A first approach on modelling staff proactiveness in retail simulations

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Content

- A philosophical excurse
  - What is ABMS
  - How can we use it in OR to model and simulate service systems
- A case study
  - Investigating the impact of management practices on company performance
    - Organisational management practices
    - People management practices
  - Modelling customer/staff interactions in a department store
  - Adding proactivity to our reactive model
- Conclusions

A philosophical excurse

A philosophical excurse

- Discrete Event Simulation (DES) and System Dynamics (SD) are the main approaches to simulation modelling in Operational Research (OR)
- Do they allow us to consider proactive behaviour?
  - This is important for realistically modelling human centric systems
  - The OR literature does not provide any guidance

- Agent Based Simulation (ABS) allows us to consider proactive behaviour
  - Does it allow us to model OR type systems?
  - What do we need to consider when we apply it to solve OR problems?

A philosophical excurse

- A word of caution:
  - Many different developments have been going on under the slogan of Agent Based Simulation in very different disciplines
  - Each discipline has its own understanding of what constitutes an agents and a multi-agent system
    - What does the OR community understand by an agent?
- Two main multi-agent system paradigms:
  - Multi-agent decision systems
    - Usually embedded agents or a simulation of embedded agents
    - Focus is on decision making
  - Multi-agent simulation systems
    - The multi-agent system is used as a model to simulate some real-world domain and recreate some real world phenomena

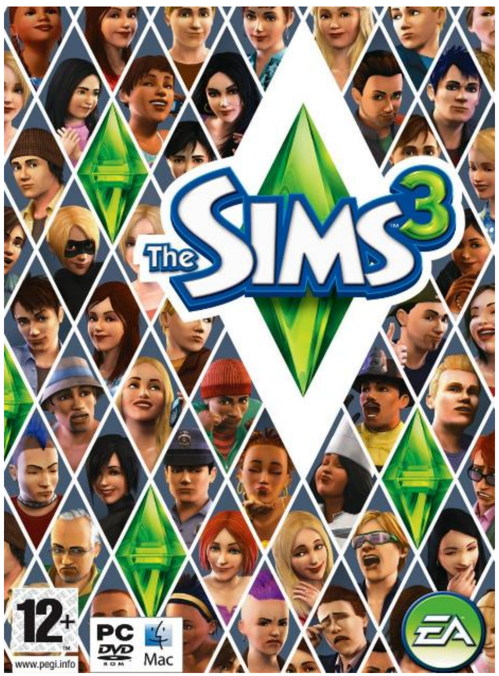
A philosophical excurse

- 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

A philosophical excurse

- The Sims: Interactive Organisational Agent-Based Simulation



A philosophical excursion

- Classification: Empirical embeddedness [Boero and 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 decision making process (depends on model purpose)
  - Probabilistic: representing decisions using distributions
  - Rule based: modelling the decision making process

A philosophical excurse

- Comparing attributes of DES and ABS [Siebers et al. 2010]

DES models	ABS models
Process oriented; focus is on modelling the system in detail, not the entities	Individual based; focus is on modelling the entities and interactions between them
Top down modelling approach	Bottom up modelling approach
One thread of control (centralised)	Each agent has its own thread of control (decentralised)
Passive entities, i.e. something is done to the entities while they move trough the system; intelligence (e.g. decision making) is modelled as part in the system	Active entities, i.e. the entities themselves can take on the initiative to do something; intelligence is represented within each individual entity
Queues are a key element	No concept of queues
Flow of entities through a system; macro behaviour is modelled	No concept of flows; macro behaviour is not modelled, it emerges from the micro decisions of the individual agents
Input distributions are often based on collect/measured (objective) data	Input distributions are often based on theories or subjective data

A philosophical excurse

- Getting Practical: Simulating Service Systems
  - Using a combined DES/ABS approach

- 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)

