A Multi-Agent Simulation of Retail Management Practices

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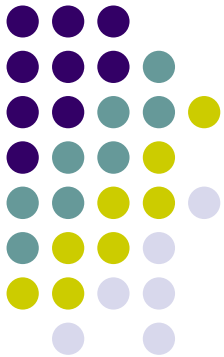


Salford Seminar on 17/03/2009

This is an updated version considering the comments from the audience

My Research Interest & Projects

- Research interest
  - The application of computer simulation to study human-centric complex adaptive systems
- Projects
  - The Impact of Human Performance Variation on the Accuracy of Manufacturing System Simulation Models
  - A Multi-agent Simulation of Retail Management Practices
  - Modelling and Analysing the Cargo Screening Process

Content

- Agent-Based Modelling and Simulation
  - Simulation
  - Agents
- Case Study (Retail Management Practices)
  - Motivation
  - Research Questions
  - Data Collection
  - The Concepts
  - Implementation
  - Experiments
- Conclusions

Agent-Based Modelling and Simulation

Simulation

Agents

Simulation (1/3)

- Methods in Operations Research
  - Linear Programming
  - Network Analysis
  - Meta Heuristics
  - Queuing Theory
  - Game Theory
  - Simulation

Simulation (2/3)

- General
  - Simulation is 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.

- Our Focus: Dynamic Stochastic Systems Simulation
  - Dynamic
    - Modelling a time sequence of changes
  - Stochastic
    - Based on conditional probabilities
    - Results from several runs will form a distribution

Simulation (3/3)

- Continuous (deterministic)
  - System Dynamics Simulation Example
    - Aggregate view; differential equations
- Discrete (stochastic)
  - Discrete Event Simulation (DES) Example
    - Process oriented (top down); one thread of control; passive objects
  - Agent Based Simulation (ABS) Example
    - Individual based (bottom up); each agent has its own thread of control; active objects

Agents (1/3)

- Agents are objects with attitude
  - 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

Agents (2/3)

- Interactive Organisational Agent-Based Simulation

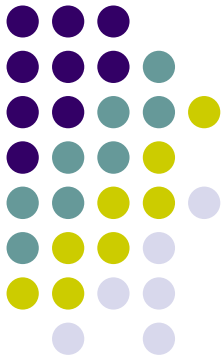
Agents (3/3)

- Purpose (empirical embeddedness) [Boero & Squazzoni, 2005]
  - Case-based (specific circumscribed empirical phenomena)
    - Example: Evolutionary studies of prehistoric societies
  - Typification (specific classes of empirical phenomena)
    - Example: Simulating issues related to land use management
  - Theoretical abstractions (pure theoretical models)
    - Example: Flocks of boids

- Agent goals and behaviours
  - Probabilistic (representing decisions using distributions)
  - Rule based (modelling the decision making process)

CASE STUDY

Motivation
Research Questions
Data Collection
The Concepts
Implementation
Experiments



Motivation (1/2)

- The retail sector is one of the biggest contributors to the productivity gap between UK, EUROPE and USA
- There is a link between management practices and company's productivity but it is not well understood
- Current OR studies most often focus on operational management practices and ignore people management practices and they often don't consider the development of the system over time

Motivation (2/2)

- Advantage of ABS Models over Steady-State Models
  - We can study ...
    - the process of getting to an equilibrium state
    - non-equilibrium systems
    - a management practice prior to its implementation
  - We can consider ...
    - high levels of heterogeneity
    - effects of behaviour during the runtime
    - irrational behaviour
  - We can understand as well as predict system behaviour

