ABM for Management Decision Support [Spring 2013]

Lecture 2

Agent-Based Modelling and Simulation Case Studies

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UNITED KINGDOM · CHINA · MALAYSIA

Content Lecture 2

- Case Study 1
  - Department Store Customer Service
- Case Study 2
  - Office Energy Consumption
- Case Study 3
  - Forced Innovation Adoption

Recap: Simulation Paradigms

- System Dynamics (continuous, deterministic)
  - **Aggregate view**; differential equations
    - Modelling methods: Causal loop diagrams; stock and flow diagrams
- Discrete Event (discrete, stochastic)
  - **Process oriented** (top down); one thread of control; passive objects
    - Modelling methods: Process flow diagrams; activity cycle diagrams
- Agent Based (discrete, stochastic)
  - **Individual centric** (bottom up); each agent has its own thread of control; active objects
    - Modelling methods: UML (class diagrams + state chart diagrams) + Equations
- Multi-Method (linked or integrated)

1

Case Study 1

(For more details see Siebers and Aickelin 2011)

A queuing system

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Case Study 1: Context

1

- 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

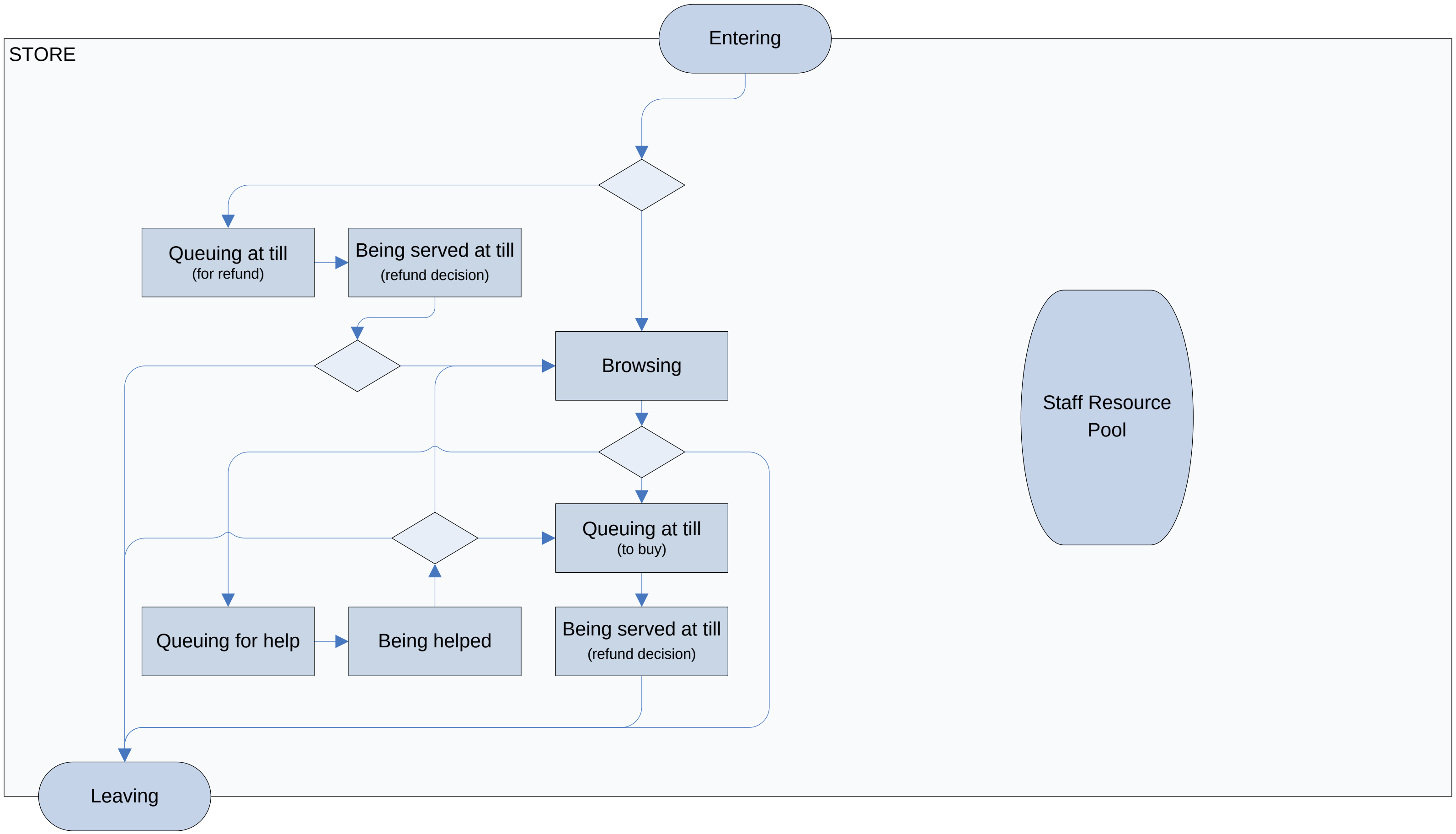
- Problem:
  - How can we model proactive customer service behaviour?

