the result of some random process (probabilities are involved and known, expected values usually used, …) – stochastic MCDM models (and financial, economic, …)
- Decision making under **IGNORANCE**
  - The evaluations depend on the result of some proces, but nothing is known concerning the process (probabilities of states of nature or weights of criteria are not known) – some crucial piece of information is unavailable

Evaluation of a decision support model

- What is a good model? – **MODEL VALIDATION**
- What is a stable/reliable model?
- How sensitive is the model to
  - Our estimates of weights
  - Our estimates of probabilities
  - Our evaluations
  - … → **SENSITIVITY ANALYSIS**

- Intuition, expectations, understandability, meeting unspoken requirements, …

Decision support model validation

What is a good model?

If I tell you the model suggests you to buy 1 000 EUR worth of stock A.

If I tell you the model suggests to give the heart to this patient, he might have better chance to live.

How would you decide whether to "trust" the model?

Decision support model validation

A good decision support model…

- … provides results that are not counterintuitive
- … provides expected results to “prototypical” cases
- … provides results that can be understood (and deviations from “the outcomes that come to mind” can be reasonably explained and accepted)
- … is such that the decision maker is willing to trust it

AND YES WE ARE TALKING ABOUT TRUSTING MATHEMATICS…

Decision support model – sensitivity analysis

A good decision support model…

- … provides reasonable results even if we did not use the exactly correct values
- … will keep suggesting the same (or very similar) result even if the weights / evaluations / probabilities change slightly

If it does not do that, it may still be a good model. We might just use it wrong sometimes…

Criteria I

There are several possible classifications of criteria, e.g.:

- **Nominal** (possible values: 1, blue, 3.14, Alex, …), no operations available (just =)
- **Ordinal** (possible values: 1, blue, 3.14, Good, …), <,>,min,max available
- **Cardinal** (possible values: usually numerical) <,>,min,max,+,-,x,/,… available
  - Cardinal without natural min and max
  - Cardinal with natural min and max

Criteria II

- **Benefit-type criteria** (“the more the better”)
- **Cost-type criteria** (“the less the better”)
- **Specific-value-preferred-type criteria** (“the closer to XX the better”) – can be transformed into the previous type

- **Qualitative** (nonnumerical in nature) – can be nominal, ordinal
- **Quantitative** (numerical in nature)

Criteria III

- **Independent criteria** (“uncorrelated”)
- **Dependent criteria** (“correlated”)
  - Redundancy type interaction (“positive correlation”=partial overlap, measure partly the same)
  - Synergy type interaction (desired values of them support each other and result in a good relationship “the whole is better than the sum of its parts”)
  - Contradicting criteria (“negative correlation” – if one gets better, the other gets worse)

Ideally we want to work with independent criteria. Dependent criteria require more sophisticated methods (Choquet integral, FES,…) to be properly used in the models.

Criteria IV

- It is reasonable to **aggregate values** of criteria **only if:**
  - The criteria are of the **same type**
  - The values are on the **same scale**

  (then averages such as WA,OWA,GM,… can be used)

or

  - We are able to **transform** the criteria values **to the same scale** (standardization, utility function, fuzzy goals, …)

or

  - We know how to **use fuzzy expert systems**

Criteria V

The set of criteria $C_1, \ldots, C_k$ is usually required to be:

- **Complete** (no important criterion is missing)
- **Non-redundant**
- **Minimal** (the fewer the criteria the better)
- **Operationally defined** (we know well what the criteria mean)
- **Measurable**

Weights of criteria I

Weights of criteria capture the (relative) importance of criteria. They might reflect:

- How many times C_i is more important than C_j
- By how many units is C_i more important than C_j
- How much C_i and C_j contribute to the overall goal **(absolute type information)**
- How many units of C_i compensate one unit of C_j

- Based on the interpretation of weights the model needs to be chosen

Weights of criteria II

We work either with

- “**raw**” weights $v_1, \dots, v_k$ such that

$$\sum_{i=1}^{k} v_i \neq 1$$

- Or with “**normalized**” weights $w_1, \dots, w_k$ such that $w_i = \frac{v_i}{\sum_{i=1}^{k} v_i}$ and

$$\boldsymbol{\sum_{i=1}^{k} w_i = 1}$$

Weights of criteria III – weights determination

Direct methods

- Assigning points from a scale (say 1…10) + normalizing
- Continuous graphical scale + normalization
- Distributing 100 points among criteria
- Metfessel allocation

Methods using the information on the ordering of criteria

- Expressing all in terms of the least/most important (whose weight is set to e.g. 1)

Weights of criteria IV – weights determination

Indirect methods

- Pairwise comparison method
- Saaty's method

Methods using the information on evaluations wrt. criteria

- Compensation method
- Method assigning weights based on the ranges of criteria values

+ utility function, fuzzy set approach…

Basic types of MCDM models

Type 1 – mathematical programming

$P = \{1\}; \;\; X; \;\; M;$ $\qquad M: X \to R$

- 1 rational decision maker
- known set of alternatives $X = \{x_1, \ldots, x_l\}$
- one criterion
- possible constraints

Class of MCDM methods

→ **Mathematical programming, optimization** (single-criterion)

Type 2 – game theory

$$P = \{1, \dots, n\}; \quad X_1, \dots, X_n; \quad M_1, \dots, M_n; \quad M_i : X_1 \times \cdots \times X_n \to R$$

- n rational decision makers (“players”)
- known set of strategies $X_1, \dots, X_n$ of each player
- one criterion (payoff)
- Known payoff functions of each player $M_1, \dots, M_n$

Class of MCDM methods

→ **Game theory**

Type 3 – decision making under risk

$$P = \{1\};\quad X;\quad M;\quad M: X \times Y \rightarrow R$$
$$Q = \{1\};\quad Y$$

- 1 rational decision maker
- known set of alternatives $X = \{x_1, \dots, x_l\}$
- 1 irrational decision maker (nature, chance)
- one criterion
- possible constraints

Class of MCDM methods

→ **Decision making under risk, ignorance; games against nature**

Type 4 – MCDM

$P = \{1\}; \quad X; \quad \boldsymbol{M}; \qquad \boldsymbol{M}: X \to R^k$

- 1 rational decision maker
- known set of alternatives $X = \{x_1, \dots, x_l\}$
- multiple criteria $C_1, \dots, C_k$
- possible constraints

Class of MCDM methods

→ **MCDM (AHP, TOPSIS); vector optimization,**

Type 5 – multi-expert MCDM

$$P = \{1, \dots, n\}; \;\; \mathrm{X}_1, \dots, X_n; \;\; \boldsymbol{M}_1, \dots, \boldsymbol{M}_n$$

- n rational decision makers
- known sets of alternatives $X_i = \{x_1^i, \dots, x_l^i\}$
- no irrational decision makers
- multiple criteria

Class of MCDM methods

→ **Multi-expert MCDM, consensus modelling**

Other Types can be also considered

Up to the most general type

$$P = \{1, \dots, n\}; \;\; \mathrm{X}_1, \dots, X_n; \;\; \boldsymbol{M}_1, \dots, \boldsymbol{M}_n$$
$$Q = \{1, \dots, m\}; \;\; Y_1, \dots, Y_m;$$