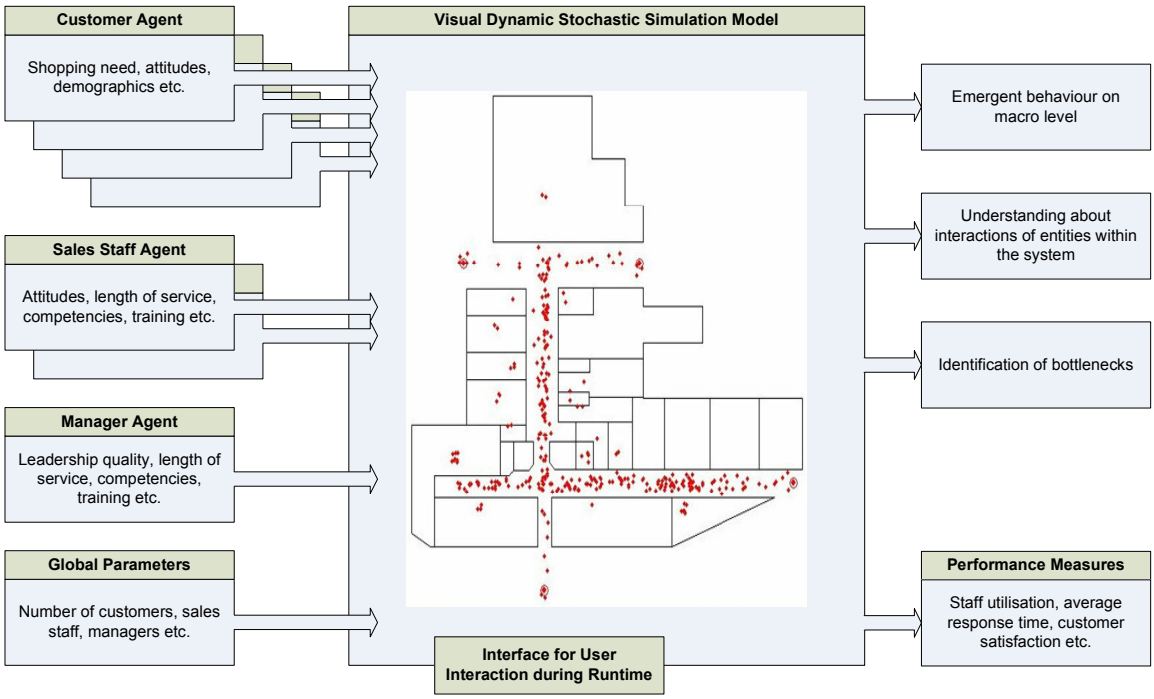
Research Questions & Method

- Research questions:
  - Is agent-based simulation a suitable tool to better understand the relationship between people management practices and retail performance?
  - What level of abstraction should we use?
- Method:
  - Case study approach
  - Individual departments within department store
  - Using agent-based modelling and simulation
  - Incorporating variables from different levels of analysis

Data Collection

- Two case studies at two different locations
  - Two departments within a department store
  - Informal participant observations
  - Staff interviews
  - Informational sources internal to the case study organisation

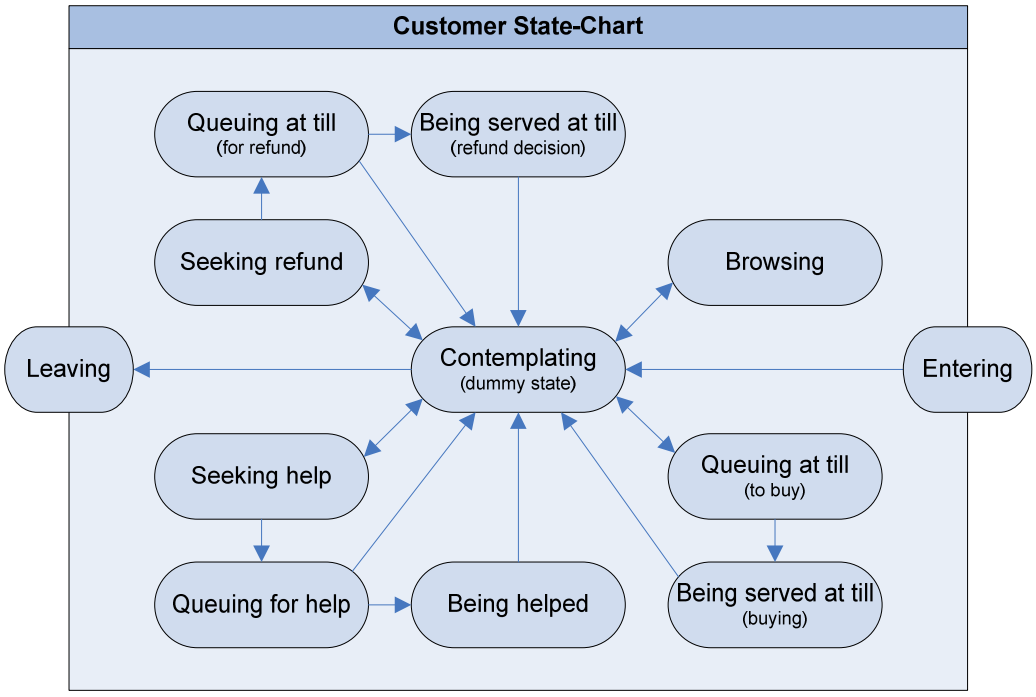
The Concepts (1/4)



The Concepts (2/4)

- Mapping real world processes
  - We have a system where customers have to queue for services (requires process oriented modelling)
  - We have a heterogeneous population of autonomous individuals (requires individual based modelling)

The Concepts (3/4)



The Concepts (4/4)

- Decision logic:
  - Frequency distributions for 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 for supporting decision making

event	probability it occurs
someone makes a purchase after browsing	0.37
someone requires help	0.38
someone makes a purchase after getting help	0.56

Implementation (1/11)

- Software: AnyLogic v5.5
  - Multi-method simulation software (SD, DES, ABS, DS)
  - State charts + Java code
- Level of abstraction
  - Agent-based models can be developed at different levels of abstraction, from very simple to very complex
  - We have developed our simulation model in an iterative manner, raising the level of complexity in each step

