Simulation and modelling social systems

29.5.2017

Simulation and modelling

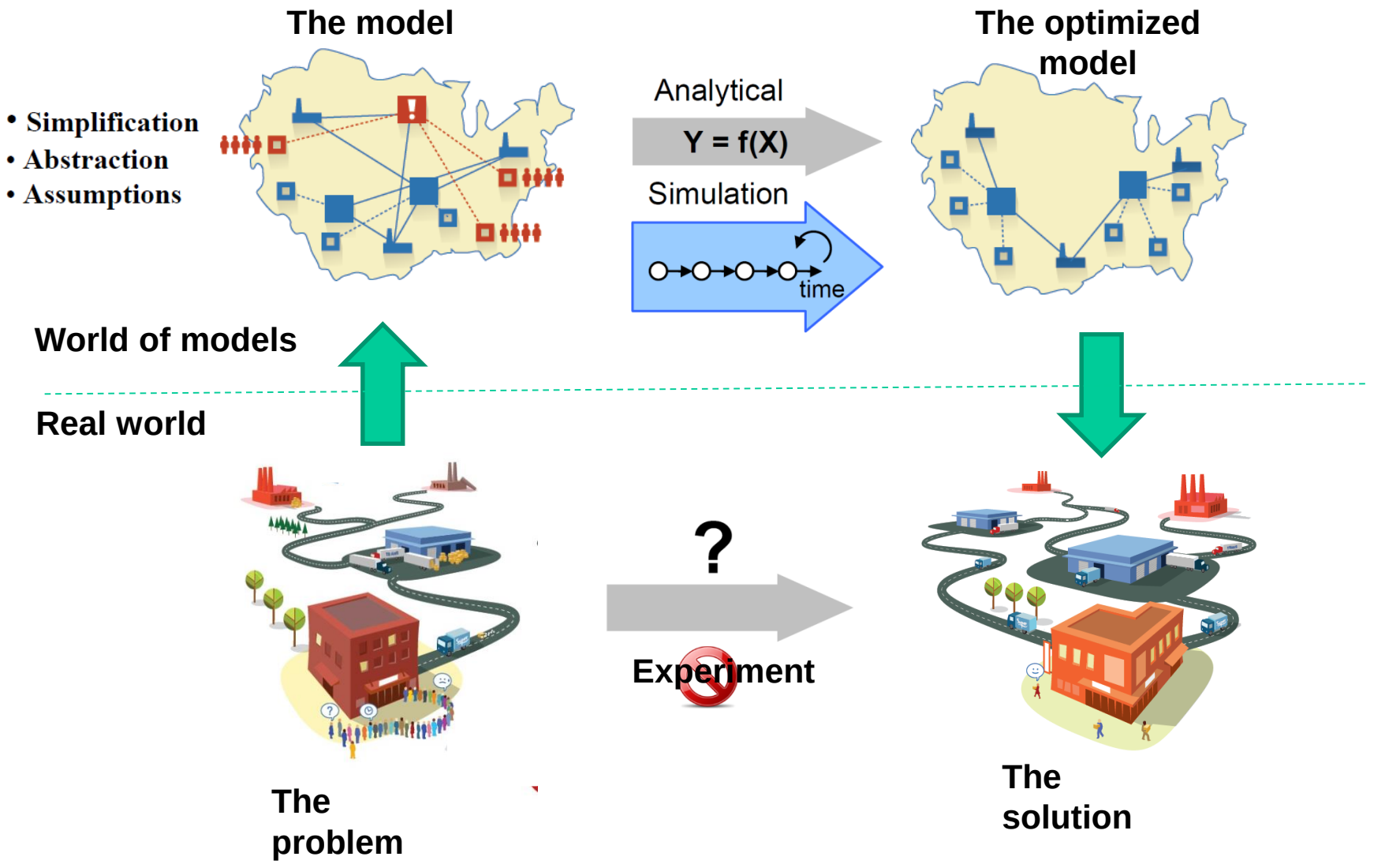
Simulation and modelling – very broad term – methods and applications to imitate or mimic real systems, usually via computer.

Applies in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games.

A soldier in a heavy-wheeled-vehicle driver simulator

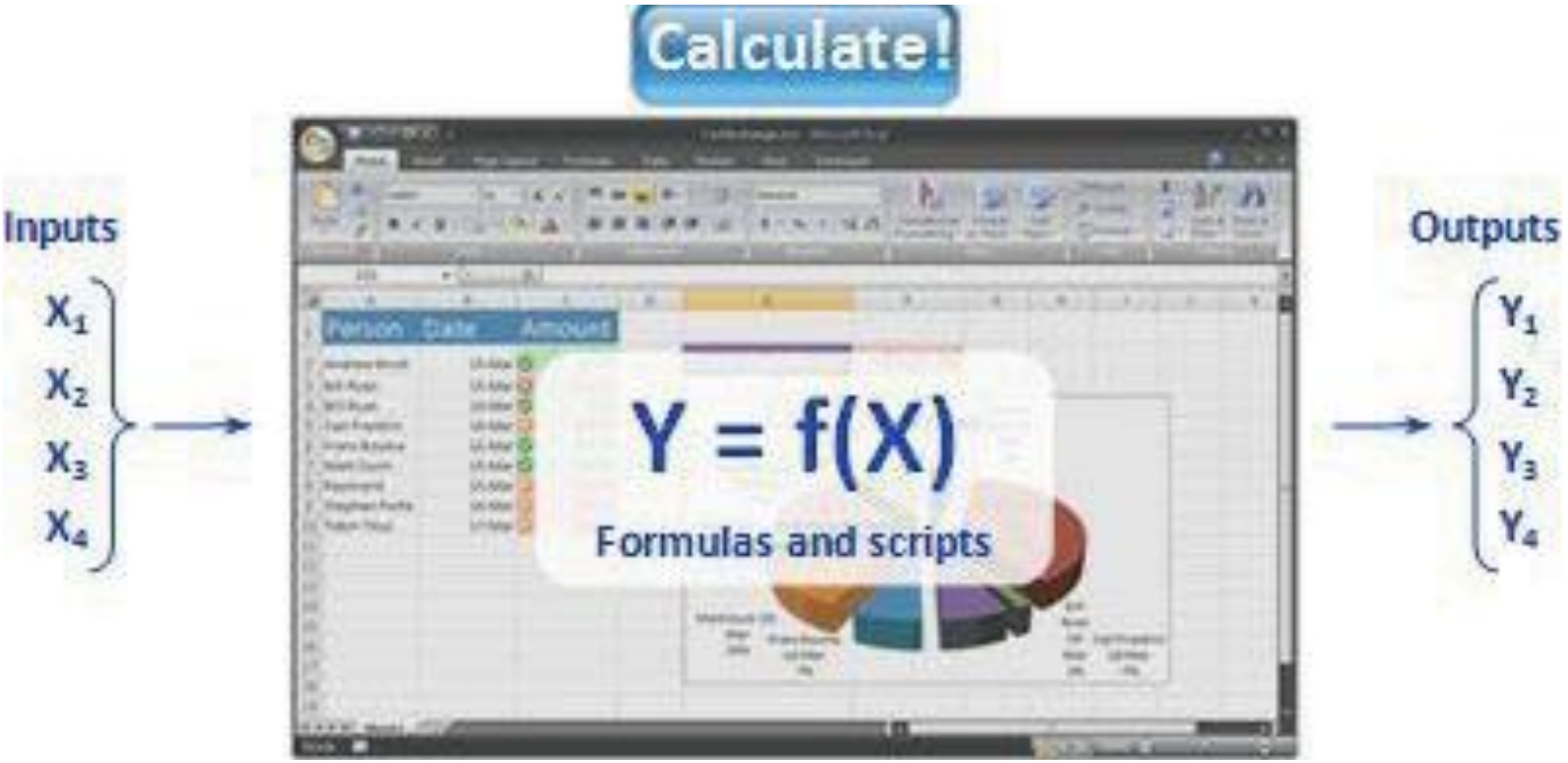
Wooden mechanical horse simulator during WW1

From real world to the world of models



Borshchev (2013): The big book of simulation and modelling

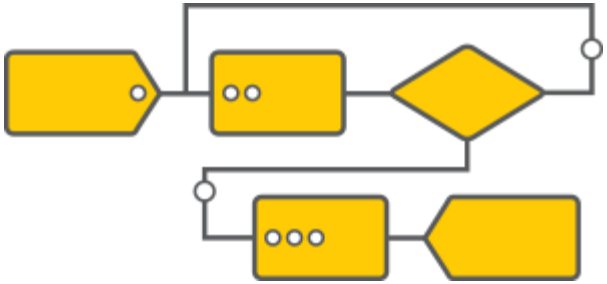
Analytical model



Simulation model

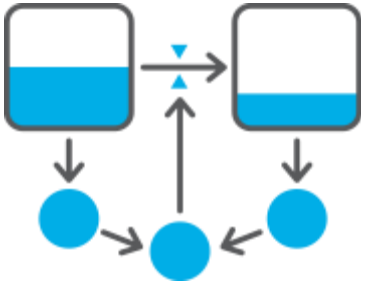
Three different methods for simulation and modelling

In simulation modeling, a *method* is a framework we use to map a real world system to its model. You can think of a method as a type of language or a sort of "terms and conditions" for model building.