Case Study 1: Modelling

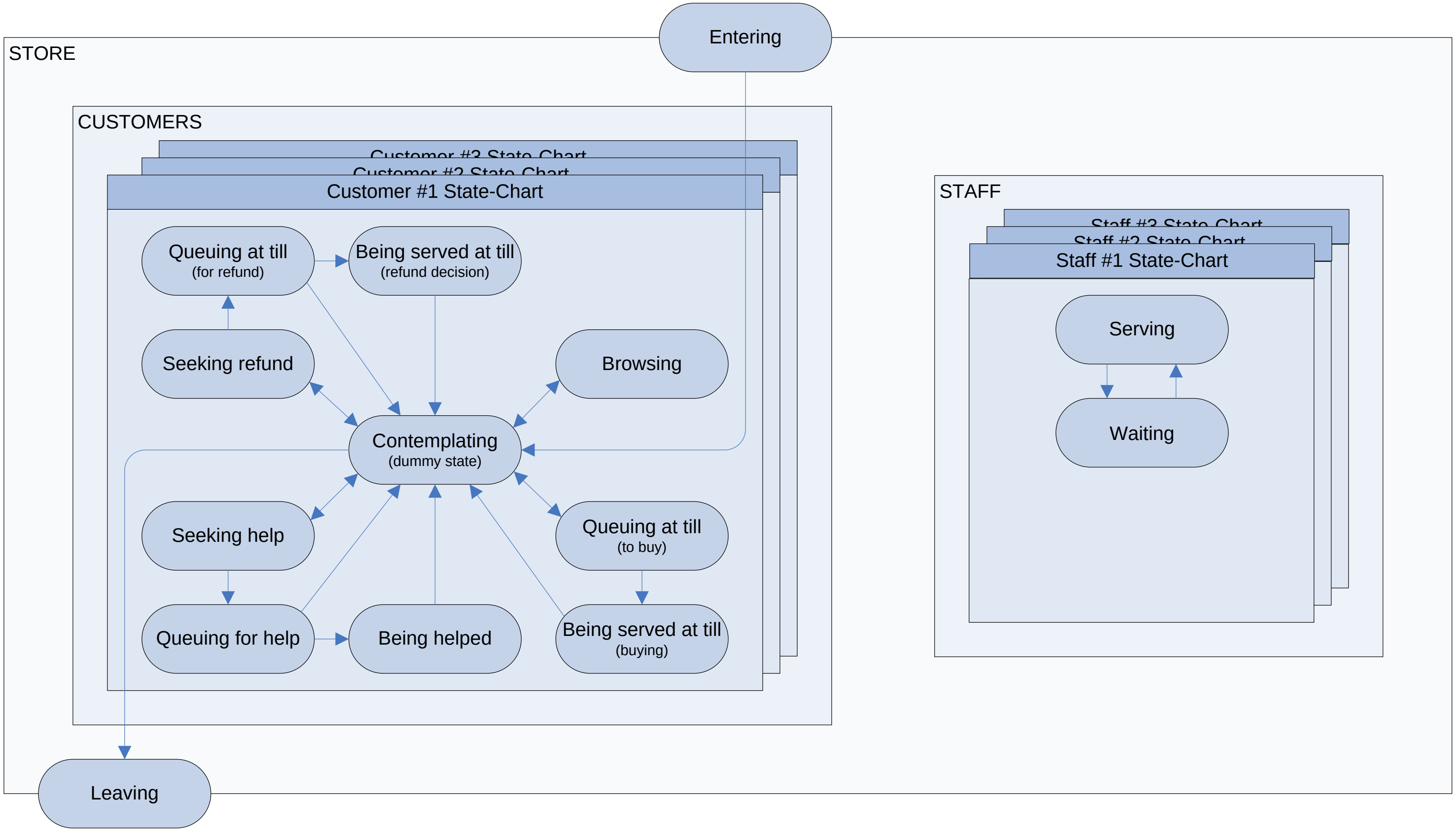
1

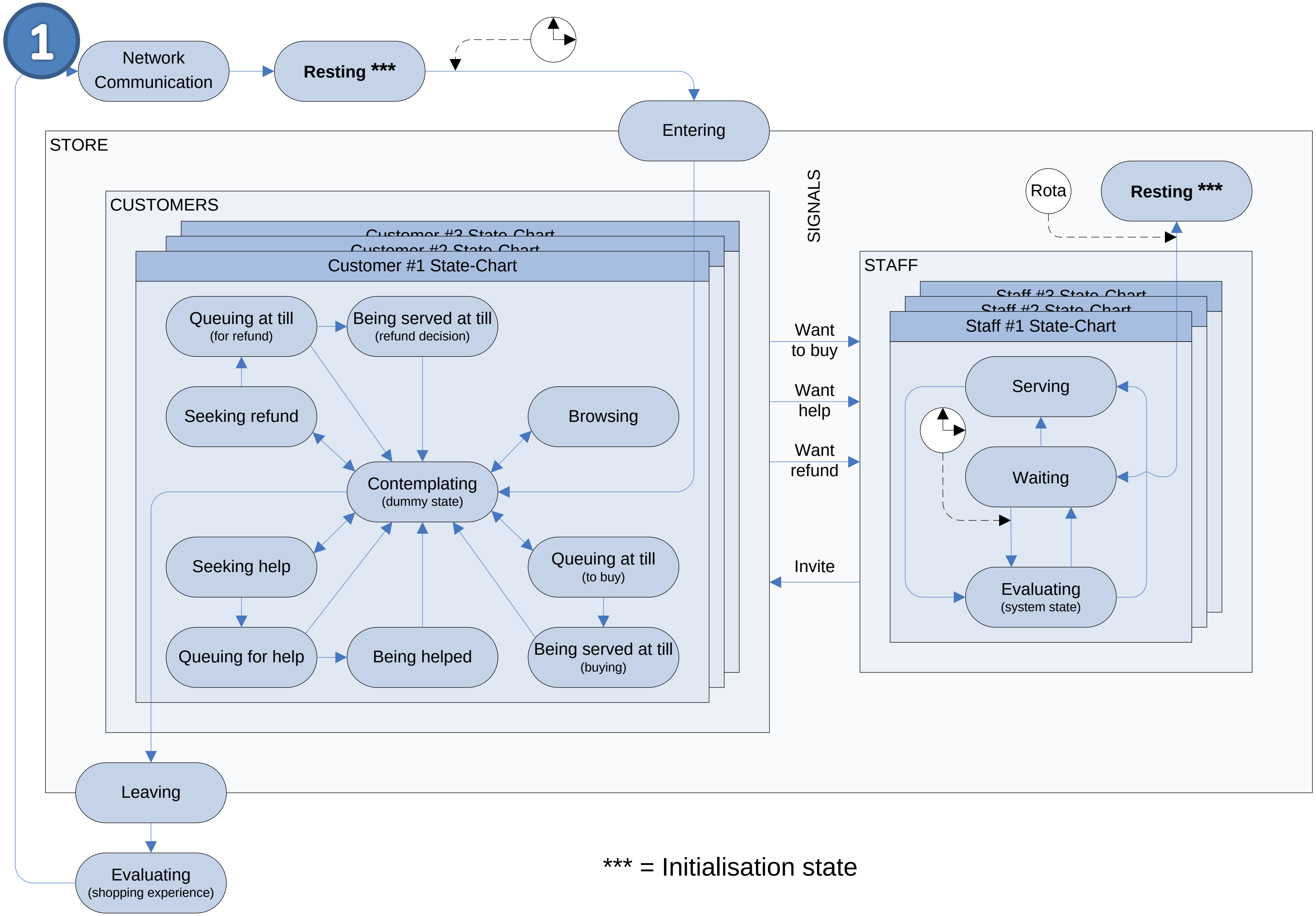
- Two case studies at two different locations
  - Two departments (A&TV and WW) at two department stores
- Knowledge gathering
  - Informal participant observations
  - Staff interviews
  - Informational sources internal to the case study organisation

Case Study 1: Modelling



Case Study 1: Modelling

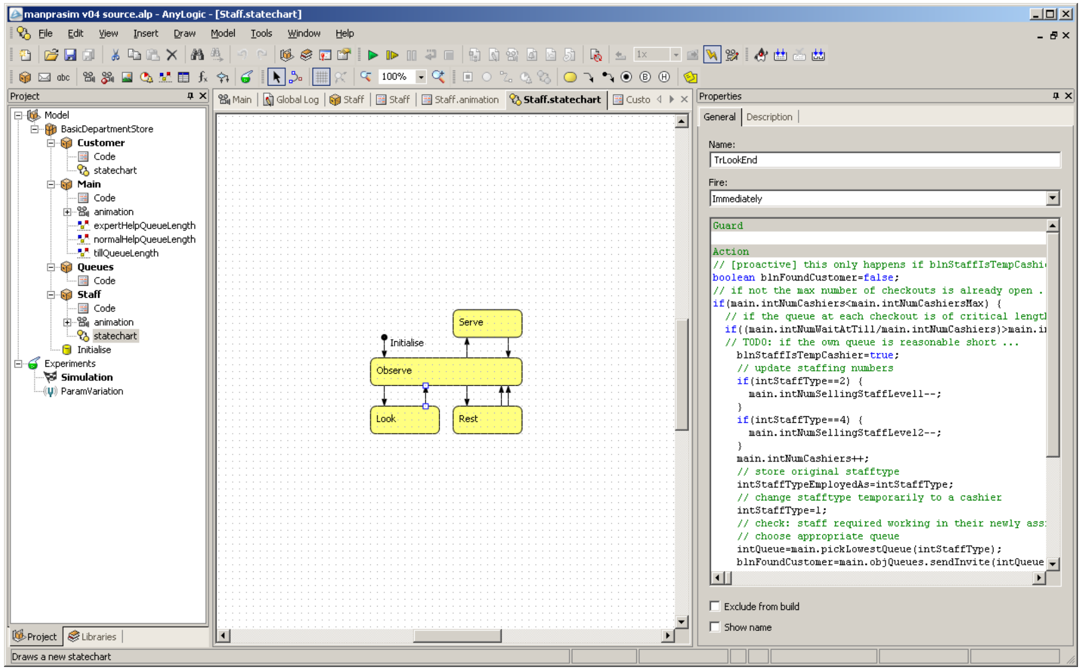




*** = Initialisation state

Case Study 1: Implementation

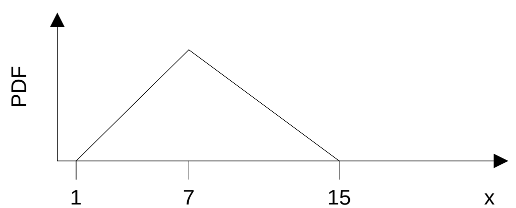
- Software: AnyLogic v5 (later translated into v6)
  - Multi-method simulation software (SD, DES, ABS, DS)
  - State charts + Java code