Implementation (2/11)
ManPraSim v1

- Features:
  - Based on case study data
  - Staff types: cashiers, 2 x selling staff, section managers
  - Customer types: general customer
- Management practices:
  - Training: staff at different training levels
  - Empowerment: refund decisions; staff learning on the job
- Drawbacks:
  - Homogeneous customers; no study of long term effects possible

Implementation (3/11)
ManPraSim v2

- Main additions:
  - Realistic footfall & opening hours
  - Customer types
  - Finite population

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

- Management practices:
  - Effect of previously studied ones on different customer types

Implementation (4/11)
ManPraSim v3

- Main additions:
  - Staff pool
  - Noise reduction mode
  - Customer evolution through external stimulation (word of mouth with static pool)

$$n_{additional\ customers\ per\ day} = (n_{satisfied(d-1)} - n_{dissatisfied(d-1)}) * af * cr$$
$$n_{customers\ per\ day} = n_{known\ customers\ per\ day} + n_{additional\ customers\ per\ day}$$

- Management practices:
  - Effect of previously studied once on customer evolution

Implementation (5/11)
ManPraSim v4

- Main additions:
  - Customer evolution through external stimulation (word of mouth with dynamic pool)

$$n_{core\ customers\ per\ day} = \frac{dynamic\ pool\ size * n_{known\ customers\ per\ day}}{static\ pool\ size}$$
$$n_{customers\ per\ day} = n_{core\ customers\ per\ day} + n_{additional\ customers\ per\ day}$$

  - Customer evolution through internal stimulation (triggered by memory of ones own previous shopping experience)

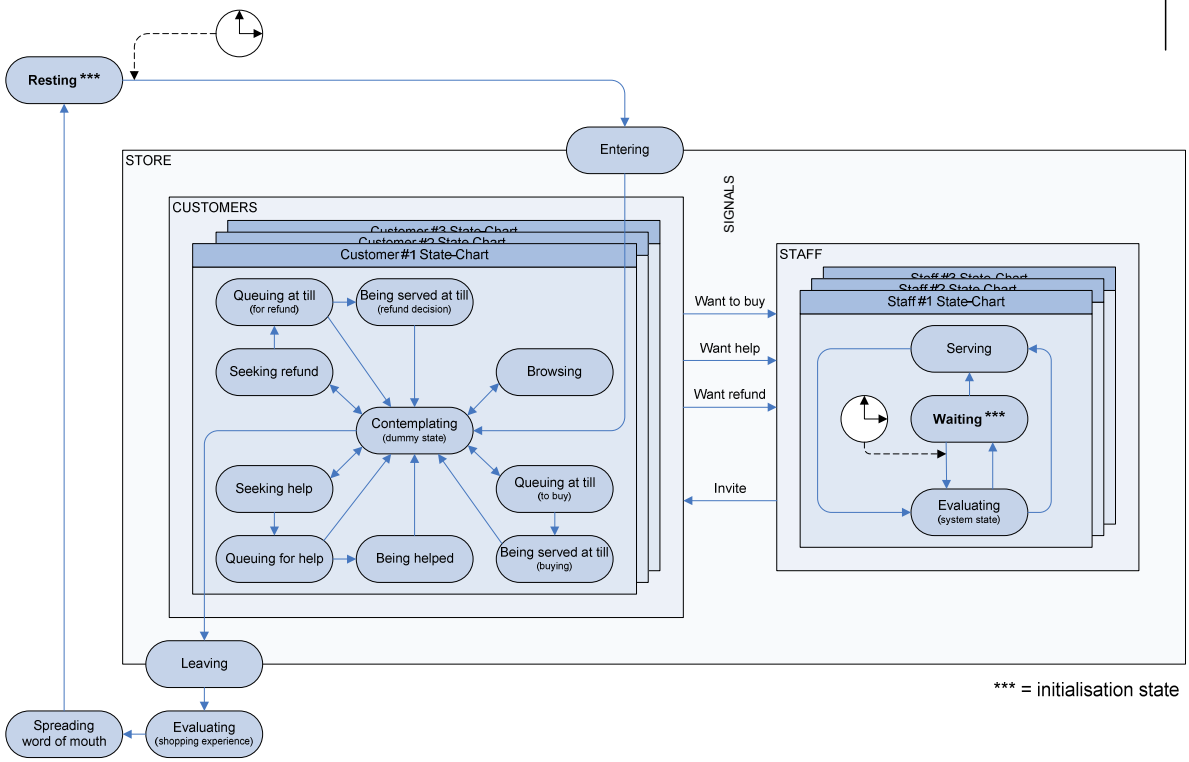
- Management practices:
  - Effect of previously studied once on customer evolution

