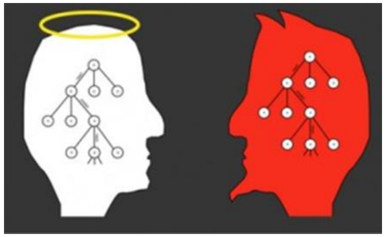

Simulation in a Nutshell

Game Theory meets Object Oriented Simulation
Special Interest Group

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Introduction to Simulation

- System:
  - Collection of parts organised for some purpose
  - Defining a system requires setting boundaries
- Model:
  - Some form of abstract representation of a real system intended to promote understanding of the system it represents.
  - A model is a static representation of the system
- Simulation:
  - The process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and /or evaluating various strategies for the operation of the system

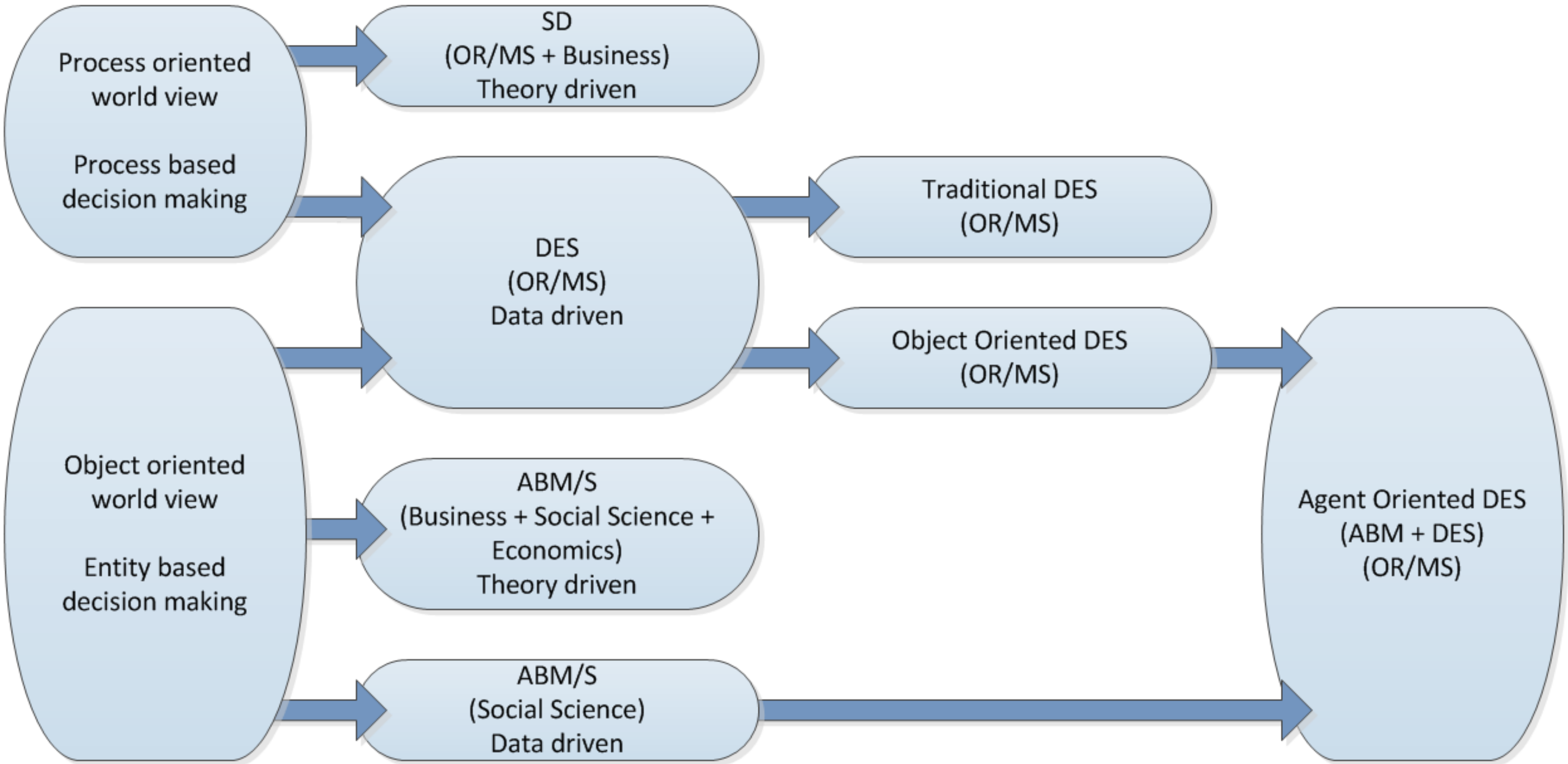
Introduction to Simulation

- What do you use simulation for?
  - To predict system performance
  - To compare alternative system designs
  - To determine the effects of alternative policies on system performance
- Simulation vs. other modelling approaches: Pros and cons?
  - Advantages:
    - Modelling variability; less restrictive assumptions; transparency; creating knowledge and understanding; visualisation, communication, interaction
  - Disadvantages:
    - Expensive; time consuming; data hungry; requires expertise; overconfidence

Introduction to Simulation

- Modelling and simulation paradigms?
  - System Dynamics Modelling (SDM) and Simulation (SDS)
    - Modelling: Causal loop diagrams; stock and flow diagrams
    - Simulation: Deterministic continuous (differential equations)
  - Discrete Event Modelling (DEM) and Simulation (DES)
    - Modelling: Process flow diagrams; activity cycle diagrams
    - Simulation: Stochastic discrete (flow oriented approach)
  - Agent Based Modelling (ABM) and Simulation (ABS)
    - Modelling: UML (class diagrams + state chart diagrams) + Equations
    - Simulation: Stochastic discrete (object oriented approach)
  - Mixed Method Modelling (MMM) and Simulation (MMS)