Communication layer

Direct interactions
Network activities

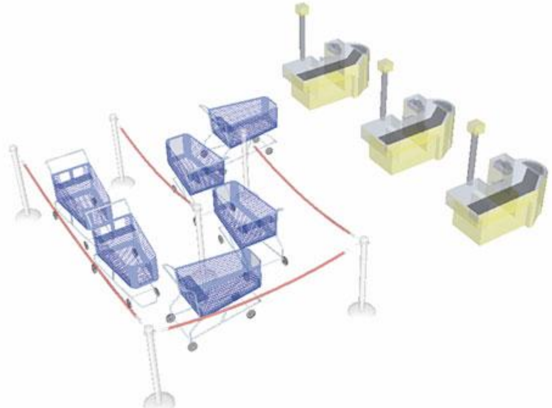
Let entities interact + communicate

Agent layer

Active entities
Behavioural state charts

Replace passive entities by active ones

DES layer



Passive entities
Queues
Processes
Resources

A Case Study

Case Study

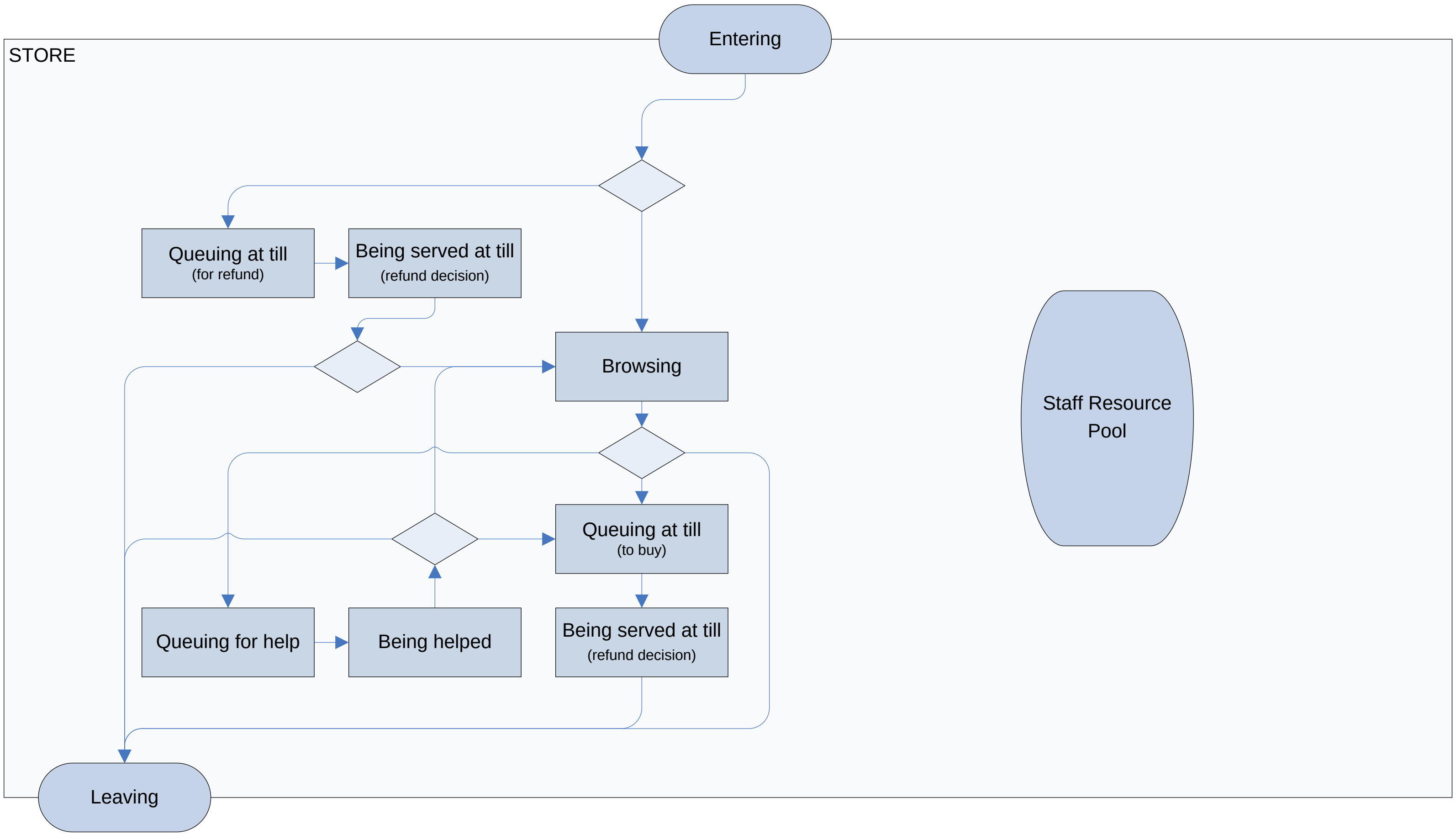
- Developing some tools for understanding the impact of management practices on company performance
  - Operational management practices are well researched
  - People management practices are often neglected
    - Difficult to simulate people as they are often unpredictable in their individual behaviour
- Case study sector: Retail (department store operations)
- Problem encountered:
  - When using real staffing rota we could not produce the transaction values of the real system; we had to use some optimised data instead
  - Can we solve this problem by adding proactive behaviour?
  - How can we add proactive behaviour?