Implementation (6/11)
ManPraSim v5

- Main additions:
  - Enhanced staff pro-activeness
    - Observing service queues and helping out
  - New set of performance measures
    - Staff utilisation for the time staff spends in different roles
    - The time customers spend in different operational blocks
    - Productivity and profitability of the system

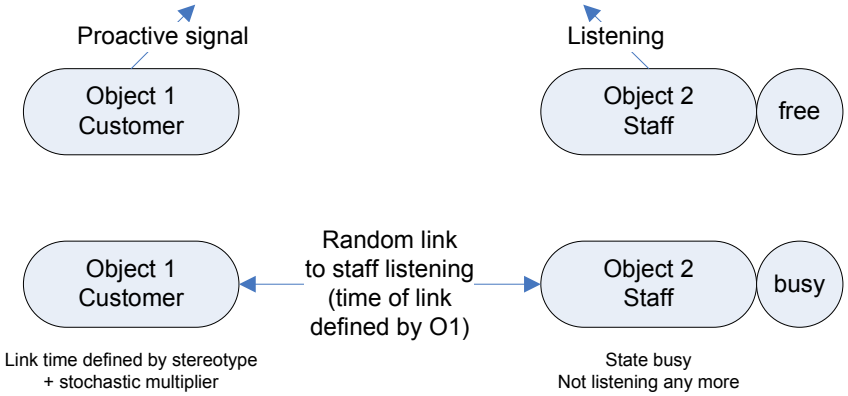
- Management practices:
  - Testing different levels of pro-activeness and different starting and terminating strategies for support activities

Implementation (7/11)



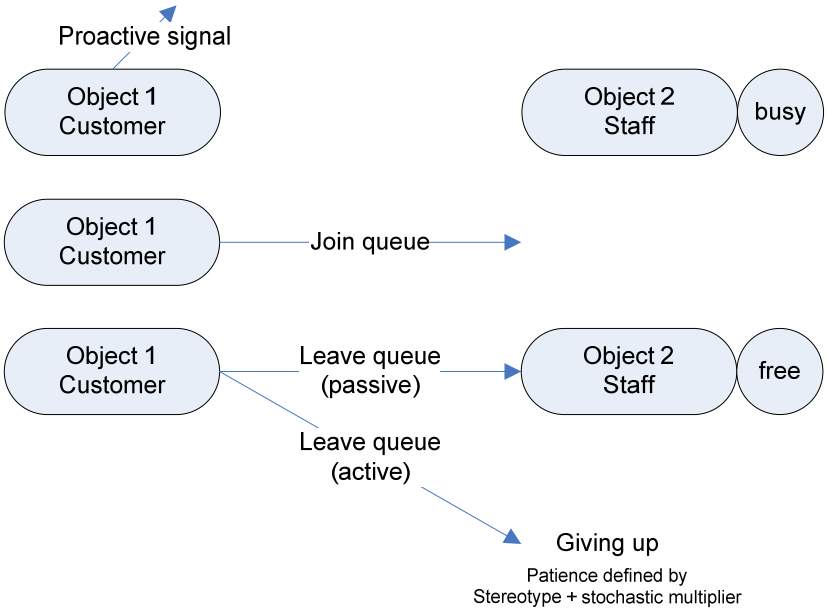
Implementation (8/11)

