Decision Support:
The DEXi Toolbox and its Applications

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and
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Context

Decision Making

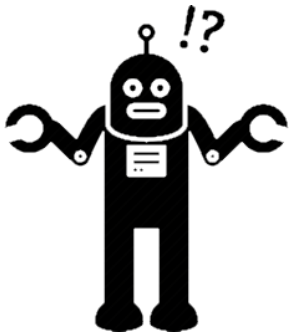
Who or what is making decisions?

human

computer

Decision Support

Decision Systems



Decision Systems

Honda Asimo

Decision Systems

- computers
- robots
- autonomous systems
- intelligent programs

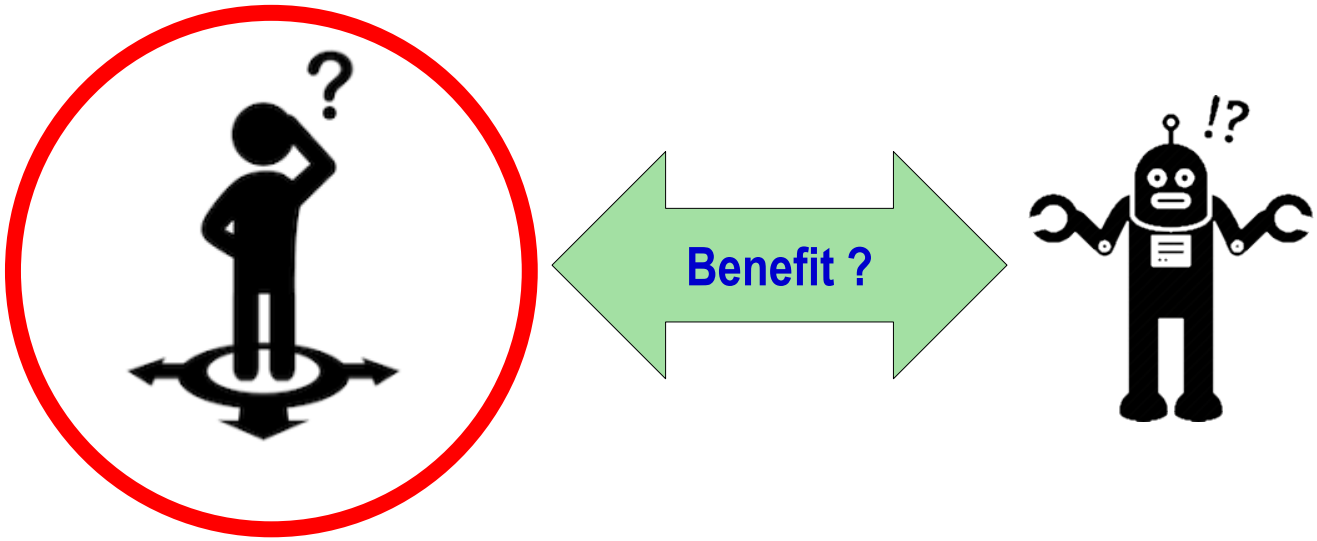
Curiosity Mars Rover

Autonomous Cars

Context

Decision Support

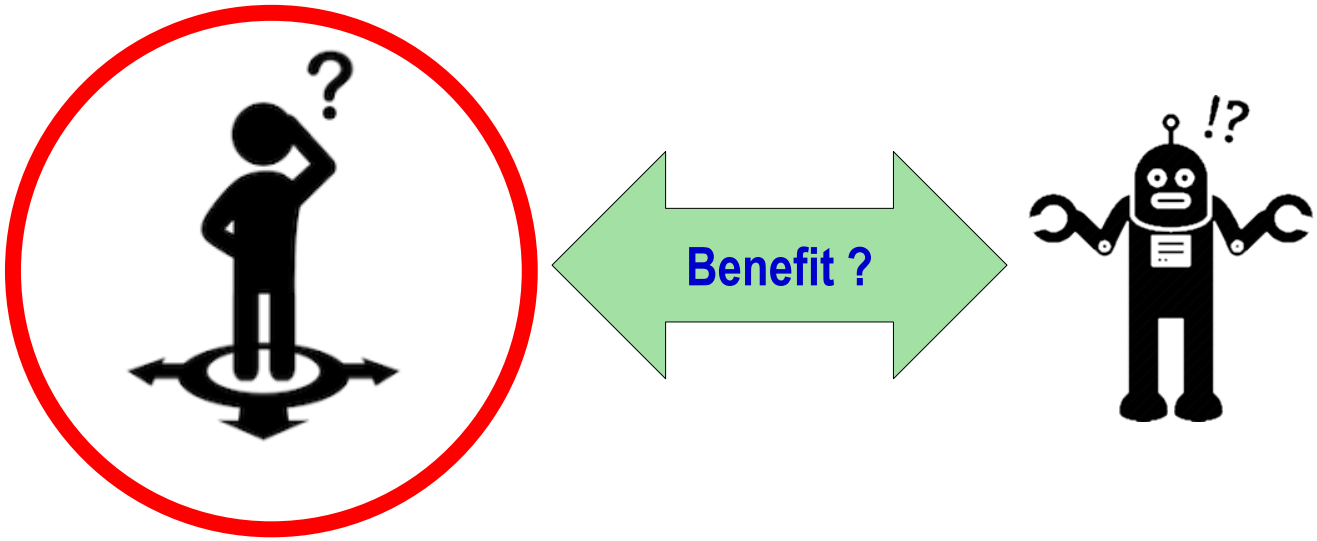
Artificial Intelligence



Context

Decision Support

Artificial Intelligence

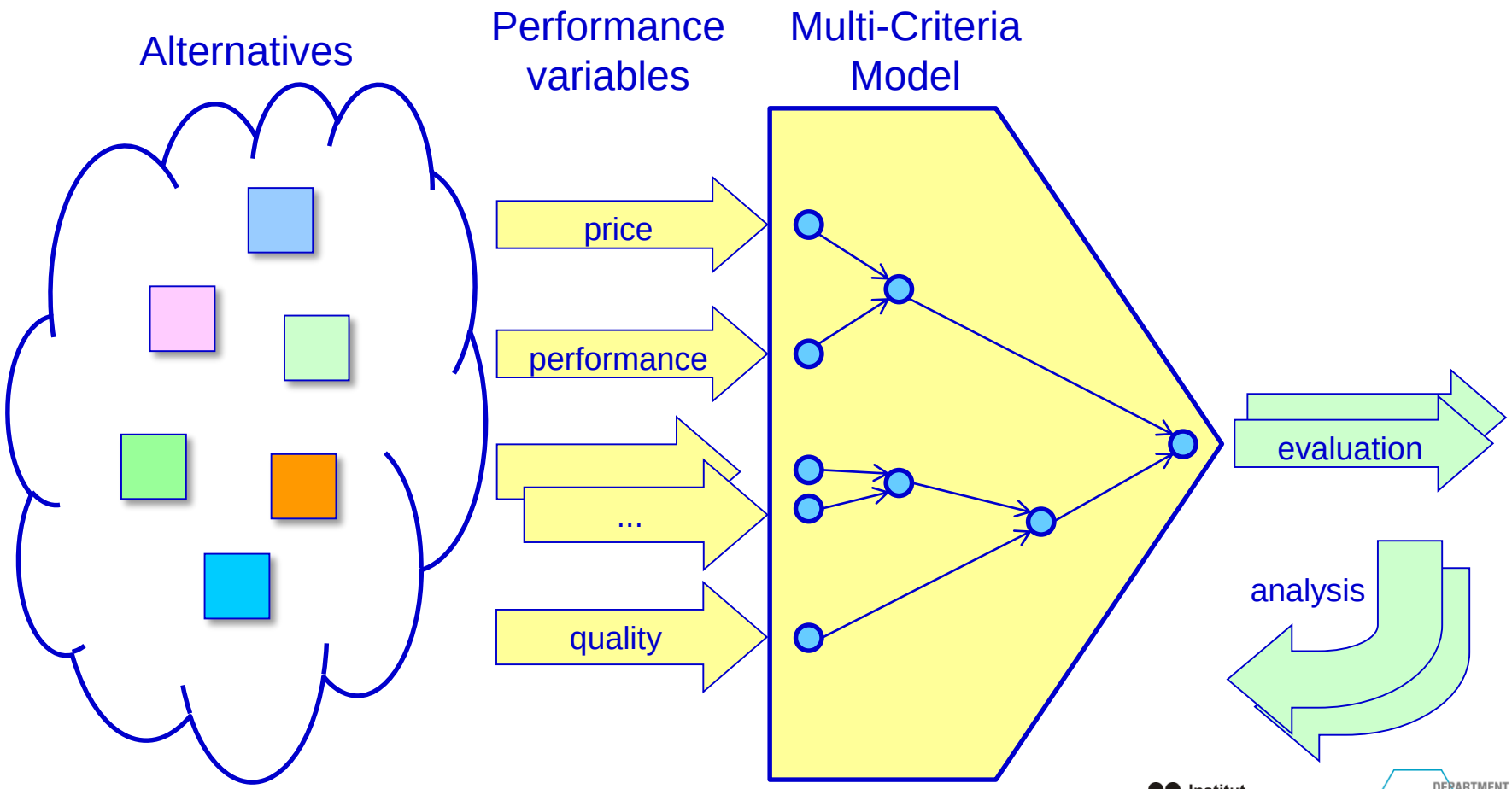


Showcase:

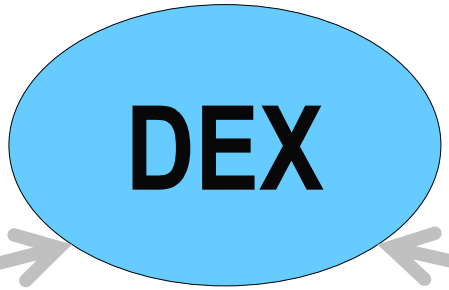
- DEX: decision modelling method
- DEXi: software
- Applications

What is DEX?

Multi-Criteria Decision Modelling Method



What is DEX?



Multi-Criteria Decision Analysis

- modeling using criteria and utility functions
- problem decomposition and structuring
- evaluation and analysis of decision alternatives

Artificial Intelligence
Expert Systems

- qualitative (symbolic) variables
- "if-then" rules
- handling imprecision and uncertainty
- transparent models, explanation

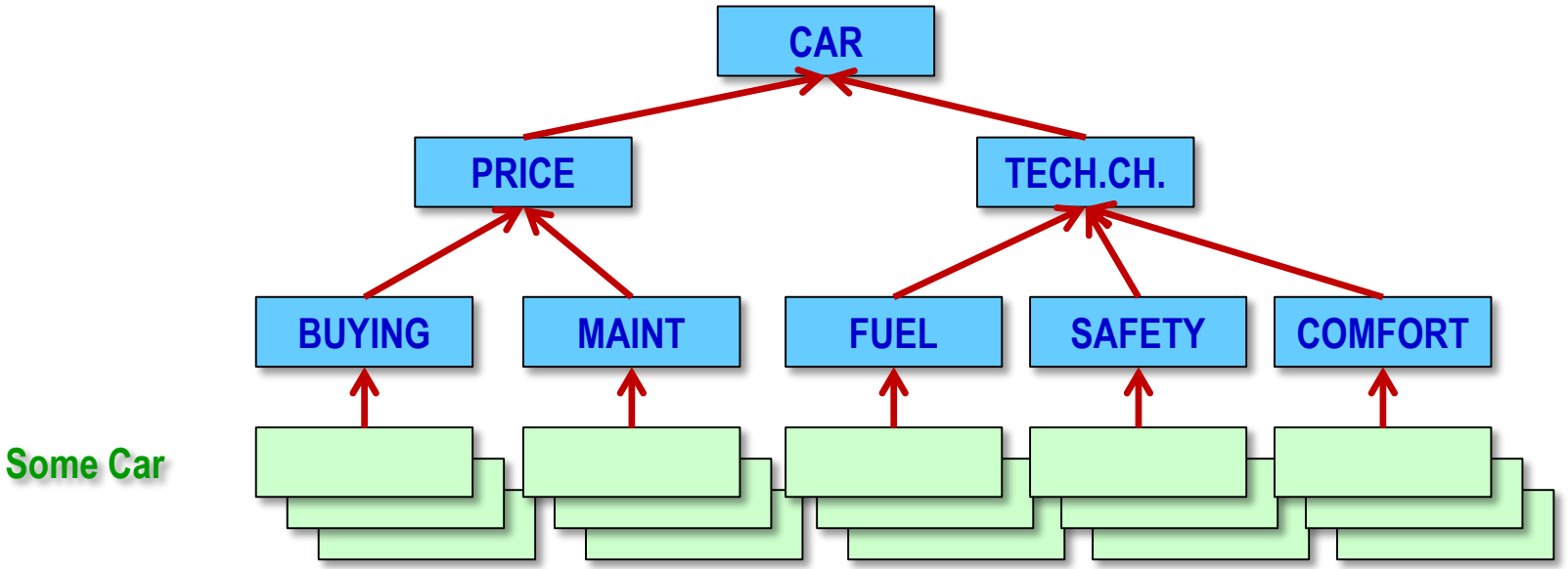
Machine Learning

DEX

Method for qualitative multi-attribute modeling

DEX is similar to other “full aggregation” multi-attribute methods:

1. Multiple attributes, hierarchically structured
2. Evaluation of alternatives: bottom-up aggregation

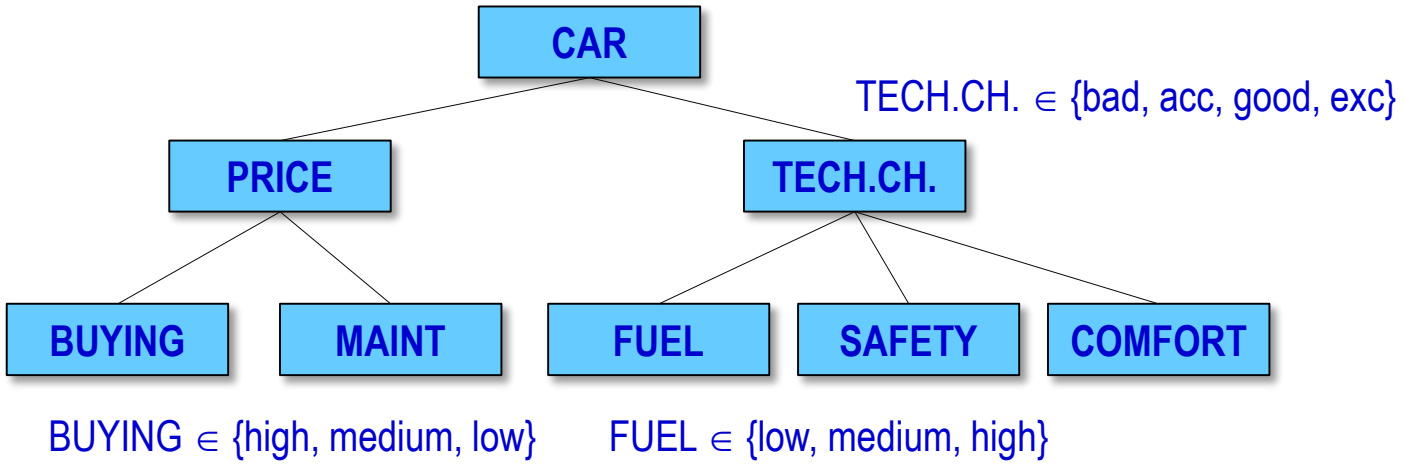


DEX

Method for qualitative multi-attribute modeling

DEX is different from the majority of multi-attribute methods:

