Introduction to Decision Support

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Programme: Information and Communication Technologies

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Addressed Topics

- Decision Making and Decision Support:
  - Basic concepts and definitions
  - Overview of scientific disciplines

- Decision Support at JSI
  with examples of projects and applications

- Rationale for including this topic in this ICT programme

Symbols

Important topic:
- required understanding
- possible exam questions

Related to contents of other ICT courses

Pay attention to related slides
above or below

Decision Making

Decision:

Conscious and *deliberate*
selection of one alternative (option)
from a set of possible ones
in order to satisfy the goals of the decision maker(s).

Making a decision:
- involves an irrevocable allocation of resources (time, money, effort, ...)
- has consequences
- is inherently subjective (subject to individual and/or societal values)

Decision Process

Decision Making:

Is a *process* that involves:

- identification of the decision problem;
- collecting and verifying relevant information;
- identifying decision alternatives;
- anticipating consequences of decisions;
- *making the decision*;
- providing rationale for the decision;
- implementing the selected alternative;
- evaluating the consequences of the decision.
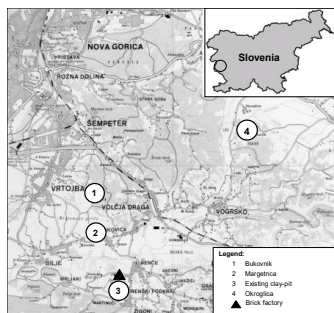
Typical stages of
Decision Analysis

Examples of Decision Problems

- Buying everyday goods
- Buying a car
- Buying a computer
- Choosing an apartment
- Buying a house
- Choosing a job
- Selecting an employee
- Study-related decisions:
      which profession, university, study programme, course, ...
- ...
- Investment decisions
- Medical decisions
- ...

Example 1: Clay-Pit Location

Bohanec, M., Rajković, V.: Multi-attribute decision modeling: Industrial applications of DEX, *Informatica* 23, 487-491, 1999.

Example 2: Electric Energy Production Strategy in Slovenia
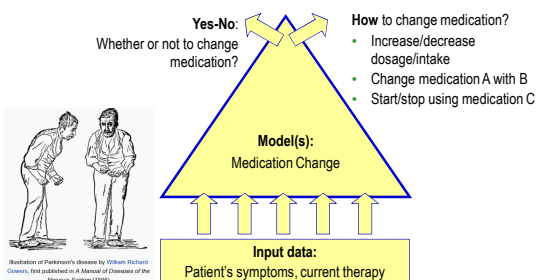
Project OVJE 2013-2014

Aims of the study:
- Identify reliable, rational, and environmentally sound production of electric energy in Slovenia by 2050
- Consider technologies: hydro, coal, oil, gas, nuclear, biomass, photovoltaic, wind
- Assess *individual technologies* and *technology mixtures*

Kontić, B., Bohanec, M., Kontić, D., Trdin, N., Matko, M.: Improving appraisal of sustainability of energy options - A view from Slovenia, *Energy Policy* 90, 154-171, 2016.
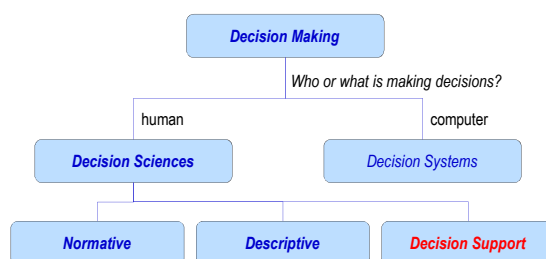
Bohanec, M., Trdin, N., Kontić, B.: A qualitative multi-criteria modelling approach to the assessment of electric energy production technologies in Slovenia. *Central European Journal of Operations Research*, 611-625, 2017.

Example 3: Medication Change for Parkinson's Disease Patients

Yes-No: Whether or not to change medication?

How to change medication?
- Increase/decrease dosage/intake
- Change medication A with B
- Start/stop using medication C

Model(s): Medication Change

Input data: Patient's symptoms, current therapy

Illustration of Parkinson's disease by William Richard Gowers, first published in *A Manual of Diseases of the Nervous System* (1886)

Marko Bohanec, et al.: A decision support system for Parkinson disease management: Expert models for suggesting medication change, *Journal of Decision Systems*, 27:sup1, 164-172, 2018.
Biljana Mileva Boshkoska, et al.: Decision support for medication change of Parkinson's disease patients. *Computer methods and programs in biomedicine*, 2020.