- Agent Interaction: Scenario 1

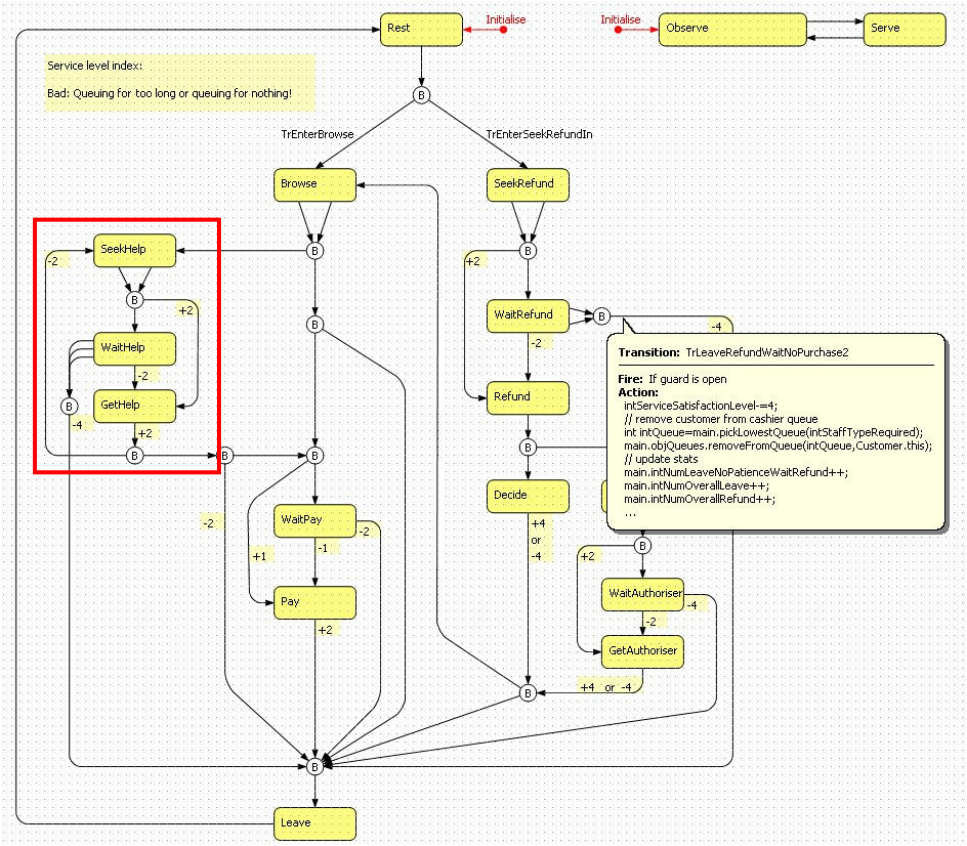


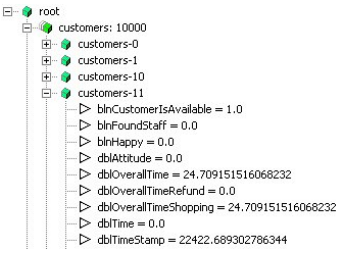
Implementation (9/11)

- Agent Interaction: Scenario 2



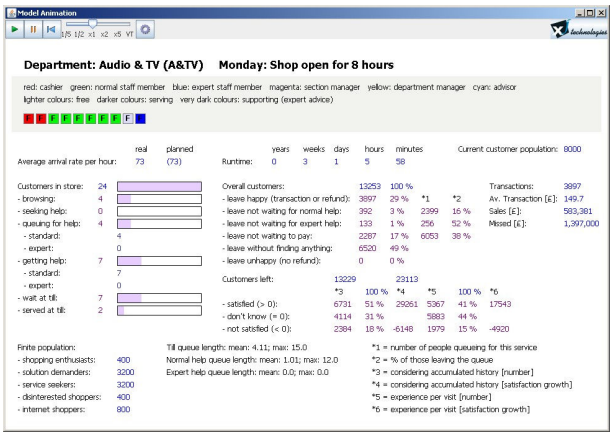
Implementation (10/11)





Implementation (11/11)

- Simulation output Example
  - When the simulation is running use the slider in the top left corner to speed up or slow down the simulation.



Experiments

- Real world (practical)
  - Staffing levels
  - Staff autonomy (refund, learning)
  - Staff training requirements

- Abstract (theoretical)
  - Extreme populations (customer types)
  - Level of detail (noise vs. noise reduction mode)
  - Different forms of customer pool implementations
  - Advertisement through spread of the word of mouth

Experiment 1 (1/2)
Staffing Levels

- 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]

Experiment 1 (2/2)
Staffing Levels

- 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

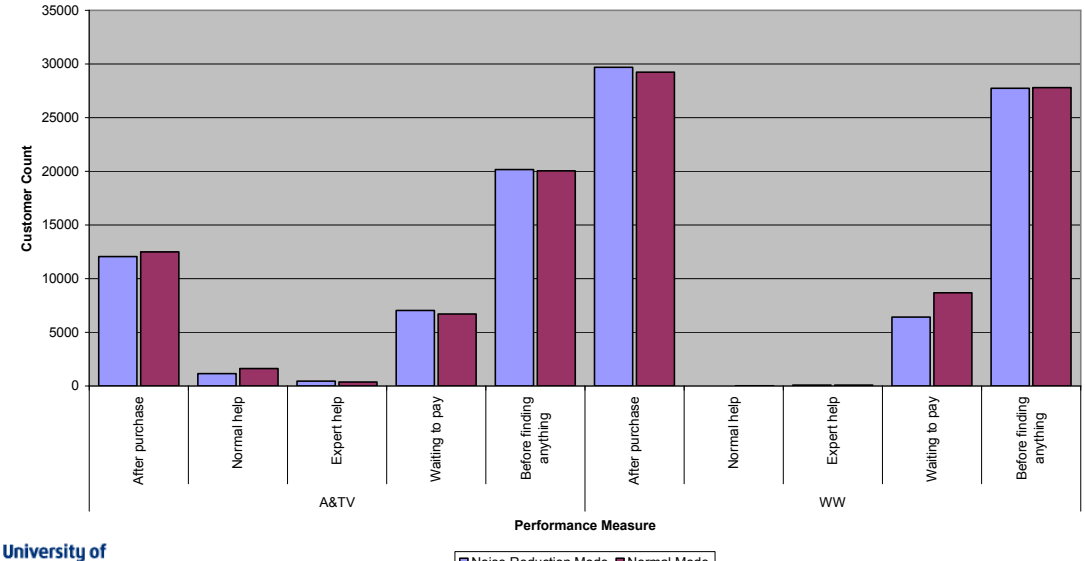
Till queue length: mean: 2.15; max: 17.0
Normal help queue length: mean: 1.56; max: 14.0