1. Attributes are discrete, symbolic, qualitative

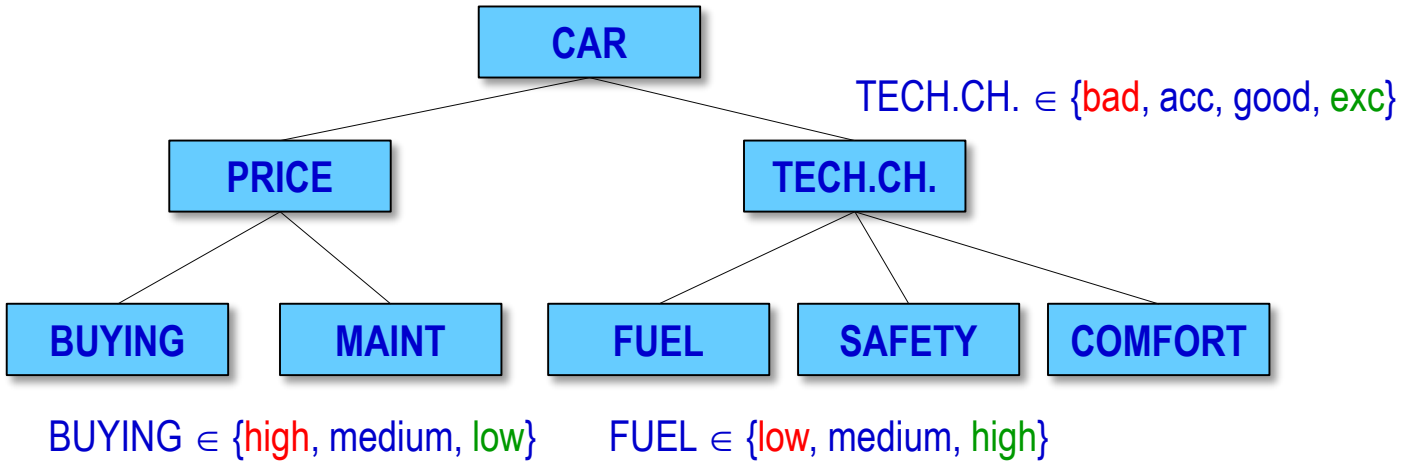


DEX

Method for qualitative multi-attribute modeling

DEX is different from the majority of multi-attribute methods:

1. Attributes are discrete, symbolic, qualitative
   Attribute scales can be unordered (categorical),
   but are typically preferentially ordered (increasing or decreasing) ← *"criteria"*

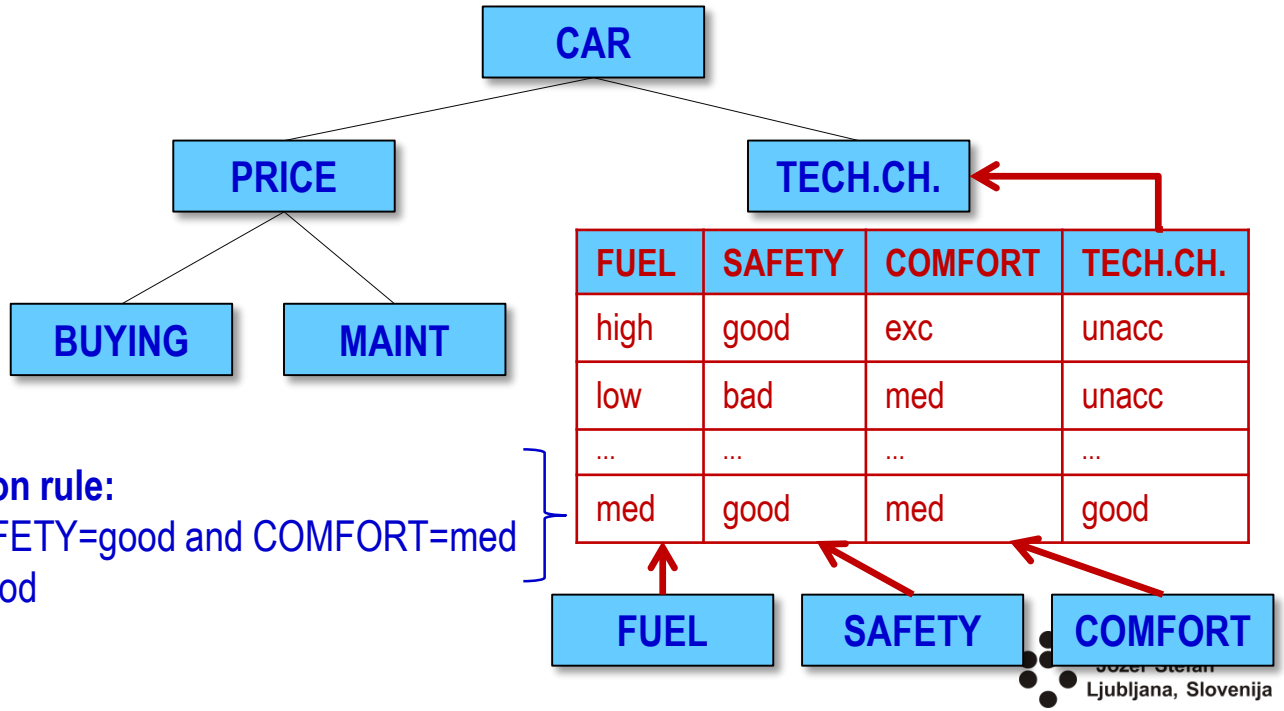


DEX

Method for qualitative multi-attribute modeling

DEX is different from other multi-attribute methods:

2. Evaluation of alternatives (aggregation) is defined by *decision tables*



Elementary decision rule:
if FUEL=med & SAFETY=good and COMFORT=med
then TECH.CH.=good

What is DEX?

Method characteristics:

1. **Multi-Attribute** (**Multi-Criteria**):
   Evaluates decision alternatives through aggregation of multiple criteria

2. **Hierarchical**:
   Attributes are structured hierarchically (as in AHP)

3. **Qualitative**:
   Attributes are discrete, verbal (e.g. "*low*", "*med*", "*high*")

4. **Rule-based**:
   Aggregation is defined by *decision rules* in *decision tables*

CEJOR
DOI 10.1007/s10100-017-0468-9

ORIGINAL PAPER

Extending the multi-criteria decision making method DEX with numeric attributes, value distributions and relational models

Nejc Trdin[1,2] · Marko Bohanec[1,2]

Abstract DEX is a qualitative multi-criteria decisio
supports decision makers in making complex deci
bly conflicting, attributes. The attributes in DEX h
are structured hierarchically. The hierarchical topol
the decision problem into simpler sub-problems. In
with qualitative values, taken from the scales of corr
hierarchy. The evaluation of alternatives is perform

2.1 DEX model

Formally, a DEX model M is a four-tuple $M = (X, D, S, F)$, where X is the set of attributes, S is the descendant function that determines the hierarchical structure of M, D is the set of value scales (domains) of attributes in X and F is the set of aggregation functions.

The set X consists of n attributes:

$$X = \{x_1, x_2, \ldots, x_n\}. \tag{1}$$

In practice, attributes are usually given a name, which uniquely identifies the attribute—for instance "price", "quality", "location", etc. In the didactic example, introduced later in Sect. 2.2, we will often denote an attribute by its name (e.g. *location*) and use a named subscript to denote related components (e.g. $D_{location}$).

Each attribute $x_i \in X$ has a corresponding value scale $D_i \in D$, which is an ordered set of symbolic (qualitative) values:

$$D_i = \left\{w_{i_1}, w_{i_2}, \ldots, w_{i_{m_i}}\right\}, l \neq k \Leftrightarrow w_{i_l} \neq w_{i_k}. \tag{2}$$

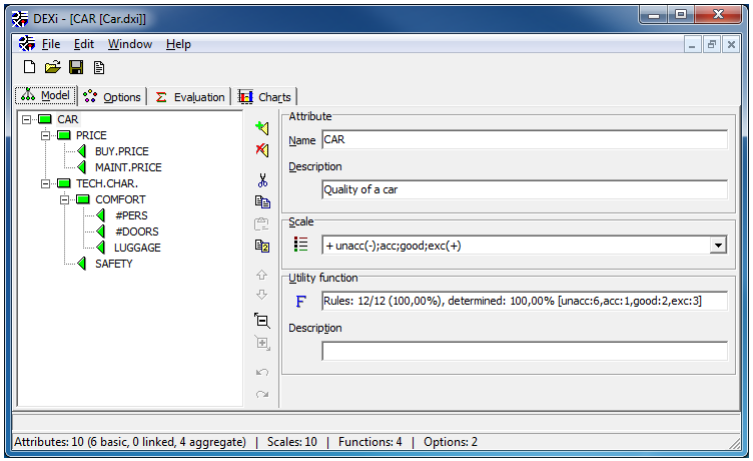
DEXi:

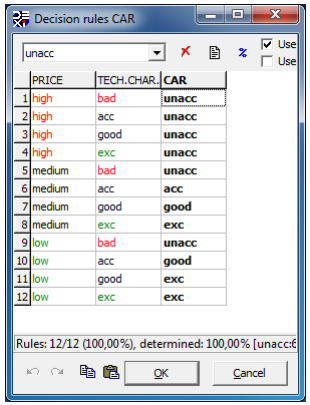
Program for Multi-Attribute Decision Making

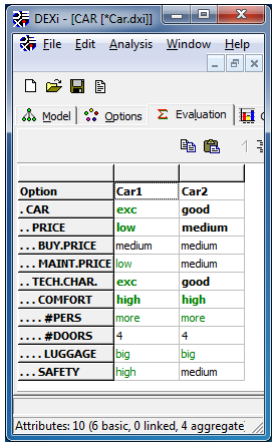
http://kt.ijs.si/MarkoBohanec/dexi.html

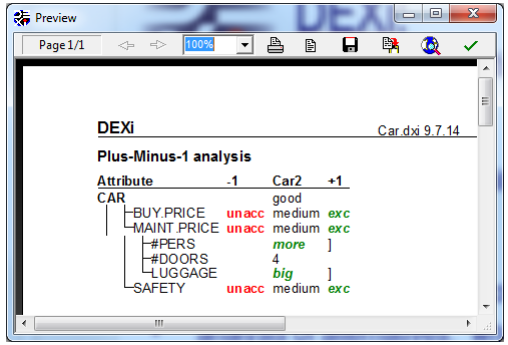
Functionality

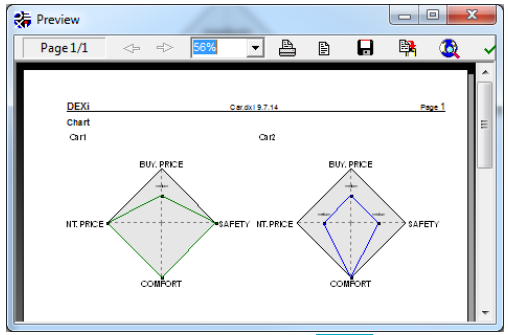
- creation and editing of qualitative DEX models:
  - model structure
  - decision tables
- acquisition and evaluation of alternatives
- analysis of alternatives: “what-if”, “±1 analysis”, comparison of alternatives, selective explanation
- tabular and graphical reports











- DEXiEval: command line DEXi evaluation
- DEXi.NET (C#), JDEXi (java) and DEXx (java): Open-source libraries

AI Methods in DEXi

Decision Support

Artificial Intelligence

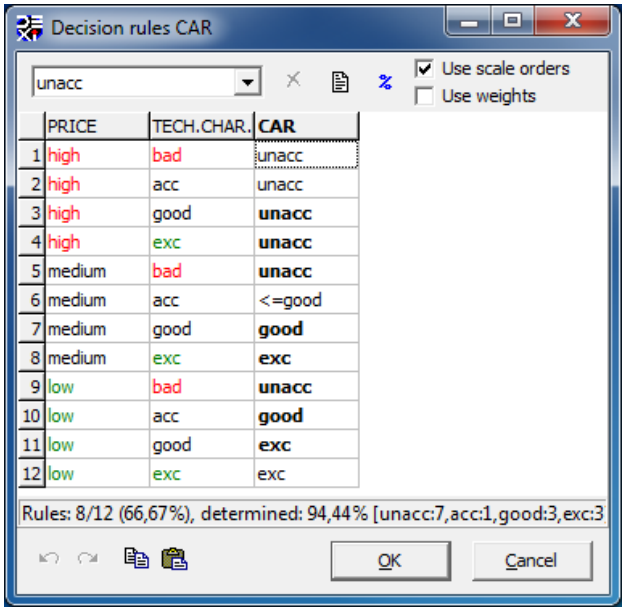
Benefit ?