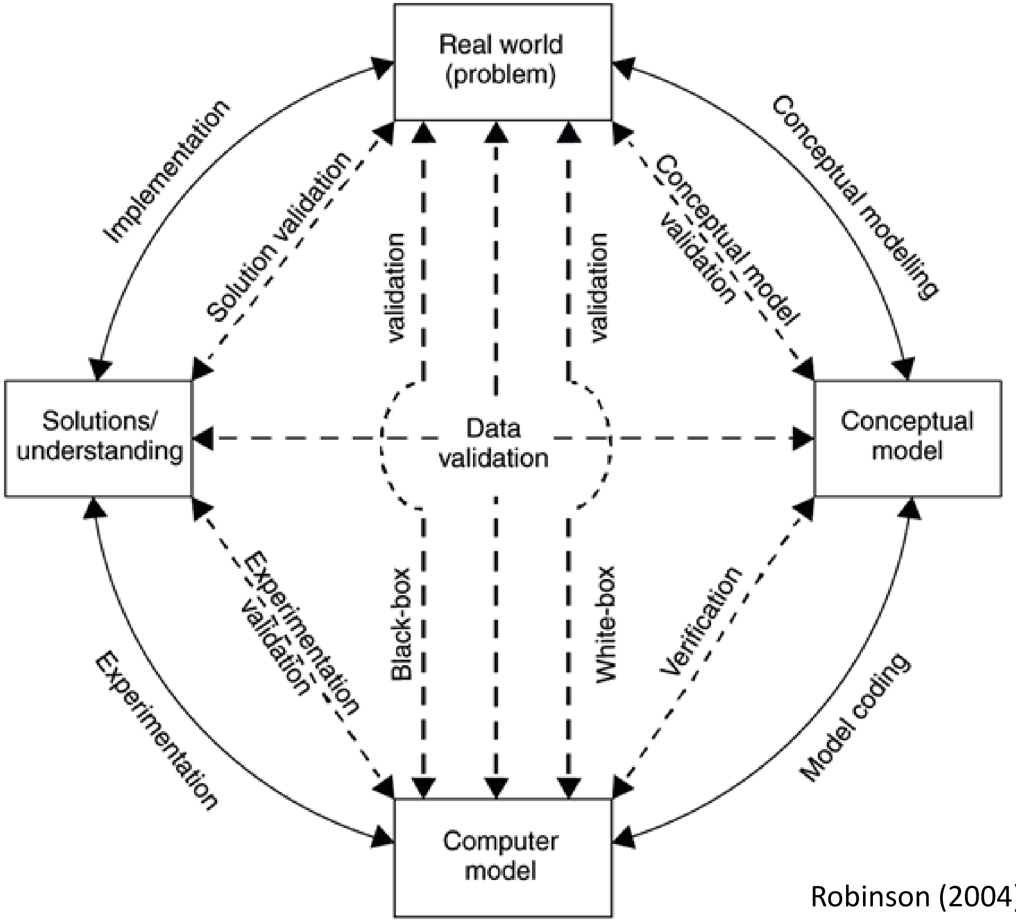
Introduction to Simulation



Data driven: Data for model formulation (in Social Sciences can be quantitative and qualitative); data for model validation
Theory driven: Theories for model formulation; data for model validation

Simulation study life cycle

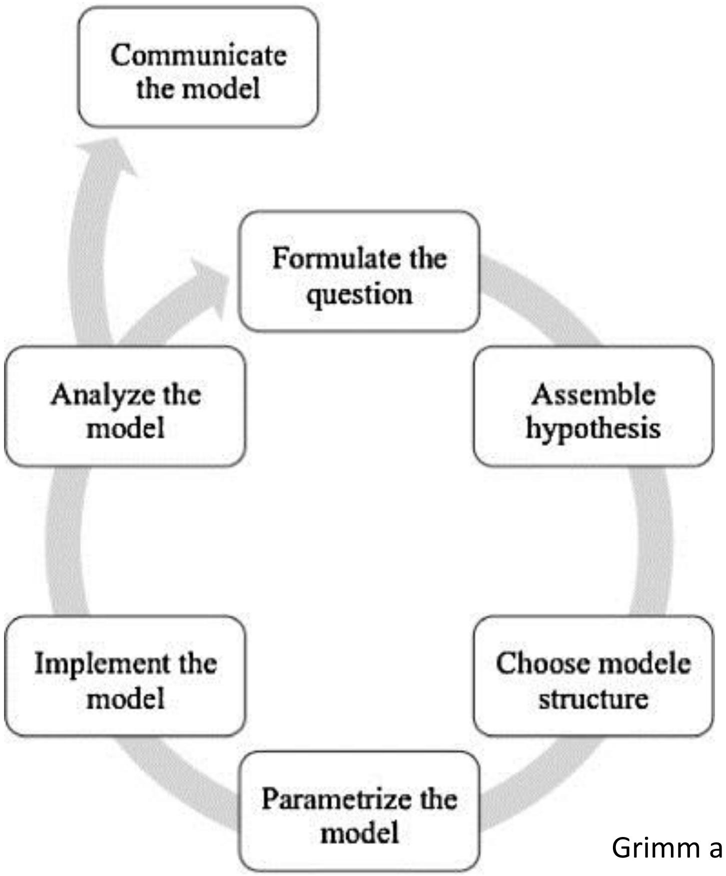
- Data driven:



Robinson (2004)

Simulation study life cycle (theory driven)

- Theory driven:



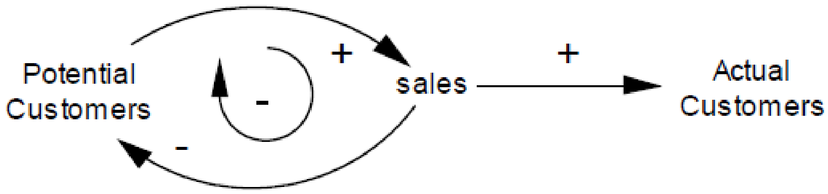
Grimm and Railsback (2005)

Simulation (Modelling) Methods

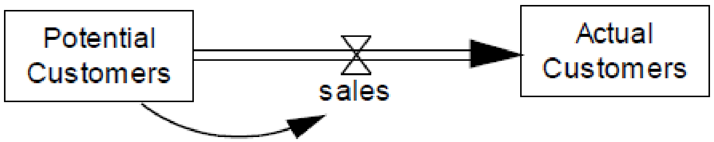
- System Dynamics:
  - System Dynamics (SD) is a methodology and computer simulation modelling technique for framing, understanding, and discussing complex issues and problems.
  - The basis of the methodology is the recognition that the structure of any system is just as important in determining its behaviour as the individual components themselves.
  - It is mostly used in long-term, strategic models and assumes high level of aggregation of the objects being modelled.
  - The range of applications includes business, urban, social, ecological types of systems.