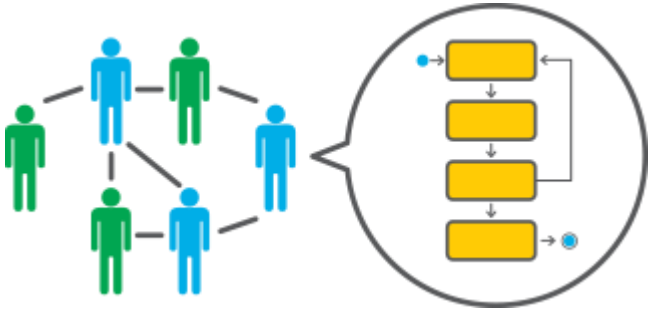
Process-centric (discrete event)

1960s



System Dynamics

1950s



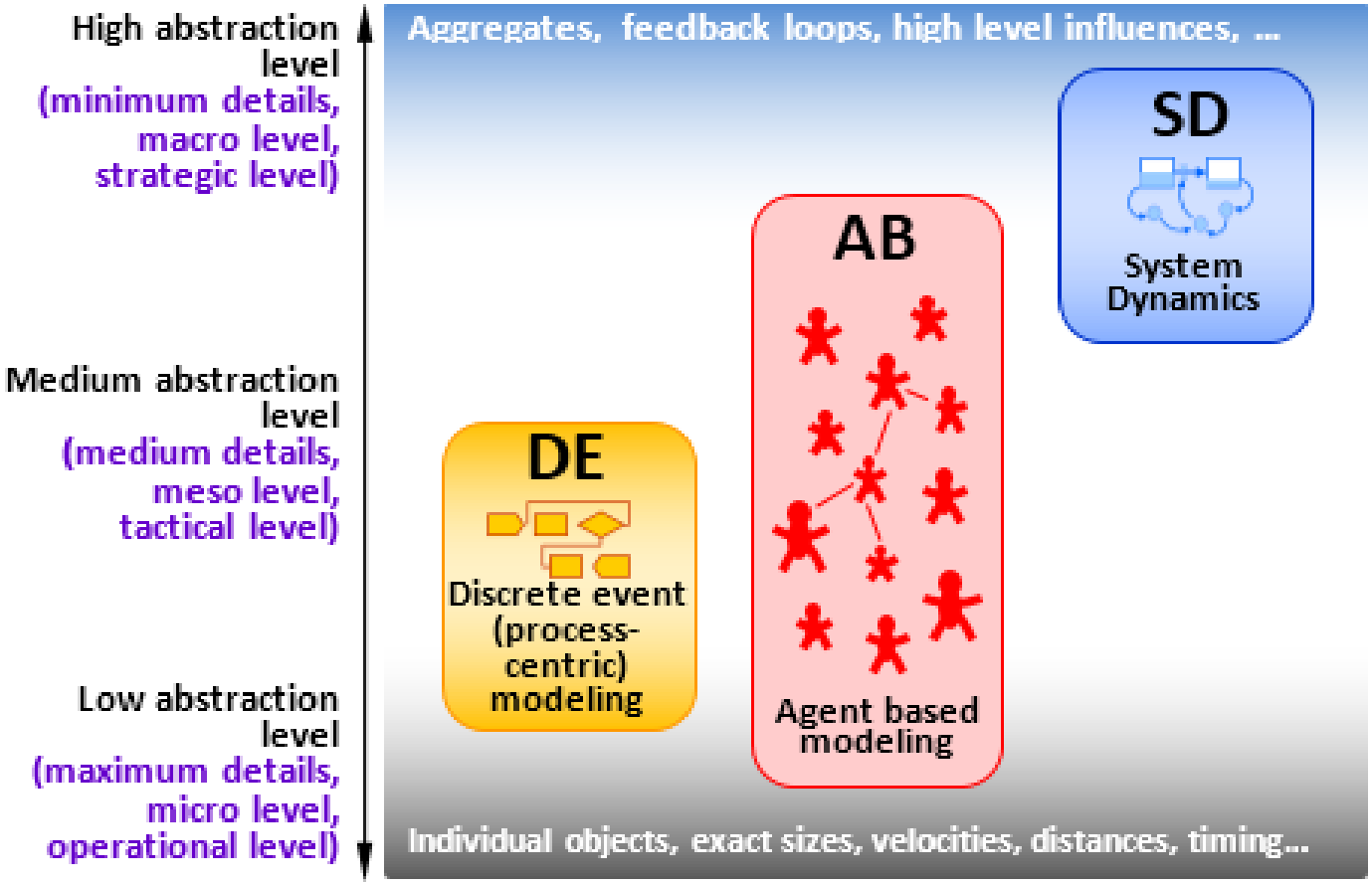
Agent Based Modeling

1990s

In simulation modeling, we have four simulation languages:

- **Stock & Flow Diagrams**
- **State charts**
- **Action charts**
- **Process flowcharts**

Each method serves a specific range of abstraction levels



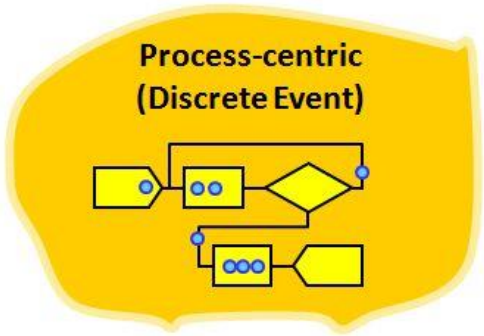
Discrete event modelling

Discrete event modeling requires a modeler to think about the system that he or she wants to model as a process - a sequence of operations that agents perform.

Typical output expected from a discrete event model includes:

- **Utilization of resources**
- **Time spent in the system or its part by an agent**
- **Waiting times**
- **Queue lengths**
- **System throughput**
- **Bottlenecks**

Anylogic Pedestradian libraries to model people movement in service processes that are located in a specific space (i.e. hospital / airport /...)



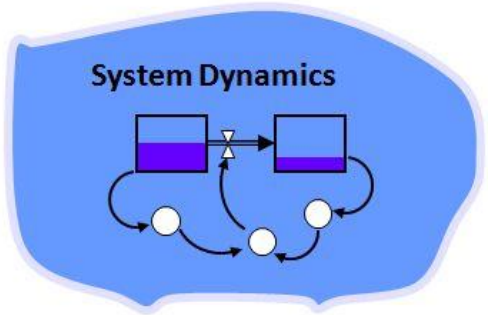
System dynamics

System dynamics requires a modeler to think about the system that he or she wants to model as a number of interacting feedback loops and stocks and relevant flows affecting them.