AI Methods

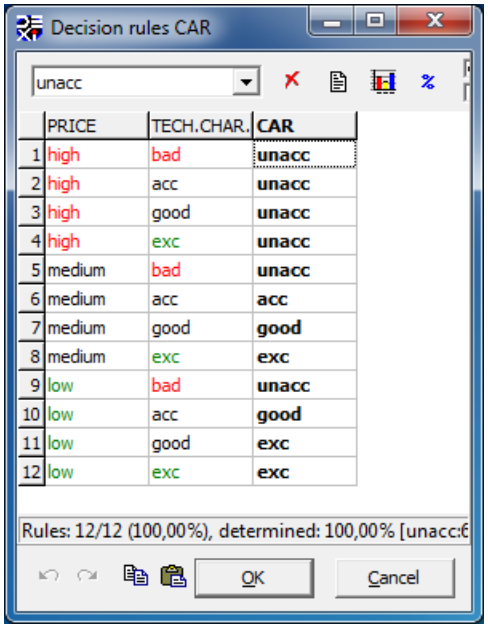
DEXi: Knowledge Acquisition

Acquisition of decision tables and decision rules

- Active support
- Three “strategies”:
  - Direct
  - ‘Use scale orders’ (based on dominance)
  - ‘Use weights’ (based on attributes’ weights)
- Validation:
  - Consistency (based on dominance)
  - Completeness (% determined function values)
- Principle:
  - ‘The user is always right’ (but warned if considered to be in error)



DEXi: Knowledge Representation

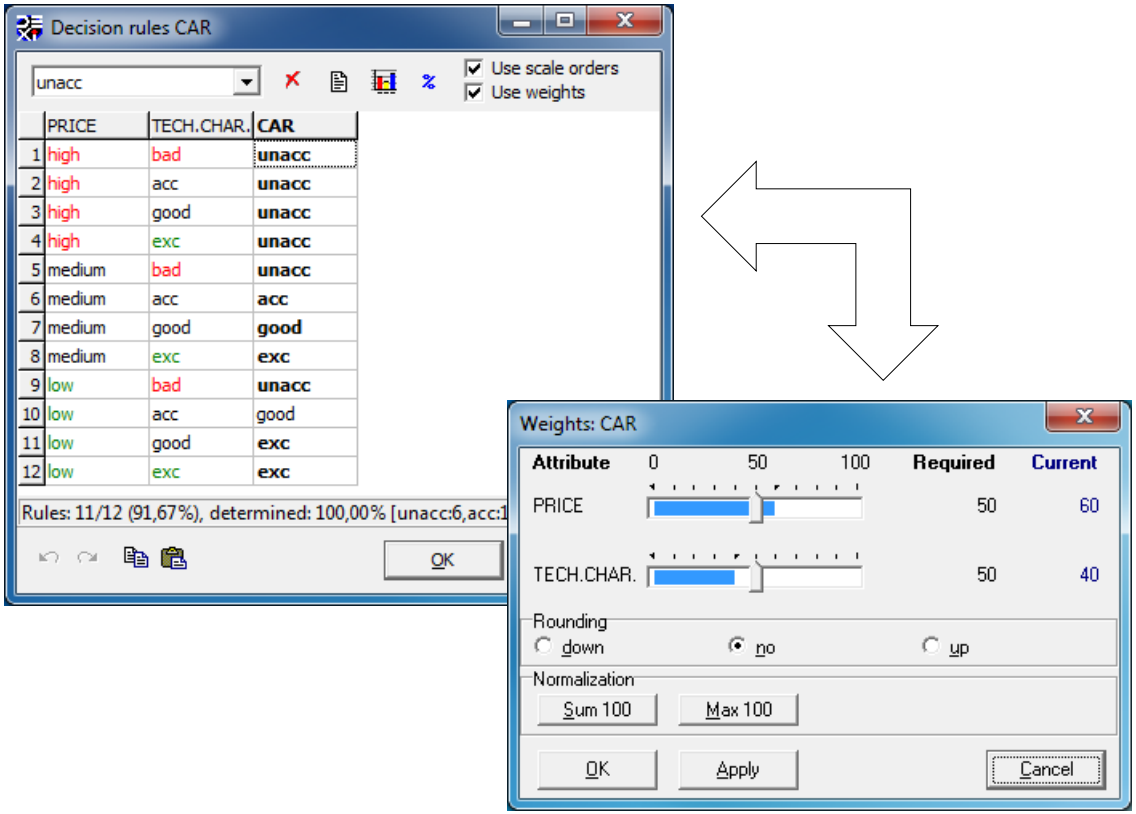


	PRICE	TECH.CHAR.	CAR
	60%	40%	
1	**high**	*	**unacc**
2	*	**bad**	**unacc**
3	medium	acc	acc
4	medium	good	good
5	***low***	acc	good
6	>=medium	***exc***	***exc***
7	***low***	>=good	***exc***

Aggregate rules

[*Rule learning*]

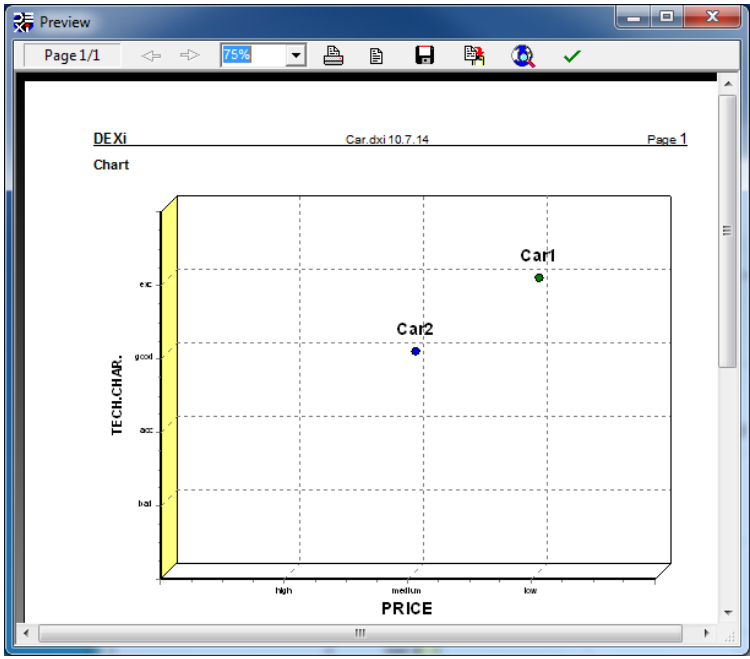
DEXi: Rules and Weights

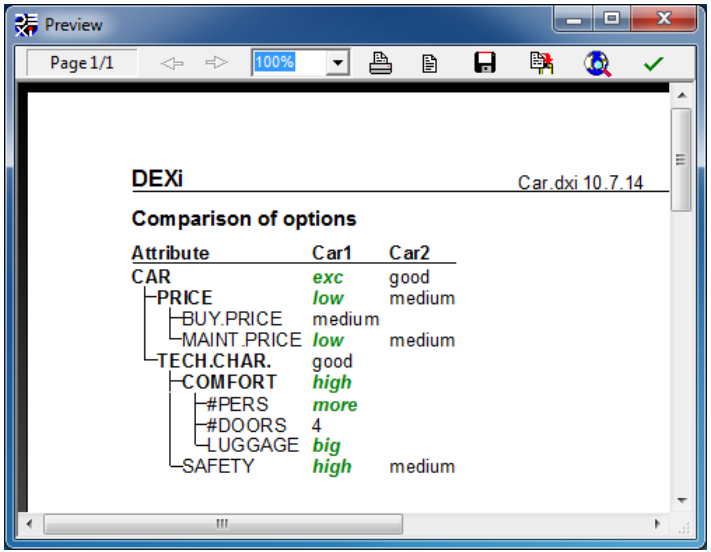


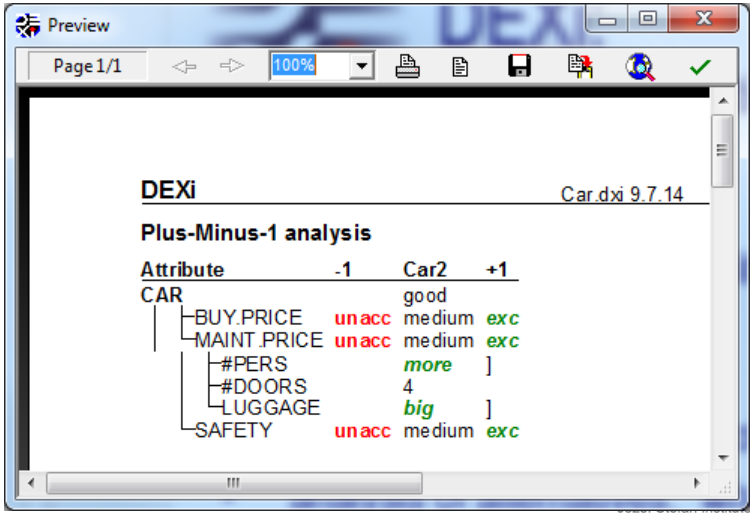
DEXi: Analysis and Explanation

Analysis of alternatives:

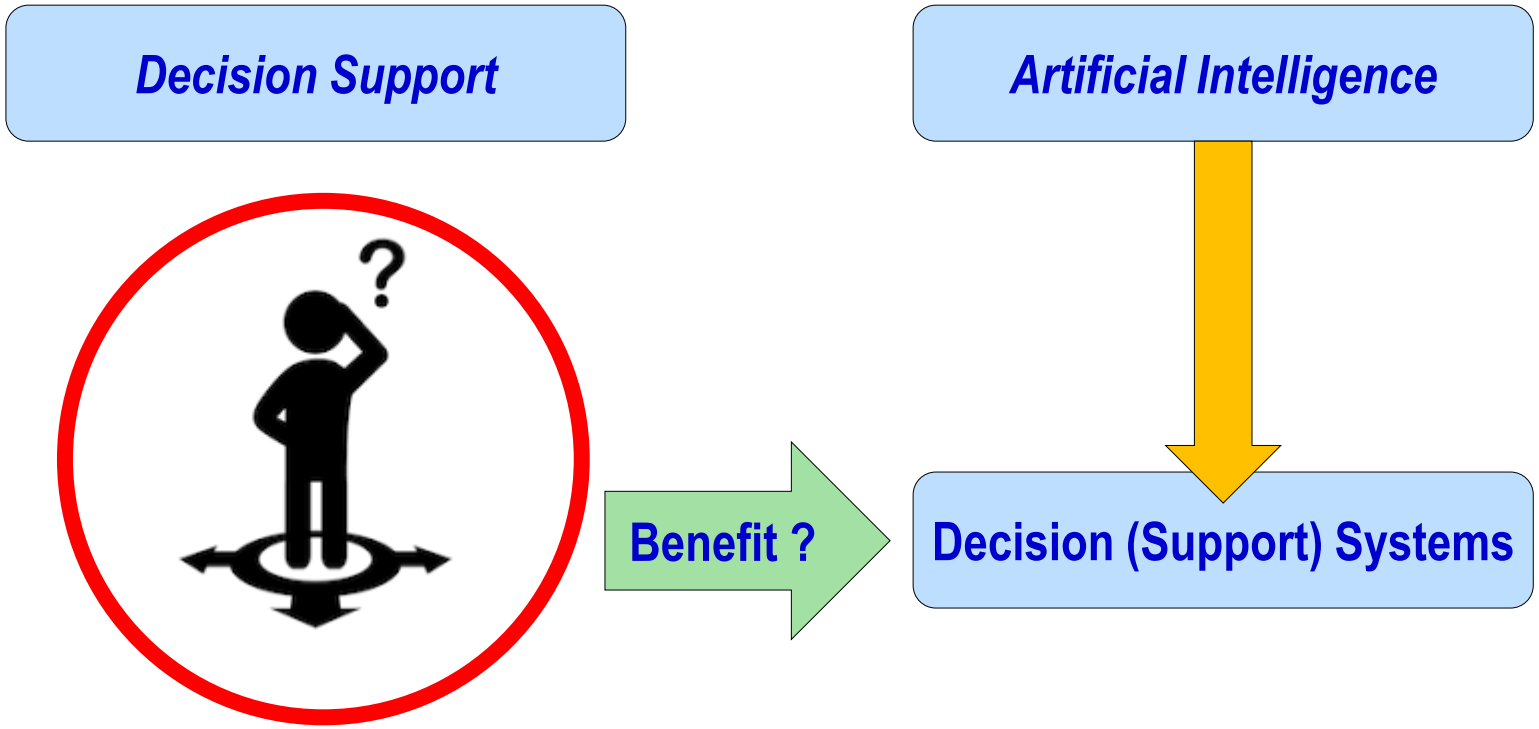
- "What-if analysis"
- "±1 analysis"
- Compare alternatives
- Selective explanation







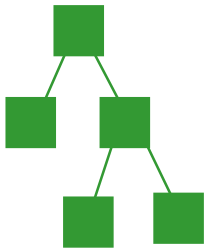
Expert Modelling for DSS



Decision Analysis and Decision Modelling

Decision Makers+
Experts+
Decision Analysts

Decision Analysis



Decision/
Evaluation
model

Evaluation

Analysis

decision
alternatives

A ☺

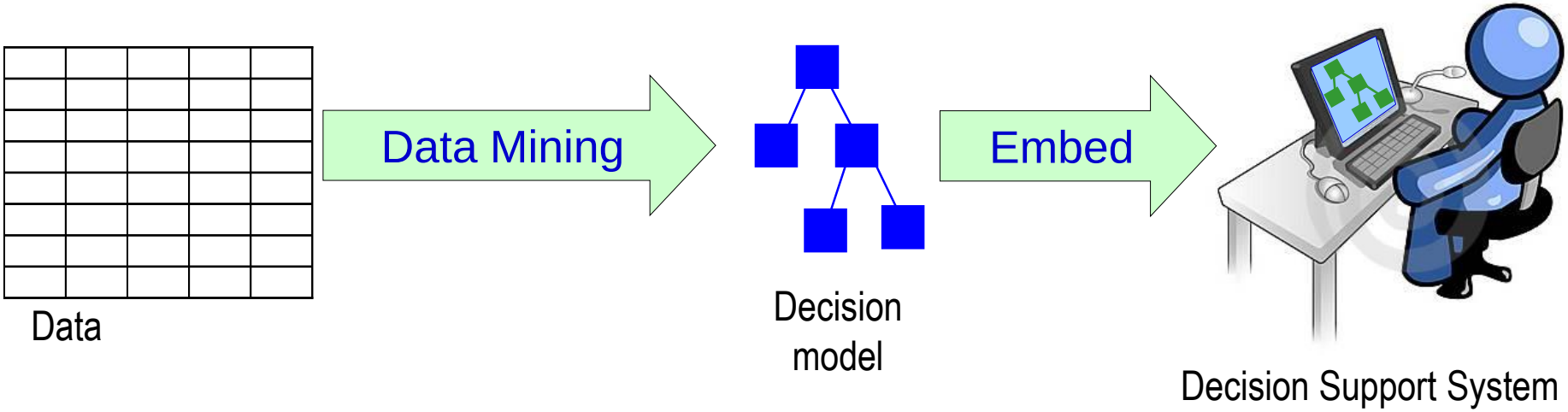
B ☹

C 😐

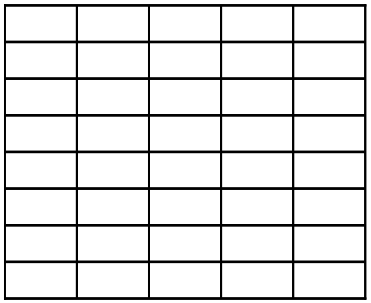
D ☺ 👍

E ☹

Data Mining → Decision Support

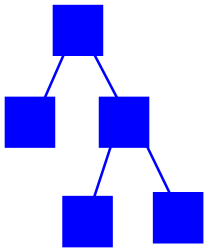


Data Mining and Expert Modelling



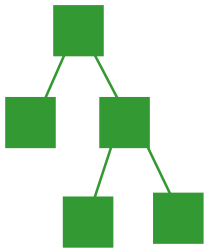
Data

Data Mining



Decision Makers+
Experts+
Decision Analysts

Expert Modelling



Decision
model

Other sources

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Ljubljana, Slovenija

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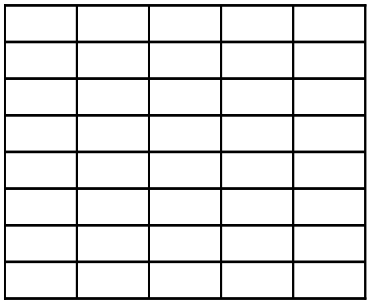
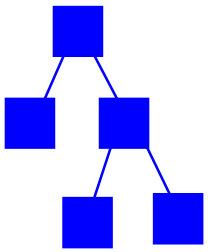
Decision Support Systems