Decision Making: Disciplines

Decision Making

Who or what is making decisions?

human — computer

Decision Sciences — **Decision Systems**

Normative — **Descriptive** — **Decision Support**

Decision Making: Disciplines

Decision Making

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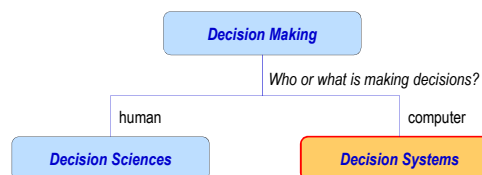
Decision Systems

Honda Asimo

Decision Systems

- computers
- intelligent programs and systems
- robots and autonomous systems

Curiosity Mars Rover — *Autonomous Cars*

Decision Making: Disciplines

Decision Making

Who or what is making decisions?

human   computer

Decision Sciences   *Decision Systems*

Normative   **Descriptive**   **Decision Support**

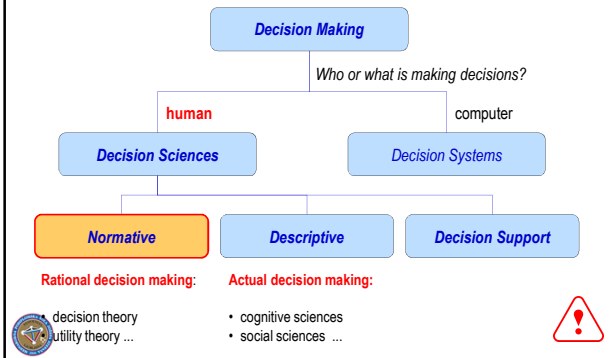**Rational decision making:**   **Actual decision making:**

- decision theory
- utility theory ...

- cognitive sciences
- social sciences ...

Preference Relations

Preference: we like/desire/prefer one thing over another
Preference relations:

$a \sim b$	indifference
$a \succ b$	strict preference
$a \succeq b$	weak preference

Some properties:
- Given any a and b, then $a \succ b, a \sim b$ or $a \prec b$
- If $a \sim b$ and $b \sim c$, then $a \sim c$
- If $a \succ b$ and $b \succ c$, then $a \succ c$
- If $a \succeq b$, then $a \succ b$ or $a \sim b$

Preference relations are *subjective*!

Decision Theory

Decision table:

		Alternatives	
		Take umbrella	Do not take umbrella
States	Rains	0.4	0
	Does not rain	0.9	1

Decision tree:

Take	Rain $p=0.8$	0.4	
0.5	No rain $p=0.2$	0.9	
0.5	Rain $p=0.8$	0	
Don't take	No rain $p=0.2$	1	
0.2			

Decision Making: Disciplines

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Rational decision making: **Actual decision making:**

- decision theory
- utility theory ...
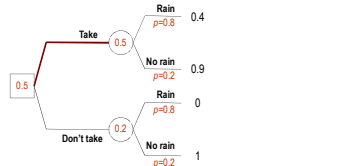
- cognitive sciences
- social sciences ...
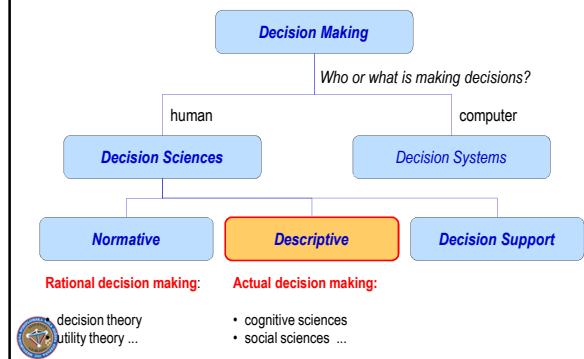
Dan Ariely: Predictably Irrational

Condition A

A

-A

B

CHAPTER 1
The Truth about Relativity
Why Everything Is Relative—Even When It Shouldn't Be
CHAPTER 3
The Cost of Zero Cost
Why We Often Pay Too Much When We Pay Nothing
CHAPTER 4
The Cost of Social Norms
Why We Are Happy to Do Things, but Not When We Are Paid to Do Them
CHAPTER 5
The Influence of Arousal
Why Hot Is Much Hotter Than We Realize
CHAPTER 7
The High Price of Ownership
Why We Overvalue What We Have
CHAPTER 9
The Effect of Expectations
Why the Mind Gets What It Expects
CHAPTER 10
The Power of Price
Why a 50-Cent Aspirin Can Do What a Penny Aspirin Can't

