General strategies for policy modelling

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Regulatory Impact Analysis: Some History

- 1960s, 1970s: First RIA approaches in several industrialised countries (Denmark, US, UK, Germany)
- PPB: Planning, Programming, Budgeting
- Microsimulation approaches to forecast effects of tax and transfer changes

Current approaches

- Policy modelling in various academic and applied projects (FIRMA, urban dynamics, PRIMA, land use change, sustainable agriculture , OCOPOMO)
- 2004: OECD RIA Inventory
- Stress tests during the financial crisis
- Stress tests of nuclear power plants and for the new Stuttgart railway station

Views on simulation can be quite different

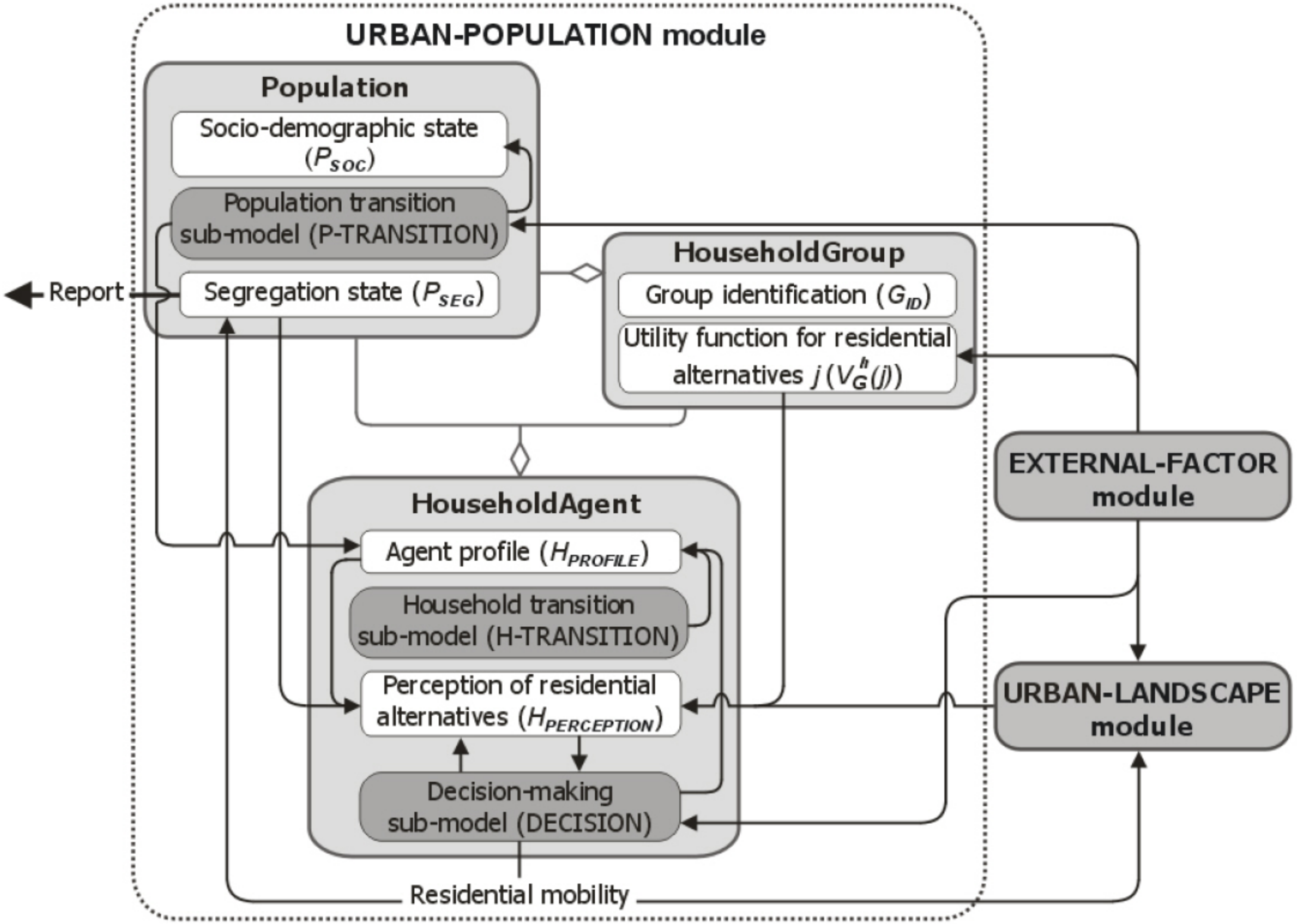
- Sugarscape:
  - the question “can you explain it?” is interpreted as “can you grow it?”, and
  - “a given macrostructure [is] ‘explained’ by a given microspecification when the latter’s generative sufficiency has been established.”
    - [Epstein and Axtell 1996:177]
- Microanalytical simulation:
  - starts from a large collection of observational data on persons and households and the population as a whole,
  - is initialised with empirical estimates of transition probabilities, age-specific birth and death rates and so on,
  - tens of thousands of software agents are created with data from real world people.
  - And all this aims at predicting something like the age structure or kinship networks of this empirical population in the far future