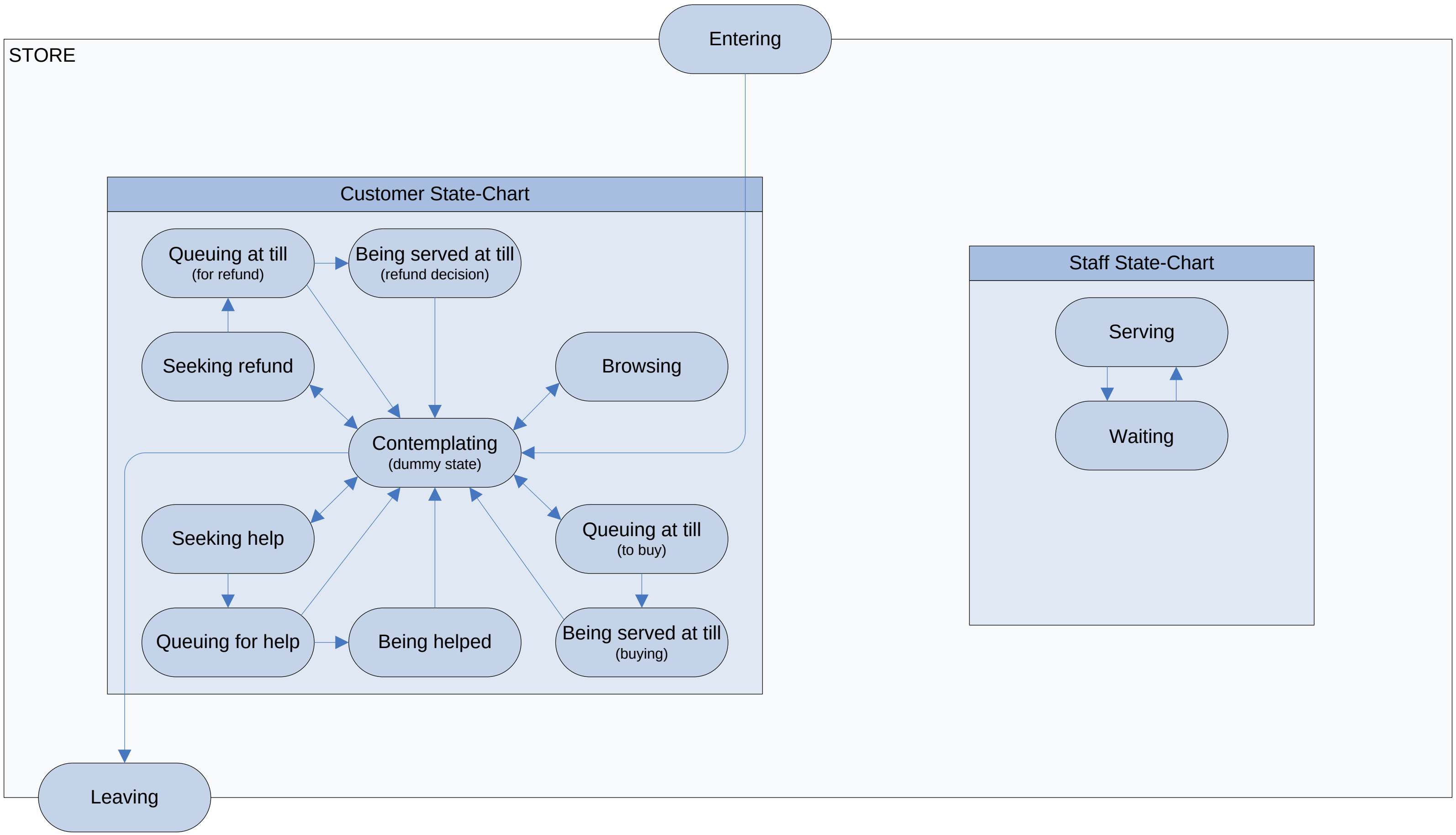
Case Study

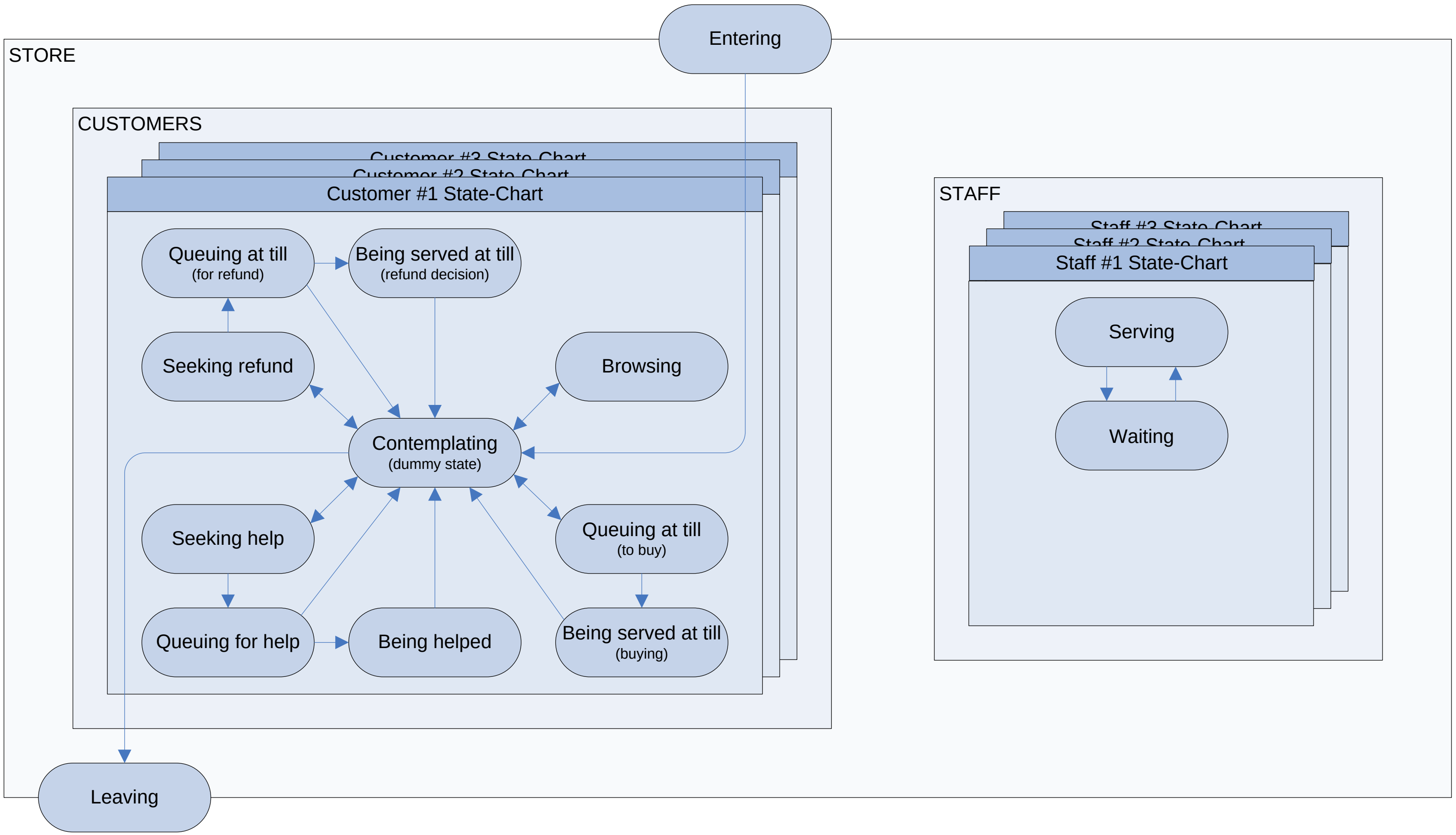
- Modelling proactive service behaviour in OR type models
  - The OR literature does not provide any guidance
  - Management literature defines proactive customer service as self started, long term oriented, and persistent service behaviour that goes beyond explicitly prescribed requirements
  - Artificial intelligence literature states that proactive behaviour can be modelled in terms of goals that the agents pursue
    - Declarative: a description of the state sought
    - Procedural: a set of plans for achieving the goal
  - Short waiting times are key to high service quality
  - Therefore: A staff agent goal is to provide best service by proactively balancing the different queues that appear in the department store.