System dynamics suggests you:

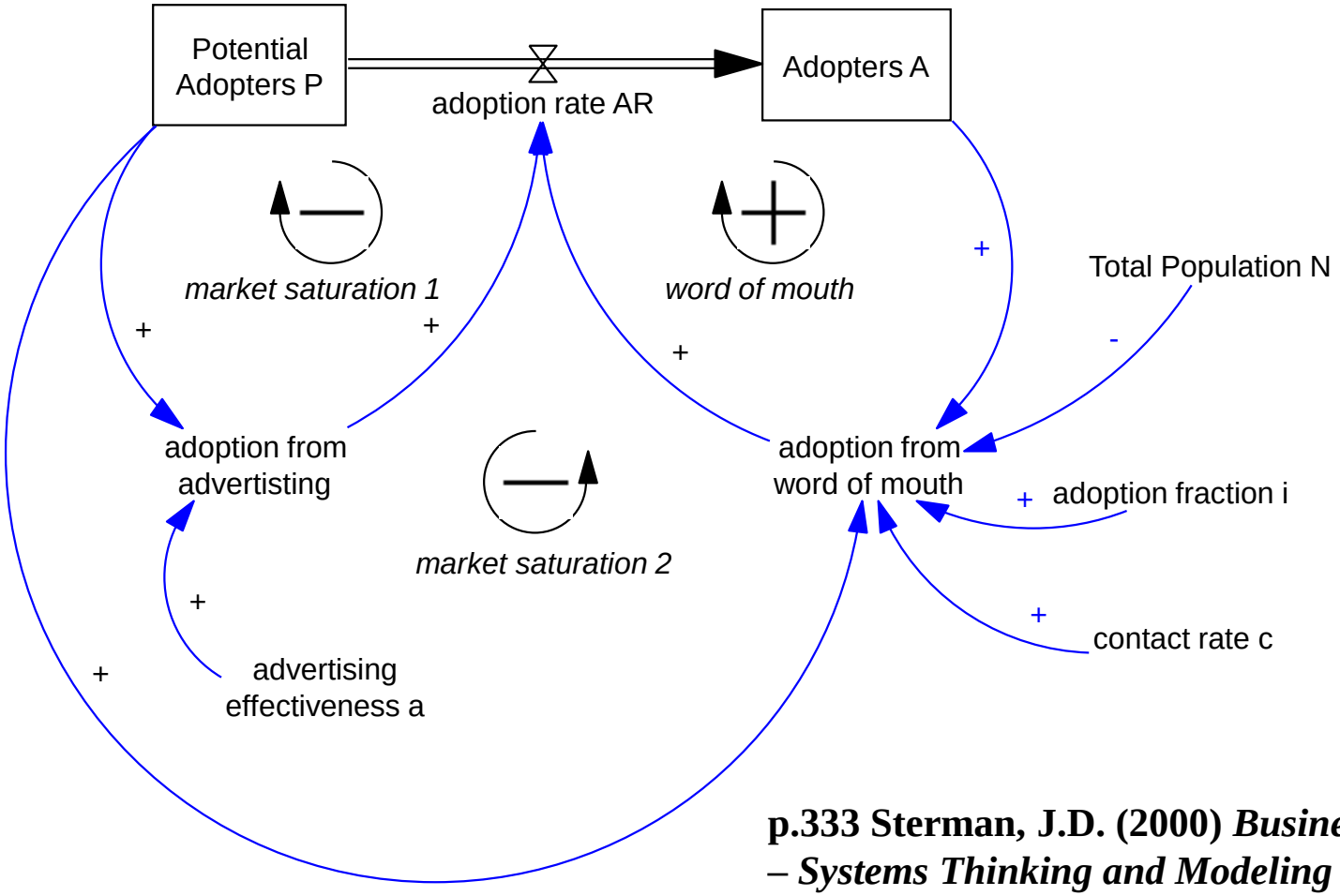
- **Model the system as a causally closed structure that defines its own behavior.**
- **Discover the system's feedback loops (circular causality) balancing or reinforcing. Feedback loops are the heart of system dynamics.**
- **Identify stocks (accumulations) and flows that affect them.**

Today, system dynamics is typically used in long-term, strategic models, and it assumes high levels of object aggregation.