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

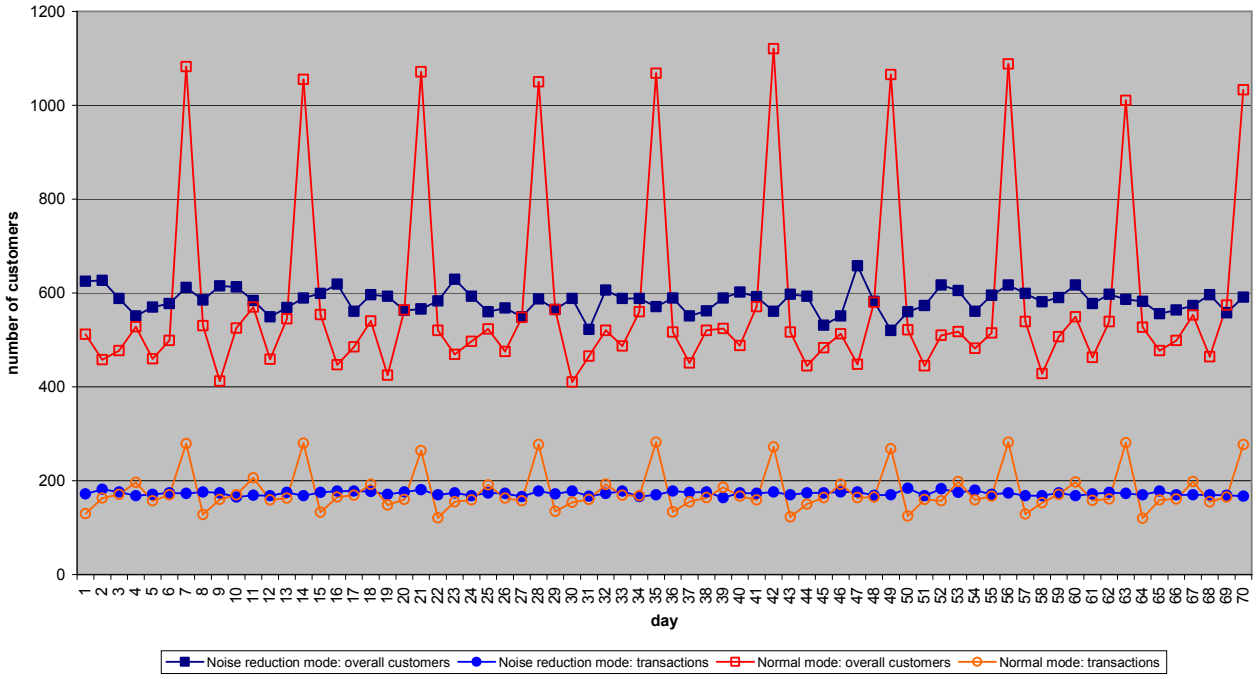
*1 = number of people queueing for this service
*2 = % of those leaving the queue
*3 = considering accumulated history [number]
*4 = considering accumulated history [satisfaction growth]
*5 = experience per visit [number]
*6 = experience per visit [satisfaction growth]

Experiment 2 (1/2)
Noise vs. Noise Reduction Mode (Average)

- Importance of considering hourly differences in customer arrival rates and daily differences in staffing and opening hours



Experiment 2 (2/2)
Noise vs. Noise Reduction Mode (Daily Measure)