Simulation (Modelling) Methods

- System Dynamics:
  - Example: Advertising for a durable good



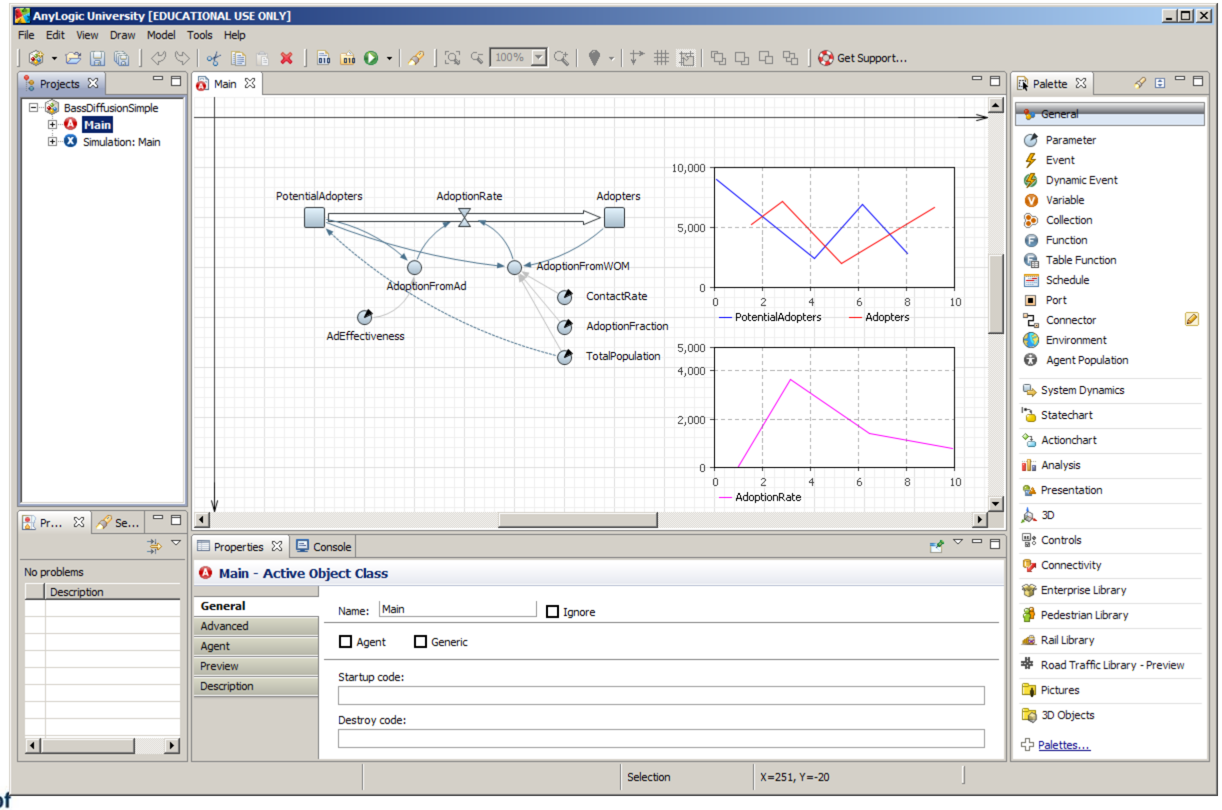
a. Causal loop diagram



b. Stock and flow diagram

Simulation (Modelling) Methods

- System Dynamics:
  - Example: Bass diffusion model



Simulation (Modelling) Methods

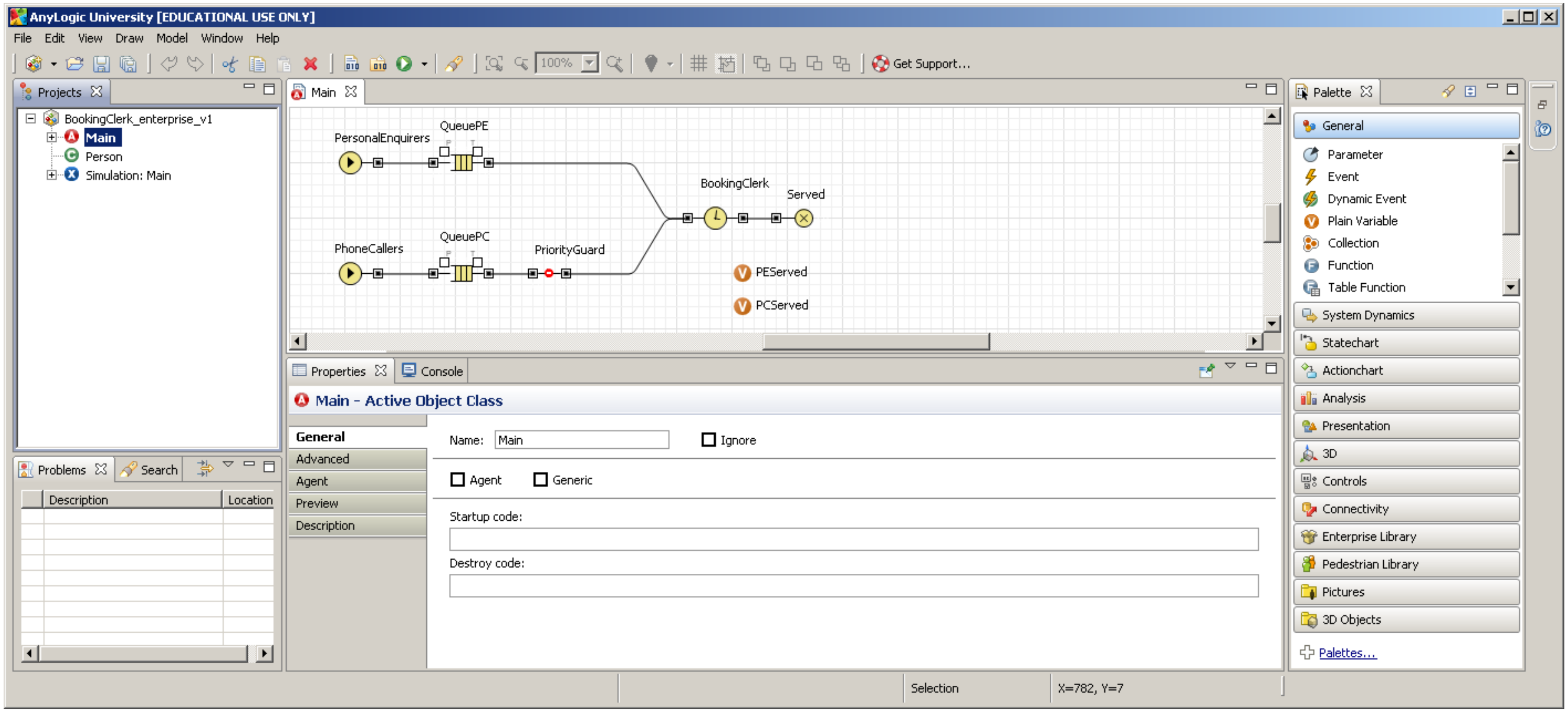
- Discrete Event:
  - Objects of the system
    - **Entities:** Individual system elements whose behaviour is explicitly tracked; organised in classes and sets; distinguishable by attributes
      - **Classes:** Permanent groups of identical or similar entities (e.g. bus passengers)
      - **Sets:** Temporary groups of identical or similar entities (e.g. passengers on a particular bus, passengers waiting in a queue)
      - **Attributes:** Items of information to distinguish between members of a class (e.g. index) or to control the behaviour of an entity (e.g. entity type)
    - **Resources:** Individual system elements but not modelled individually; treated as countable items (e.g. number of passengers waiting at a bus stop)

Simulation (Modelling) Methods

- Discrete Event:
  - Operations of entities
    - Over time entities co-operate and hence change state
      - **Event:** Instance of time in which a significant state change occurs
      - **Activity:** Operations which are initiated at an event, transforming the state of the entities
    - Entity states:
      - **Active state:** Involves the co-operation of different classes of entities; duration can be determined in advance, usually by taking a sample from an appropriate probability distribution if the simulation is stochastic
      - **Dead state:** No co-operation, entity waits for something to happen; duration cannot be determined in advance

Simulation (Modelling) Methods

- Discrete Event:
  - Example: Process flow diagram of booking clerk model (in AnyLogic)



Simulation (Modelling) Methods

- Agent-Based:
  - In Agent-Based Modelling (ABM), a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules.
  - ABM is a mindset more than a technology. The ABM mindset consists of describing a system from the perspective of its constituent units. [Bonabeau, 2002]
  - ABM is well suited to modelling systems with heterogeneous, autonomous and pro-active actors, such as human-centred systems.