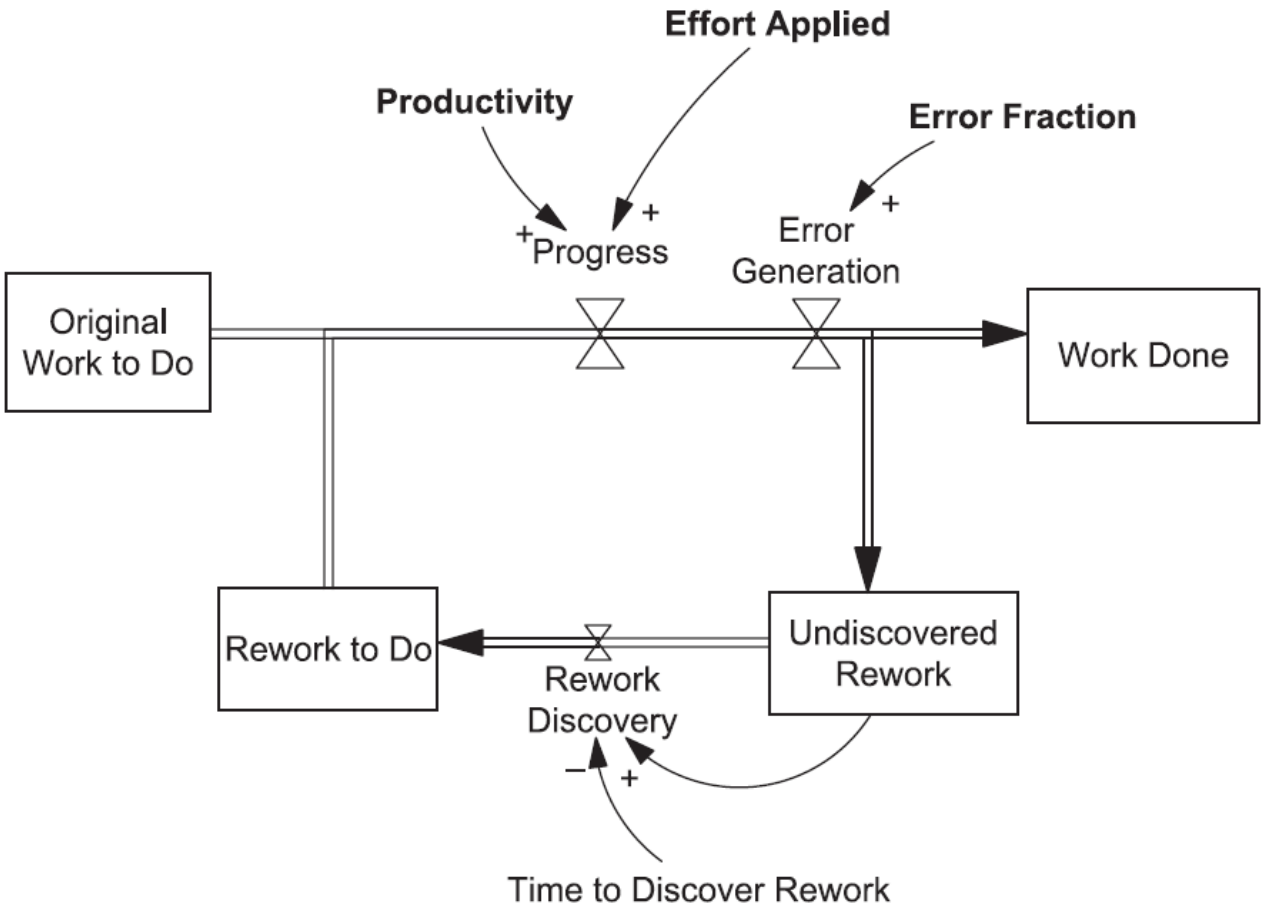
System dynamic - diffusion model

example of a simple model with stocks, flow and feedback loops

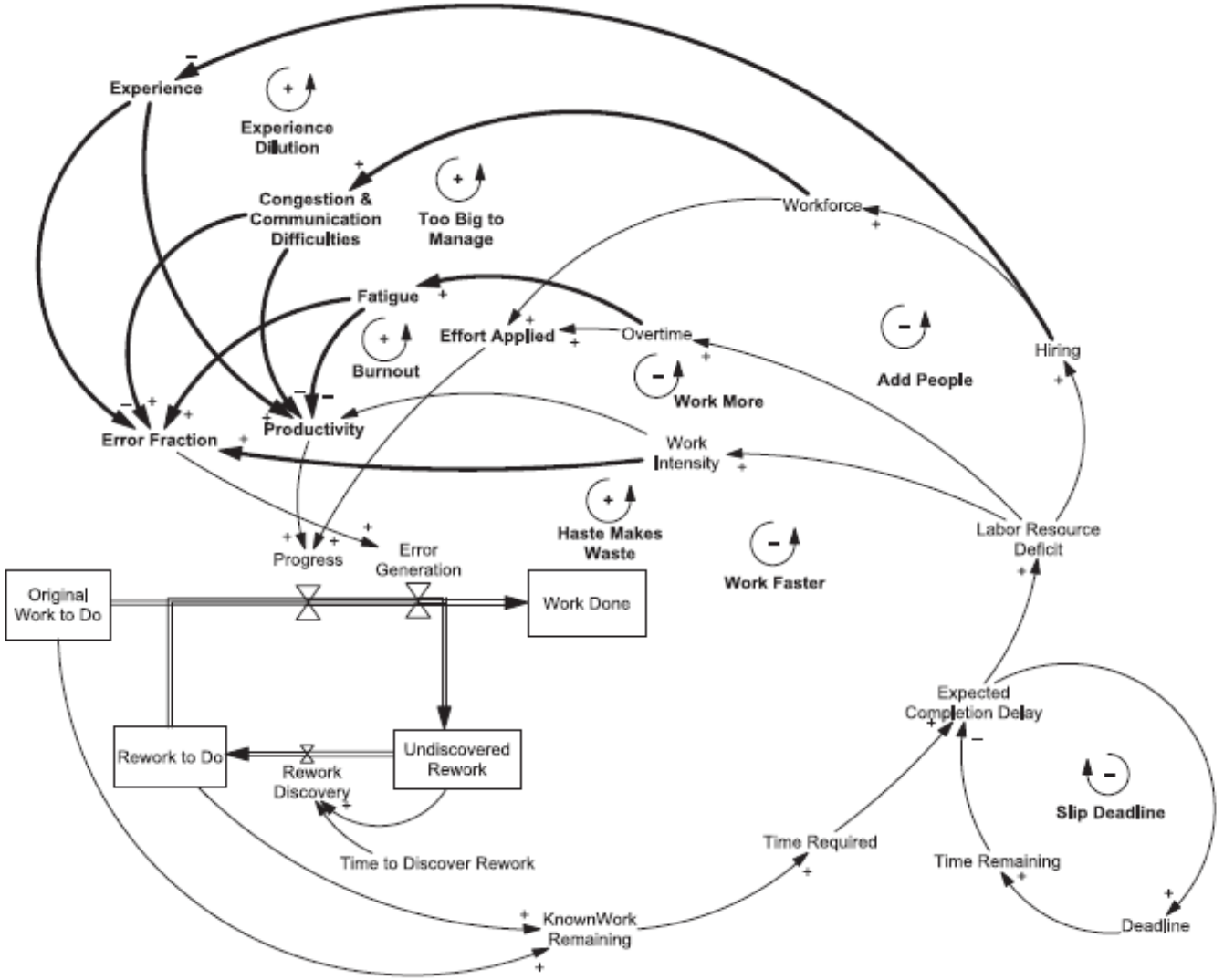


p.333 Sterman, J.D. (2000) *Business Dynamics – Systems Thinking and Modeling for a Complex World*, Irwin McGraw-Hill, Boston

Modellin project - rework cycle



Modelling projects – schedule performance



The effect of rework and controlling feedback loops for project schedule performance (Lyneis and Ford 2007)

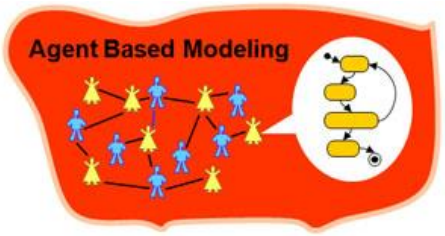
Agent-based modelling

The main feature of agent based models: they are essentially *decentralized*.

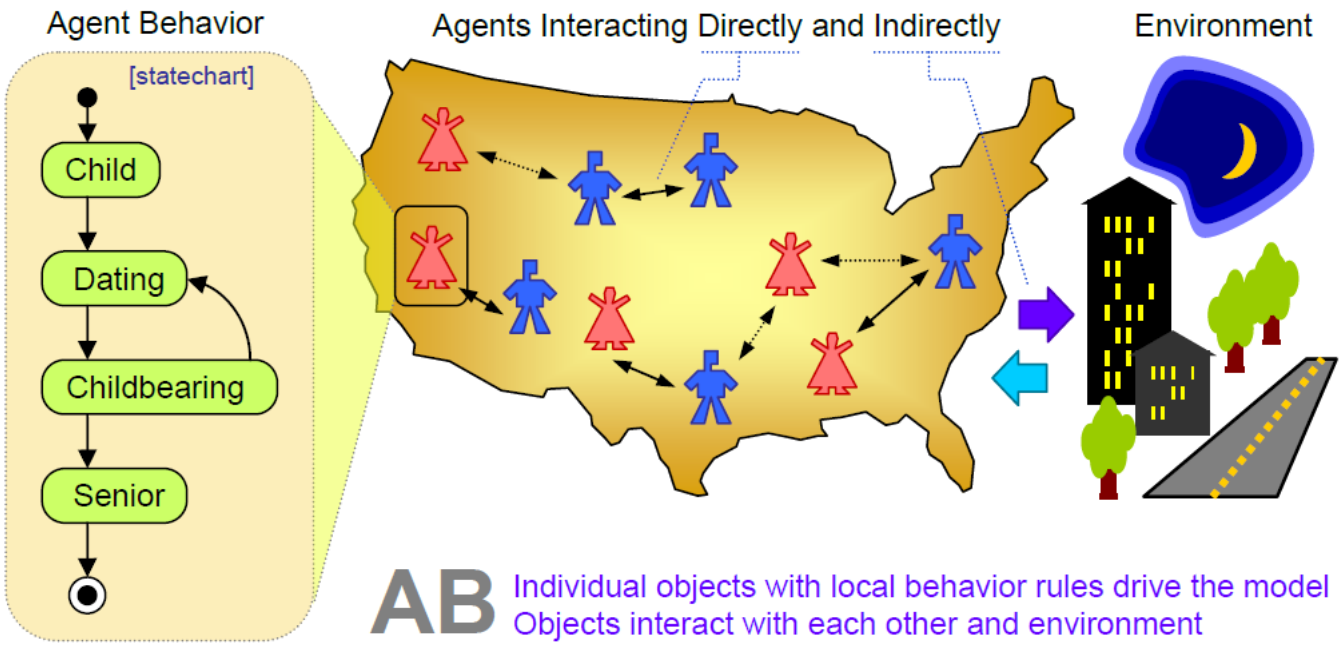
AB modeling is called bottom-up modeling. The modeler defines behavior at individual level, and the global behavior emerges as a result of many (tens, hundreds, thousands, millions) individuals, each following its own behavior rules, living together in some environment and communicating with each other and with the environment.

When to use agent-based modelling

- Medium or large number of agents
- Local and potentially complex interactions
- Temporal aspect
- Adaptative agents



Agent-based model of country population dynamics



What is agent?

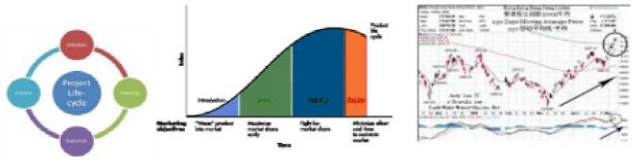
An agent is …

- **A discrete entity with its own goals and behaviors**
- **Autonomous, with a capability to adapt and modify its behaviors**

People in different roles:
consumers, citizens, employees, patients, doctors, clients, soldiers, …