Simulation as a thought experiment

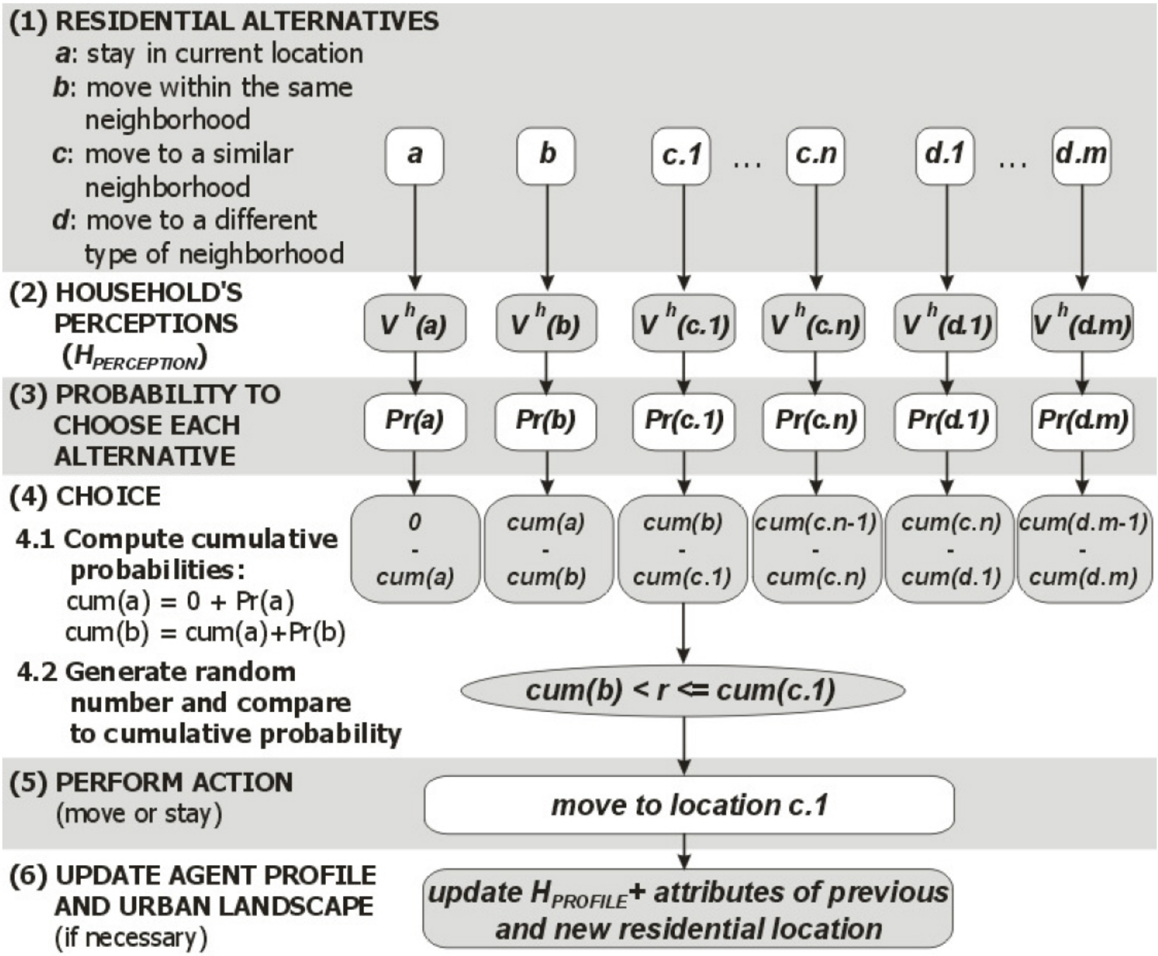
- Simulation may be seen as a thought experiment which is carried out with the help of a machine, but without any direct interface to the target system: We try to answer a question like the following.
- Given our theory about our target system holds (and given our theory is adequately translated into a computer model), how would the target system behave?
- The latter has four different meanings:
  - Which kinds of behaviour can be expected under arbitrarily given parameter combinations and initial conditions?
  - Which kind of behaviour will a given target system (whose parameters and previous states may or may not have been precisely measured) display in the near future?
  - Which state will the target system reach in the near future, again given parameters and previous states which may or may not have been precisely measured? [Troitzsch 1997]
  - Which state will the target system reach after we applied some political strategies?

Flávia F. Feitosa et al.: MASUS: A Multi-Agent Simulator for Urban Segregation, ESSA 2009, paper 30
Flávia da Fonseca Feitosa: Urban Segregation as a Complex System. An Agent-Based Simulation Approach, Diss. Geogr. Bonn 2010

Urban Development: MASUS



Urban Development: MASUS



Urban Development: MASUS

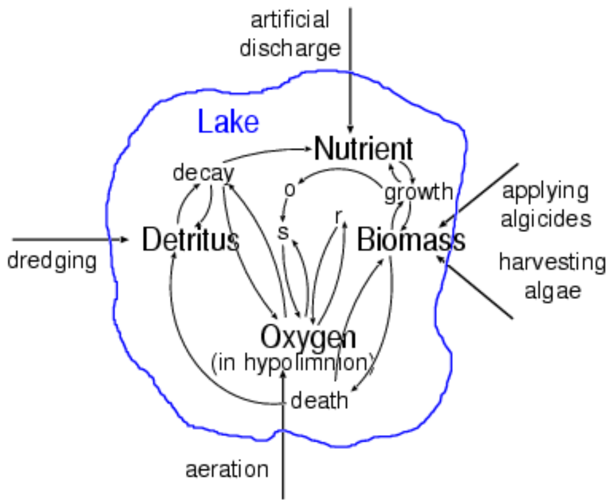
São José dos Campos, São Paulo, Brasilien 1991-2000

Spatial Isolation of Low-Income Households

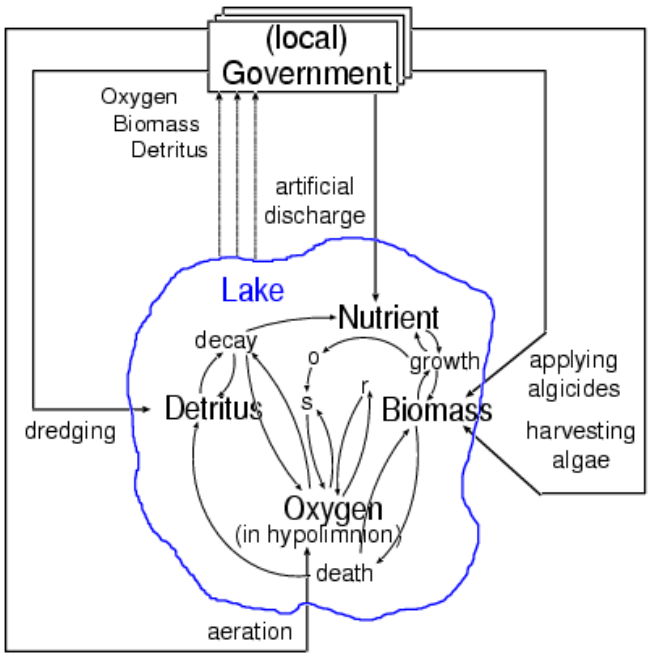
(d) Initial State 1991	(e) Simulated 2000	(f) Real data 2000