Simulation (Modelling) Methods

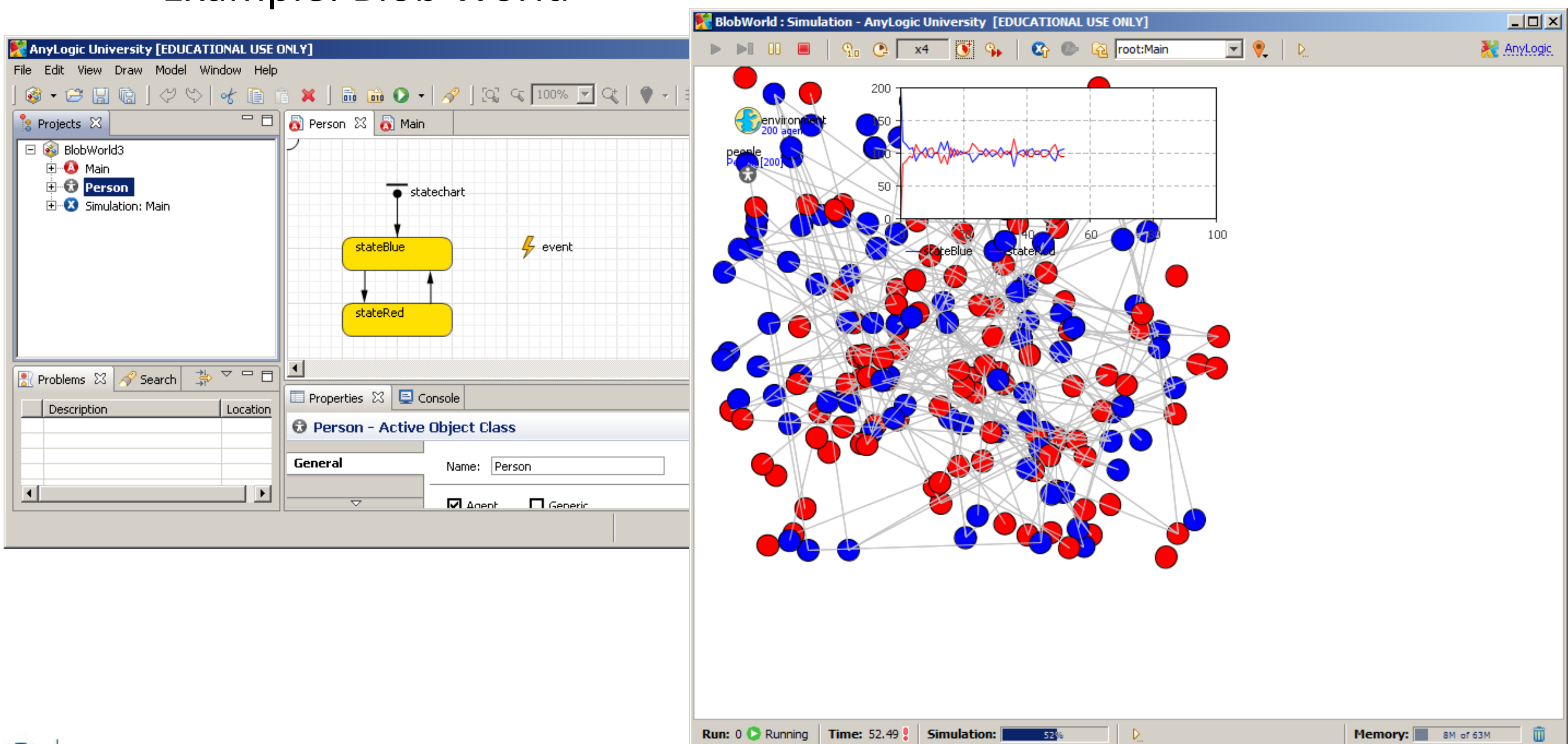
- Agent-Based:
  - What do we mean by "agent"?
    - Agents are objects with attitude!
  - Properties:
    - Discrete entities
      - With their own goals and behaviours
      - With their own thread of control
    - Autonomous
      - Capable to adapt
      - Capable to modify their behaviour
    - Proactive
      - Actions depending on motivations generated from their internal state

Simulation (Modelling) Methods

- Agent-Based:
  - The agents can represent individuals, households, organisations, companies, nations, … depending on the application.
  - ABMs are essentially decentralised
    - There is no place where global system behaviour (dynamics) would be defined; instead, the individual agents interact with each other and their environment to produce complex collective behaviour patterns.

Simulation (Modelling) Methods

- Agent-Based:
  - Example: Blob World



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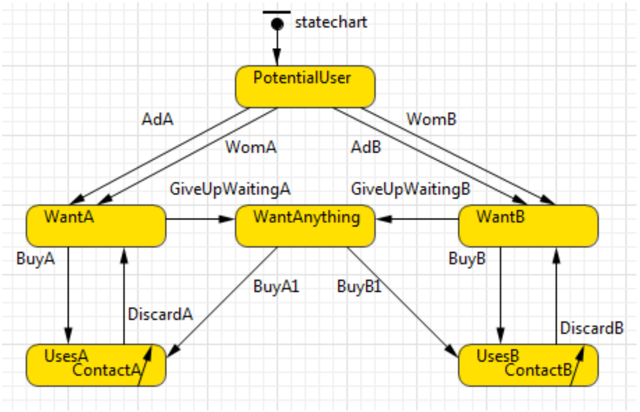
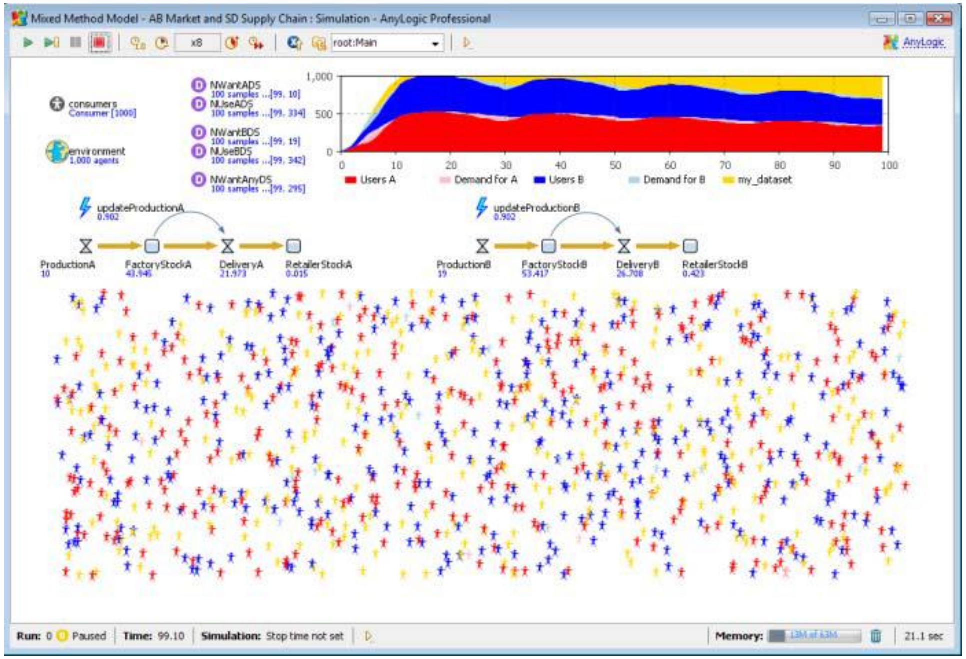
Simulation (Modelling) Methods