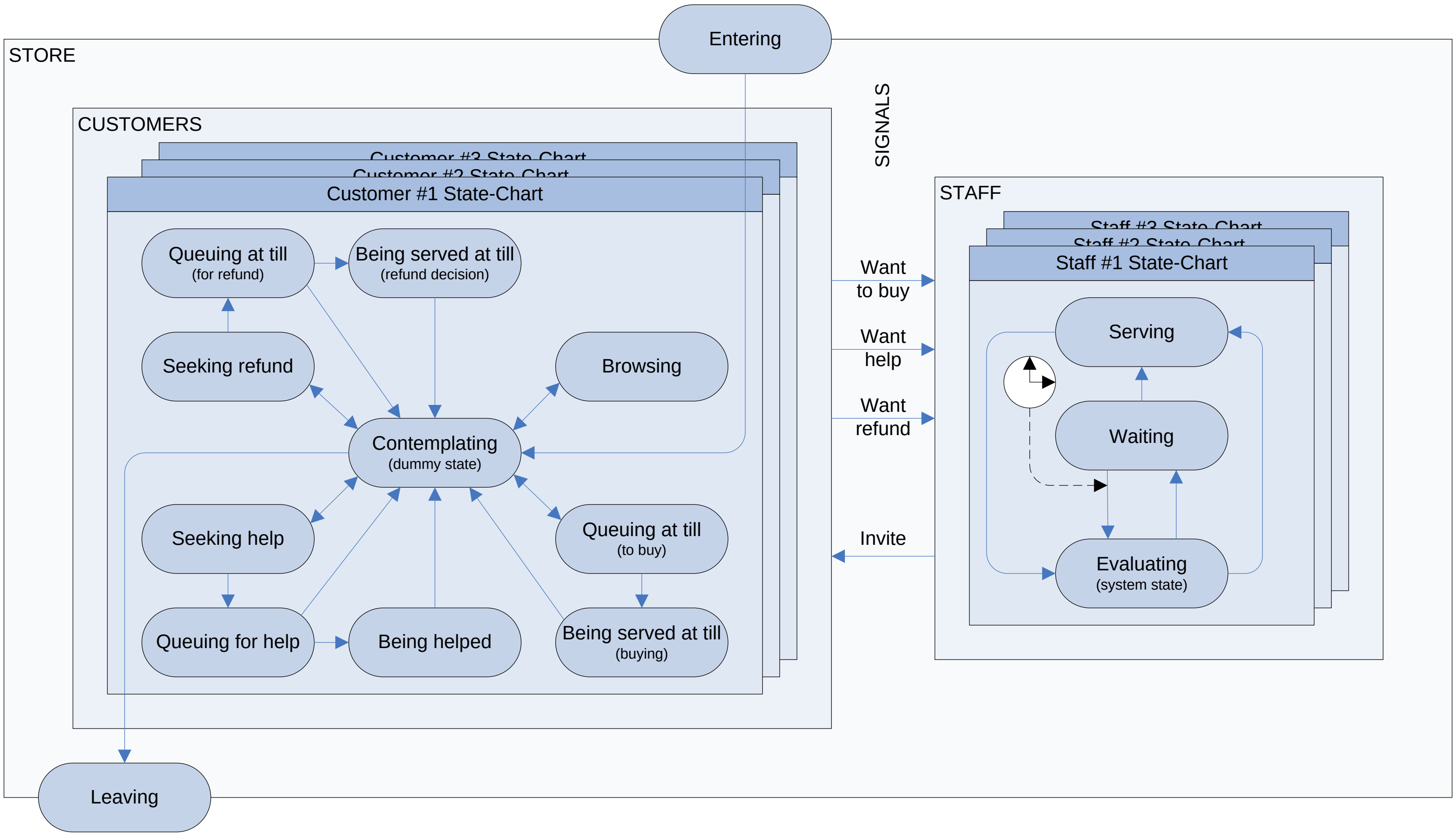
Case Study

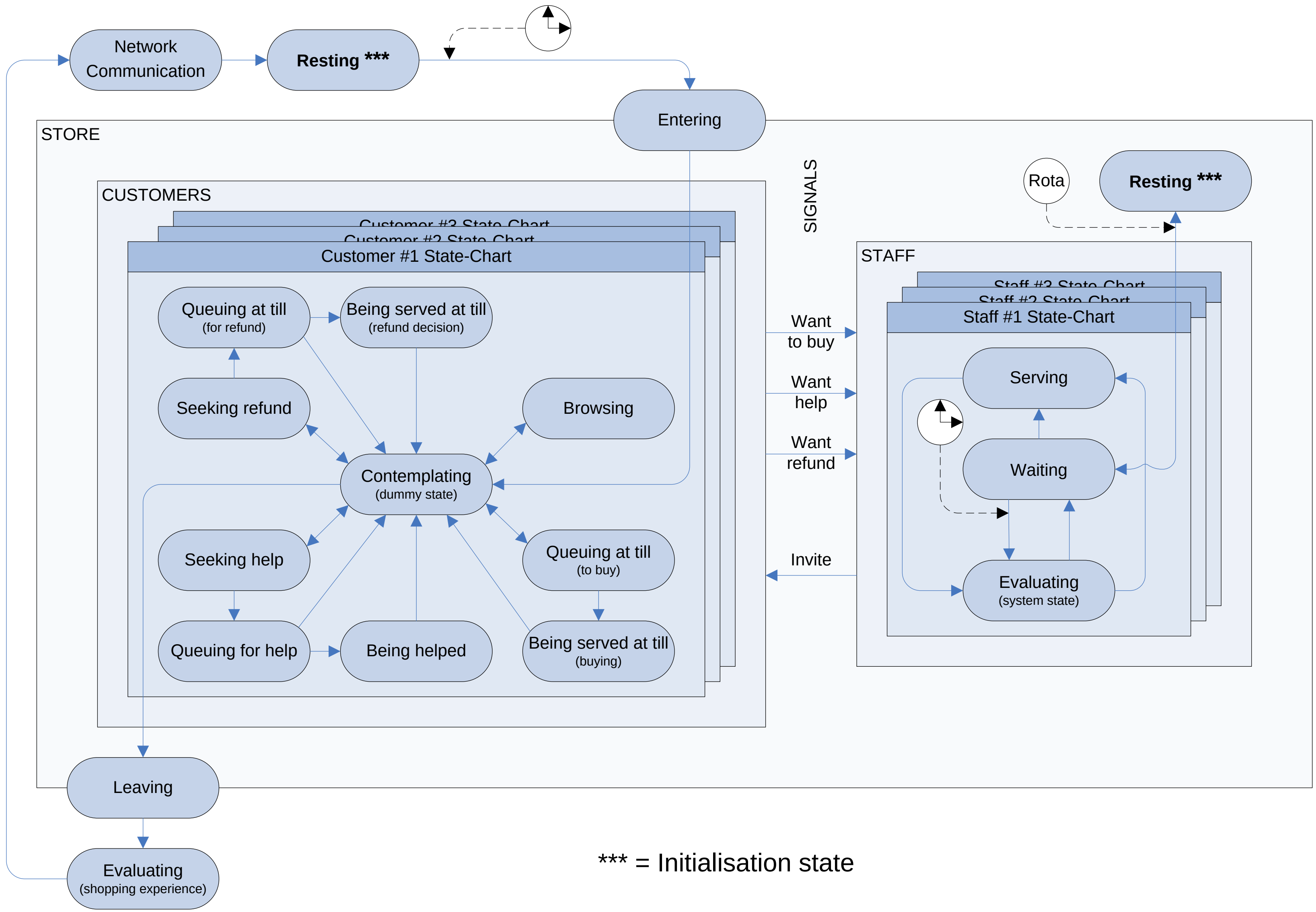
- Two case studies at two different locations
  - Two departments (A&TV and WW) at two department stores
- Knowledge gathering
  - Informal participant observations
  - Staff interviews
  - Informational sources internal to the case study organisation