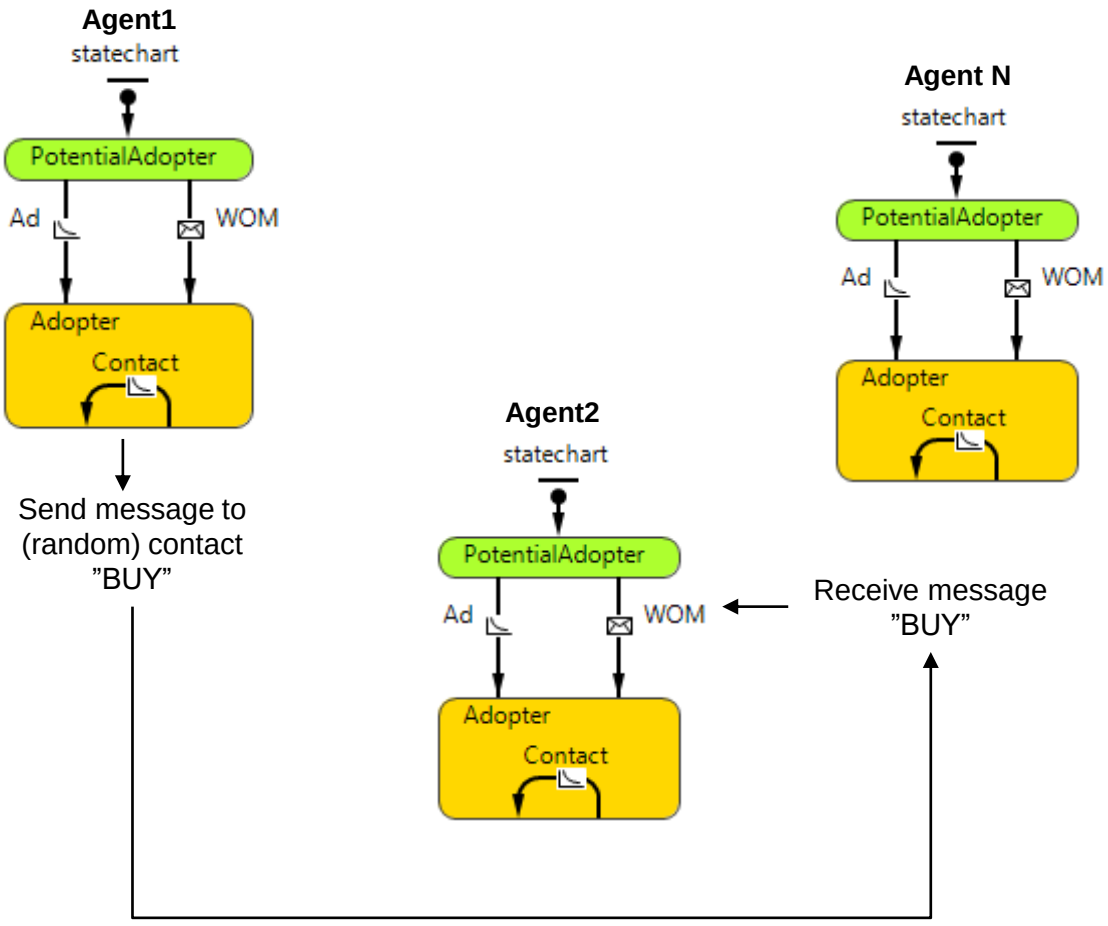
Equipment, vehicles:
trucks, cars, cranes, aircrafts, rail cars, machines, …

Non-material things:
projects, products, innovations, ideas, investments …



Organizations:
companies, political parties, countries, …

Diffusion model using agent-based modelling



N = Population size

Ad = Advertizing effectiveness

Contact = Contact rate

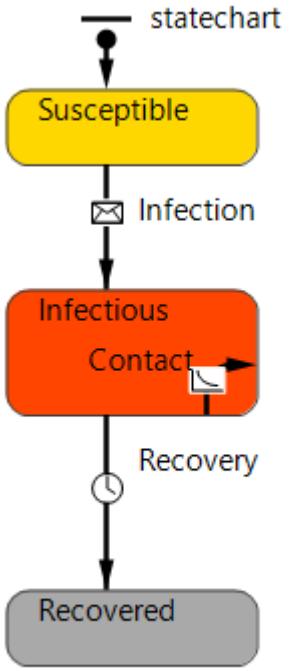
WOM = Word of mouth

SIR model

A simple model that describes the spread of disease or infection. Can be found from the example models as a system dynamics or an agent based model.

Main features:

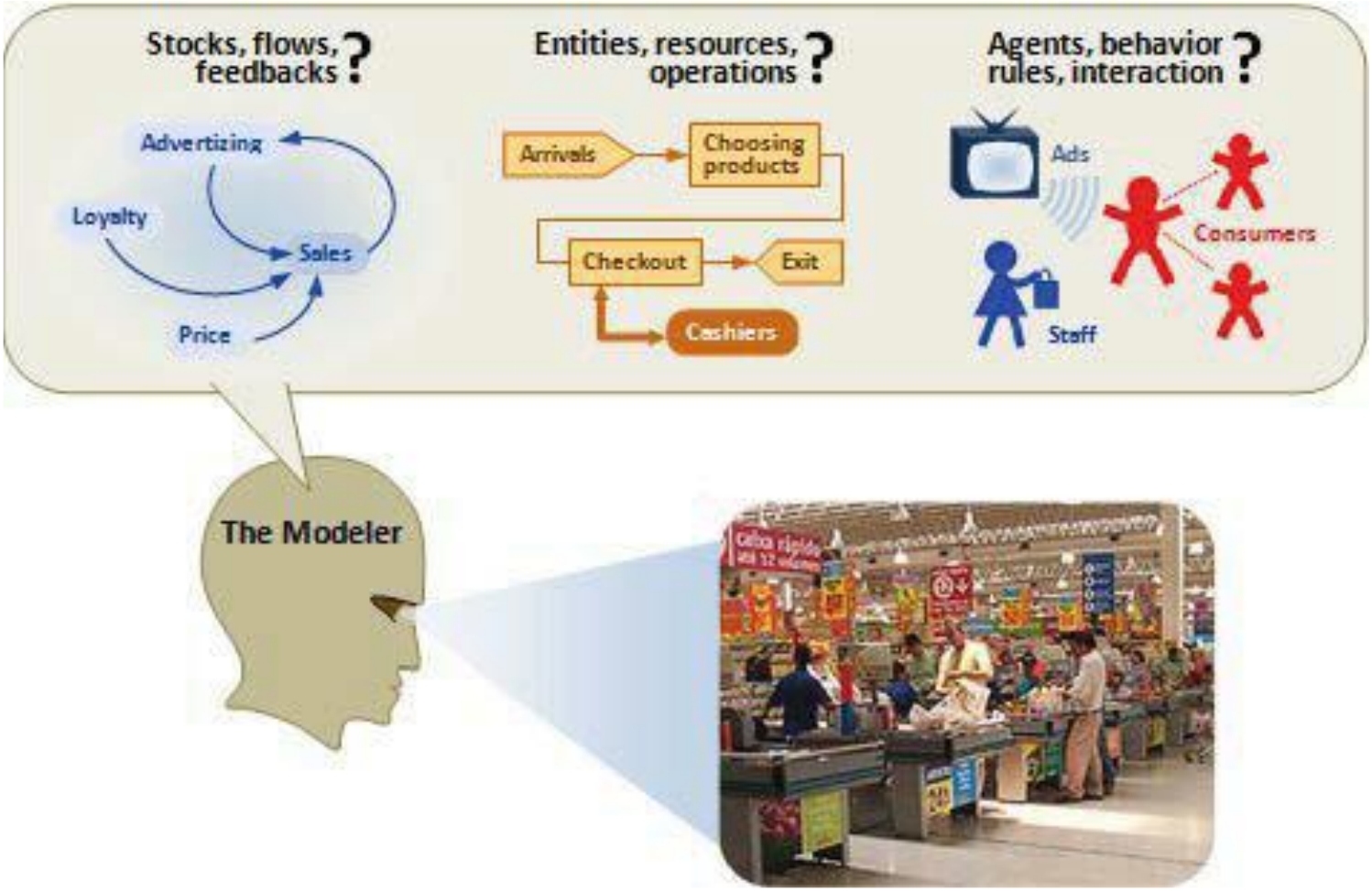
- Susceptible (individual)
  - Healthy
  - Can be infected
- Infected
  - Will take time to recover
  - In the meanwhile, can infect others
- Recovered
  - After some time the infection will pass