- Multi method: System Dynamics + Agent-Based
  - Supply chain: System Dynamics
  - Consumer market: Agent-Based





Simulation (Modelling) Methods

- Contrasting the different simulation methods:
  - System Dynamics Simulation (continuous, deterministic)
    - Aggregate view; differential equations
  - Traditional Discrete Event Simulation (discrete, stochastic)
    - Process oriented (top down); one thread of control; passive objects
  - Agent Based Simulation (discrete, stochastic)
    - Individual centric (bottom up); each agent has its own thread of control; active objects
  - Multi-Method Simulation

Case Study

Department Store Management Practices

For more details see: Siebers and Aickelin (2011)

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Case Study: Context

- Case study sector
  - Retail (department store operations)
- Developing some tools for understanding the impact of management practices on company performance
  - Operational management practices are well researched
  - People management practices are often neglected
- Problem:
  - How can we model proactive customer service behaviour?

Case Study: Modelling

- The system
  - Two departments (A&TV and WW) at two department stores
- Knowledge gathering
  - Informal participant observations
  - Staff interviews
  - Informational sources internal to the case study organisation
- Simulation modelling method
  - Combined DES and ABS (queuing system with active entities)

Communication layer

Direct interactions
Network activities

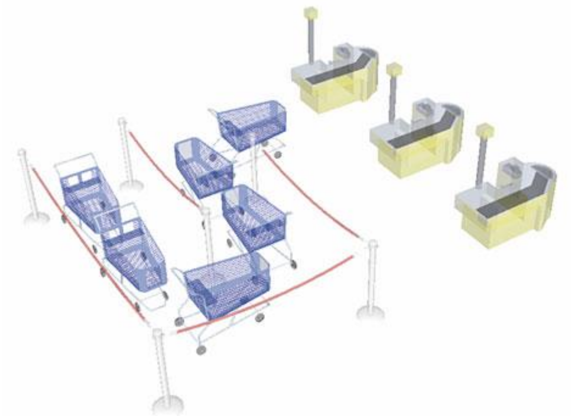
Let entities interact + communicate

Agent layer

Active entities
Behavioural state charts

Replace passive entities by active ones

DES layer



Passive entities
Queues
Processes
Resources

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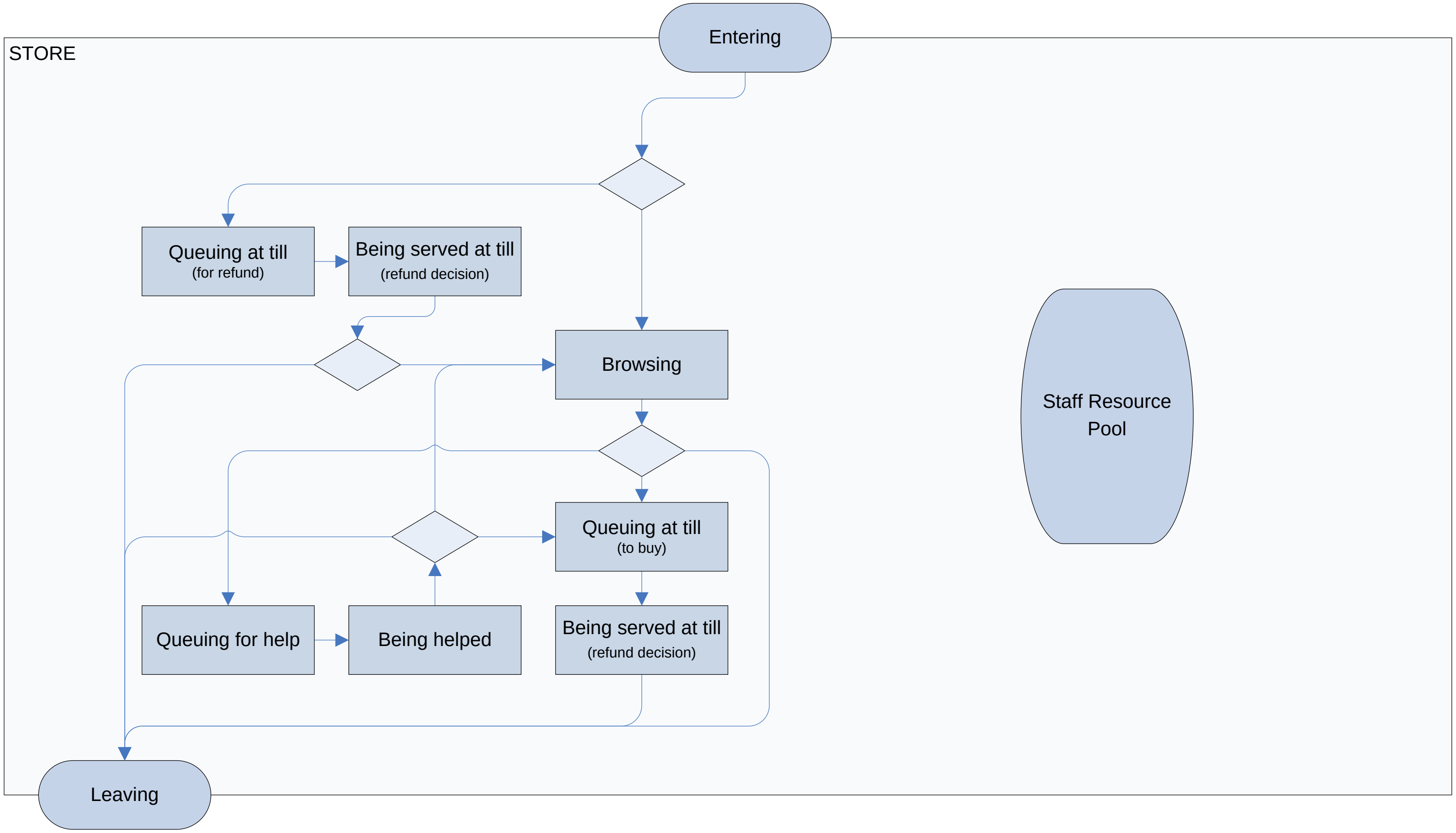
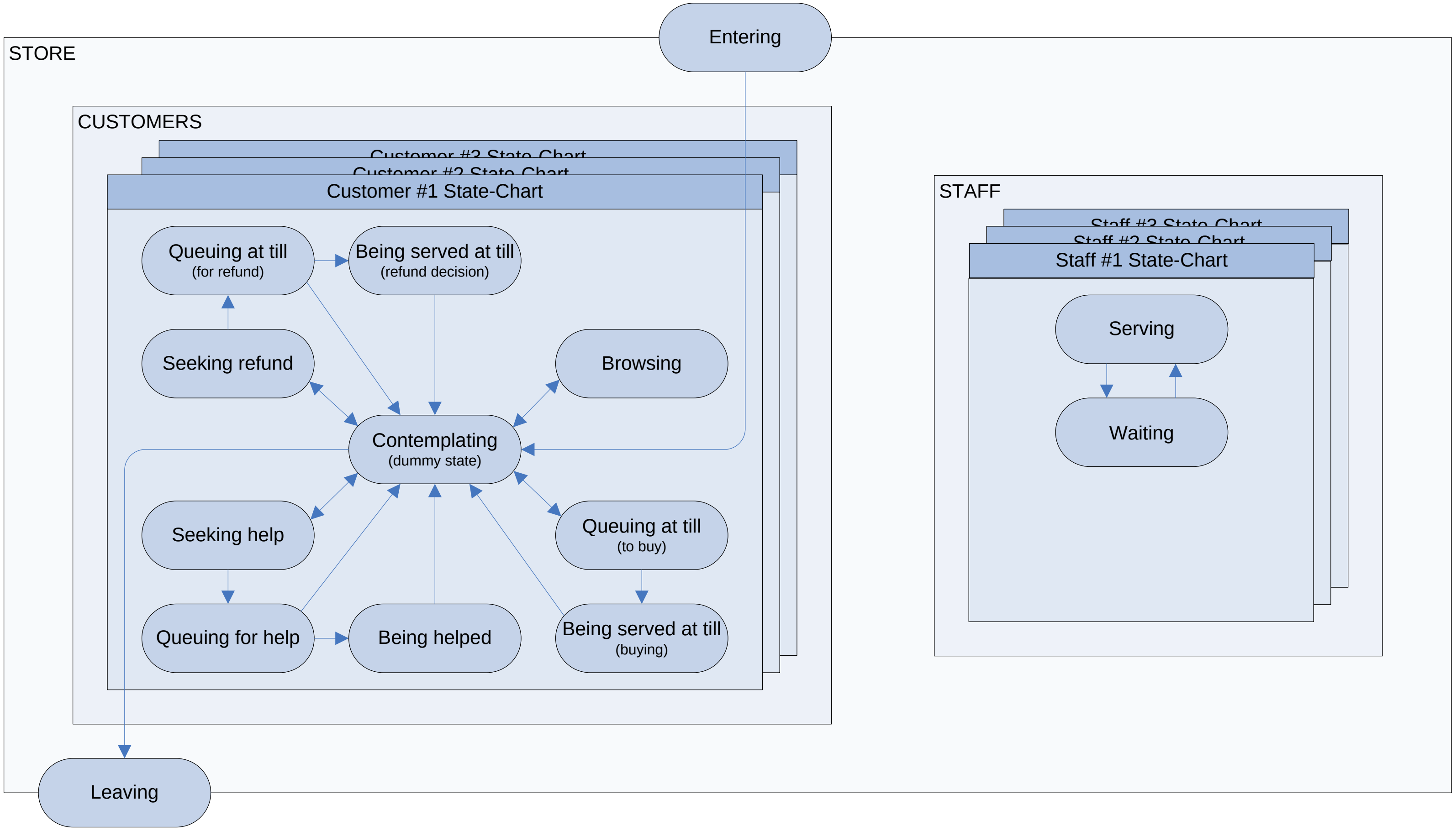
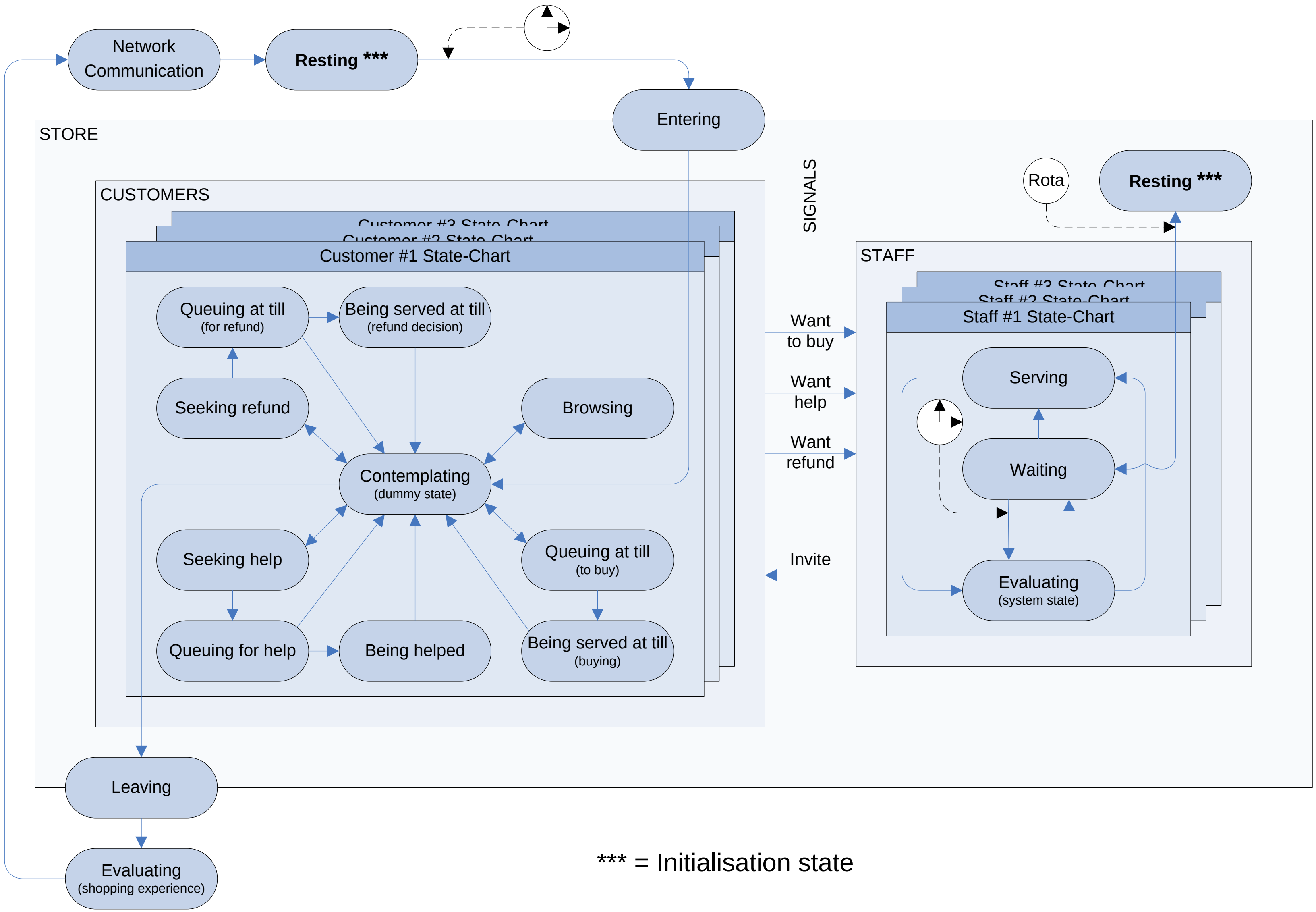
Case Study: Modelling