$\breve{Q}$ is the percentage of similar households in the neighbourhood

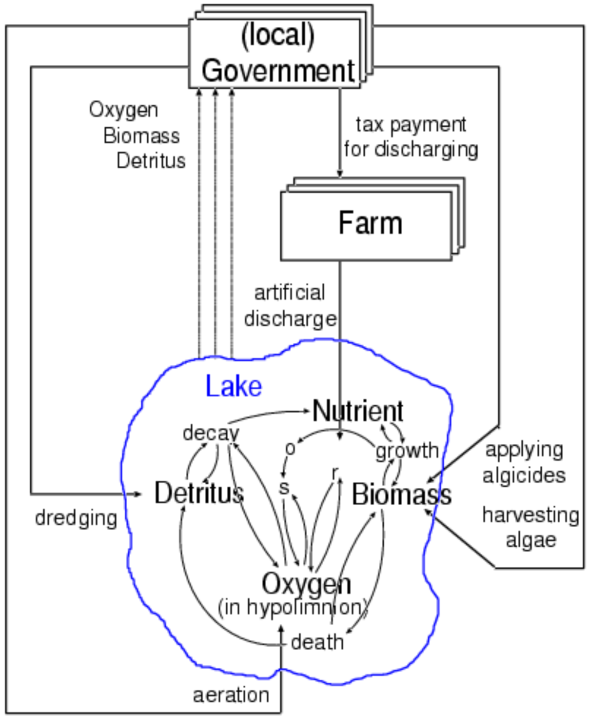
Lake Anderson revisited



Original model, System Dynamics style



Variant 1 with strategies applied within the model



Variant 2 with feedbacks on several levels

Anderson‘s model: variables

- The behaviour of the lake is described in a number of equations for the following main “level” variables:
  - **nutrient:** the amount of fertiliser and other nutrients in the lake, increased by fertiliser discharge, by respiration and decay of the biomass, and decreased by the growth of the biomass,
  - **biomass:** the amount of algae in the lake, increased by their growth, and decreased by their death rate, by respiration and, possibly, by harvesting algae,
  - **detritus:** the amount of sediment at the bottom of the lake, increased by dying algae, and decreased by detritus decay and, possibly, by the dredging the lake ground,
  - **oxygen:** the concentration of oxygen available to the algae for their metabolism; this level variable is composed of two parts, the epilimnion oxygen concentration (which is considered to be constant because oxygen is always replenished from the air above the lake surface) and the hypolimnion oxygen concentration which is increased by the diffusion of oxygen from the epilimnion into the hypolimnion, and decreased by the oxygen consumption (due both to the respiration of the algae and to the detritus decay process) and, possibly, by artificial aeration.

Jay M. Anderson: 'The Eutrophication of Lakes', in: Dennis and Donnella Meadows: *Toward Global Equilibrium*, Cambridge MA (Wright Allen) 1973, pp. 171-140

Anderson‘s model: policies

- Anderson describes five policies to avoid eutrophication of the lake:
  - **applying algicides:** the application of algicides can increase the natural death rate of the algae,
  - **dredging the detritus:** the detritus can be dredged from the ground of the lake, which results in a decrease of nutrient (which otherwise would have been produced from the detritus naturally) and in an increase in the hypolimnial oxygen concentration (because less oxygen is consumed in the detritus process),
  - **aeration of the lake:** oxygen can be bubbled into the water of the lake, thus increasing the hypolimnial oxygen concentration,
  - **harvesting algae:** biomass can be harvested, thus decreasing the biomass (and, in consequence, its oxygen comsumption and its conversion into detritus); the harvested biomass can be used for agricultural purposes,
  - **reducing nutrient (fertilizer) discharge into the lake:** Anderson suggests an artificial discharge of fertiliser into the lake which is ten times the natural discharge of nutrient from outside the lake at the beginning of most of his simulation runs; moreover he suggests a yearly increase of the artificial fertiliser discharge of two per cent if no specific measures are taken.
- These policies can be combined.

Extensions

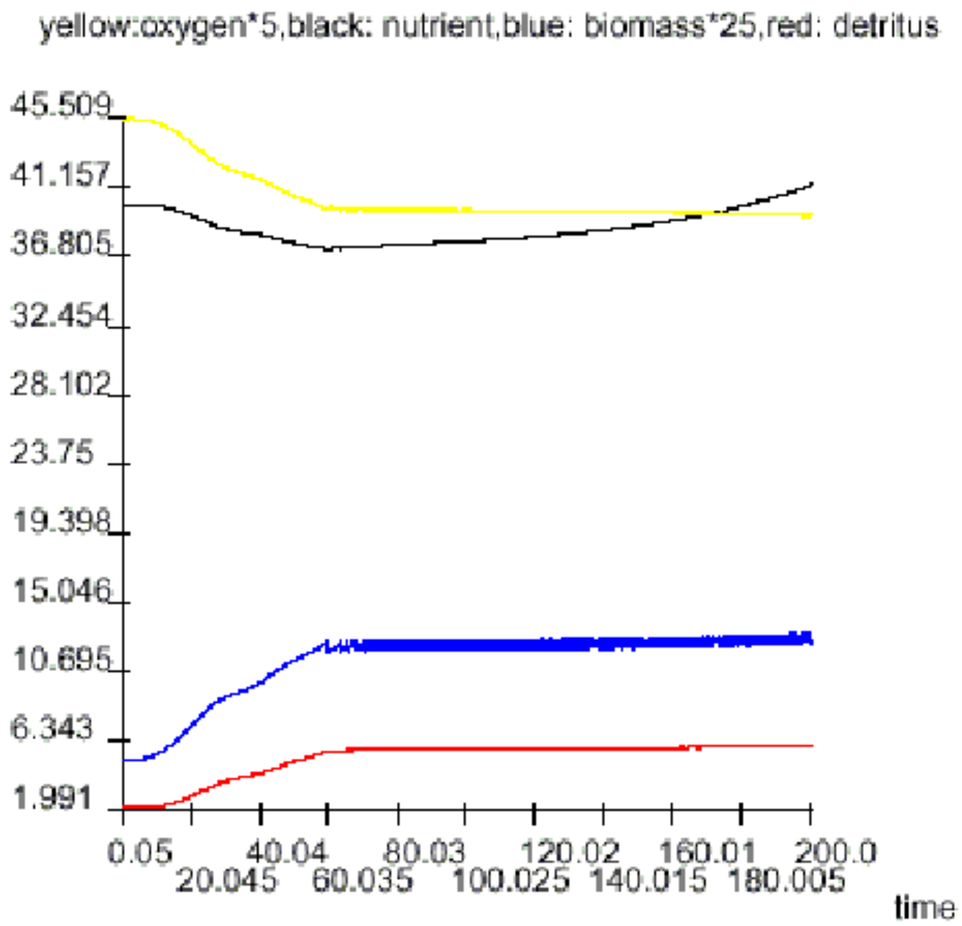
- In the original model, these policies are applied by the experimenter;
- in extended models,
  - one or more simulated “governments” or
  - other agents/agencies under the control (tax reduction, fines, …) of local authorities
- perform the task to apply strategies to avoid or fight eutrophication.

Michael Möhring and Klaus G. Troitzsch (2001): Lake Anderson Revisited by Agents. In: *Journal of Artificial Societies and Social Simulation* vol. 4, no. 3, <http://www.soc.surrey.ac.uk/JASSS/4/3/1.html>