Daniel Kahneman: Thinking, Fast and Slow

Part I. Two Systems
1. The Characters of the Story
2. Attention and Effort
3. The Lazy Controller
4. The Associative Machine
5. Cognitive Ease
6. Norms, Surprises, and Causes
7. A Machine for Jumping to Conclusions
8. How Judgments Happen
9. Answering an Easier Question
Part II. Heuristics and Biases
10. The Law of Small Numbers
11. Anchors
12. The Science of Availability
13. Availability, Emotion, and Risk
14. Tom W's Specialty
15. Linda: Less is More
16. Causes Trump Statistics
17. Regression to the Mean
18. Taming Intuitive Predictions

Part III. Overconfidence
19. The Illusion of Understanding
20. The Illusion of Validity
21. Intuitions Vs. Formulas
22. Expert Intuition: When Can We Trust It?
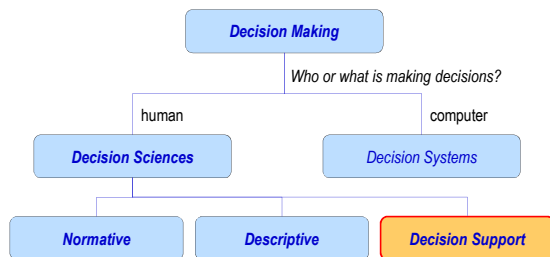23. The Outside View
24. The Engine of Capitalism
Part IV. Choices
25. Bernoulli's Errors
26. Prospect Theory
27. The Endowment Effect
28. Bad Events
29. The Fourfold Pattern
30. Rare Events
31. Risk Policies
32. Keeping Score
33. Reversals
34. Frames and Reality
Part V. Two Selves
35. Two Selves
36. Life as a Story
37. Experienced Well-Being
38. Thinking About Life'

Decision Making: Disciplines

Decision Making

Who or what is making decisions?

human — computer

Decision Sciences — **Decision Systems**

Normative — **Descriptive** — **Decision Support**

What is Decision Support?

Given the principles of <u>rational</u> decision making,
knowing that <u>actual</u> decision making can be difficult for people,
can we help the (human) decision makers to make better decisions?

Decision Support:
Providing methods and tools for *supporting* people in making difficult decisions
It is not: Making decisions *instead* or *on behalf* of people

How can we support decision making?

Data Storage, Search and Retrieval
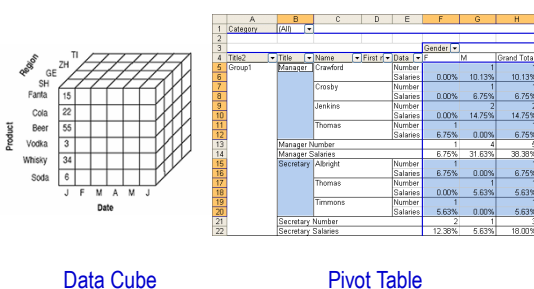
Data Cube

Pivot Table

Data Analysis and Data Mining

Trend Analysis Plot for NTotalAll
Quadratic Trend Model
Yt = 134.938 - 5.54620*t + 0.0727488*t**2

Variable
Actual
Fits

Accuracy Measures
MAPE   55.41
MAD   43.44
MSD   3777.86

http://www.theintentionexperiment.com/wp-content/uploads/2009/01/trend_analysis_plot_for_ntotalall.bmp
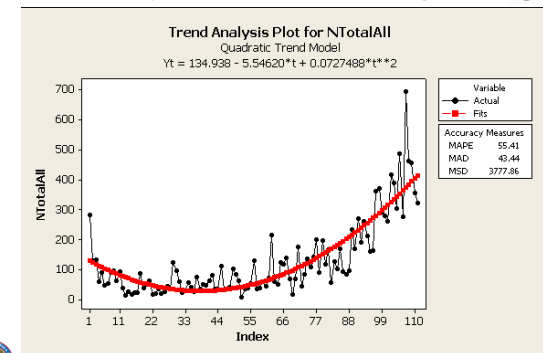
Representation and Visualisation Tools