Case Study 1: 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 1: 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

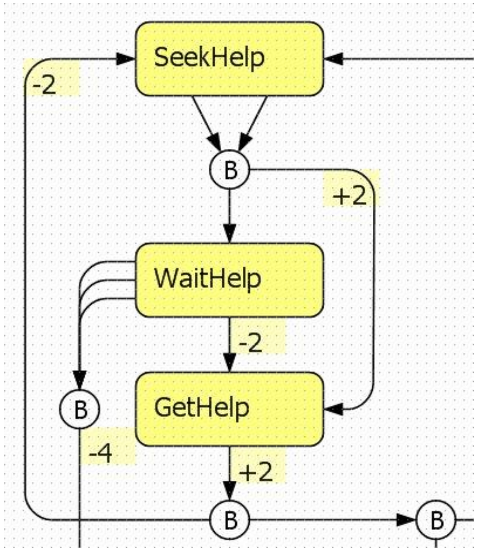
```
for (each threshold to be corrected) do  {
   if (OT < 0.5) limit = OT/2 else limit = (1-OT)/2
   if (likelihood = 0) CT = OT – limit
   if (likelihood = 1) CT = OT
   if (likelihood = 2) CT = OT + limit
}
where:       OT = original threshold
             CT = corrected threshold
             likelihood: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

1 Case Study 1: Implementation

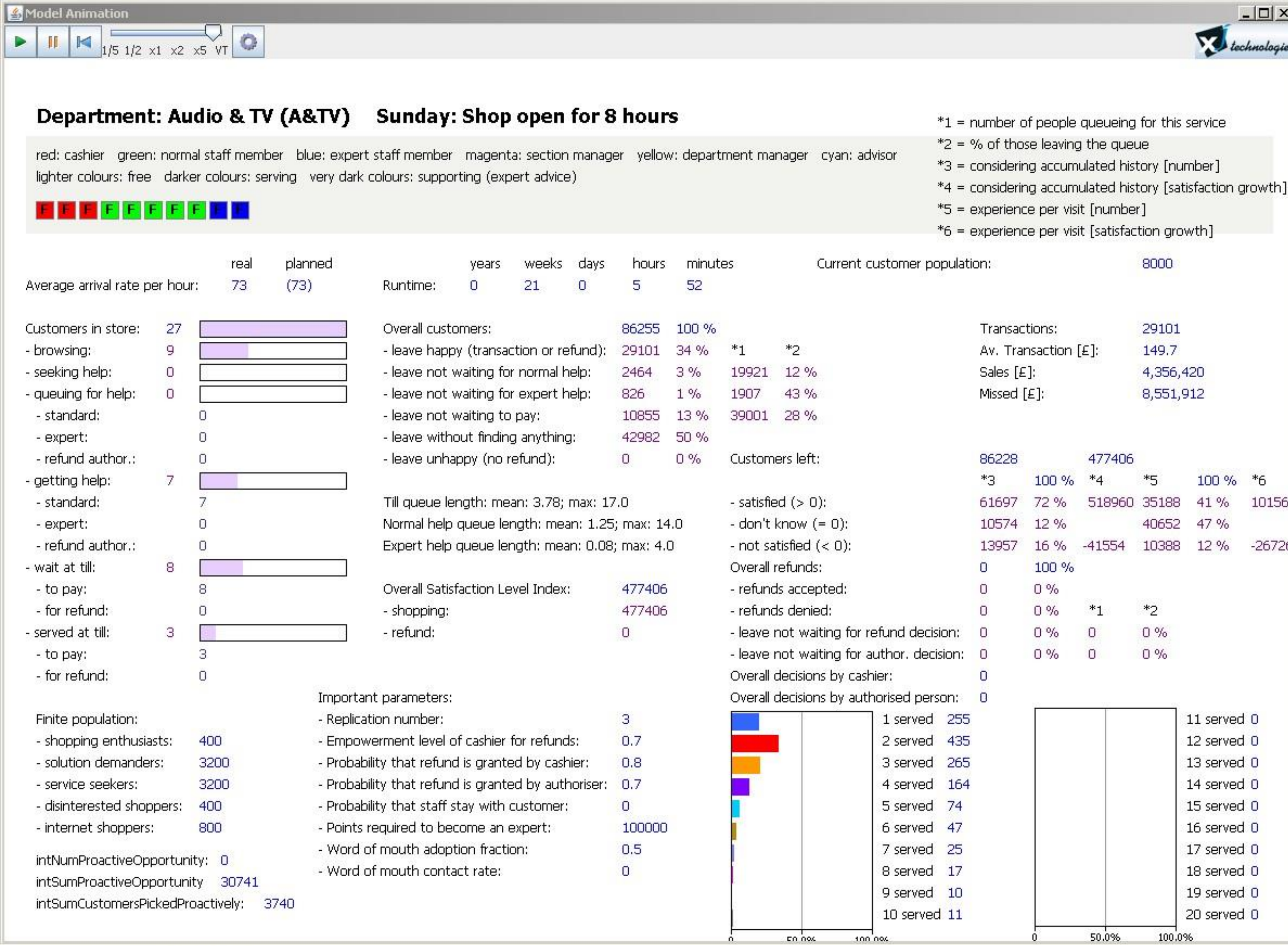
- Implementation of staff proactiveness
  - Non-cashier staff opening and closing tills proactively depending on demand and staff availability
  - Expert staff helping out as normal staff

- 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 1: 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
    - ...


Model Animation
1/5 1/2 x1 x2 x5 VT
technologies
Department: Audio & TV (A&TV)   Sunday: Shop open for 8 hours
*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]
red: cashier   green: normal staff member   blue: expert staff member   magenta: section manager   yellow: department manager   cyan: advisor
lighter colours: free   darker colours: serving   very dark colours: supporting (expert advice)
F F F F F F F F F F
real   planned
Average arrival rate per hour: 73 (73)
years weeks days hours minutes
Runtime: 0 21 0 5 52
Current customer population: 8000
Customers in store: 27
- browsing: 9
- seeking help: 0
- queuing for help: 0
- standard: 0
- expert: 0
- refund author.: 0
- getting help: 7
- standard: 7
- expert: 0
- refund author.: 0
- wait at till: 8
- to pay: 8
- for refund: 0
- served at till: 3
- to pay: 3