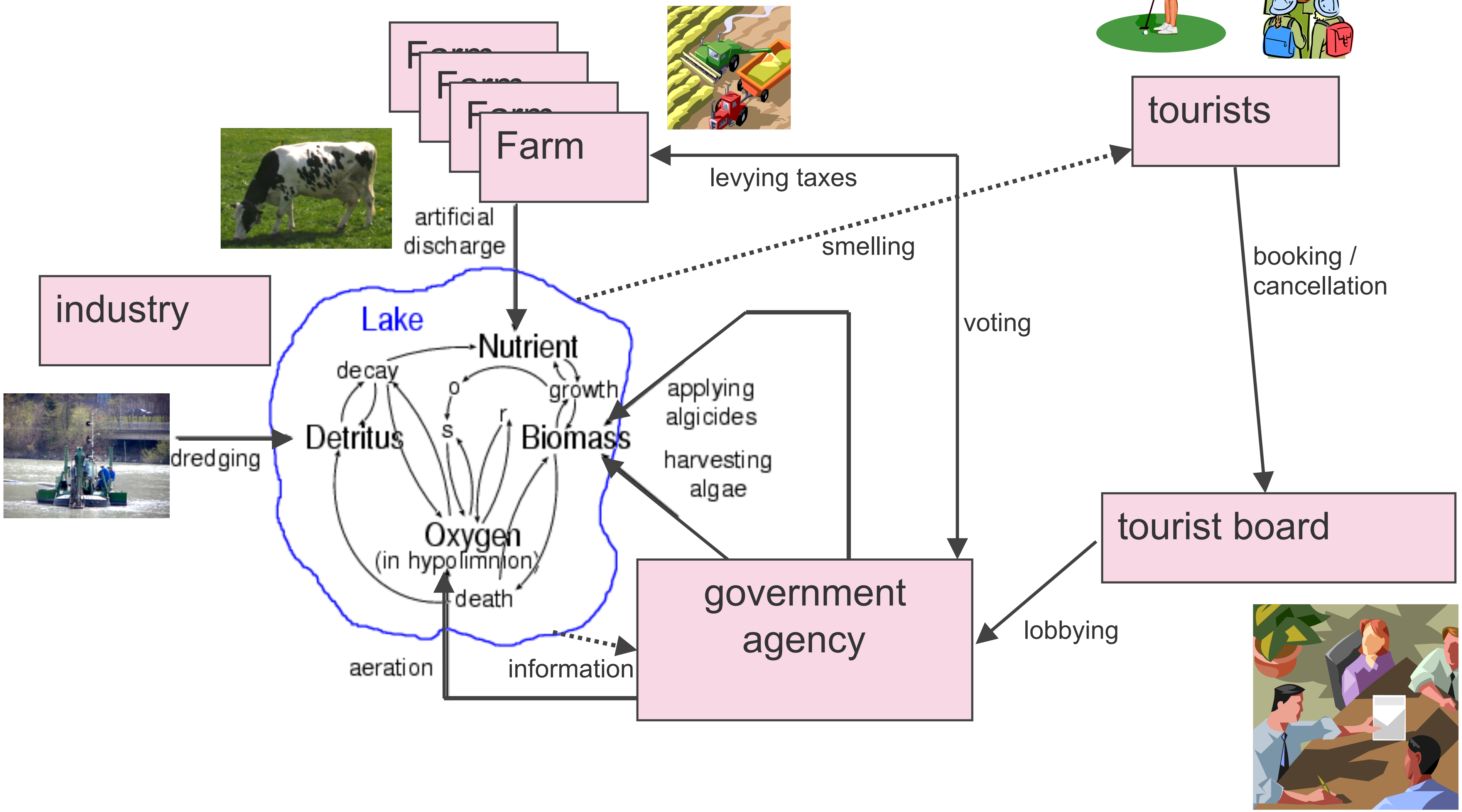
Model output (just an example)

Four local governments with behavioural rules as follows:

- **Nutrient discharge**: reduced/increased (by 2 per cent per year) while oxygen is less/greater 7.5
- **Harvesting**: done by two governments while biomass is over 0.5, done by the other two governments while biomass is over 0.75 (which is never reached in this experiment, so the two lazy governments never harvest)
- **Aeration**: done/not done while oxygen is less/over 7.5