Entering
STORE
Queuing at till
(for refund)
Being served at till
(refund decision)
Browsing
Staff Resource
Pool
Queuing at till
(to buy)
Queuing for help
Being helped
Being served at till
(refund decision)
Leaving


Entering
STORE
Customer State-Chart
Queuing at till
(for refund)
Being served at till
(refund decision)
Seeking refund
Browsing
Contemplating
(dummy state)
Seeking help
Queuing at till
(to buy)
Queuing for help
Being helped
Being served at till
(buying)
Staff State-Chart
Serving
Waiting
Leaving


Entering
STORE
CUSTOMERS
Customer #3 State-Chart
Customer #2 State-Chart
Customer #1 State-Chart
Queuing at till
(for refund)
Being served at till
(refund decision)
Seeking refund
Browsing
Contemplating
(dummy state)
Seeking help
Queuing at till
(to buy)
Queuing for help
Being helped
Being served at till
(buying)
STAFF
Staff #3 State-Chart
Staff #2 State-Chart
Staff #1 State-Chart
Serving
Waiting
Leaving

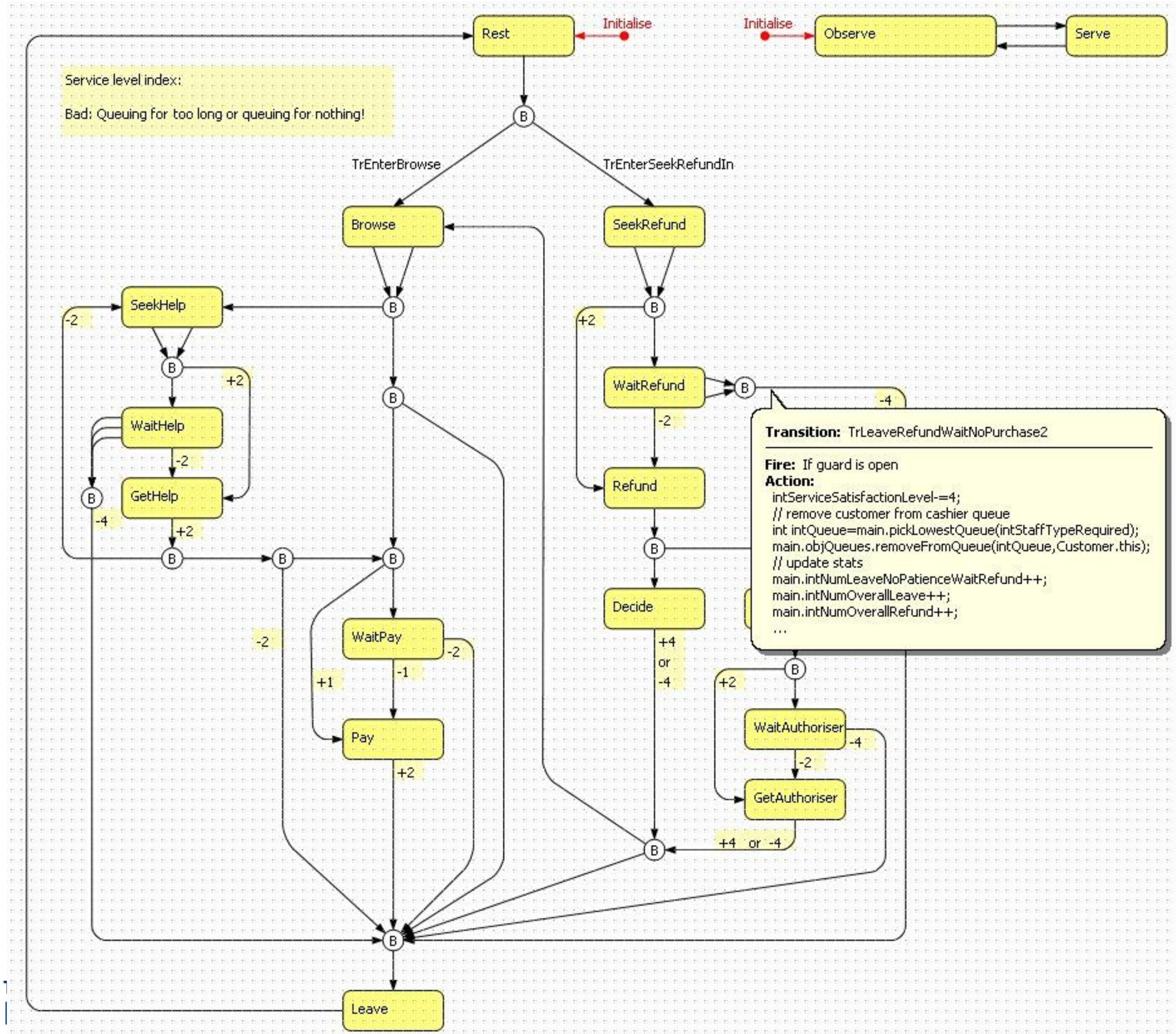

Entering
STORE
SIGNALS
CUSTOMERS
Customer #1 State-Chart
Queuing at till
(for refund)
Being served at till
(refund decision)
Seeking refund
Browsing
Contemplating
(dummy state)
Seeking help
Queuing at till
(to buy)
Queuing for help
Being helped
Being served at till
(buying)
Want
to buy
Want
help
Want
refund
Invite
STAFF
Staff #1 State-Chart
Serving
Waiting
Evaluating
(system state)
Leaving



*** = Initialisation state

Implementation

- Software: AnyLogic v5.5
  - Multi-method simulation software (SD, DES, ABS, DS)
  - State charts + Java code
- The model is available at the openabm.org website [Siebers 2011]


Rest
Initialise
Initialise
Observe
Serve
Service level index:
Bad: Queuing for too long or queuing for nothing!
B
TrEnterBrowse
TrEnterSeekRefundIn
Browse
SeekRefund
SeekHelp
-2
+2
WaitHelp
-2
GetHelp
-4
+2
-2
WaitPay
-2
-1
+1
Pay
+2
+2
WaitRefund
-4
-2
Refund
Decide
+4
or
-4
+2
WaitAuthoriser
-4
-2
GetAuthoriser
+4 or -4
Leave
Transition: TrLeaveRefundWaitNoPurchase2
Fire: If guard is open
Action:
intServiceSatisfactionLevel-=4;
// remove customer from cashier queue
int intQueue=main.pickLowestQueue(intStaffTypeRequired);
main.objQueues.removeFromQueue(intQueue,Customer.this);
// update stats
main.intNumLeaveNoPatienceWaitRefund++;
main.intNumOverallLeave++;
main.intNumOverallRefund++;
...