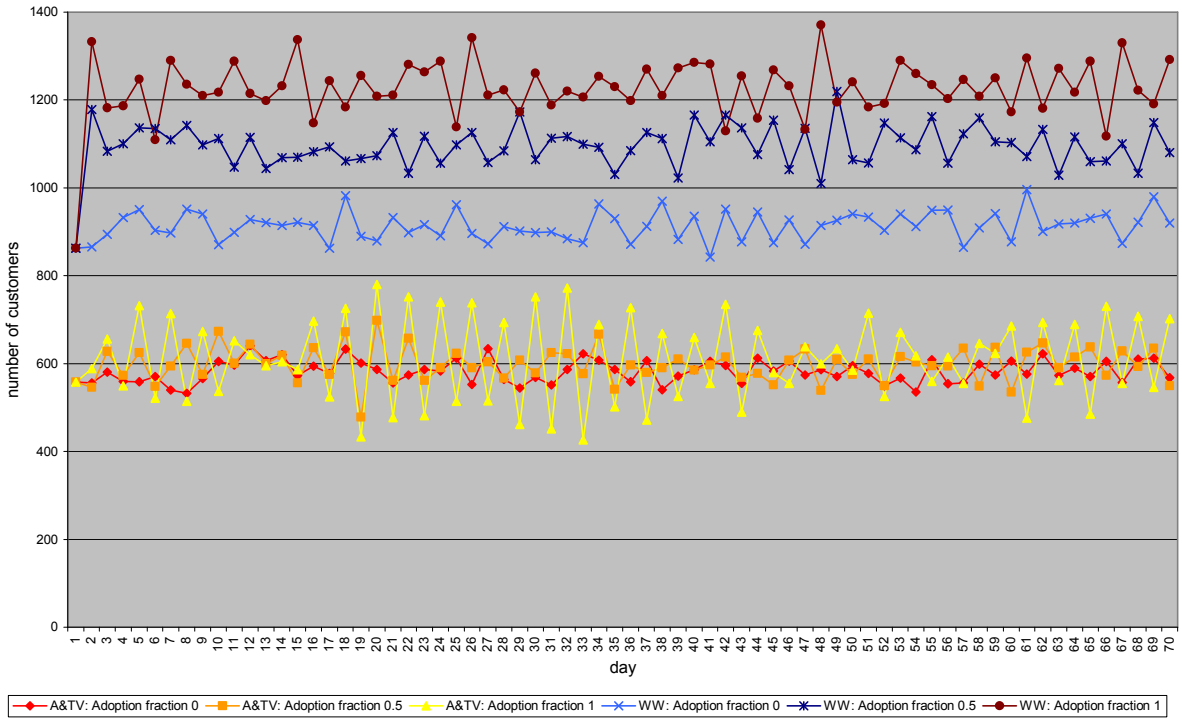
Experiment 3 (1/2)
Word of Mouth (Static Pool)

- Word of mouth impact is different for different departments

	adoption fraction	0	0.5	1	difference*1	difference*2
A&TV	overall number of customers	40755	41886	42698	1943	4.55%
	... that leave buying something	12010	12065	12085	75	0.62%
	... that leave not waiting for normal help	1050	1283	1682	632	37.57%
	... that leave not waiting for expert help	459	446	466	7	1.50%
	... that leave not waiting to pay	7161	7508	7603	442	5.81%
	... that leave without finding anything	20075	20584	20862	787	3.77%
	adoption fraction	0	0.5	1	difference*1	difference*2
WW	overall number of customers	63957	76643	85837	21880	25.49%
	... that leave buying something	29634	30063	30225	591	1.96%
	... that leave not waiting for normal help	2	44	91	89	97.80%
	... that leave not waiting for expert help	63	129	185	122	65.95%
	... that leave not waiting to pay	6450	13363	17955	11505	64.08%
	... that leave without finding anything	27808	33044	37381	9573	25.61%

*1: ((adoption fraction = 1) - (adoption fraction = 0))
*2: ((adoption fraction = 1) - (adoption fraction = 0)) / (adoption fraction = 1)

Experiment 3 (2/2)
Word of Mouth (Static Pool)