- for refund: 0
Overall customers: 86255 100 %
- leave happy (transaction or refund): 29101 34 % *1 *2
- leave not waiting for normal help: 2464 3 % 19921 12 %
- leave not waiting for expert help: 826 1 % 1907 43 %
- leave not waiting to pay: 10855 13 % 39001 28 %
- leave without finding anything: 42982 50 %
- leave unhappy (no refund): 0 0 %
Till queue length: mean: 3.78; max: 17.0
Normal help queue length: mean: 1.25; max: 14.0
Expert help queue length: mean: 0.08; max: 4.0
Overall Satisfaction Level Index: 477406
- shopping: 477406
- refund: 0
Transactions: 29101
Av. Transaction [£]: 149.7
Sales [£]: 4,356,420
Missed [£]: 8,551,912
Customers left: 86228 477406
*3 100 % *4 *5 100 % *6
- satisfied (> 0): 61697 72 % 518960 35188 41 % 101567
- don't know (= 0): 10574 12 % 40652 47 %
- not satisfied (< 0): 13957 16 % -41554 10388 12 % -26726
Overall refunds: 0 100 %
- refunds accepted: 0 0 %
- refunds denied: 0 0 % *1 *2
- leave not waiting for refund decision: 0 0 % 0 0 %
- leave not waiting for author. decision: 0 0 % 0 0 %
Overall decisions by cashier: 0
Overall decisions by authorised person: 0
Finite population:
- shopping enthusiasts: 400
- solution demanders: 3200
- service seekers: 3200
- disinterested shoppers: 400
- internet shoppers: 800
intNumProactiveOpportunity: 0
intSumProactiveOpportunity 30741
intSumCustomersPickedProactively: 3740
Important parameters:
- Replication number: 3
- Empowerment level of cashier for refunds: 0.7
- Probability that refund is granted by cashier: 0.8
- Probability that refund is granted by authoriser: 0.7
- Probability that staff stay with customer: 0
- Points required to become an expert: 100000
- Word of mouth adoption fraction: 0.5
- Word of mouth contact rate: 0
1 served 255