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

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
```

Implementation

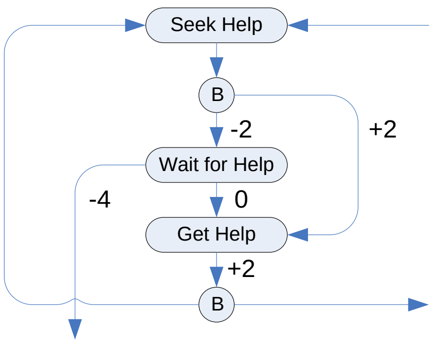
- Implementation of staff proactiveness (1/2)
  - Non-cashier staff opening and closing tills proactively depending on demand and staff availability; expert staff helping out as normal staff
  - Task priorities that need to be considered
    - 1: Continue as temporary cashier unless a stop strategy has come true
    - 2: If expert staff, help out as section manager (might be required for refund process)
    - 3: If normal service staff or expert staff, help out as temporary cashier
    - 4: If expert staff, help out as normal service staff
    - If none of these is applicable, wait for a given time and then check again if role swap is required

Implementation

- Implementation of staff proactiveness (2/2)
  - Parameters to control proactive behaviour
    - P1: Maximum number of customers to serve as a temporary cashier
    - P2: Critical queue length for opening/closing additional tills
    - P3: Minimum number of staff required to cope with original task
    - P4: Maximum numbers of open tills
    - P5: Stop strategy: Stop service as temporary cashier when either P1 or P2has been reached
    - P6: Check if support at the till is needed every 2 minutes (deterministic or random checks)

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 …



Implementation

- 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)
- Modular design: Features can be switched on/off

Implementation

- Validation
  - We used the V&V framework proposed by Robinson (2004)
    - Conceptual model validation
    - Data validation
    - White box (micro) validation
    - Black box (macro) validation
    - Experiment validation
    - Solution validation (not possible)
    - Verification

Model Animation

1/5 1/2 x1 x2 x5 VT

Department: Audio & TV (A&TV)   Sunday: Shop open for 8 hours

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

*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]

	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

			*1	*2
Overall customers:	86255	100 %		
- leave happy (transaction or refund):	29101	34 %		
- 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 %		

Transactions:	29101
Av. Transaction [£]:	149.7
Sales [£]:	4,356,420
Missed [£]:	8,551,912

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

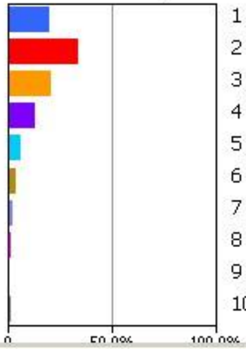
	*3		*4	*5		*6
Customers left:	86228	100 %	477406		100 %	
- satisfied (> 0):	61697	72 %	518960	35188	41 %	101567
- don't know (= 0):	10574	12 %		40652	47 %	
- not satisfied (< 0):	13957	16 %	-41554	10388	12 %	-26726

			*1	*2
Overall refunds:	0	100 %		
- refunds accepted:	0	0 %		
- refunds denied:	0	0 %		
- 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			

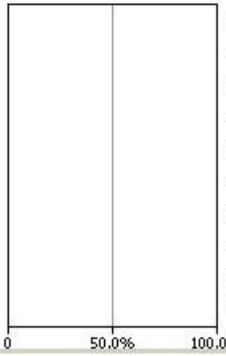
Finite population:	
- shopping enthusiasts:	400
- solution demanders:	3200
- service seekers:	3200
- disinterested shoppers:	400
- internet shoppers:	800

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

Experimentation

- 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
- Validation
  - Testing parameters

Experimentation

- Proactivity Experiments [Siebers et al 2011]
  - Validation

Parameter Settings	Audio & TV (outputs: means of weekly averages; deviations: relate to the real world value)								
Scenario	real world	a		b		c		d	
Staffing	real	optimised		optimised		real		real	
Number of {cashiers; normal staff; expert staff}	{1;10;1}	{2;6;2}		{2;6;2}		{1;10;1}		{1;10;1}	
Proactive	yes	no		yes		no		yes	
Outputs	**Mean**	**Mean**	**Deviation**	**Mean**	**Deviation**	**Mean**	**Deviation**	**Mean**	**Deviation**
Transactions	1787.09	1203.43	32.66%	1387.25	22.37%	615.70	65.55%	1346.22	24.67%

Parameter Settings	Womenswear (outputs: means of weekly averages; deviations: relate to the real world value)								
Scenario	real world	a		b		c		d	
Staffing	real	optimised		optimised		real		real	
Number of {cashiers; normal staff; expert staff}	{2;13;1}	{3;8;2}		{3;8;2}		{2;13;1}		{2;13;1}	
Proactive	yes	no		yes		no		yes	
Outputs	**Mean**	**Mean**	**Deviation**	**Mean**	**Deviation**	**Mean**	**Deviation**	**Mean**	**Deviation**
Transactions	3172.35	2931.43	7.59%	3138.00	1.08%	2004.97	36.80%	2977.20	6.15%

Experimentation

- Proactivity Experiments [Siebers et al 2011]
  - Sensitivity Analysis

Parameter Settings	Audio & TV (outputs: means of weekly averages)									
Number of {cashiers; normal staff; expert staff}	{4;7;1}		{1;10;1}		{1;10;1}		{1;10;1}		{1;10;1}	
Proactive	no		yes		yes		yes		yes	
Critical queue length	-		1		2		3		4	
Outputs	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number of customers that leave happy (purchase)	1875.47	5.16	1833.18	6.99	1627.22	3.77	1348.48	2.85	1161.97	3.16
% of customers that leave happy (purchase)	45.87%	0.15%	44.84%	0.17%	39.85%	0.07%	32.99%	0.09%	28.42%	0.08%
% of customers that leave not waiting for normal help	2.35%	0.04%	1.08%	0.05%	0.75%	0.03%	0.46%	0.02%	0.32%	0.02%
% of customers that leave not waiting for expert help	1.86%	0.04%	1.95%	0.03%	1.92%	0.03%	1.89%	0.04%	1.88%	0.03%
% of customers that leave not waiting to pay	0.43%	0.03%	2.27%	0.05%	7.40%	0.09%	14.56%	0.05%	19.23%	0.10%

Conclusions

- Conclusions
  - Combined DES/ABS allows the consideration of proactive behaviour in service system models which has a positive impact on the accuracy of the simulation outputs
  - To find the right settings for proactivity parameters is difficult (due to the high correlation of the parameters)

Conclusions

- Future outlook
  - Study the impact of teamwork related management practices
  - Exploring other ways for implementing the agent decision making processes
  - Reusable ABS components (archetypes; templates)
  - From academia to business: What is needed?
    - Clients should be involved in the whole process

References

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