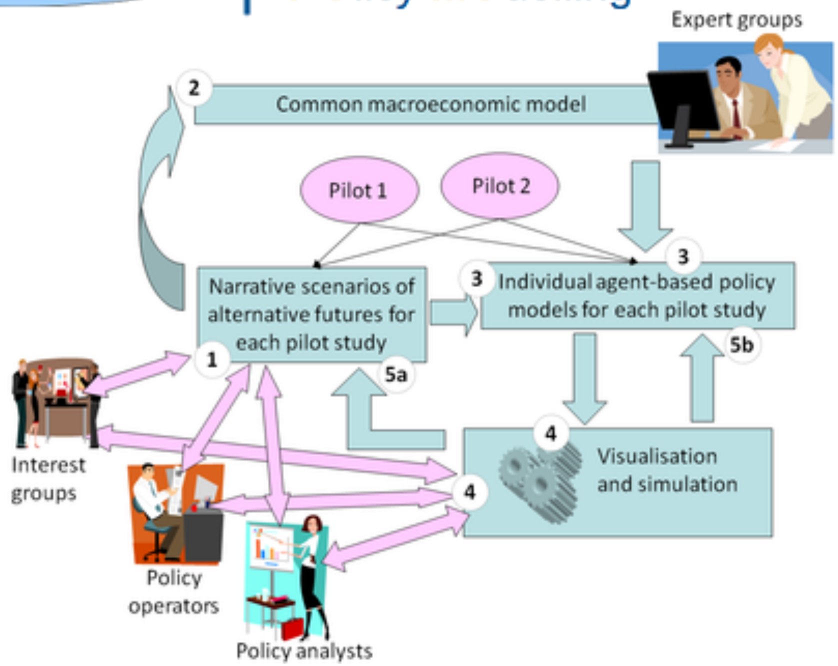
Additional stakeholders



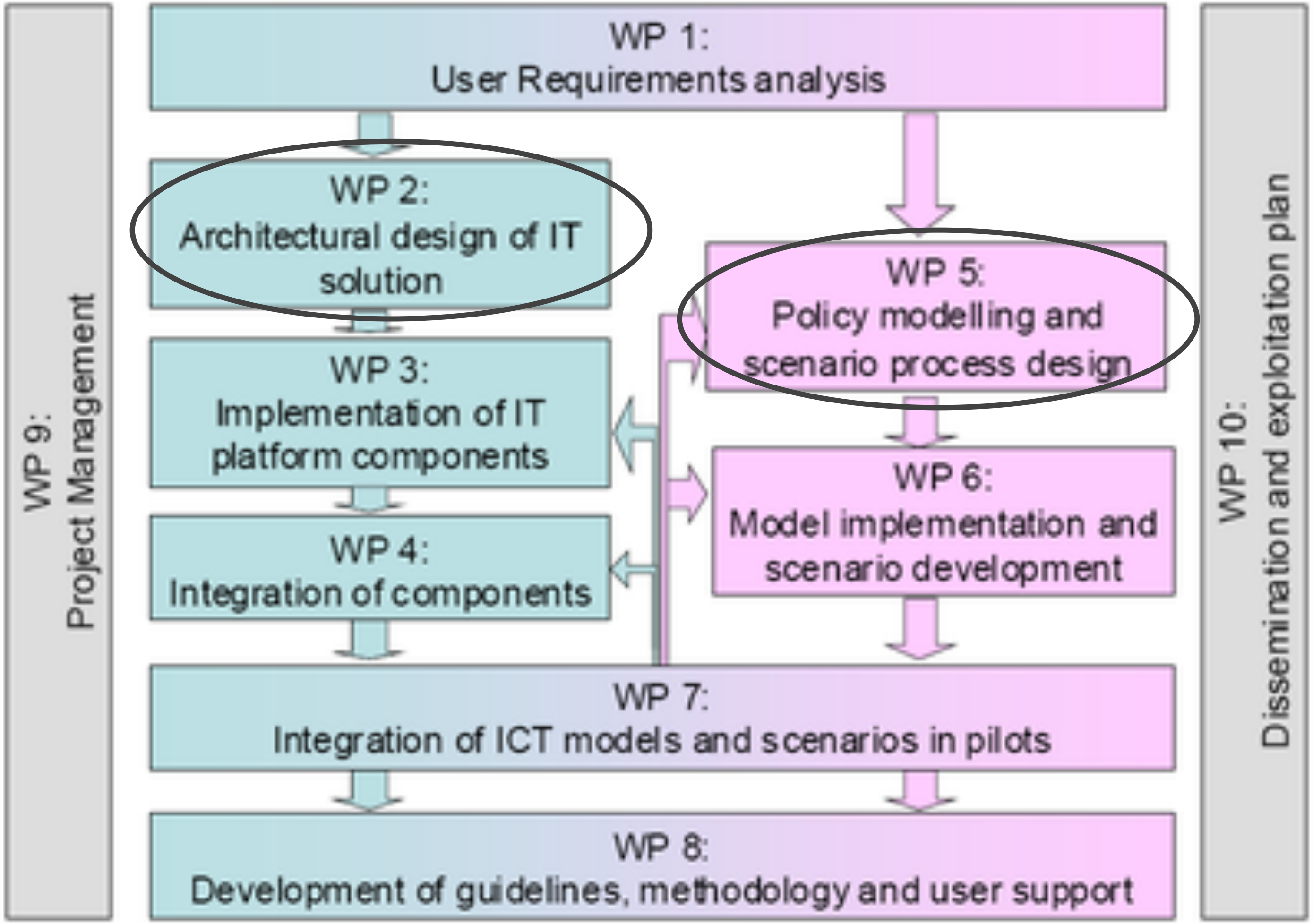
OCOPOMO: Aims

OCOPOMO Open COllaboration for POlicy MOdelling

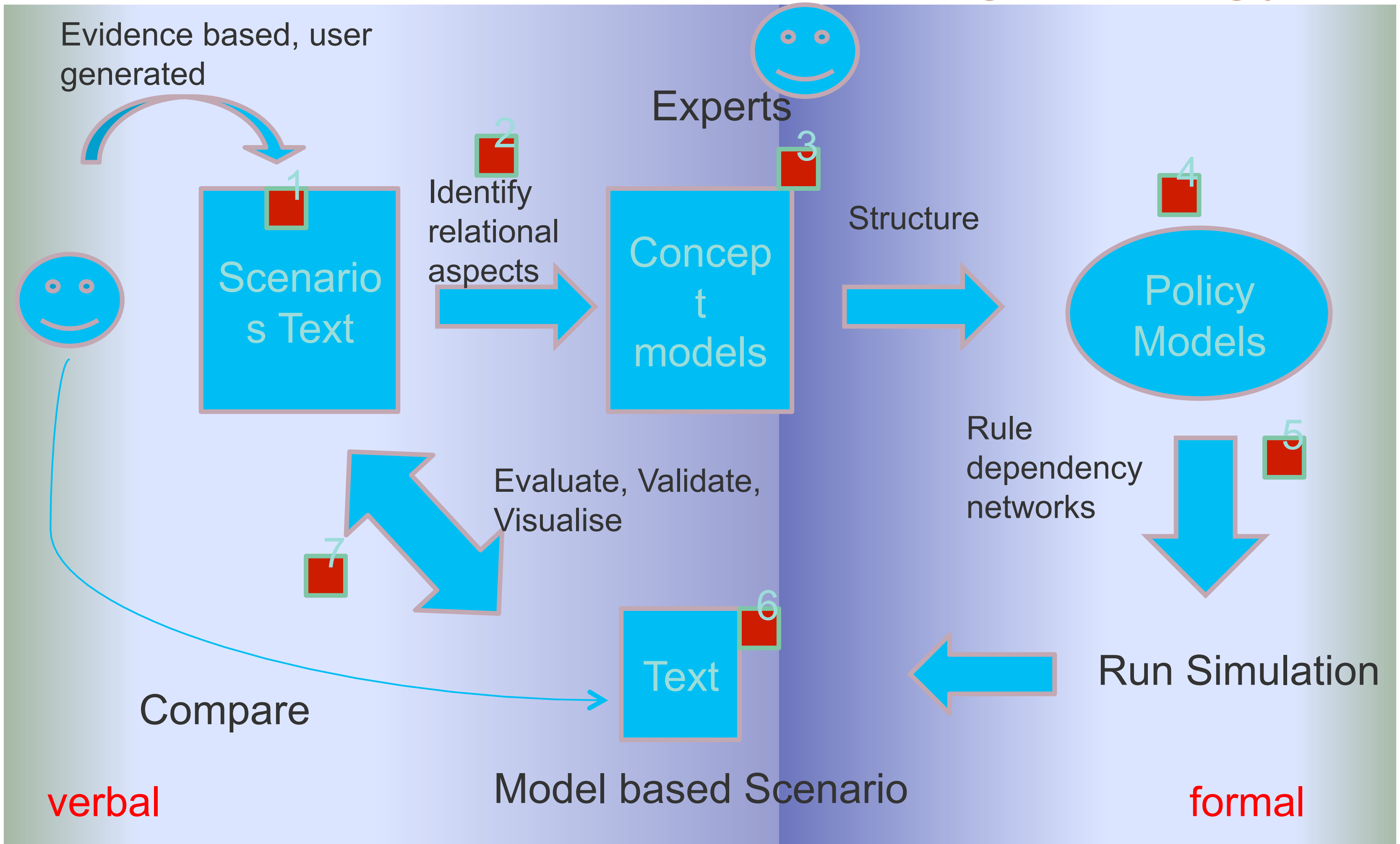
- OCOPOMO aims at defining and demonstrating a new approach to policy formation that resolves crucial issues involved with prevailing approaches.
- This project provides an innovative "off the mainstream" bottom-up approach to social policy modelling, combined with e-governance tools and techniques, and advanced ICT technologies.
- The OCOPOMO project will create an ICT-based environment integrating lessons and practical techniques from complexity science, agent based social simulation, foresight scenario analysis and stakeholder participation in order to formulate and monitor social policies to be adopted at several levels of government.