2 served 435
3 served 265
4 served 164
5 served 74
6 served 47
7 served 25
8 served 17
9 served 10
10 served 11
11 served 0
12 served 0
13 served 0
14 served 0
15 served 0
16 served 0
17 served 0
18 served 0
19 served 0
20 served 0
0 50.0% 100.0%

Case Study 1: 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

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

Till queue length: mean: 4.23; max: 19.0

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

*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]

1 Case Study 1: 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]

2

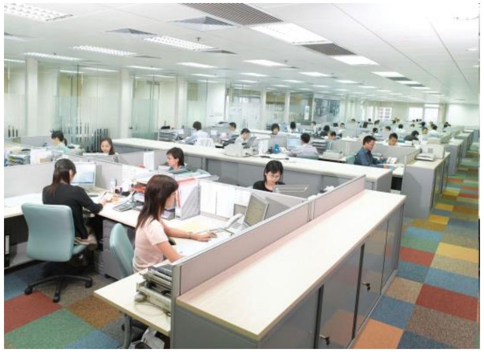
Case Study 2

(For more details see Zhang et al 2010)

A non-queuing system

Case Study 2: Context

2



- Office building energy consumption
  - We focus on modelling electricity consumption
  - Organisational dilemma
    - Need to meet the energy needs of staff
    - Need to minimise its energy consumption through effective organisational energy management policies/regulations

- Objective
  - Test the effectiveness of different electricity management strategies, and solve practical office electricity consumption problems

Case Study 2: Modelling

- Electricity consumption
  - **Base electricity consumption:** security devices, information displays, computer servers, shared printers and ventilation systems.
  - **Flexible electricity consumption:** lights and office computers
- Current electricity management technologies
  - Each room is equipped with light sensors
  - Each floor is equipped with half-hourly metering system
- Strategic questions to be answered
  - Automated vs. manual lighting management
  - Local vs. global energy consumption information

Case Study 2: Modelling

2