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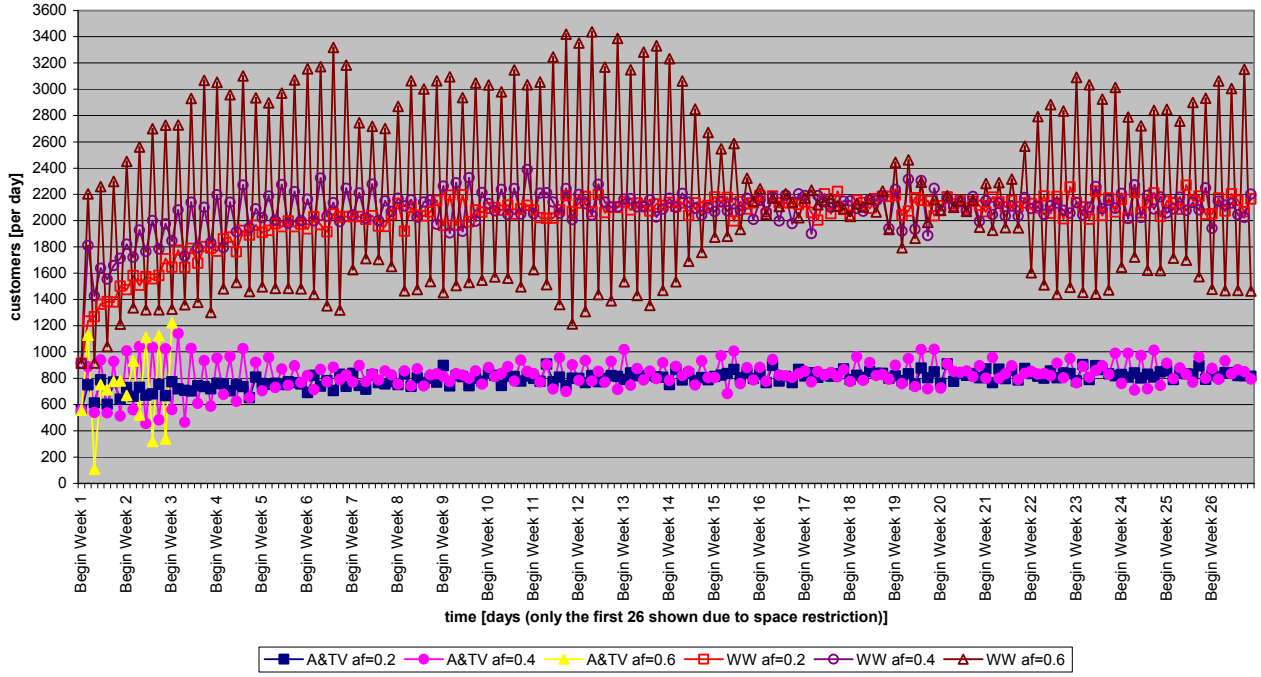
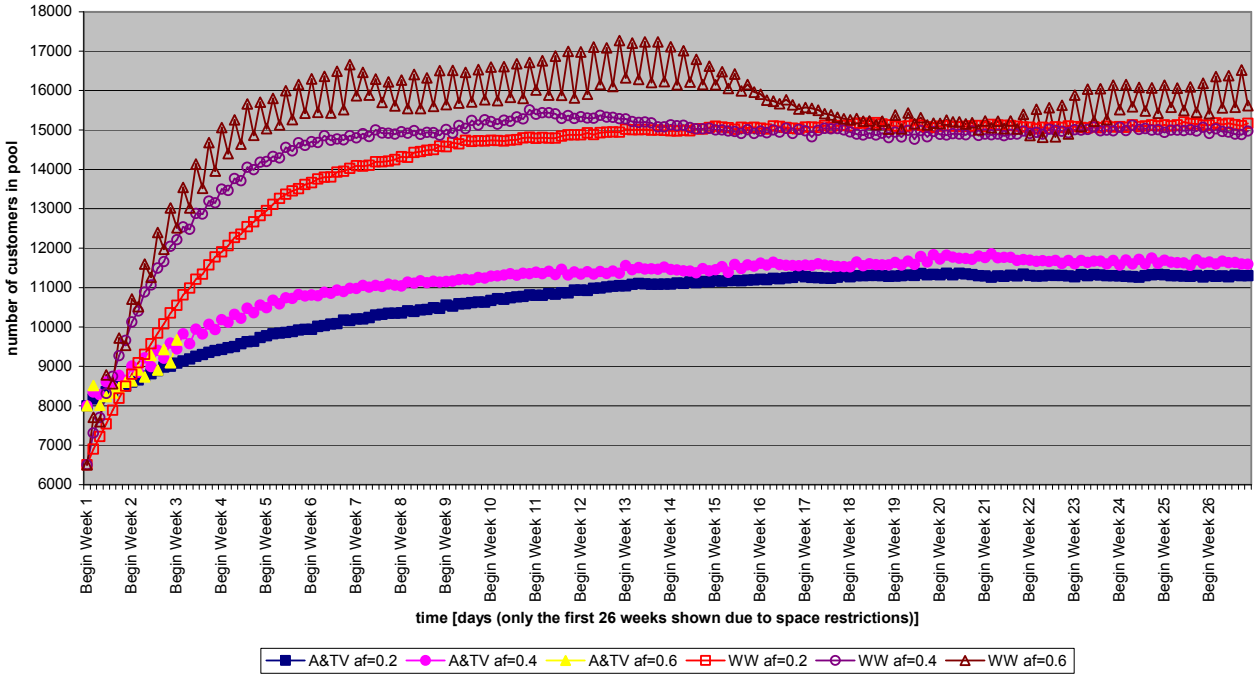
Experiment 4 (1/2)
Word of Mouth (Dynamic Pool)

- Daily count of customers (dynamic pool, varying af.)



Experiment 4 (2/2)
Word of Mouth (Dynamic Pool)

- Customer pool size (dynamic pool, varying af.)



Conclusions

Conclusions

Questions

Conclusions

- Findings:
  - Agent-based modelling and simulation is a useful tool for investigating retail management practices
  - Some of the details we modelled did not have a big impact on model behaviour / output but were adding some noise

- Research opportunities:
  - Comparing probabilistic and rule based decision making
  - Comparing different simulation techniques
  - Study the impact of teamwork related management practices

Questions?

- References:
  - Boero, R. and Squazzoni, F. (2005). “Does Empirical Embeddedness Matter? Methodological Issues on Agent-Based Models for Analytical Science” Journal of Artificial Societies and Social Simulation, 8(4)