Case Study: Modelling

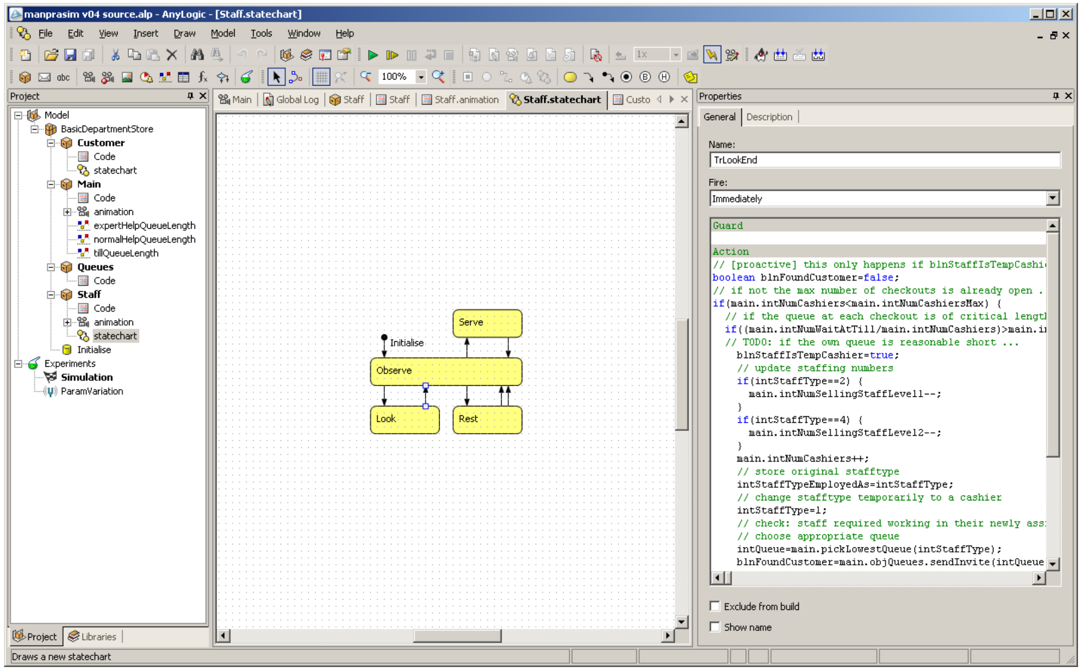




*** = Initialisation state

Case Study: Implementation

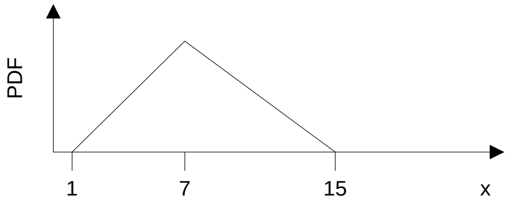
- Software: AnyLogic v5 (later translated into v6)
  - Multi-method simulation software (SD, DES, ABS, DS)
  - State charts + Java code



Case Study: Implementation

- Knowledge representation
  - Frequency distributions for determining state change delays

Situation	Min.	Mode	Max.
Leave browse state after …	1	7	15
Leave help state after …	3	15	30
Leave pay queue (no patience) after …	5	12	20



  - Probability distributions to represent decisions made

Event	Probability of event
Someone makes a purchase after browsing	0.37
Someone requires help	0.38
Someone makes a purchase after getting help	0.56

```
boolean x=(Math.random()<0.37)?true:false;
```

Case Study: Implementation

- Implementation of customer types

Customer type	Likelihood to			
	buy	**wait**	**ask for help**	**ask for refund**
Shopping enthusiast	high	moderate	moderate	low
Solution demander	high	low	low	low
Service seeker	moderate	high	high	low
Disinterested shopper	low	low	low	high
Internet shopper	low	high	high	low

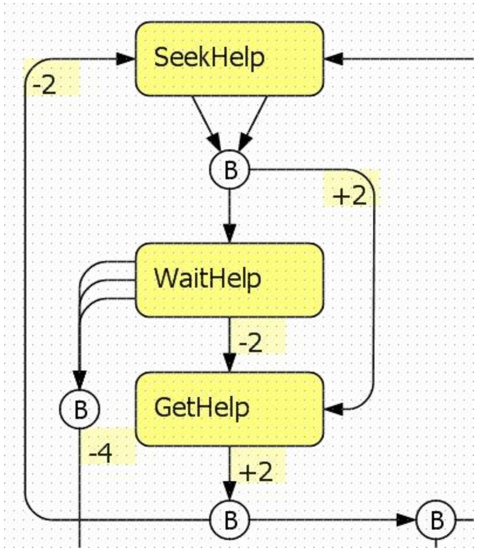
```
for (each threshold to be corrected) do  {
   if (OT < 0.5) limit = OT/2 else limit = (1-OT)/2
   if (likelihood = 0) CT = OT – limit
   if (likelihood = 1) CT = OT
   if (likelihood = 2) CT = OT + limit
}
where:      OT = original threshold
            CT = corrected threshold
            likelihood: 0 = low, 1 = moderate, 2 = high
```

Case Study: Implementation

- Implementation of staff proactiveness
  - Non-cashier staff opening and closing tills proactively depending on demand and staff availability
  - Expert staff helping out as normal staff