OCOPOMO: Work packages



OCOPOMO: General modelling strategy



OCOPOMO: Identification of relational aspects

Phrase in a scenario description	Issue	Category	Characteristic of issue	Model component
Cheese should be produced by farmers along Hadrian's Wall.	Agricultural products	State: Alternative or multivariate	If alternative: {"dairy", "wool", "cereal", "meat", "beer", "vegetable"} or if multivariate: <dairy x_s per cent, wool x_f per cent, cereal x_n per cent, meat x_w per cent, beer x_b per cent, vegetable x_h per cent>	Condition part of a rule in an agent's rulebase, fact
		Goal (description of desired future state)		Also a fact
	produced	State change (ways and means, measures to be taken)	Action description: *install milking machine and cheese kettle to produce cheese*	Action part of a rule in an agent's rulebase, to be determined by analysing possible ways from current states to goals
	Agricultural enterprises	Actor	Endowed with a rule base, a fact base and goals	Agent class

- this process is supported by CAQDAS
- from this a fact and rule base is derived for each (type of) agent

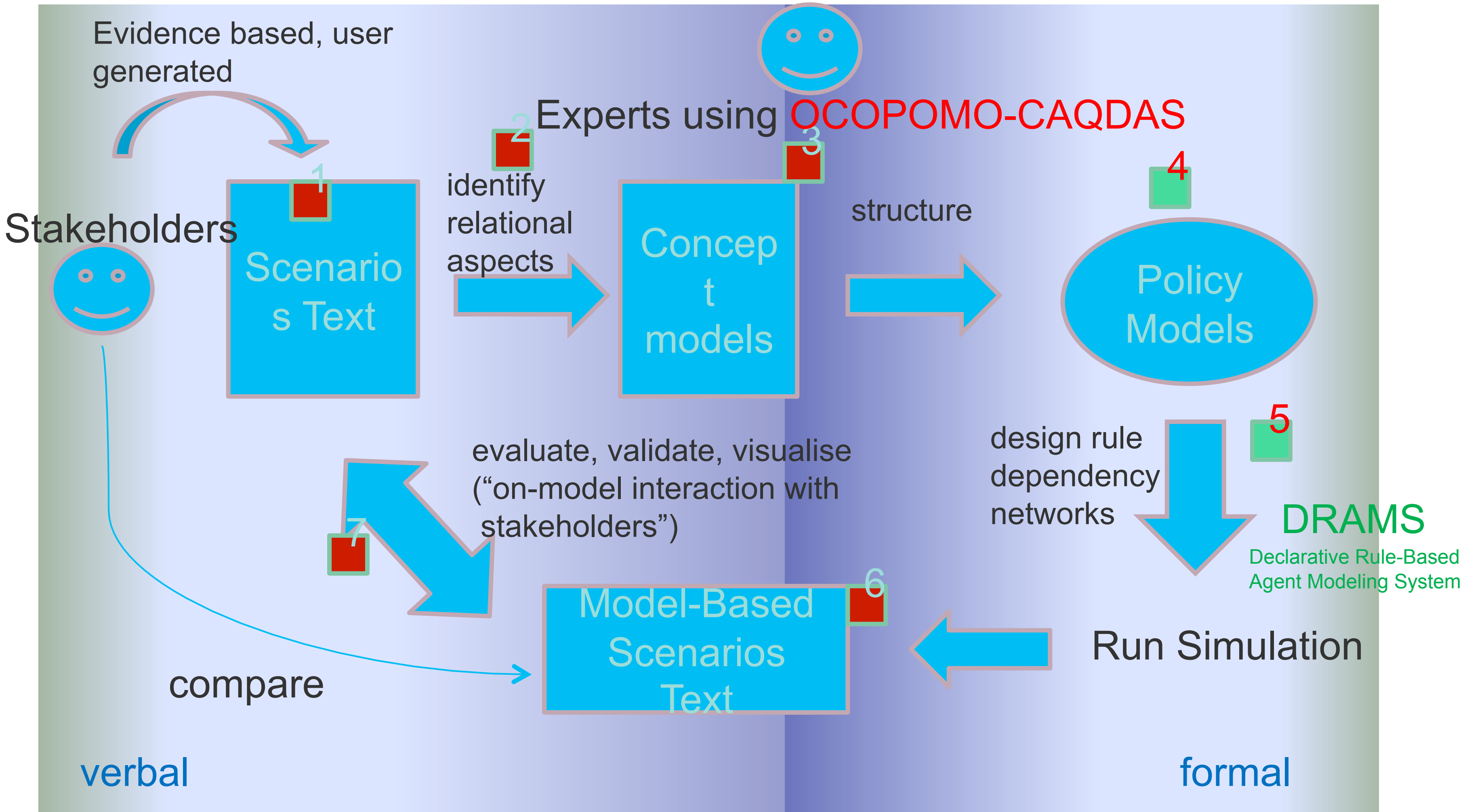
OCOPOMO: Identification of rules

Model structure	Model components	Name	Natural language description	Formal language description
Agent "farmer along Hadrian's Wall"	Structure	Farmer_Along Hadrian_s_Wall	Agent class	class farmer{...}
	Facts	Current state	The current distribution of agricultural products produced	Class EnvironmentState { double productClass Percentages[]; double soilCapacity; double lengthOfSummer; double priceOfCheese; …}
			The current state of soil and climate	
			The current market price for high qualtiy cheese	
		Desired state	The desired distribution of of agricultural products produced	PlanningGoal [objective cheese] [objective minimumProfit] [priority high]
			The minimum desired profit	
		Danger	Production cost per kilogram might exceed the price per kilogram in the farm shop	Danger [cheese] [losses]