- The mathematical model
  - $C_{total} = C_{base} + C_{flexible}$
    - where $C_{flexible} = \beta 1 * Cf1 + \beta 2 * Cf2 + \ldots + \beta n * Cfn$
    - and $Cf1 \ldots Cfn$ = maximum electricity consumption of each flexible appliance
    - and $\beta 1 \ldots \beta n$ = parameters reflecting the behaviour of the electricity user
      - β close to 0 = electricity user switches flexible appliances always off
      - β close to 1 = electricity user leaves flexible appliances always on
  - $C_{total} = C_{base} + (\beta 1 * Cf1 + \beta 2 * Cf2 + \ldots + \beta n * Cfn)$

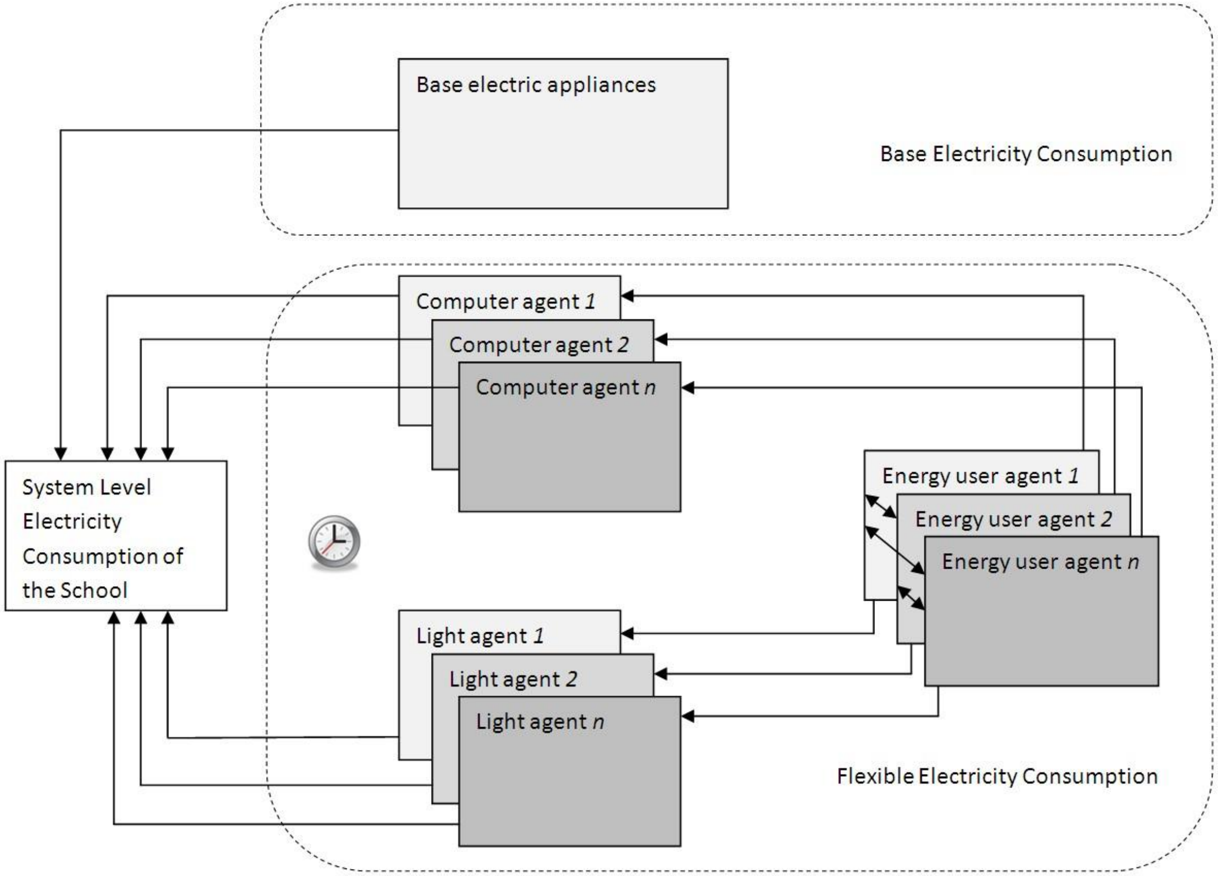
2 Case Study 2: Modelling

- Knowledge gathering
  - Consultations with the school's director of operations and the university estate office
  - Survey amongst the school's 200 PhD students and staff on electricity use behaviour (response rate 71.5%)

- User stereotypes
  - Working hour habits
    - Early birds, timetable compliers, flexible workers
  - Energy saving awareness
    - Environment champion; energy saver; regular user; big user

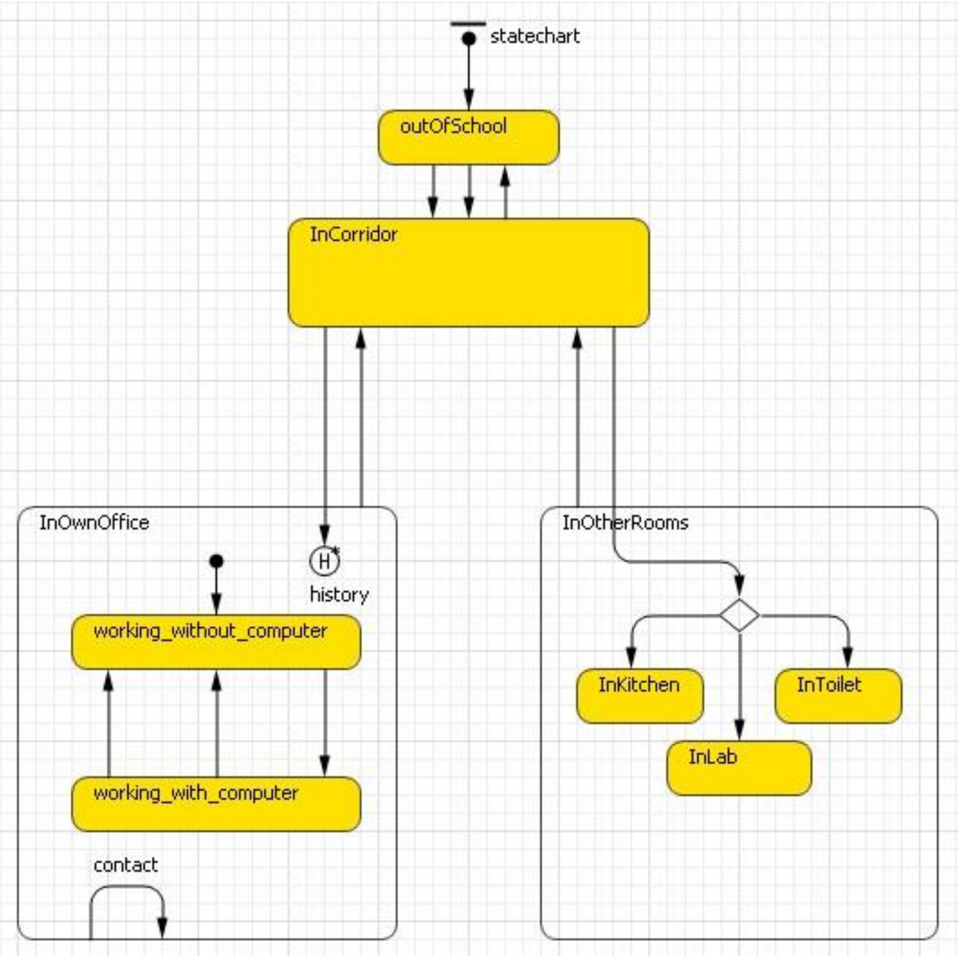
Case Study 2: Modelling

- Conceptual model



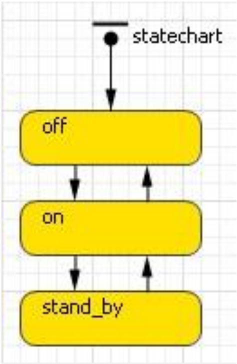
Case Study 2: Modelling

- Energy user agent
  - Proactive

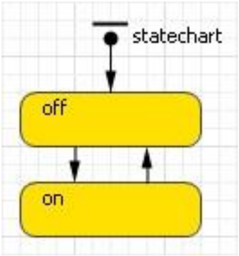


Case Study 2: Modelling

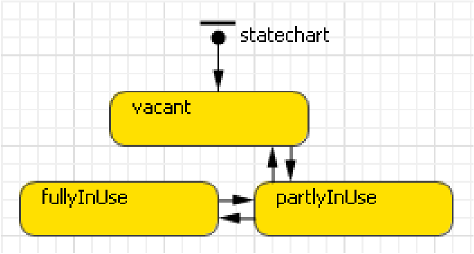
- Computer agent
  - passive



- Light agent
  - passive



- Office agent
  - passive



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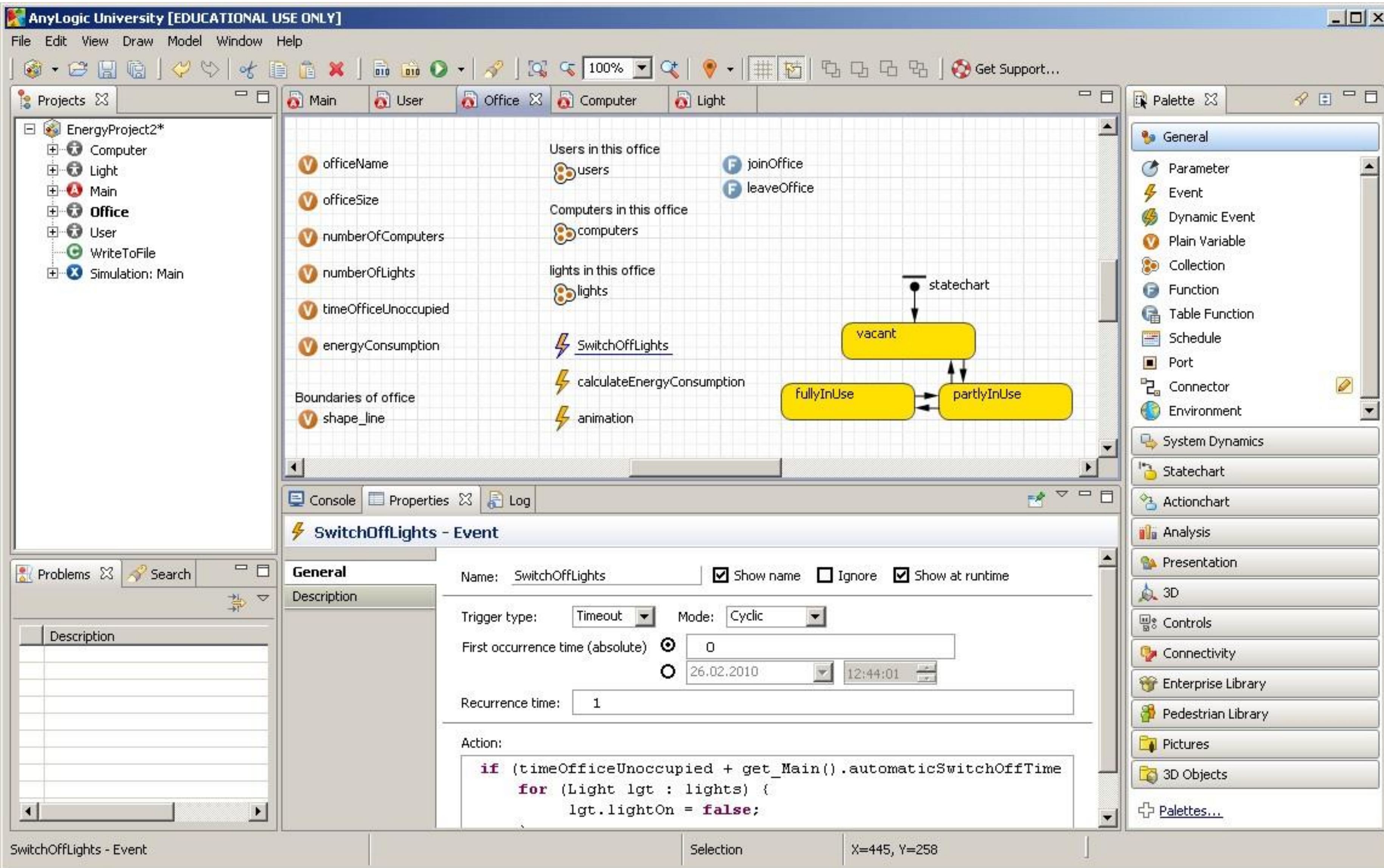
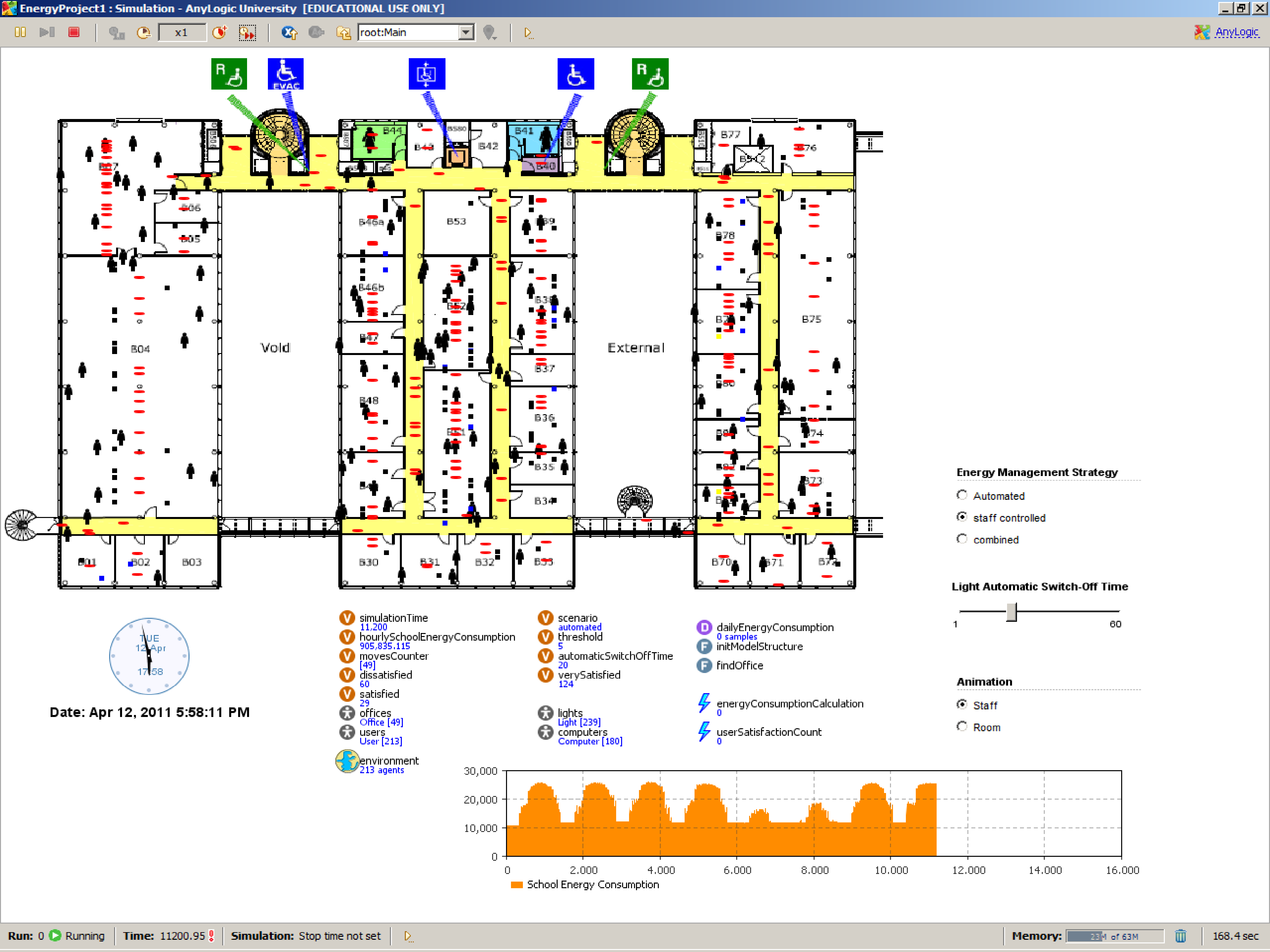
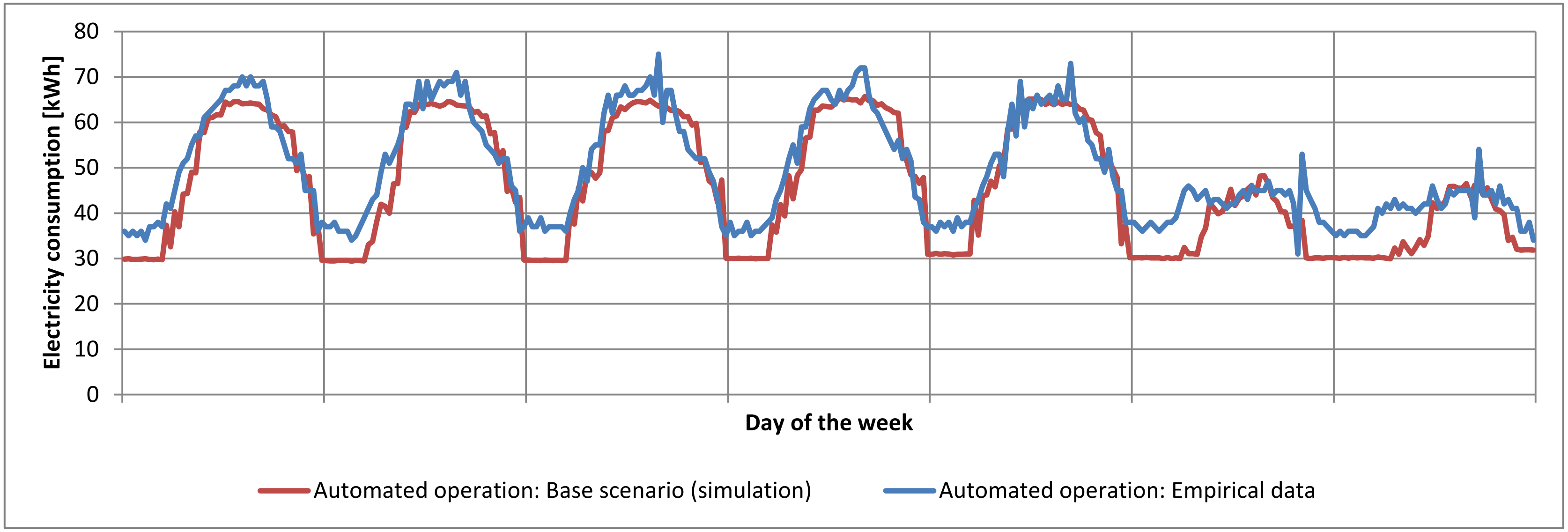
Case Study 2: Implementation




EnergyProject1 : Simulation - AnyLogic University [EDUCATIONAL USE ONLY]
x1
root:Main
AnyLogic