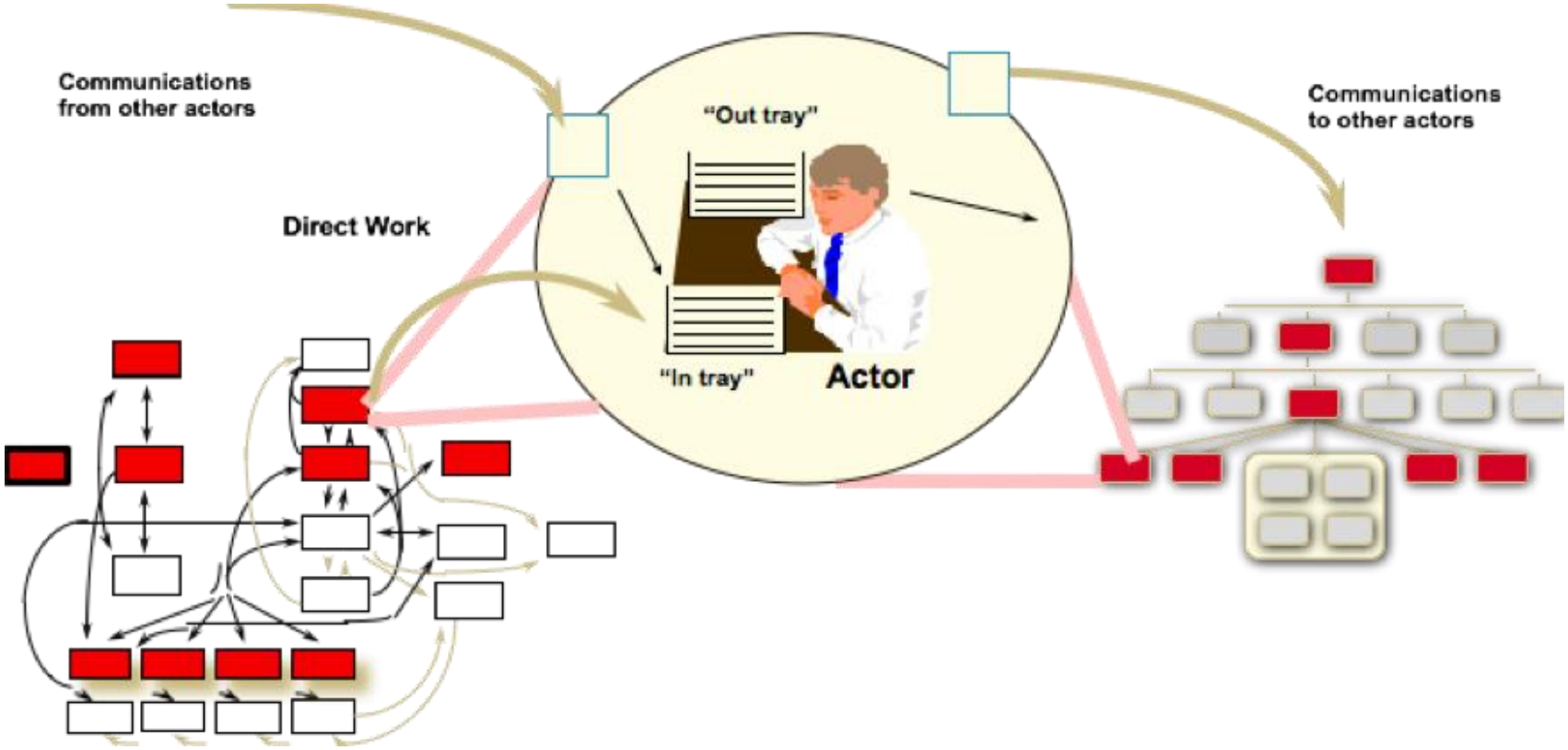
In short:

"How can we model this as an agent based system?"

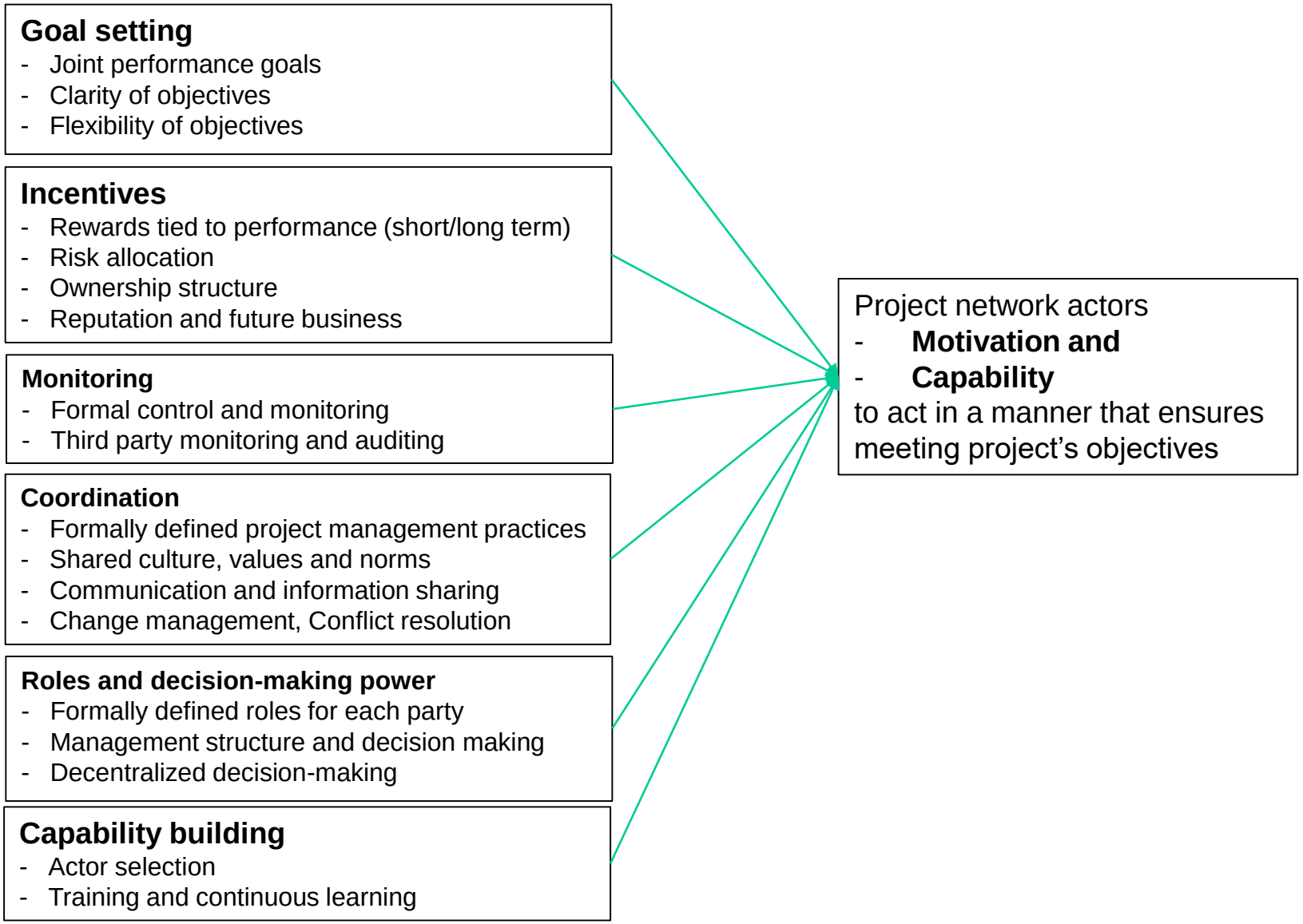
Choosing the modelling method



VTD model of actor information processing (Stanford University)



Governance in project networks



How to simulate governance mechanisms?

From a perspective of agent-based modelling we need to describe both project task network and (inter-organizational) project network, and define processes how project work is allocated to actors.