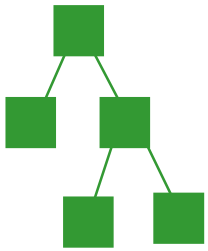
Data

Data Mining



Decision Makers+
Experts+
Decision Analysts

Decision Analysis



Decision
model

Other sources

Decision Support System

DEX Applications

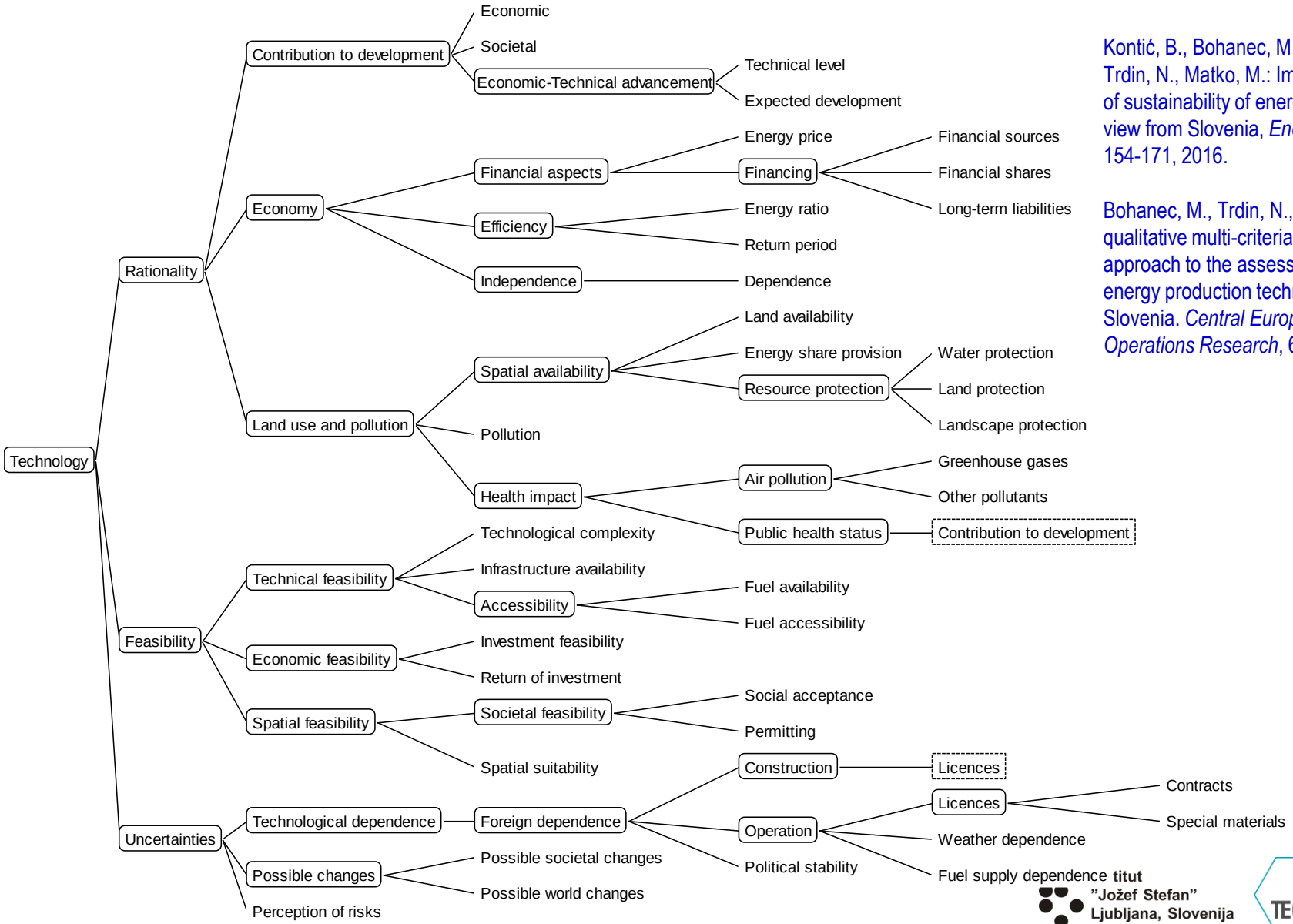
- **Computer Technology**: software, hardware, IT tools, programming languages, DBMS, DSS, OCR
- **Projects**: investments, research, R&D, tenders
- **Organisations**: public enterprises, banks, business partners
- **Schools**: quality of schools, programmes and teachers, school admission, choosing sports
- **Management**: production, portfolio management, trade, personnel (employees, jobs, teams), privatization, motorway
- **Production**: location of facilities, technology, logistics, suppliers, office operations, construction, electric energy production, sustainability
- **Ecology and Environment**: dumpsite/deposit assessment and remediation, emissions, ecological impacts, soil quality, ecosystem, sustainable development, protected areas
- **Medicine and Health Care**: risk assessment (breast cancer, diabetes, ski injuries), nursing, technical analysis, knowledge management, healthcare network
- **Agriculture and Food Production**: economic and ecological effects of GMO, (un)approved GMO, crop protection, hop hybrids, garden quality
- **Tourism**: nature trail, tourism farm facilities, mountain huts
- **Services**: loans, housing loans, public portals, public services, leasing
- **Other**: cars, hotels, electric motors, radars, game devices, awards, roof covering, data mining

Electric Energy Production Technologies

Project OVJE, 2013-14

- 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*

Electric Energy Production Technologies

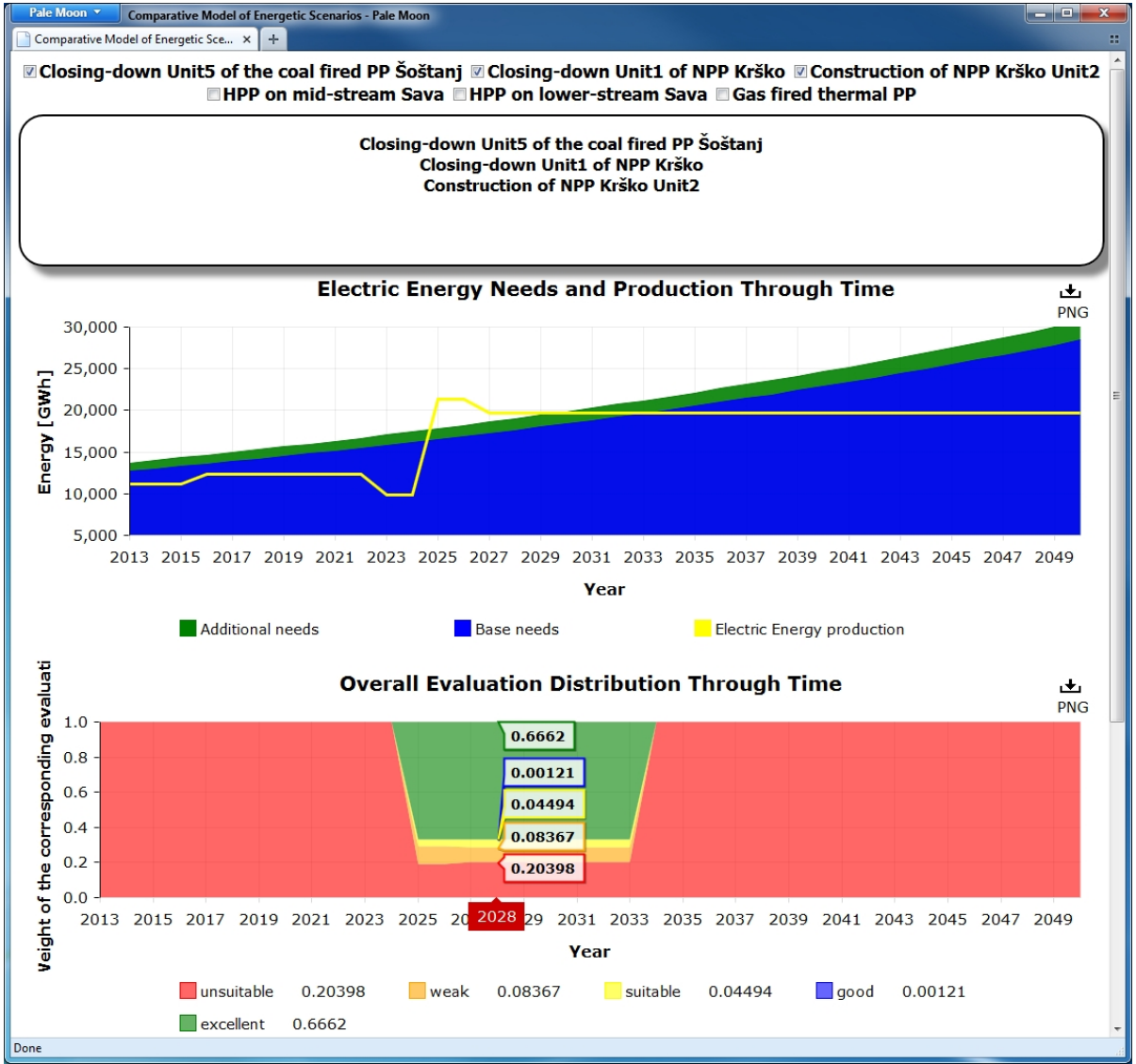


Kontić, B., Bohanec, M., Kontić, D., Trdin, N., Matko, M.: Improving appraisal of sustainability of energy options - A view from Slovenia, *Energy Policy* 90, 154-171, 2016.

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.

Decision Support System

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



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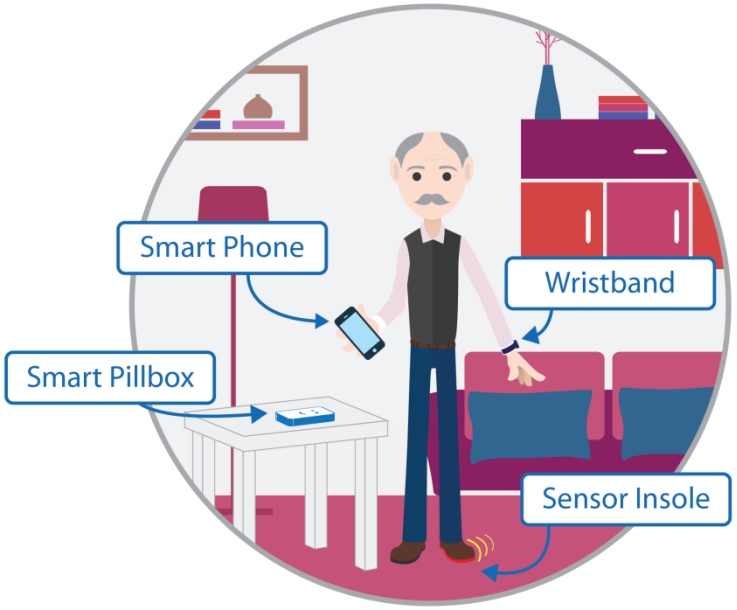
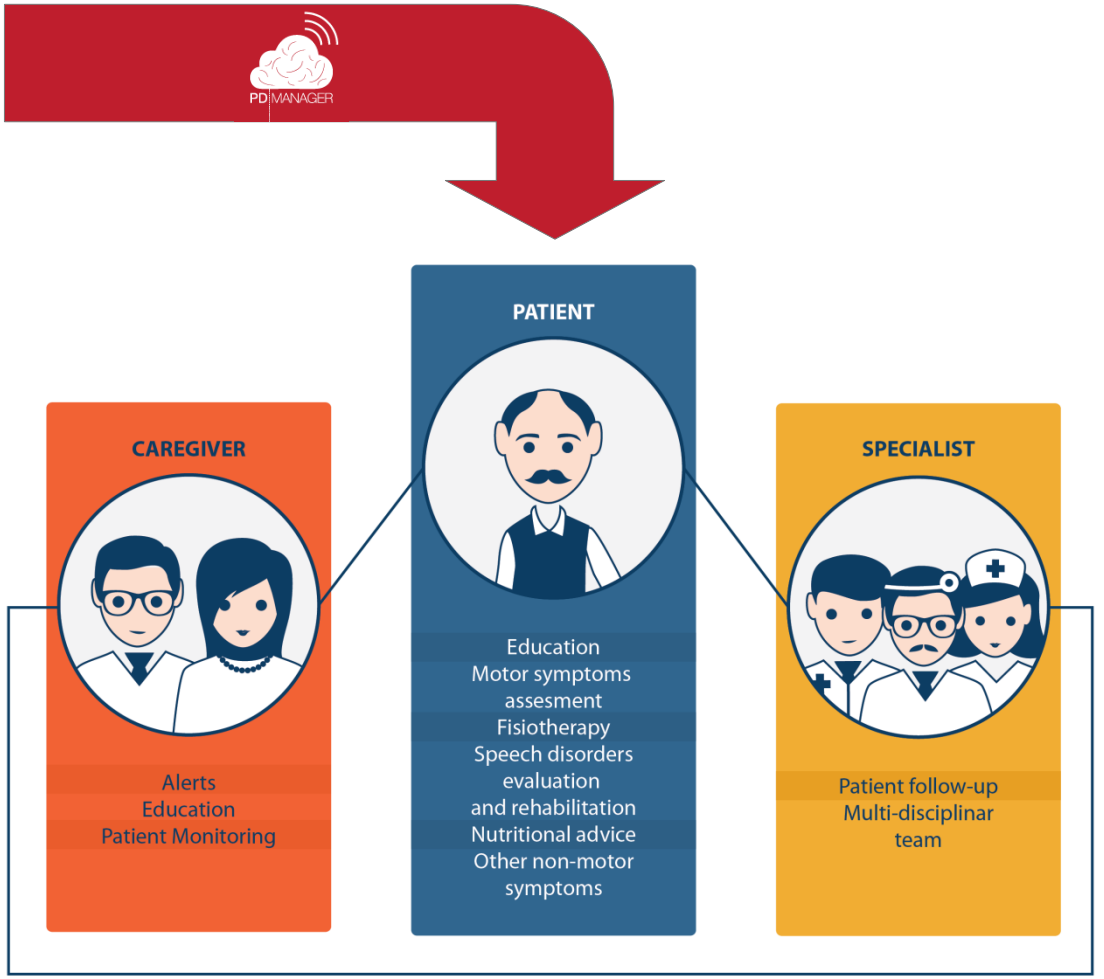
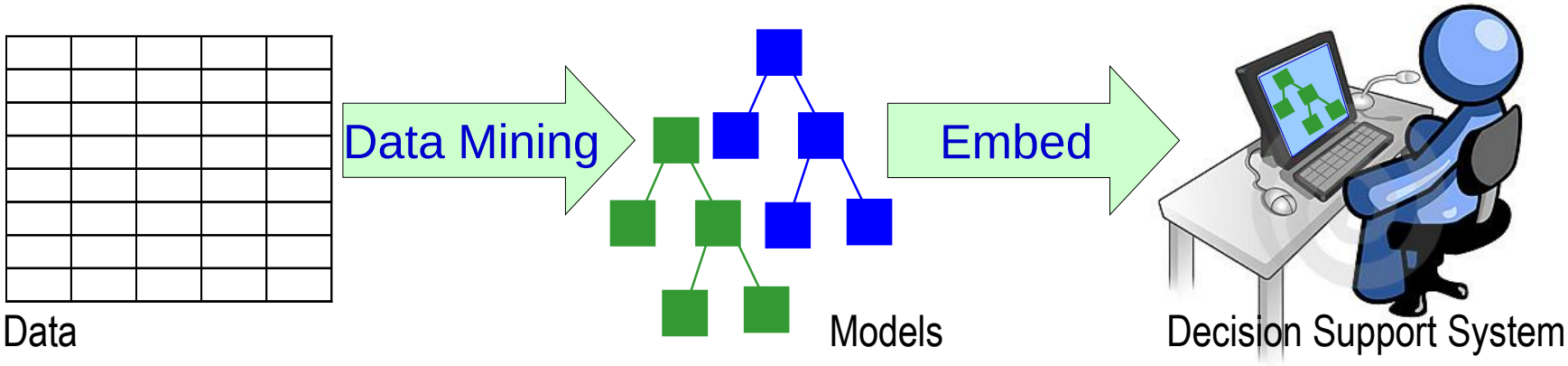
PD_manager Project



Parkinson's Disease Patient



PD_manager Project



Patient data:

- Sensor measurements
- Medical record
- Therapies
- Physical assessment
- Psychological assessment
- Nutrition data
- Adherence data
- ....