https://en.wikipedia.org/wiki/Data_visualization
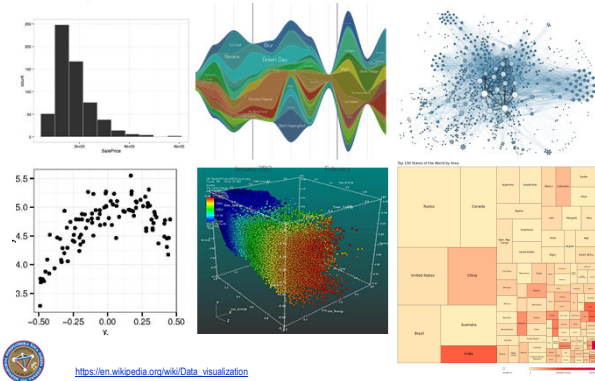
Central Decision Support Disciplines

Decision Support

Operational Research
- mathematical formulation of the decision problem
- searching for optimal solutions

Decision Analysis
- decision process, stages
- modeling
- evaluation and analysis
- finding 'sufficiently good' solutions

Decision Support Systems
- information systems
- aimed at decision support
- business intelligence
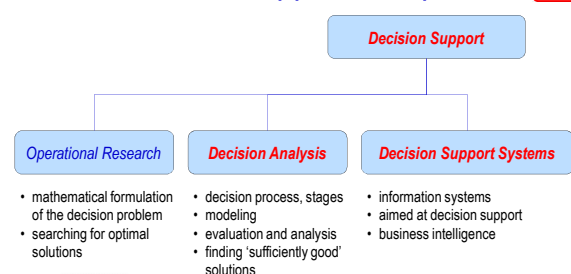
Decision Analysis ⚠

Decision Analysis: "Applied Decision Theory"

Provides a framework for analyzing decision problems by:

- structuring and breaking them down into more manageable parts,

- explicitly considering the:
  – possible alternatives,
  – available information
  – uncertainties involved, and
  – relevant preferences

- developing <u>models</u> for the evaluation and analysis of alternatives

- following a systematic procedure (stages) ⬆

- with the aim to arrive at "sufficiently good" decisions ("satisficing")

Evaluation Models ⚠

Alternatives — Performance variables (price, performance, ..., quality) — Evaluation model — evaluation — analysis

Types of Models in Decision Analysis ⚠

Decision Trees

Invest — Succeed / Fail — Do not invest
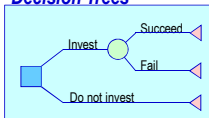
Multi-Attribute Utility Models

Investment — Costs, Risks, Results

Influence Diagrams

Invest? — Success? — Return
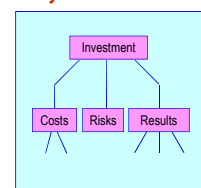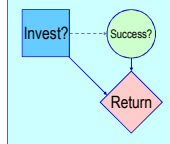
Examples of Decision Models

pairwise comparison

Alternative	A	B	C	D
A		–1	1	0
B			1	1
C				–1
D				

multi-attribute model

Weight	Attribute	A	B	C	D
10	Salary	8	10	6	5
7	Interestingness	4	8	2	6
5	Location	4	2	9	1
5	Safety	4	6	9	2
4	Image	8	9	7	7
3	Promotion	6	4	8	10
3	Co-workers	2	0	4	8
	Evaluation	204	244	228	189

Job — Work (Interestingness, Satisfaction) — Benefits (Salary, Knowledge, Other (Promotion, Image)) — Organisation (Location, Co-workers, Flexibility)

hierarchical multi-attribute model
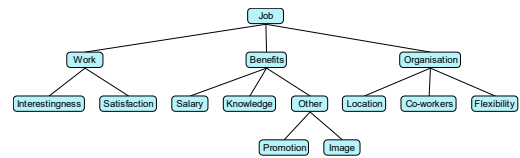
Decision Support Systems (DSS) ⚠

Decision Support Systems:
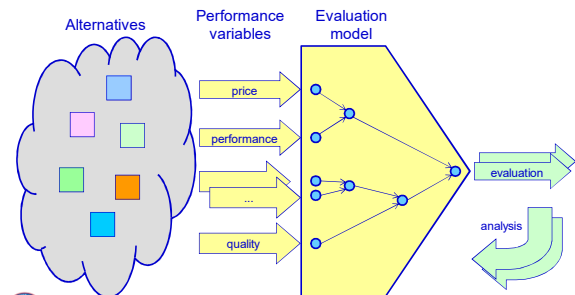- interactive computer-based information systems
- that support decision-making activities

Characteristics:
- DSS incorporate both data and models;
- they are designed to assist managers in their decision processes in semistructured (or unstructured) tasks;
- they support, rather than replace, managerial judgment;
- their objective is to improve the quality and effectiveness (rather than efficiency) of decisions.