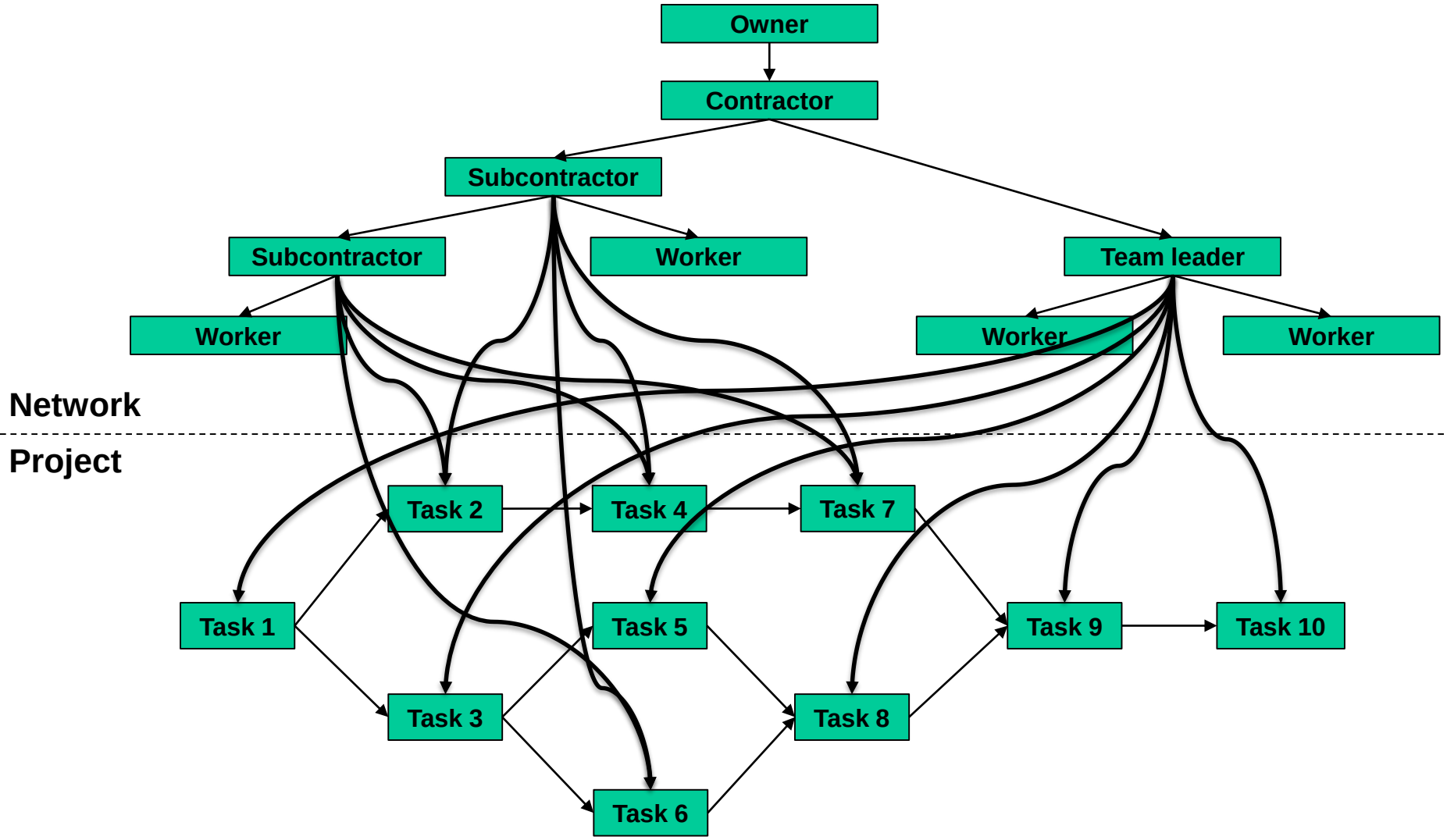
Task network:

- What are the tasks specific attributes and how are tasks related?
- What is the state of a task and decision making rules / processes that change the state?
- How is work related to tasks allocated to actors?

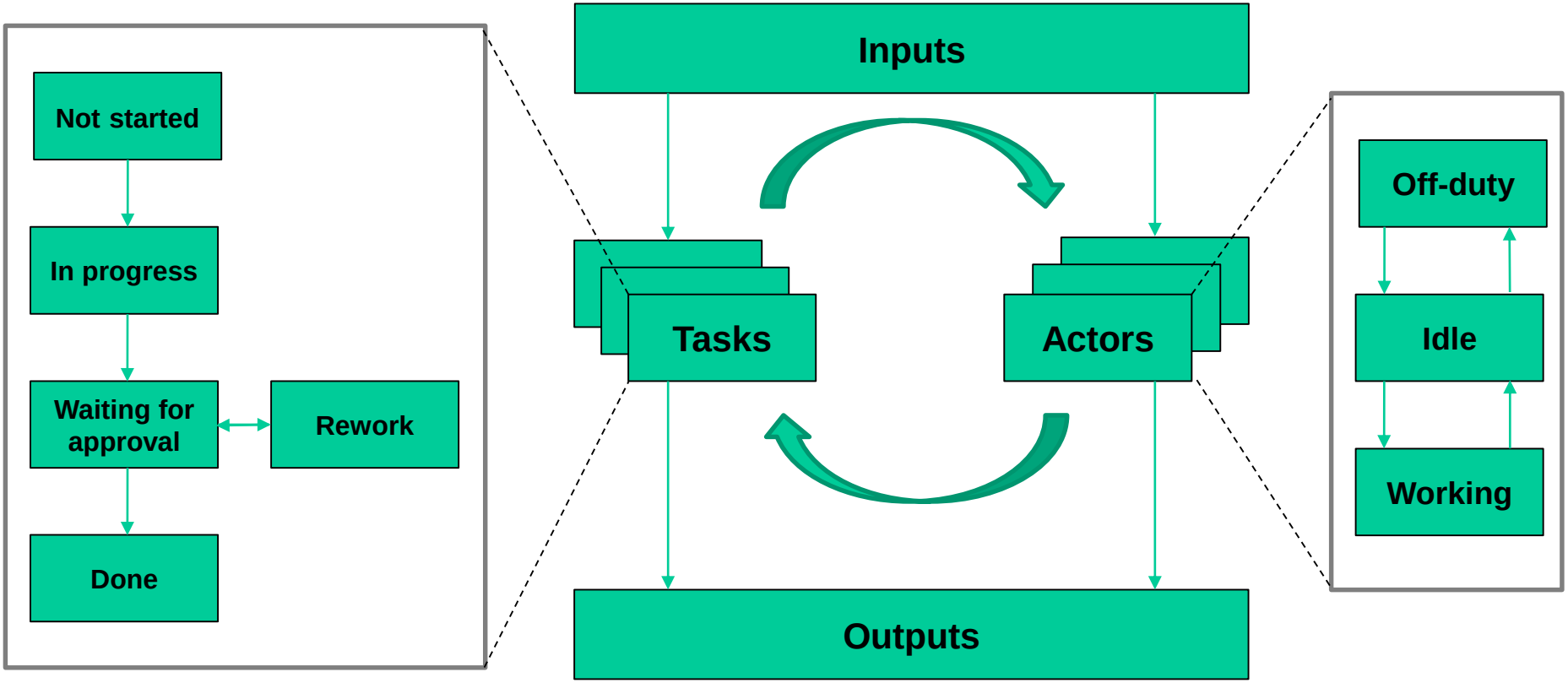
Actor network:

- What are actors specific attributes and when/how do they change?
- What is a state of each actor in the project network (idle, working, meetings, etc…)?
- What are the decision making rules that change the state of an actor or to which specific work they allocate their time?
- How are actors related to each other? How do those relationships change?
- How communicate actors with each other? What do they share? What do they know about other actors or environments (project status)?