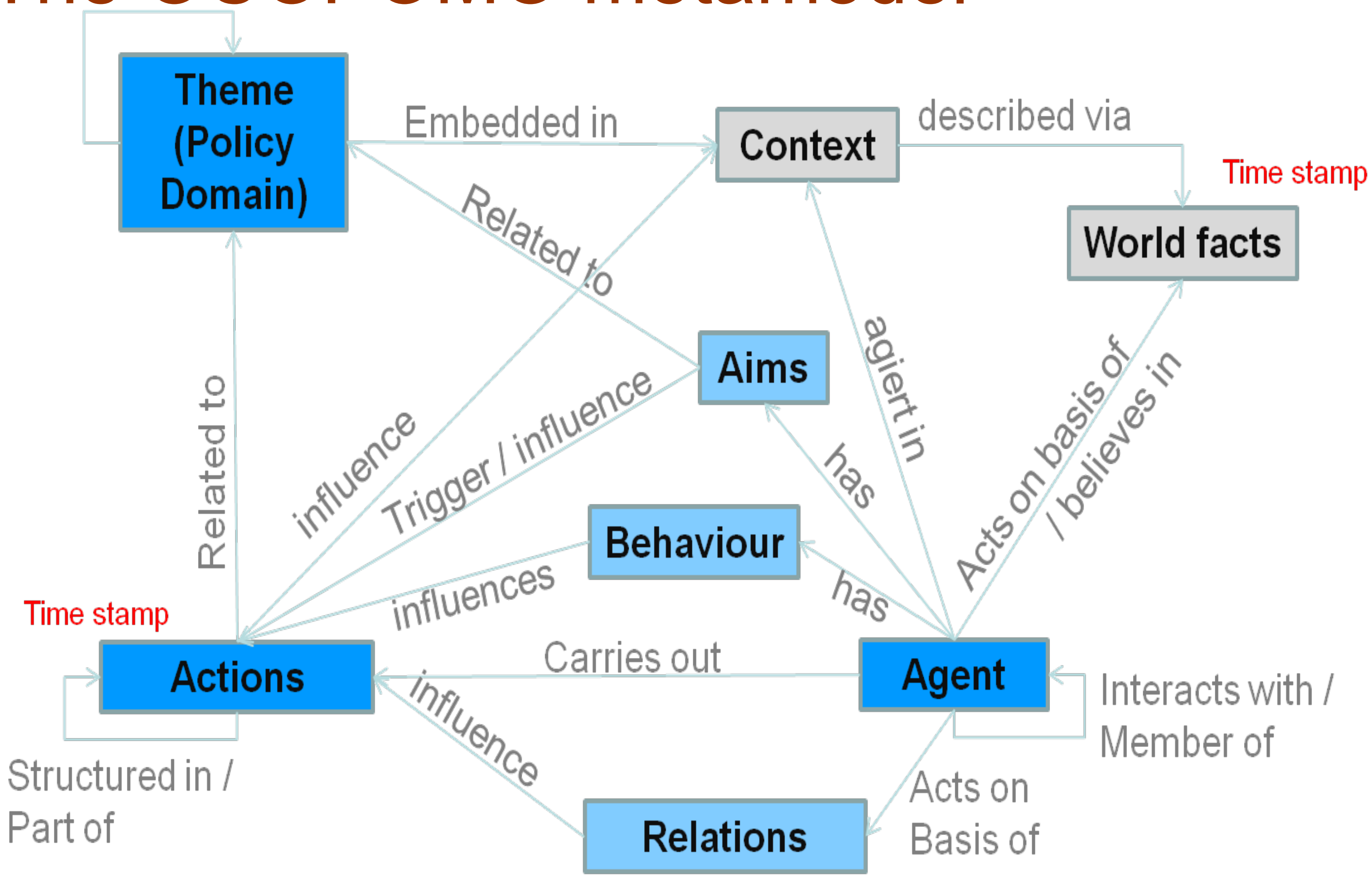
	Rules		If it is true that dairy is profitable then start milk and cheese production.	If (noDanger){
				Purchase(cheeseKettle);
				Install(milkingMachine);
				}

	Actions	delete	(not necessary in this context)	Method uninstall(device){ …}
		install	Install device of a certain type	Method install(device){ …}

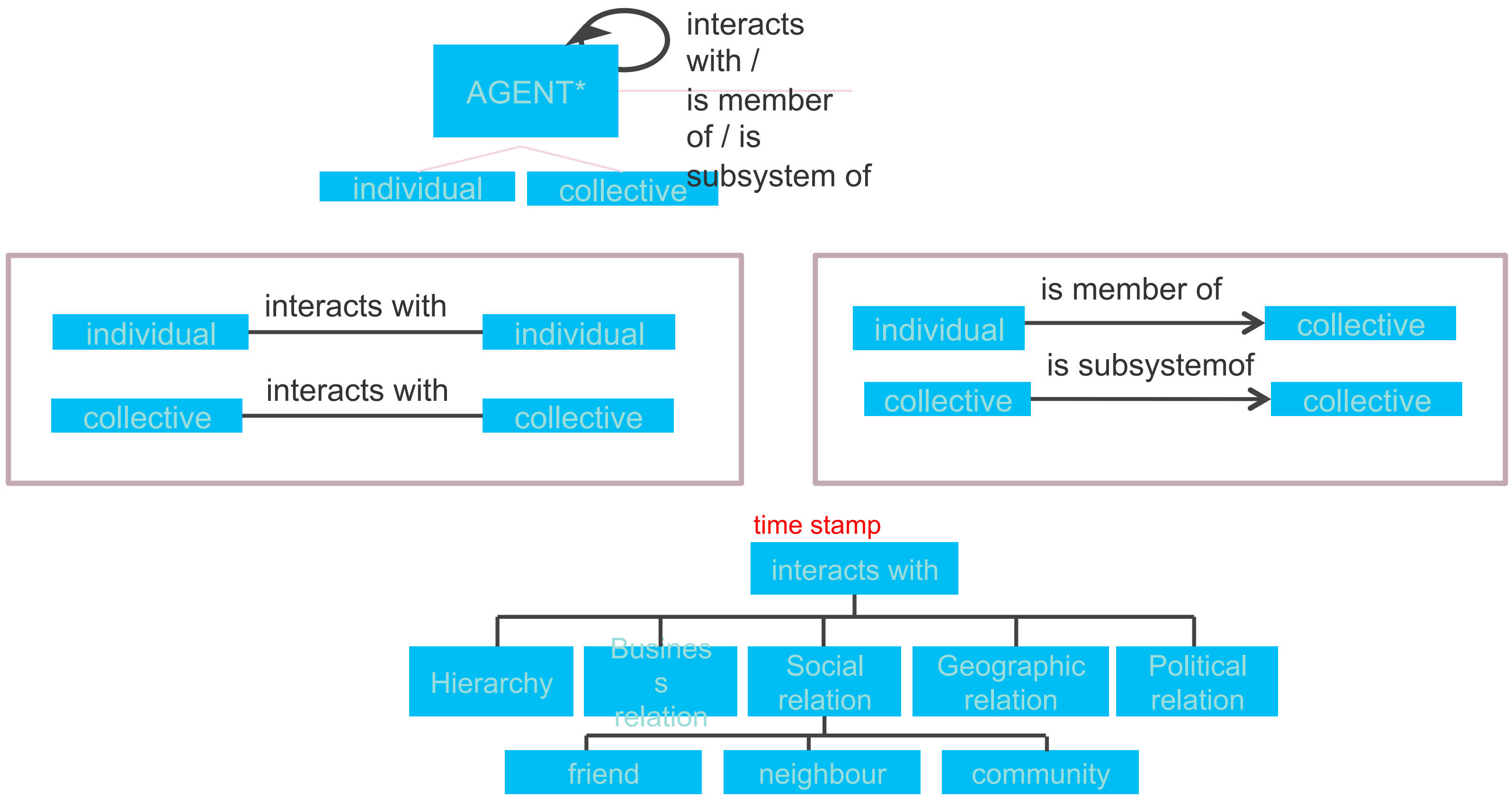
OCOPOMO: so far achieved



The OCOPOMO metamodel



OCOMPOMO: architecture (draft, part 2)



Declarative vs. procedural programming

- Declarative: describe what remains invariant
  - functional: MIMOSE (obsolete), DYNAMO (obsolete), …
  - logical: Prolog, SDML, DRAMS
- Procedural: describe how it works
- Which is more easily understood by non-programmers (stakeholders)?

Forward chaining vs. backward chaining

- Backward chaining starts with a possible future state and finds out whether and under which conditions it can be reached (given transformation rules)
- Forward chaining starts with the description of a current state and of the rules which transform any current state into a future possible state.
- Forward chaining can predict several future possible states.