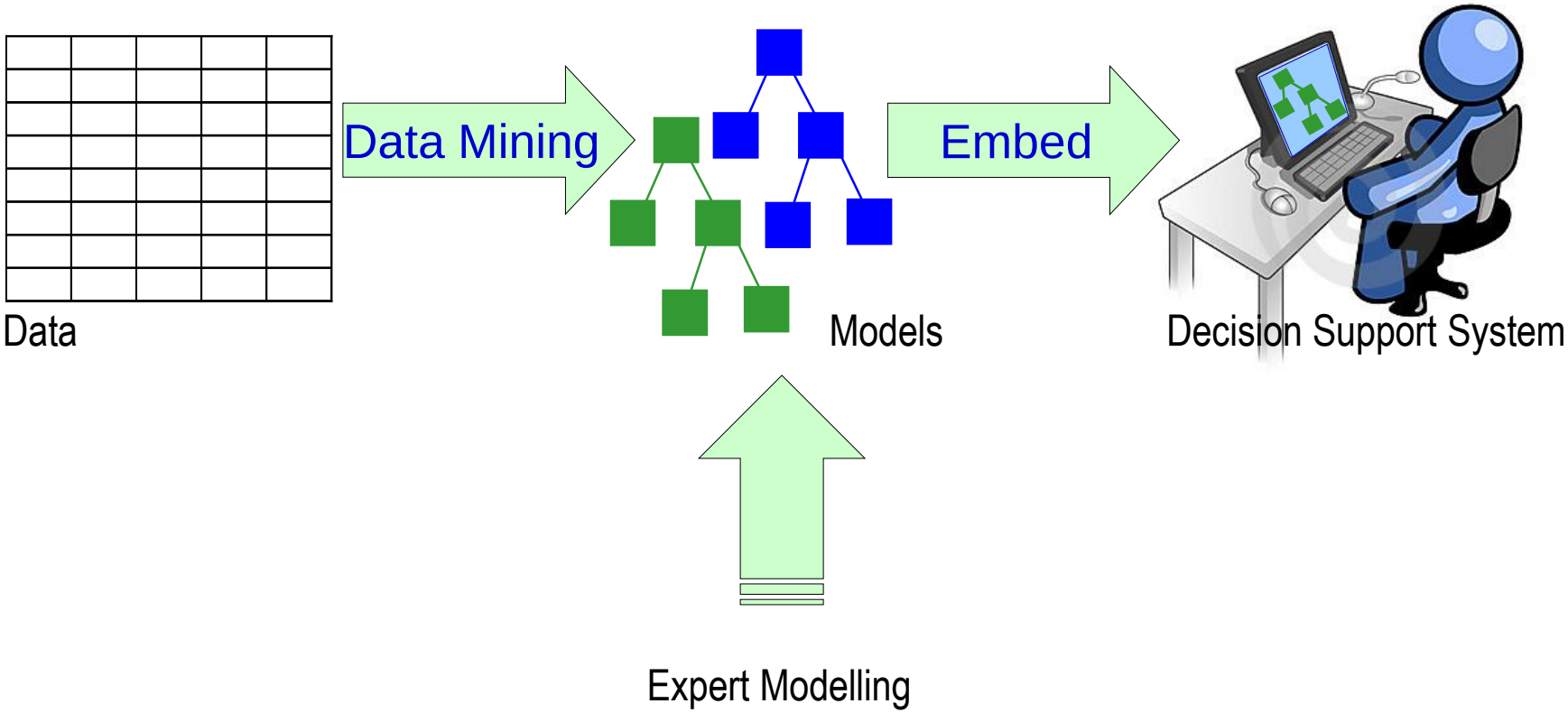
Models for:

- Detection of symptoms
- Assessment of patient's state
- Suggestion of therapies, e.g. medication change
- ...

PD_manager DSS:

- Patient monitoring
- Assessment of symptoms
- Assessment of therapies
- Suggestion of therapies
- ...

Expert Modelling was Essential



Medication Change for Parkinson's Disease Patients

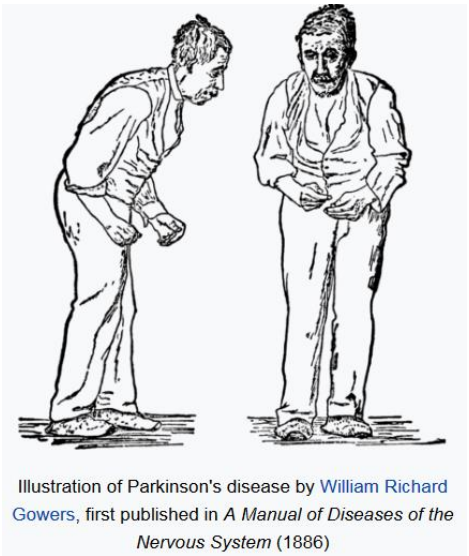


Illustration of Parkinson's disease by William Richard Gowers, first published in *A Manual of Diseases of the Nervous System* (1886)

Yes-No:
Whether or not to change medication?

Model(s):
Medication Change

Input data:
Patient's symptoms, current therapy

How to change medication?

- Increase/decrease dosage/intake
- Change medication A with B
- Start/stop using medication C

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.

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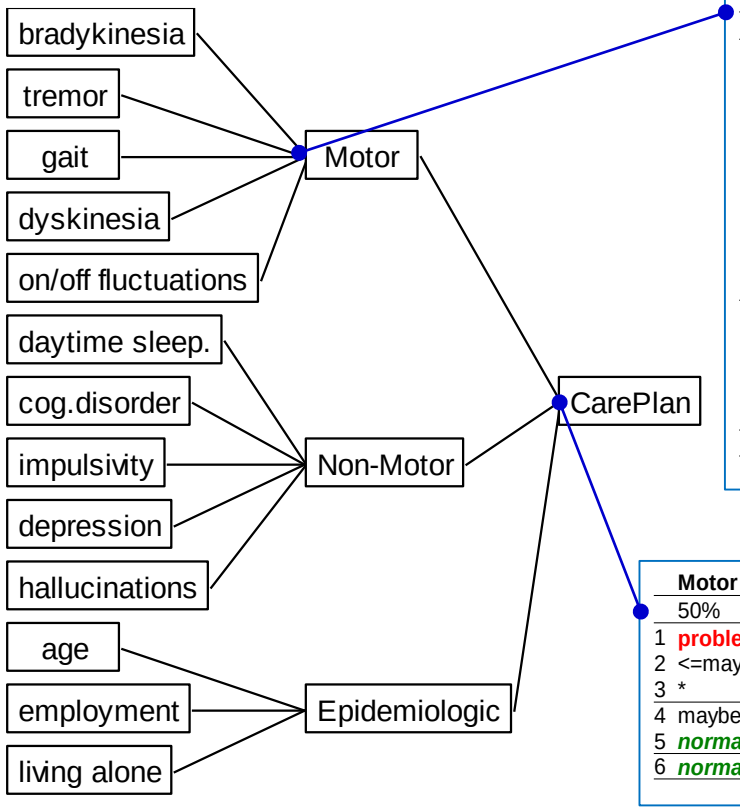
Department of Knowledge Technologies
Jožef Stefan Institute

Parkinson's Disease: Medication Change

Model developed by an expert

Structure



Decision rules

	bradykinesia	tremor	gait	dyskinesia	on/off fluctuations	Epidemiologic	Motor
	19%	19%	24%	13%	15%	10%	
1	problematic	problematic	*	*	*	*	problematic
2	problematic	*	*	<=problematic	*	*	problematic
3	problematic	*	*	*	problematic	*	problematic
4	problematic	*	*	*	*	active	problematic
5	*	problematic	*	<=problematic	*	*	problematic
6	*	problematic	*	*	problematic	*	problematic
7	*	problematic	*	*	*	active	problematic
8	*	*	problematic	*	*	*	problematic
9	*	*	*	severe	*	*	problematic
10	*	*	*	*	problematic	active	problematic
11	problematic	normal	normal	normal	normal	passive	maybe
12	normal	problematic	normal	normal	normal	passive	maybe
13	normal	normal	normal	problematic	*	passive	maybe
14	normal	normal	normal	>=problematic	problematic	passive	maybe
15	normal	normal	normal	problematic	normal	*	maybe
16	normal	normal	normal	normal	normal	*	normal

	Motor	Non-Motor	Epidemiologic	CarePlan
	50%	50%	0%	
1	problematic	*	*	change
2	<=maybe	<=maybe	*	change
3	*	problematic	*	change
4	maybe	normal	*	maybe
5	normal	maybe	*	maybe
6	normal	normal	*	no_change

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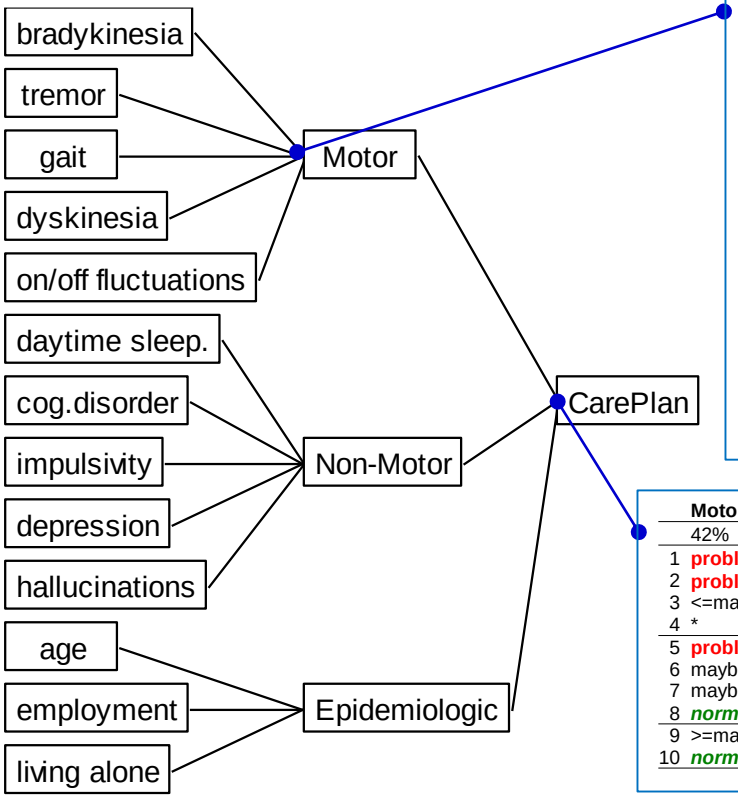
Example: Medication Change