Void
External
B04
B01
B02
B03
B30
B31
B32
B33
B34
B35
B36
B37
B42
B44
B53
B70
B71
B75
B76
B77
Energy Management Strategy
Automated
staff controlled
combined
Light Automatic Switch-Off Time
1
60
Animation
Staff
Room
TUE
12 Apr
17:58
Date: Apr 12, 2011 5:58:11 PM
simulationTime
11,200
hourlySchoolEnergyConsumption
905,835.115
movesCounter
[49]
dissatisfied
60
satisfied
29
offices
Office [49]
users
User [213]
environment
213 agents
scenario
automated
threshold
5
automaticSwitchOffTime
20
verySatisfied
124
lights
Light [239]
computers
Computer [180]
dailyEnergyConsumption
0 samples
initModelStructure
findOffice
energyConsumptionCalculation
0
userSatisfactionCount
0
30,000
20,000
10,000
0
0
2.000
4.000
6.000
8.000
10.000
12.000
14.000
16.000
School Energy Consumption
Run: 0 Running
Time: 11200.95
Simulation: Stop time not set
Memory:
168.4 sec

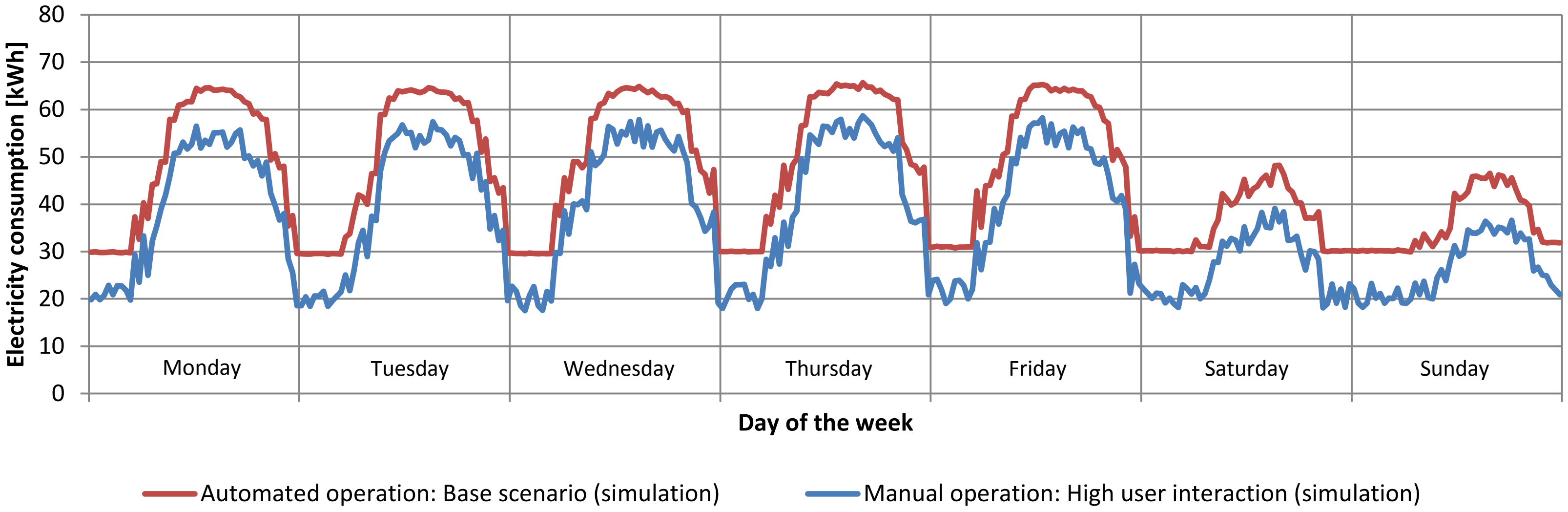
Case Study 2: Experimentation

- Validation
  - Comparing **simulation** and **empirical results**



Case Study 2: Experimentation

- Scenario #1
  - Comparing **automated** and **manual operation** (low user interaction)



3

Case Study 3

(For more details see Zhang et al 2012)

A non-queuing system

Case Study 3: Context

3

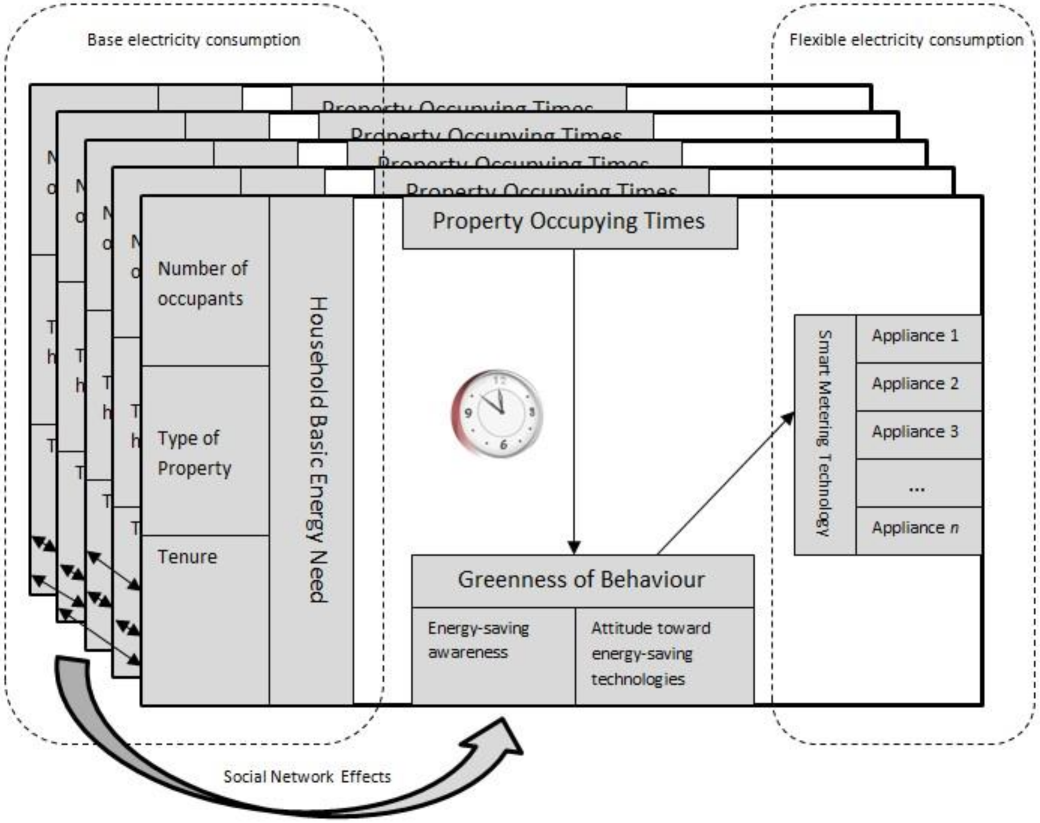
- Modelling the effects of user learning on forced innovation diffusion
  - Technology adoption theories assume that users' acceptance of an innovative technology is on a voluntary basis
  - Sometimes the adoption decisions are made by a few authoritative individuals and implemented enforcedly

- Our Focus is on:
  - Classical consumer learning theories
  - Residential energy consumer in the City of Leeds
  - Interventions that local authorities can take to manage smart metering deployments