Example: Traffic Control DSS

Sensor data — processing — Traffic situation states — monitoring & analysis — complex states — Expert-developed decision models — incident detection — Alarm — notification — message — operator — message — Variable message signs — driver
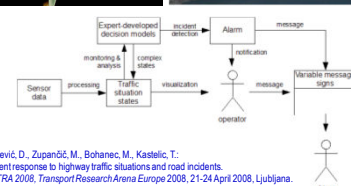
Omerčević, D., Zupančič, M., Bohanec, M., Kastelic, T.:
Intelligent response to highway traffic situations and road incidents.
Proc. TRA 2008, Transport Research Arena Europe 2008, 21-24 April 2008, Ljubljana.

Decision Support Research at JSI

http://kt.ijs.si/MarkoBohanec/dss.html

Decision Support
supporting people in complex decision-making processes

Decision Analysis

Multi-Attribute Modeling

Qualitative Multi-Attribute Modeling

- Tools
- Applications
- DSS development

1. Decision Analysis and Decision Modelling

decision alternatives

Decision Makers+
Experts+
Decision Analysts

Decision Analysis → Decision/ Evaluation model

Evaluation

Analysis

A 🙂
B 🙁
C 😐
D 🙂👍
E 🙁

Clay-Pit Location Model

SITE SUITAB

ENVIRONMENT — FEASIBILITY

ATTRACT — VULNERAB — SOC-PSYCH — TECHN — ECONOM

- develop
- site char.
- land attr.

- pollution
- valuation
- land use

- transport
- construct
- land org.

- direct
- indirect

Model for Electric Prod. Technologies

DEXi:
Program for Multi-Attribute Decision Making

http://kt.ijs.si/MarkoBohanec/dexi.html

Functionality
- creation and editing of qualitative DEX models:
  - model structure
  - decision tables
- acquisition and evaluation of alternatives
- analysis of alternatives: "what-if", "±1 analysis", comparison of alternatives, selective explanation
- tabular and graphical reports

2. Data Mining and Decision Modelling

Data

Data Mining

Decision Makers+
Experts+
Decision Analysts

Decision Analysis

Decision model

Other sources

3. Decision Support Systems

DSS for Electric Prod. Technologies

http://sepo.ijs.si/naloge/OVJE/energetic_scenario_comparative_model/

From Models to Decision Support System

Requirements:
- Completeness:
    - considering all relevant aspects of the decision problem
    - providing answers for all possible inputs
- Correctness: providing correct (valid, right) information
- Consistency: logical and preferential consistency
- Comprehensibility of provided information for the user
- Convenience: easily accessible, timely information, appropriate for the task

Overview of Disciplines

Take-Home Messages

- Decision is an act, decision-making is a process
- Decision Sciences vs. Decision Systems = human vs. machine decision making
- Main disciplines in *Decision Sciences*:
    - Normative: concerned with rational (ideal, theoretical) decision making
    - Descriptive: concerned with actual (human, practical) decision making
    - Decision Support: combining the two in order to help people in making decisions (and not to make decisions on behalf of them)
- *Decision Support*:
    - very wide area, involving everything from "pen-and-pencil" to advanced AI systems
    - Central disciplines: Operational research, Decision analysis, Decision Support Systems
- *Decision Analysis*:
    - a systematic approach: structuring the decision problem and identifying its key elements
    - developing and using models: decision trees, influence diagrams, multi-attribute models, ...
- *Decision Support Systems*: Information systems "aimed at decision support"
- *Decision Support at JSI*:
    - Key tasks and projects: developing decision models and DSSs for solving complex decision problems
    - Key approaches: expert modelling, possibly combined with data mining (and optimization)
    - Key tool: DEXi, software for developing qualitative multi-attribute models