Model developed from data

Structure

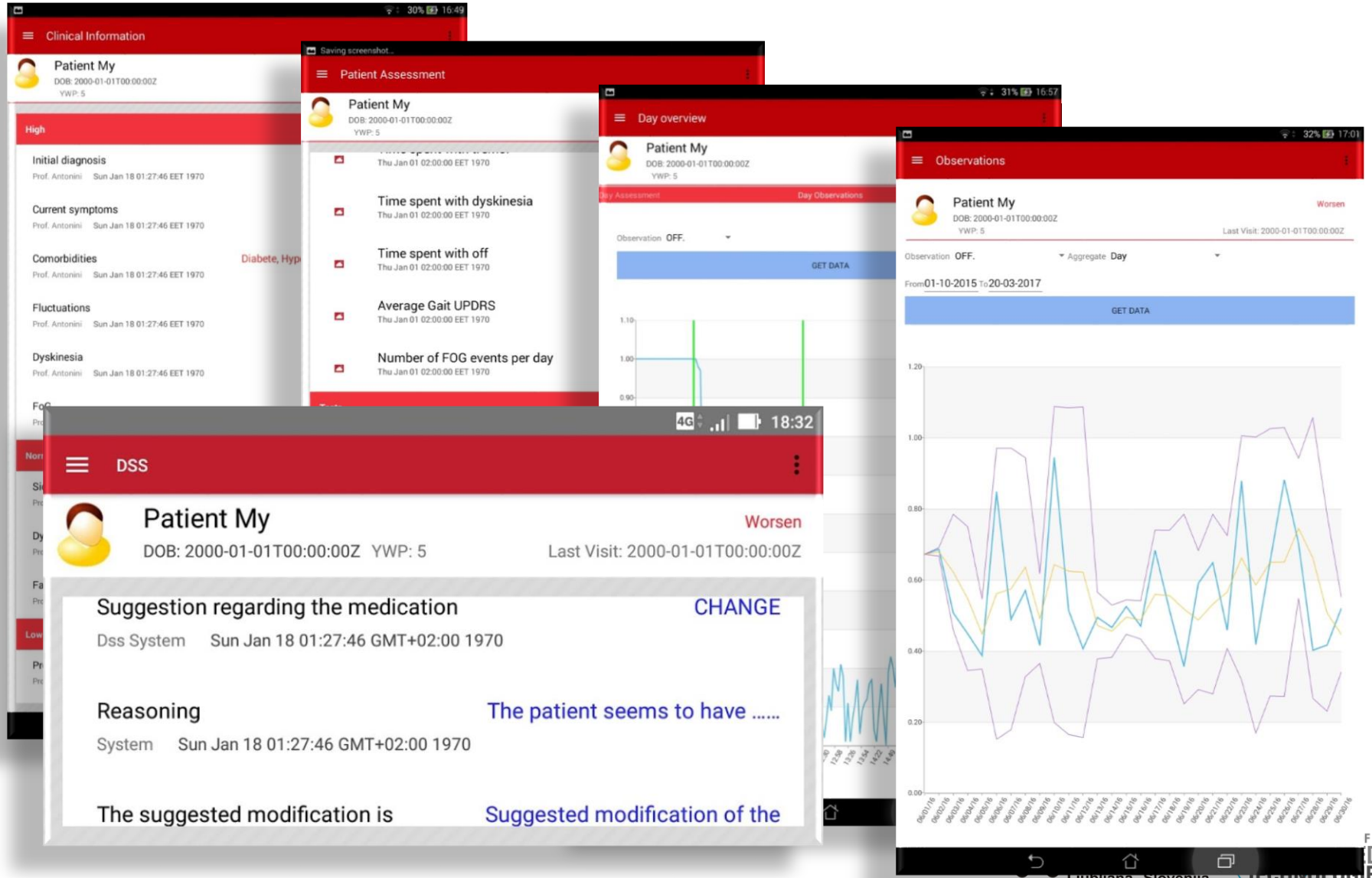


Decision rules

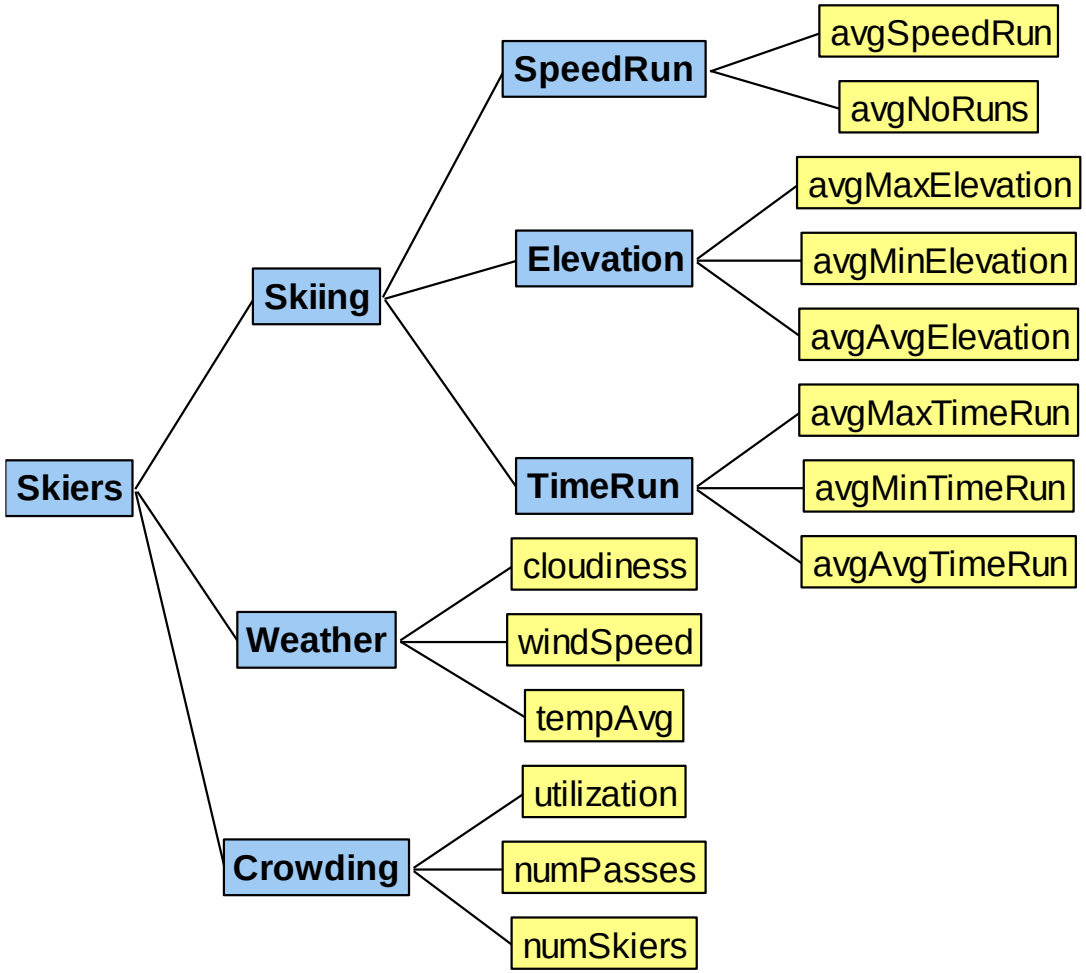
	bradykinesia	tremor	gait	dyskinesia	on/off fluctuations	Motor
	14%	6%	30%	28%	22%	
1	problematic	*	problematic	<=problematic	*	problematic
2	problematic	*	problematic	*	problematic	problematic
3	*	problematic	problematic	*	problematic	problematic
4	*	*	problematic	<=problematic	problematic	problematic
5	*	*	*	severe	*	problematic
6	problematic	*	problematic	normal	normal	maybe
7	*	problematic	problematic	normal	normal	maybe
8	problematic	*	normal	problematic	*	maybe
9	problematic	*	normal	>=problematic	problematic	maybe
10	*	problematic	normal	>=problematic	problematic	maybe
11	*	*	normal	problematic	problematic	maybe
12	normal	problematic	problematic	>=problematic	normal	maybe
13	normal	*	problematic	problematic	normal	maybe
14	normal	normal	problematic	normal	problematic	maybe
15	*	*	normal	normal	normal	normal
16	normal	*	normal	>=problematic	normal	normal
17	normal	normal	*	normal	normal	normal
18	normal	normal	normal	normal	*	normal

	Motor	Non-Motor	Epidemiologic	CarePlan
	42%	37%	21%	
1	problematic	<=maybe	*	change
2	problematic	*	active	change
3	<=maybe	problematic	*	change
4	*	problematic	active	change
5	problematic	normal	passive	maybe
6	maybe	maybe	*	maybe
7	maybe	>=maybe	active	maybe
8	normal	problematic	passive	maybe
9	>=maybe	normal	passive	no_change
10	normal	>=maybe	*	no_change

PD_manager App for the Doctor



Ski Injury Prediction



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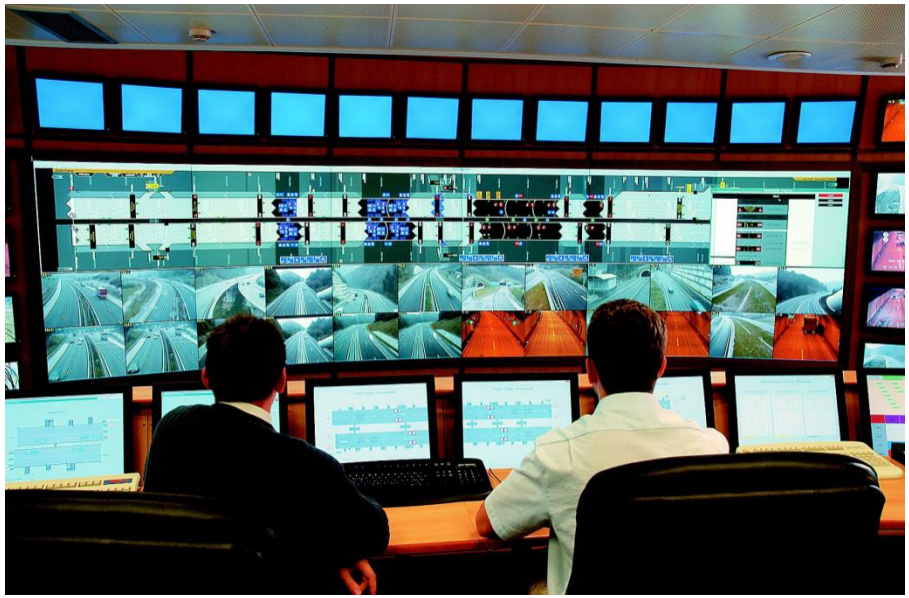
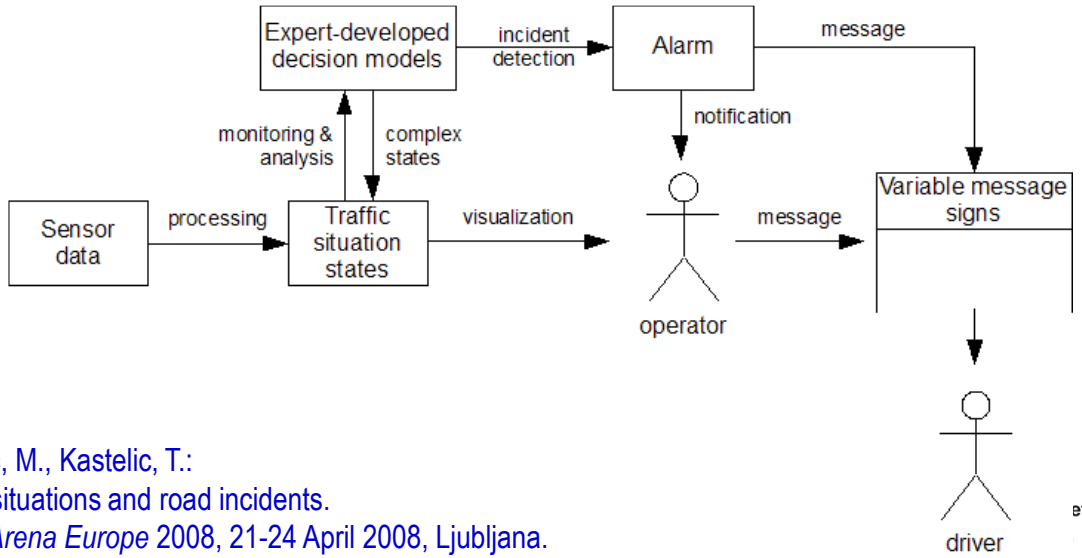
Traffic Control Center





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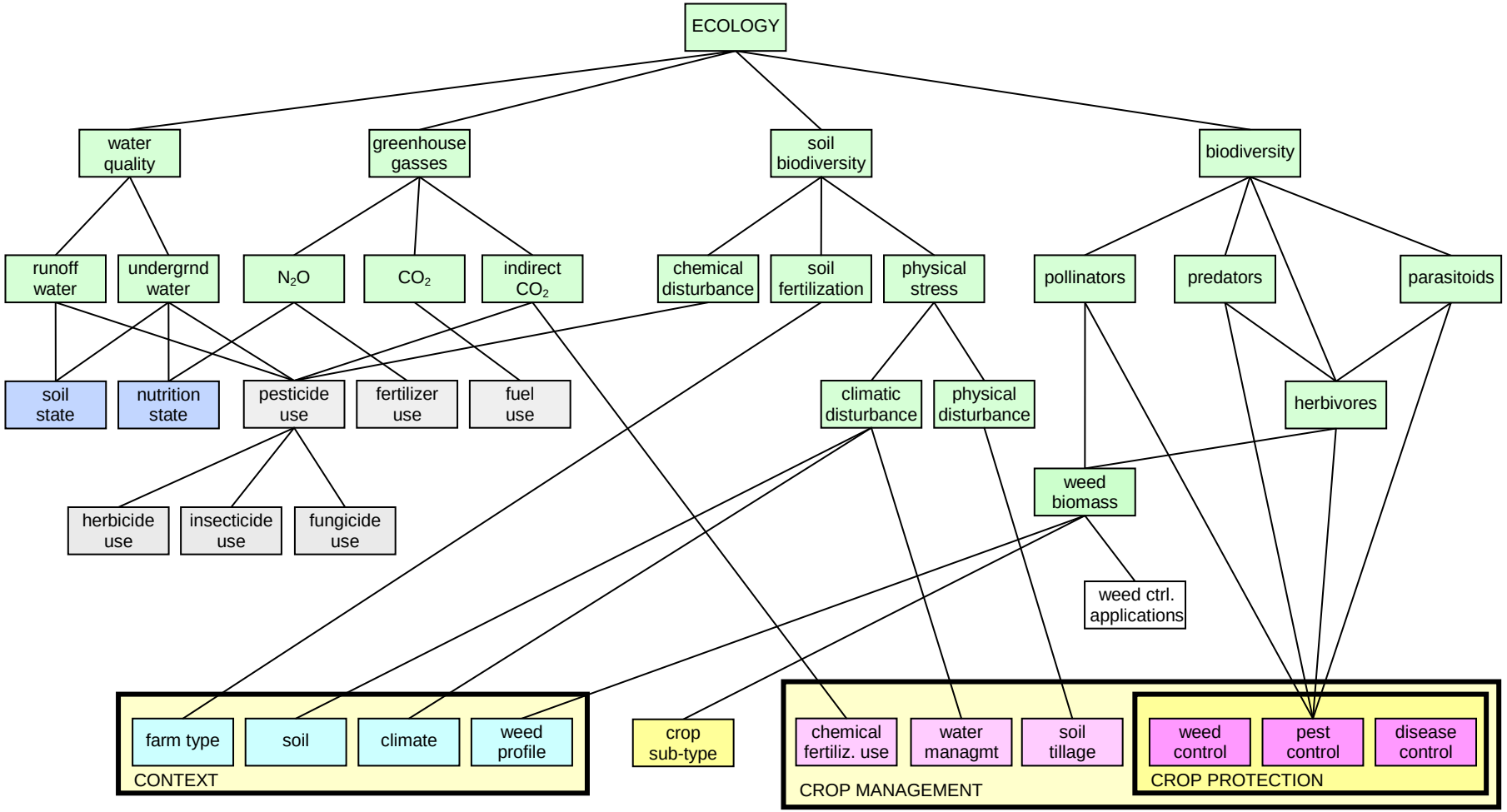
Cropping Systems: Ecology Part



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Ecological Modelling 215, 247-261, 2008.

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Using a multi
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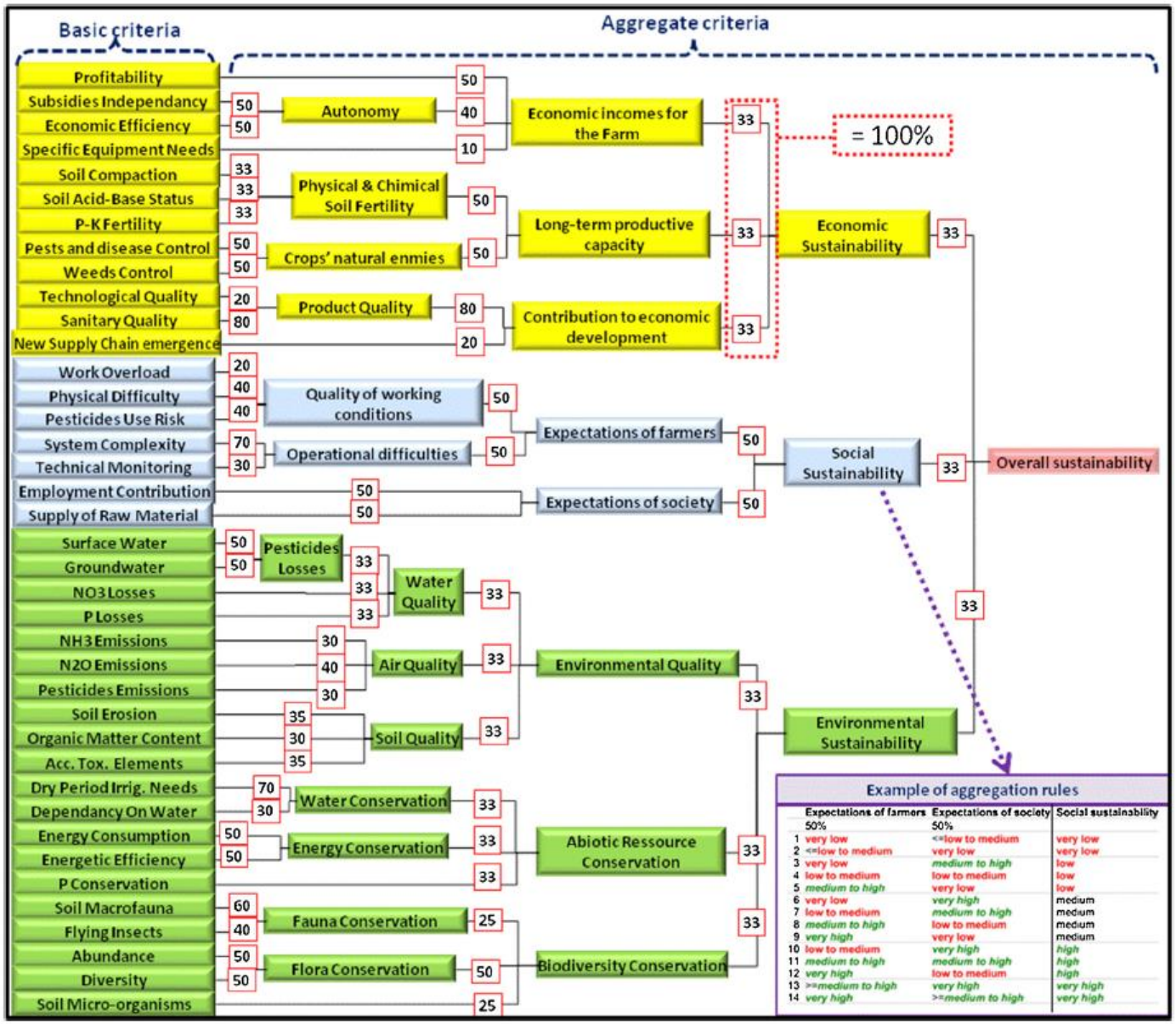

Fig. 1. Sustainability criteria information processing and aggregation in the MASC 2.0 decision tree. Numerical values in the decision tree displayed in red boxes represent the weights (expressed in %) proposed by the designers of the MASC model.