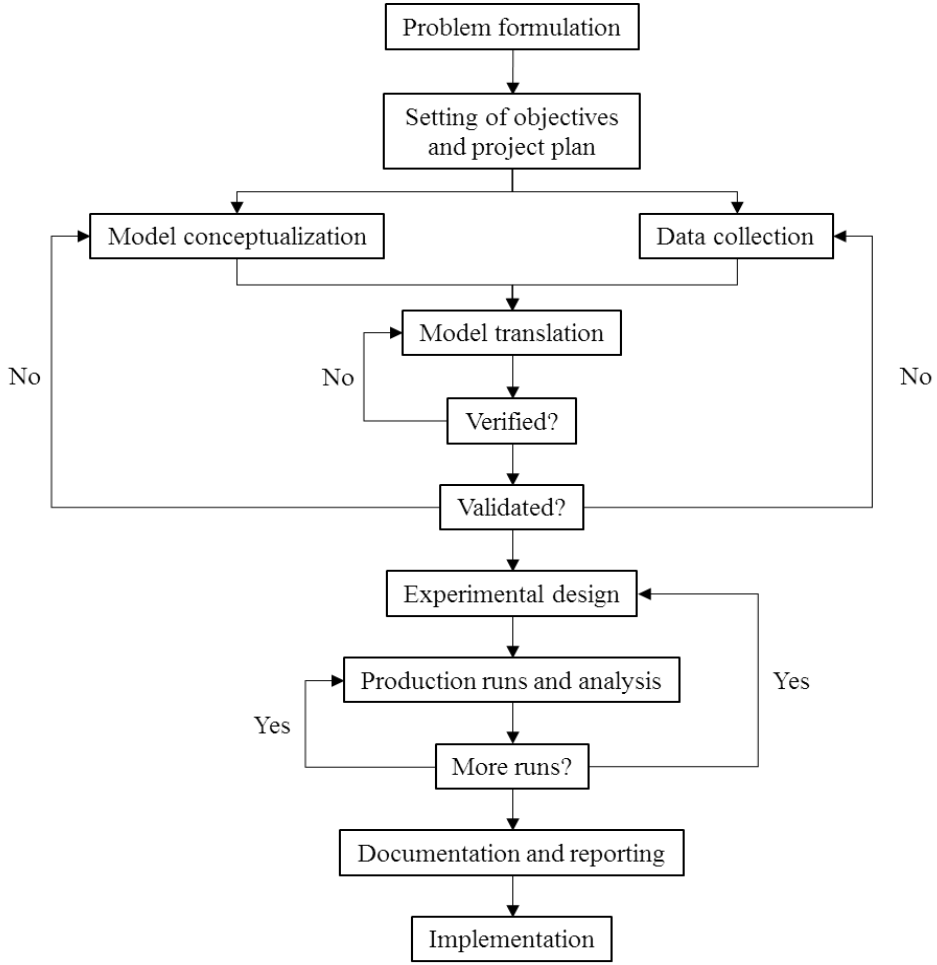
Actor network and task network



Flow of the model



Process for simulation and modelling study



Banks et al. (2010): Discrete event system simulation

Conceptual model

- **The conceptual** model is a non-software specific description of the computer simulation model, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model.
  - Objectives: the purpose of the model/project and requirements derived from objectives (such as flexibility, visualization,…)
  - Inputs (or experimental factors) that can be altered to outputs (or responses) that reports results from a run of the simulation model
  - Content of the model: components that are represented and their interactions based on a) model boundary, b) the level of detail
  - Assumptions that are made: uncertainties and beliefs about the real world being modelled
  - Simplifications are incorporated in the model to enable more rapid model development and use, and to improve transparency

Keep the model simple!

Simple models…

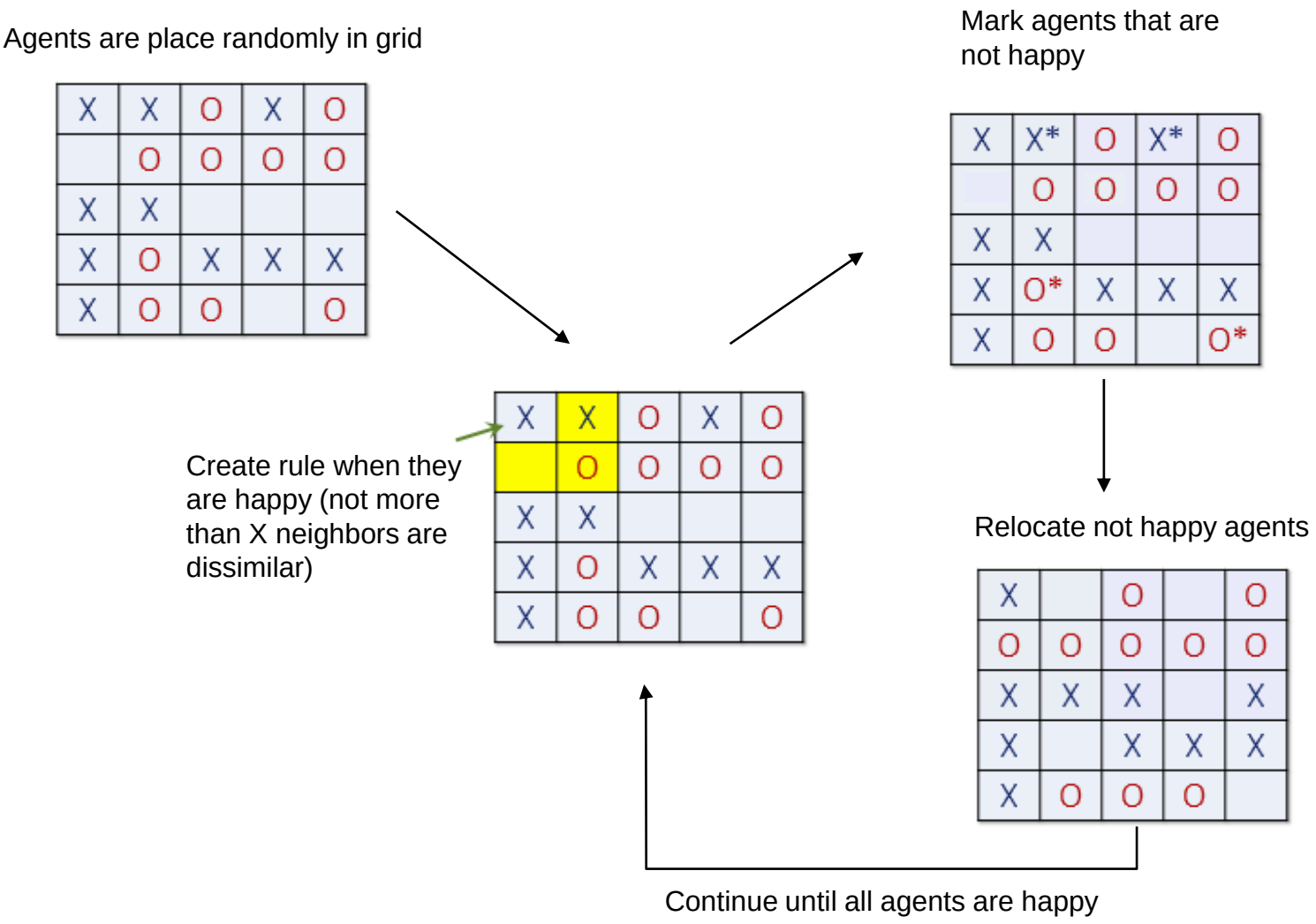
- Can be developed faster
- Are more flexible
- Require less data
- Run faster
- Transparent (content of the model is easier to understand)
- Results are easier to interpret

“perfection is achieved, not when there is nothing left to add, but when there is nothing left to take away” (Antoine de Saint Exupery)

Example: conceptual model of segregation

- Objectives: the purpose of the model is to provide a simple visualization to teach how segregation appears over time when people have even modest tendency to stay close to similar people. The model should be as simple as possible in simple to create and allow more features to be added later.
- Inputs: tendency to move if surrounded by dissimilar people, number of people in a specific area
- Outputs: number of people that are happy (surrounded by similar people)
- Content of the model: closed area or landscape where people live, people (yellow and red), rules how they decided to move to different location (#of neighbours that have to be dissimilar), random move to any free location
- Assumptions that are made: all persons are similar except one attribute (yellow/red), all locations in the model are similar and anybody can move to free location, there is no cost to move, etc…

Exercise: segregation model



References

- Bosshchev A., (2013). The big book of simulation modelling: multimethod modeling with Anylogic 6.
- Borshchev A., Filippov A. (2004) . From System Dynamics and Discrete Event to Practical Agent Based Modeling: Reasons, Techniques, Tools. The 22nd International Conference of the System Dynamics Society, July 25 - 29, 2004, Oxford, England
- Davis J., Eisenhardt K., Bingham C. (2007). Developing theory through simulation methods. Academy of Management Review 32(2): 480-499
- Harrison R., Carroll G., Carley K. (2007). Simulation modeling in organizational research. Academy of Management review 32(4):1229-1245
- Langley A. (1999). Strategies for theorizing from process data. Academy of management review. 24(4): 691-710.
- Miller K. (2014). Agent-based modelling and organization studies: A critical realist perspective. Organization studies. 1-22
- Mäki U. (2011). Models and the locus of their truth. Synthese 180(1): 47-63.
- Rand W., Rust R. (2011). Agent-based modeling in marketing: guidelines for rigor. International journal for research in marketing 28(3):167-280.
- Robinson (2008): Conceptual modelling for simulation Part1: Definition and requirements. Journal of the Operational Research Society, 59(3): 278-290
- Van de ven (2007). Engaged scholarship: a guide for organizational and social research. Oxford University Press.