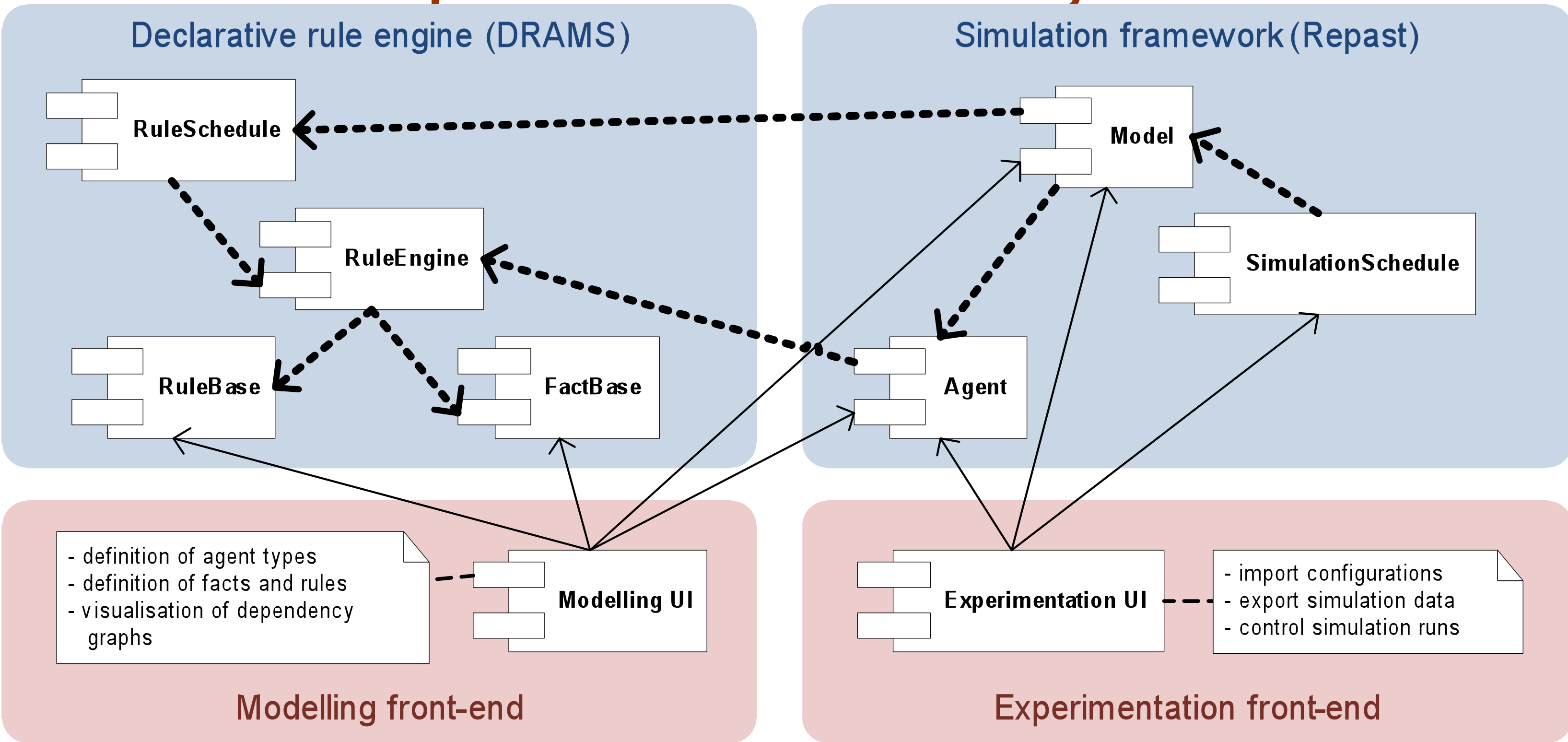
OCOPOMO's declarative rule engine (1)

- consists of
  - fact base: stores information about the state of the world in the form of facts
  - rule base: stores rules representing knowledge how to process certain facts stored in fact bases, consists of a condition part (called left-hand side, LHS) and an action part (called right-hand side, RHS).
  - inference engine: controls the inference process by selecting and processing the rules which can fire on the basis of certain conditions in order to draw conclusions from existing facts.

OCOPOMO's declarative rule engine (2)

- represents rules quite close to natural language description
- represents human approaches to reasoning and problem solving
- Rule engines in agent-based models
  - model agent reasoning via expert system
  - model other agent behaviour with imperative code
- Existing software products
  - use static fact bases which causes performance bottleneck with dynamic simulation data
  - restrict agent autonomy due to shared rule engine

DRAMS/Repast simulation system



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SEVENTH FRAMEWORK PROGRAMME

Distributed forward chaining

- Several agents may have different rule sets (and perhaps even different descriptions of the current state).
- Some of the possible futures one agent predicts may exclude some of the possible futures other agents might predict.
- Agent groups might negotiate possible futures.

DRAMS design

- Distributed rule engines
  - Arbitrary number of agent types with type-specific rule bases and initial fact base configurations
  - Arbitrary number of instances (objects) for each agent type with individual fact bases
  - One global rule engine, containing "world knowledge"
- Communication between agents
  - Reading and writing access to the shared global fact base
  - (Reading and) writing access to other agents' fact bases

How it works

```
processSchedule(time t){
  while new facts are available at time t
  loop
    find all agent instances for which
                   new facts are available;
    foreach agent instance
    loop
      find all rules for which new facts
                   are available at time t;
      foreach rule
      loop
        evaluate LHS;
        if evaluation result==true then
           execute RHS;
                    // e.g. generate new facts
        end if;
      end loop;
    end loop;
  end loop;
}
```

simulation framework

declarative rule engine

simulation framework

Current scenarios

- Kosice Self-Governing Region (Slovakia) Strategy for the use of renewable energy resources
- Campania Region (Italy) Policy decision support on the best regional allocation of EU

The current economic and financial crisis, our inability to predict dramatic changes in the economy and society, and our ease in ignoring warnings are all factors that shed light on the need for

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SEVENTH FRAMEWORK PROGRAMME

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- DRAMS has been developed in OCOPOMO mainly by Ulf Lotzmann.

- References:

  - Ulf Lotzmann, Ruth Meyer 2011: DRAMS – a declarative rule-based agent modelling system, in: Tadeusz Burczynski, Joanna Kolodziej, Aleksander Byrski, Marco Carvalho, eds.: Proceedings 25th European Conference on Modelling and Simulation, Krakov: European Council for Modelling and Simulation, pp. 77—83
  - Melanie Bicking, Klaus G. Troitzsch, Maria Wimmer 2010: Regulatory Impact Assessment: Modelling and Simulation to Facilitate Policy Choices, in: Andreas Ernst, Silke Kuhn, eds.: Proceedings of the 3rd World Congress on Social Simulation WCSS2010 (CD-ROM). Kassel, Germany: Center for Environmental Systems Research, University of Kassel
  - Maria A. Wimmer, Melanie Bicking, 2011: Collaborative Scenario Building for Policy Modelling. In Proceedings of tGov Workshop '11 (tGOV11), Brunel University, West London (to appear)