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Improving th… maize with a…

Benoît Ricci [a,b,*]
Frédérique Ange…

[a] INRA, UAR1240 Eco-innov…
[b] Agroécologie, AgroSup Dij…
[c] AgroParisTech, UMR1048 …
[d] INRA, UMR1048 SADAPT, …

Criteria	Description	Scale	In this study
FarmerChoice	Farmer's choice	GM / NGM	
GMvarietyAcc	*Access to GM varieties*	*Diff / Med /Easy*	*Fixed*
AgroTech	Agronomic and technical criteria	Unfav / Neut / Fav *	
Skills	Farmer's and employees' knowledge and skills	Unfav / Neut / Fav	
TechnicalExperience	Technical skills and experience	Low / Med / High	Variable
ProtectionKnowledge	Knowledge of weeds, pest and diseases recognition	Low / Med / High	Variable
StrategyAdvice	Availability of relevant advice for strategy	Absent / Present	Variable
AgronomicalCriteria	Agronomic criteria	Unfav / Neut / Fav	
GeoCharacteristics	Geometric characterisitcs of the field	Unfav / Neut / Fav	
Size	Size of the field	Small / Med / Large	Variable
ShapeConstraints	Length/Width ratio	Unfav / Neut / Fav	Variable
TempIsolation	*Possibility of using temporal isolation*	*No / Yes*	*Fixed*
PestPressure	*Corn borer pressure*	*Low / Med / High*	*Fixed*
Organ…			
D…			
O…			
Machi…			
S…			
C…			
SocioEco			
Econo…			
In…			
G…			
Sensit…			
R…			
S…			

* Unfavorable t…

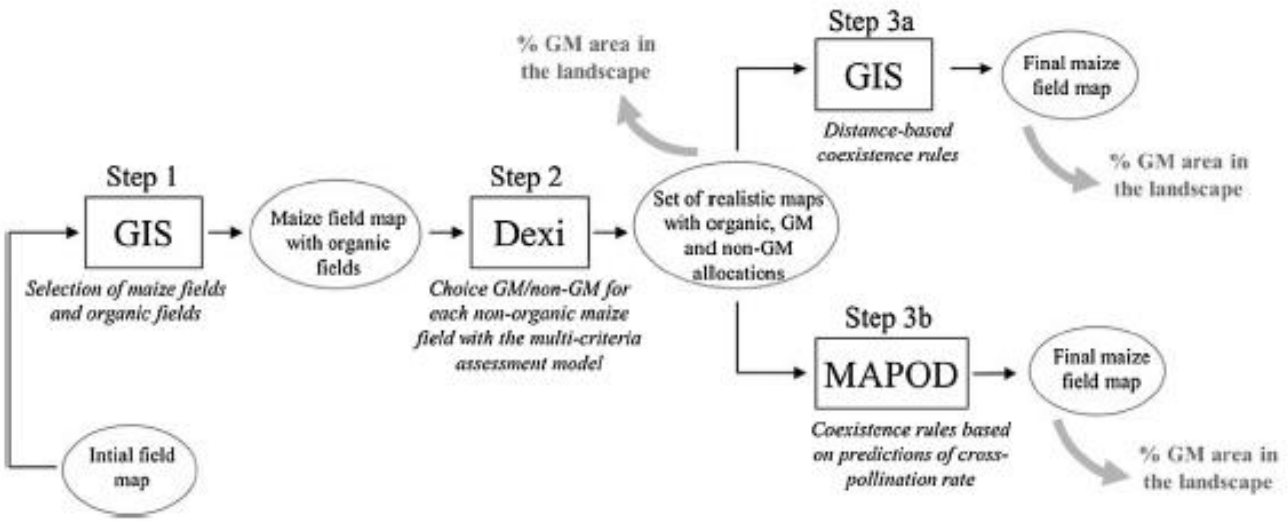

Fig. 2. Flowchart of the global procedure developed for comparison of the two types of coexistence rules.

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Ex-ante sustainal systems

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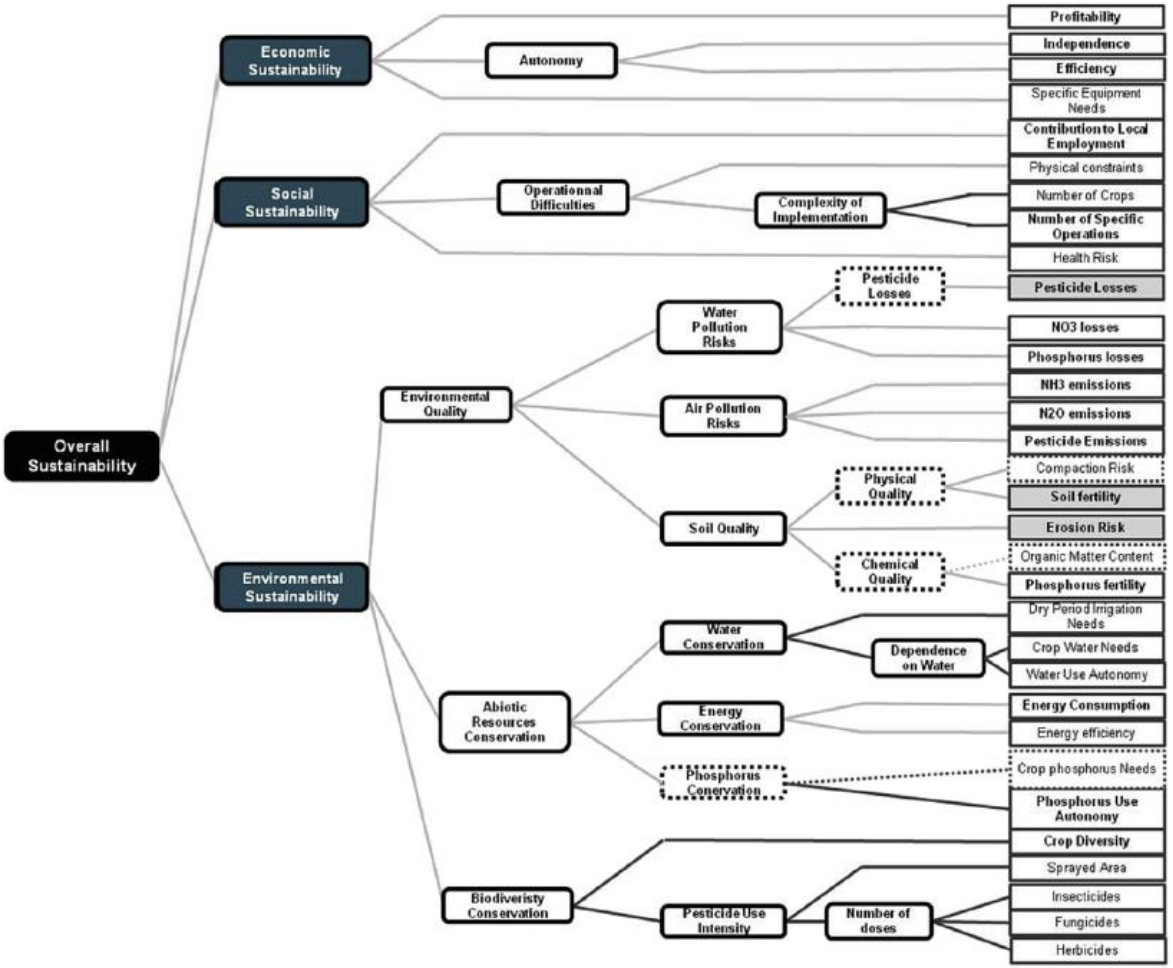

Fig. 2. Adapted tree of sustainability with the disappearance of indicator in dotted line, including compaction risk, organic matter content, dry period irrigation needs, crop water needs, compared to Sadok et al. (2009). Indicators modified to fit the local context are shown in grey. Pesticide losses, soil fertility and erosion risk were calculated using the indicators developed by Tixier et al. (2008).

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Risk-Based Decision Support Model for Offshore Installations

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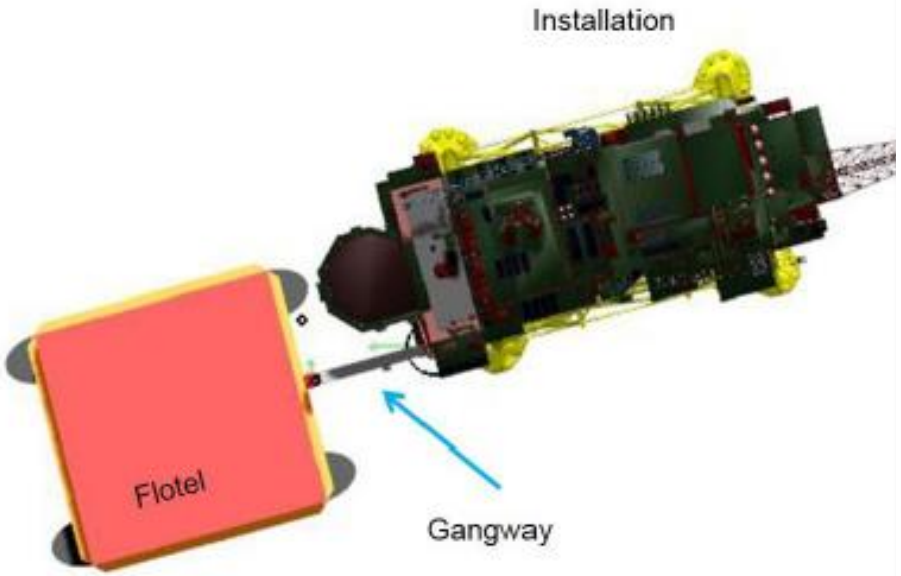
SINTEF Digital, Oslo, Norway
Bjørn Nygård, Ole Petter Rosland
Statoil ASA, Stavanger, Norway
Bernt Kvam Randeberg
Oilfield Technology Group, Sandnes, Norway

Figure 1
Gangway connection from flotel to installation



- **Attribute**
- **Gangway operational risk**
  - **Floatel criticality state**
    - **DP class status**
      - DP class compliance
      - Operation mode
    - Station keeping performance
    - **Drift-off collision risk**
      - DP force/thrust direction
      - DP force/thrust amplitude
  - **Gangway criticality state**
    - Real-time gangway stroke
    - Real-time gangway elevation
    - **Present heading deviation from recommendation (weather-dependent)**
      - Present heading deviation from recommendation
      - ***Measured weather***
    - Gangway stroke statistics
    - **Gangway stroke forecast in six hours**
      - Number of existing gangway forecasts above alarm limit
      - Heading deviation from recommendation in six hours
  - **Weather**
    - **Measured weather**
      - **Waves**
        - Significant wave height
        - Wave direction
        - Wave period (Tp)
      - **Wind**
        - Wind speed
        - Wind direction
      - **Sea current**
        - Sea current speed
        - Sea current direction
    - **Forecasted weather**
      - **Waves forecast**
        - Significant wave height forecast
        - Wave direction forecast
        - Wave period (Tp) forecast
      - **Wind forecast**
        - Wind speed forecast
        - Wind direction forecast
  - **Installation criticality state**
    - Operational activity state
    - Drilling and well activity
    - POB above lifeboat capacity
    - Exhaust exposure
    - Visiting vessel