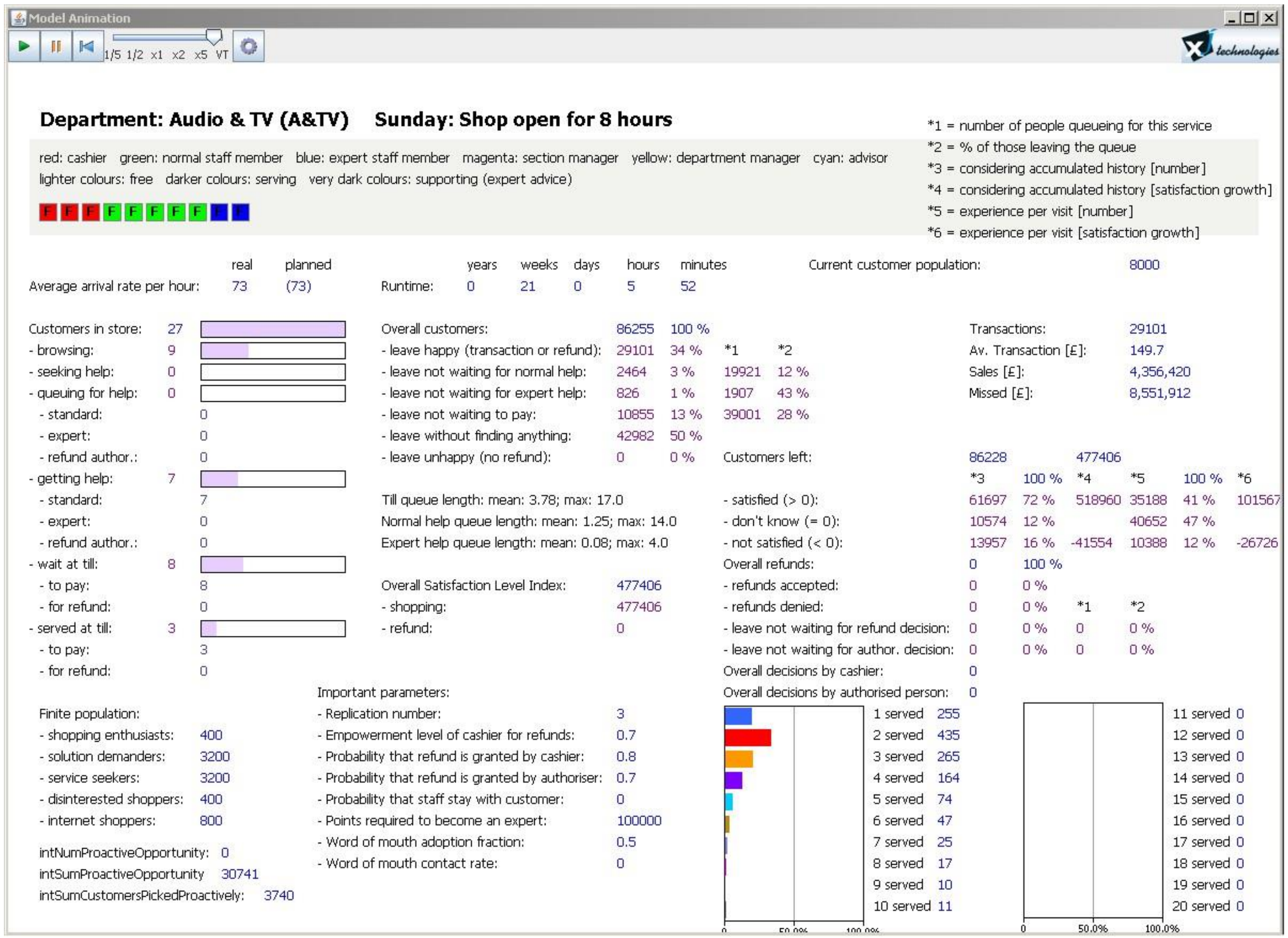
- Other noteworthy features of the model
  - Realistic footfall and opening hours
  - Staff pool (static)
  - Customer pool (dynamic)
  - Customer evolution through internal stimulation (triggered by memory of ones own previous shopping experience)
  - Customer evolution through external stimulation (word of mouth)

Case Study: Implementation



- Performance measures
  - Service performance measures
    - Service experience
  - Utilisation performance measures
    - Staff utilisation
    - Staff busy times in different roles
  - Level of proactivity
    - Frequency and duration of role swaps
  - Monetary performance measures (productivity and profitability)
    - Overall staff cost per day
    - Sales turnover
    - Sales per employee
    - ...

Case Study: Implementation



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Case Study: Experimentation

- A&TV: 2 cashiers, 4 normal staff, 4 expert staff

Overall customers:	41235	100 %		
- leave happy (transaction or refund):	12057	29 %	*1	*2
- leave not waiting for normal help:	930	2 %	8839	11 %
- leave not waiting for expert help:	134	0 %	583	23 %
- leave not waiting to pay:	7468	18 %	19128	39 %
- leave without finding anything:	20646	50 %		

Transactions:	12057
Av. Transaction [£]:	149.7
Sales [£]:	1,804,933
Missed [£]:	4,367,947

Till queue length: mean: 4.23; max: 19.0

Normal help queue length: mean: 1.09; max: 13.0

Customers left:	41235		122742			
	*3	100 %	*4	*5	100 %	*6
- satisfied (> 0):	24972	61 %	144905	15682	38 %	48215
- don't know (= 0):	8085	20 %		19670	48 %	
- not satisfied (< 0):	8178	20 %	-22163	5883	14 %	-13796

*1 = number of people queueing for this service
*2 = % of those leaving the queue
*3 = considering accumulated history [number]
*4 = considering accumulated history [satisfaction growth]
*5 = experience per visit [number]
*6 = experience per visit [satisfaction growth]

Case Study: Experimentation

- A&TV: 3 cashiers, 6 normal staff, 1 expert staff

Overall customers:	40960	100 %		
- leave happy (transaction or refund):	16800	41 %	*1	*2
- leave not waiting for normal help:	1724	4 %	10958	16 %
- leave not waiting for expert help:	761	2 %	1085	70 %
- leave not waiting to pay:	1687	4 %	15605	11 %
- leave without finding anything:	19988	49 %		

Transactions:	16800
Av. Transaction [£]:	149.7
Sales [£]:	2,514,960
Missed [£]:	3,616,752

Customers left:	40960		136411			
	*3	100 %	*4	*5	100 %	*6
- satisfied (> 0):	27979	68 %	152775	18512	45 %	50894
- don't know (= 0):	7579	19 %		18924	46 %	
- not satisfied (< 0):	5402	13 %	-16364	3524	9 %	-11610

Till queue length: mean: 2.15; max: 17.0

Normal help queue length: mean: 1.56; max: 14.0

*1 = number of people queueing for this service
*2 = % of those leaving the queue
*3 = considering accumulated history [number]
*4 = considering accumulated history [satisfaction growth]
*5 = experience per visit [number]
*6 = experience per visit [satisfaction growth]

Questions or Comments

References

- Grimm and Railsback (2005) Individual-based modeling and ecology
- Robinson (2004) Simulation: The practice of model development and use. Wiley, Chichester, UK.
- Siebers and Aickelin (2011) A first approach on modelling staff proactiveness in retail simulation models. Journal of Artificial Societies and Social Simulation, 14(2): 2