Case Study 3: Modelling

3

- Residential Energy Consumer (REC) template



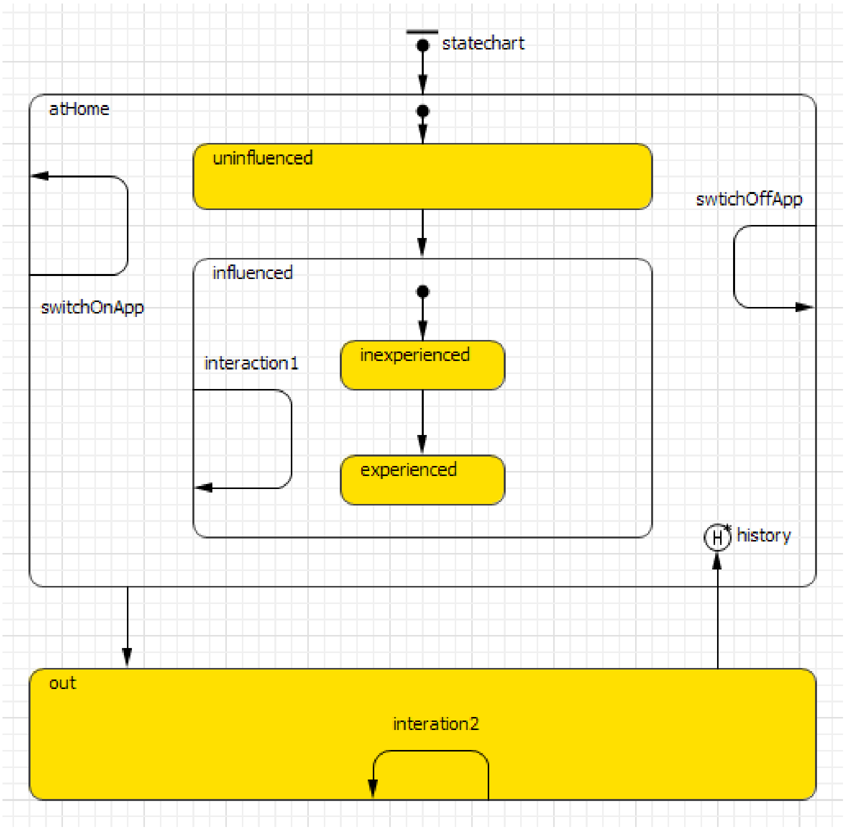
Case Study 3: Modelling

- Residential Energy Consumer (REC) archetypes

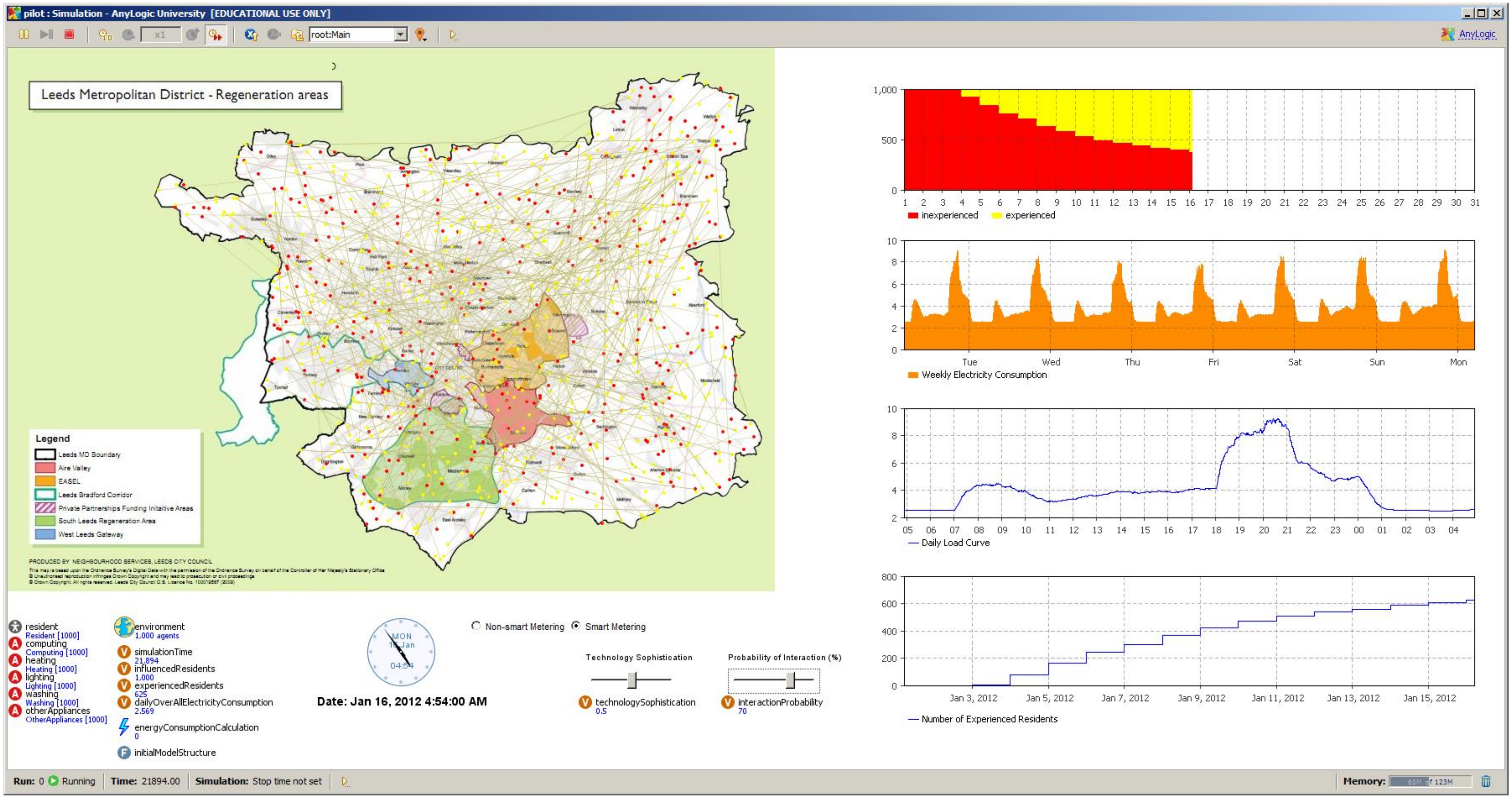
	Attributes		
Archetype	Property energy efficiency	Greenness of behaviour	Duration of daytime occupancy
1: Pioneer Greens	High	High	Short
2: Follower Greens	Low	High	Short
3: Concerned Greens	Low	High	Long
4: Home-Stayers	High	High	Long
5: Unconscientious Wasters	High	Low	Short
6: Regular Wasters	Low	Low	Short
7: Daytime Wasters	High	Low	Long
8: Disengaged Wasters	Low	Low	Long

Case Study 3: Modelling

- Residential Energy Consumer (REC) agent

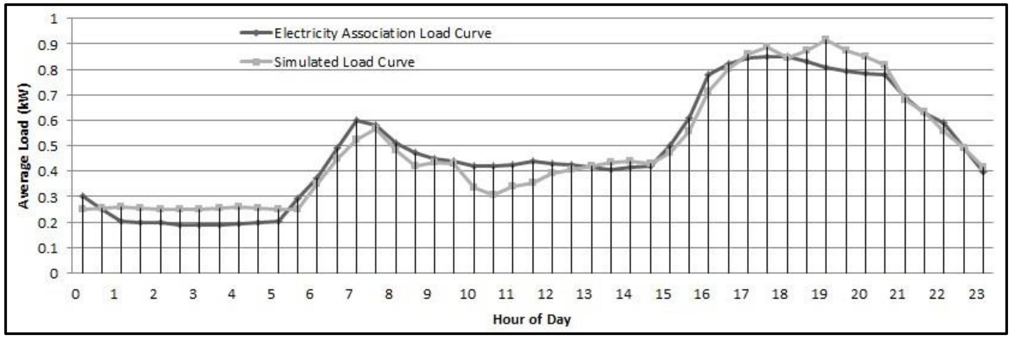


Case Study 3: Implementation

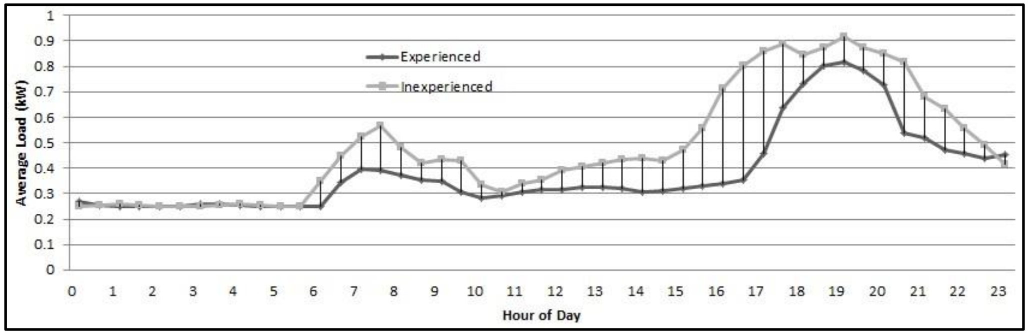


Case Study 3: Experimentation

- Validation: Simulated Load Curve vs. Real Load Curve



- Experiment: Inexperienced vs. Experiences REC



Further Reading

- Siebers and Aickelin (2008) Introduction to Multi-Agent Simulation
- Macal and North (2007) Agent-Based Modeling and Simulation: Desktop ABMS
- Bonabeau (2002) Agent-Based Modeling: Methods and Techniques for Simulating Human Systems

Questions or Comments

References

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- Siebers, P.O. and Aickelin, U. (2011) A first approach on modelling staff proactiveness in retail simulation models. Journal of Artificial Societies and Social Simulation, 14(2): 2
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- Zhang, T., Siebers, P.O. and Aickelin, U. (2012) Modelling the Effects of User Learning on Forced Innovation Diffusion. In: Proceedings of the UK OR Society Simulation Workshop 2012 (SW12), 26-28 March, Worcestershire, UK