Take-Home Messages

Decision Support

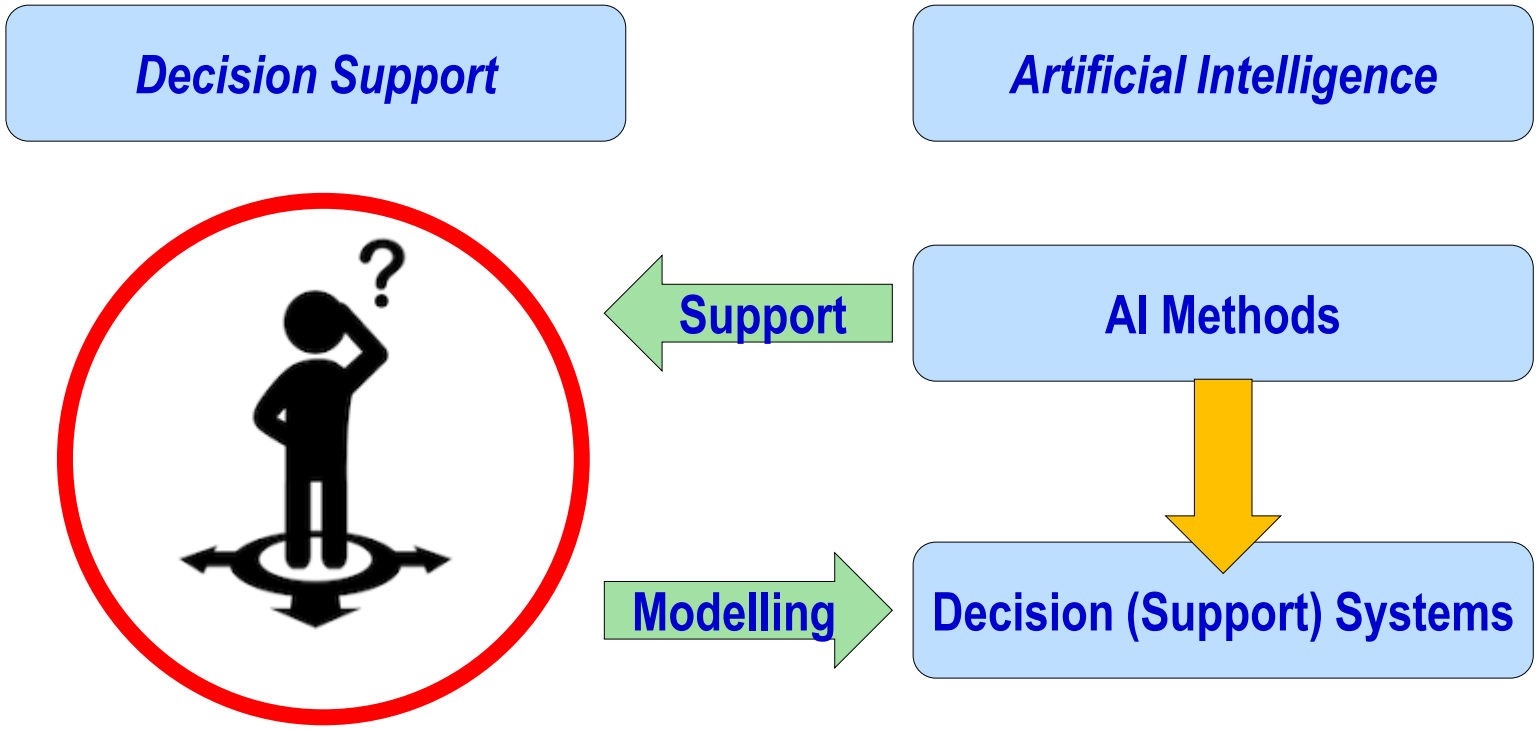
Artificial Intelligence

Support

AI Methods

1. AI methods can support human decision-making

Take-Home Messages



1. AI methods can support human decision-making
2. Expert modelling can improve decision (support) systems

Thank You

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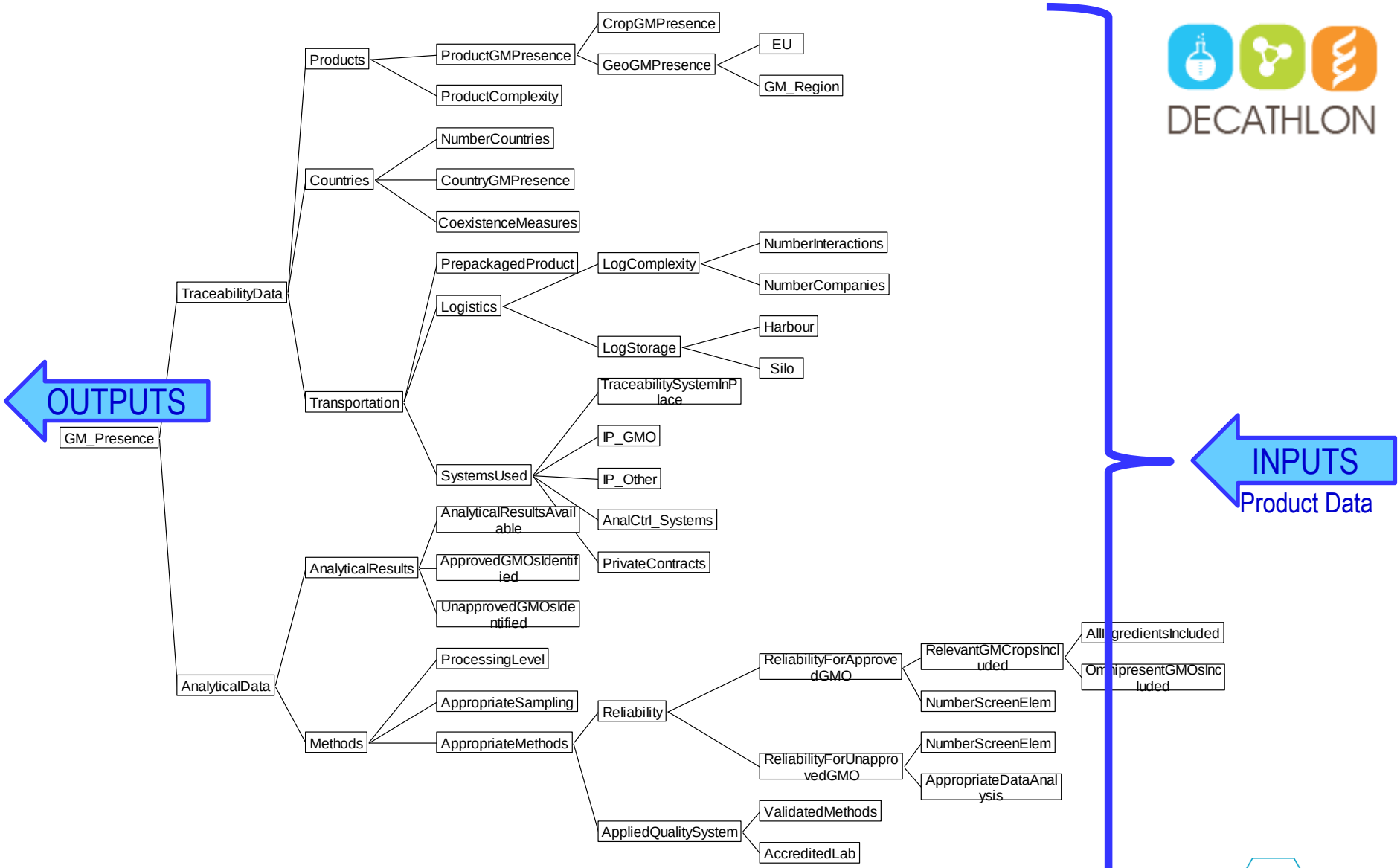
http://kt.ijs.si/MarkoBohanec/dexi.html

GMO Presence in Food and Feed



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DSS for the Assessment of GM Products

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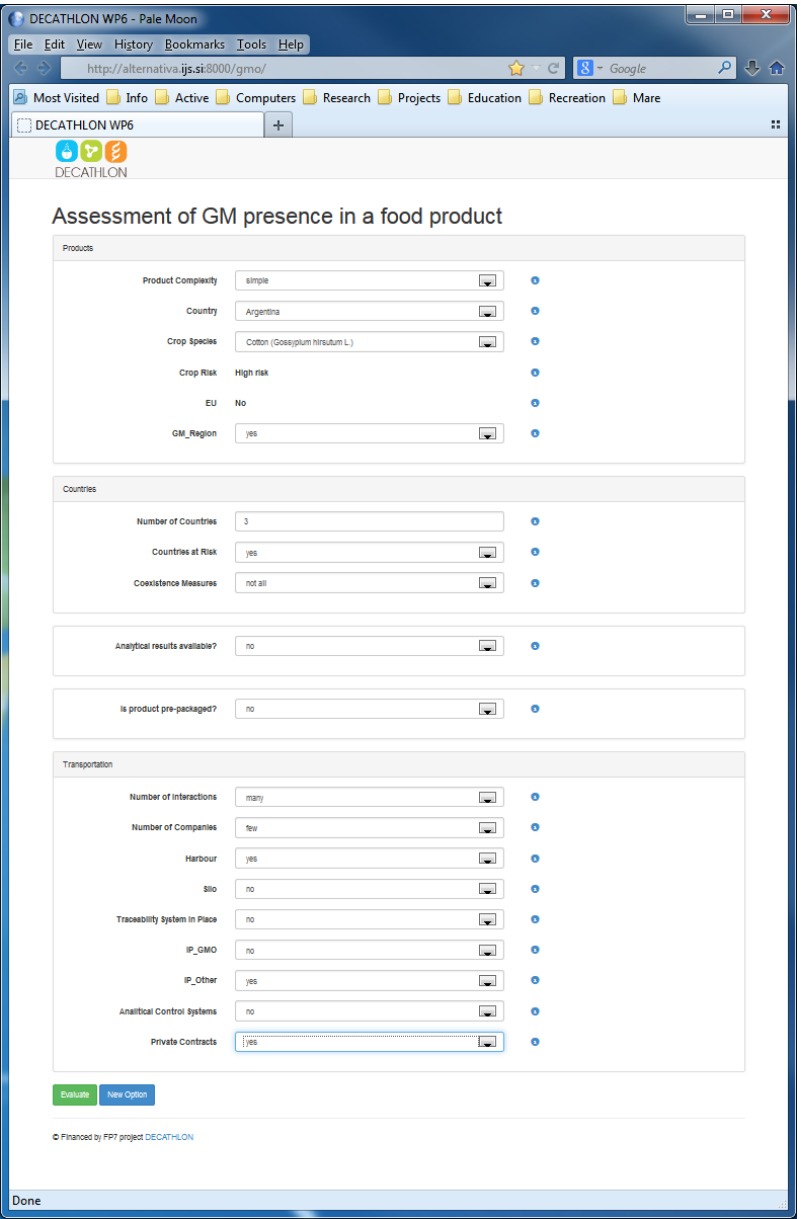
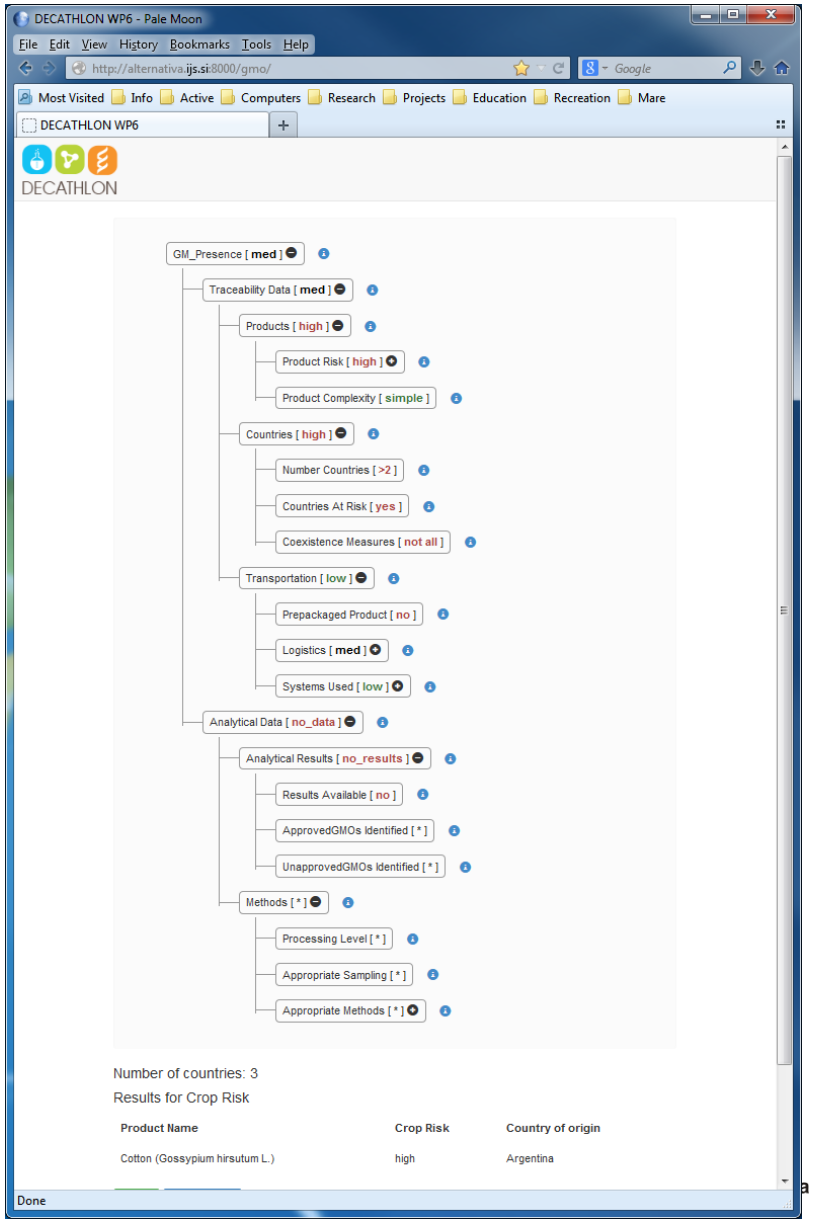
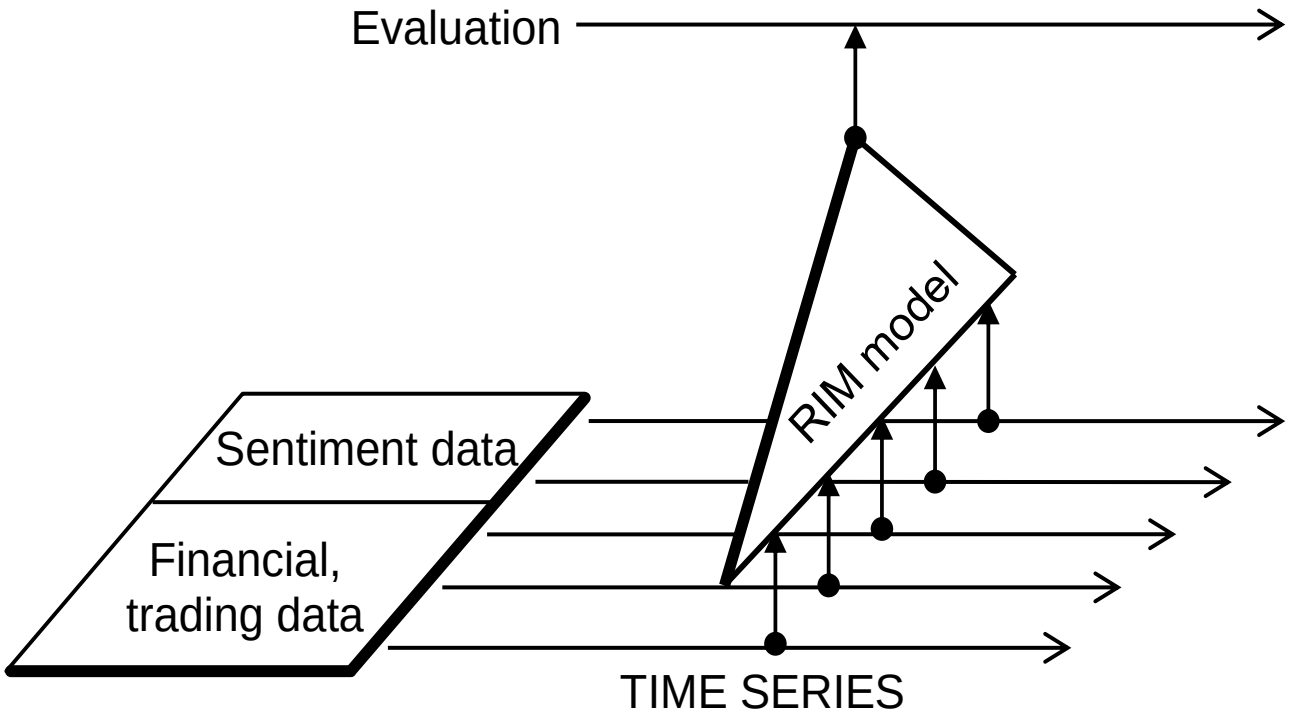




Assessment of Reputation Risk in Banks

FP7 ICT
2010-2013

Large scale information extraction and integration infrastructure for supporting financial decision making



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