# Simulation

**A Key Technique in Operational Research**


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## Content



1. Operational Research
2. Manufacturing Systems Simulation: An Introduction
3. Human Performance Modelling in Manufacturing Systems Simulation
4. Agent-Based Modelling and Simulation: An Introduction
5. Simulating the Impact of Management Practices on Retail Productivity
6. Summary & Conclusions

# Operational Research (OR)

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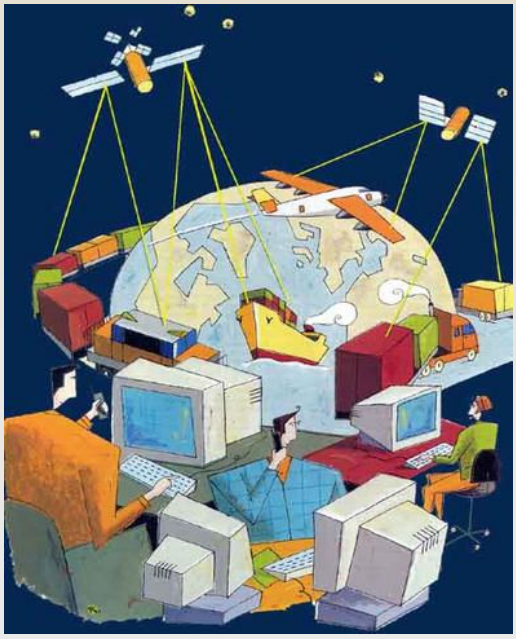
## Synonyms:

- Operations Research; Systems Analysis

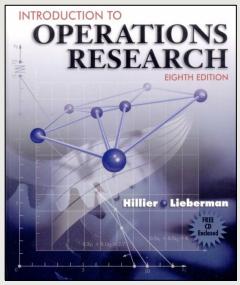
## Definition:

- The discipline of applying advanced analytical methods to help make better decisions.



## Analytical methods used (examples):

- Linear Programming
- Network Analysis
- Meta Heuristics
- Queuing Theory
- Game Theory
- Simulation








# What is Simulation (1/2)?

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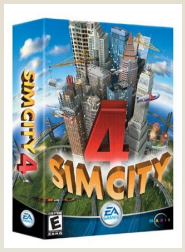


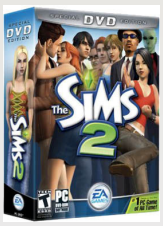


# What is Simulation (2/2)?

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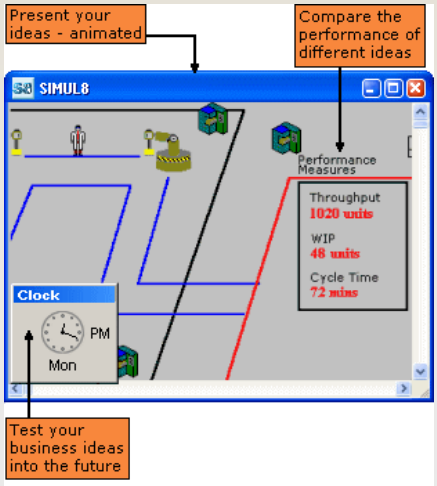
## Definition:

- Simulation is 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.

## Purpose of simulation:

- Gaining insight into the operation of a system
- Developing operating or resource policies to improve system performance.
- Testing new concepts and/or systems before implementation.
- Gaining information without disturbing the actual system.








# Simulation Modelling Classifications

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## Static vs. Dynamic:

- Static: No attempts to model a time sequence of changes.
- Dynamic: Updating each entity at each occurring event.

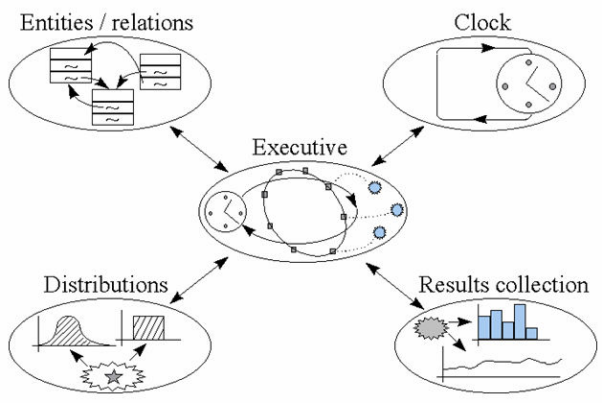
## Deterministic vs. Stochastic:

- Deterministic: Rule based.
- Stochastic: Based on conditional probabilities.

## Discrete vs. Continuous:

- Discrete: Changes in the state of the system occur instantaneously at random points in time as a result of the occurrence of discrete events.
- Continuous: Changes of the state of the system occur continuously over time.

# Elements of a Discrete Event Simulation Model




- Entities: Tangible elements (temporary/permanent) found in the real world.
- Logical Relationships: Link the different entities together.
- Executive: Controlling the time advance (dynamic behaviour of the model).
- Random number generator: Used to provides stochastic behaviour.





# Common Types of OR Simulation Applications

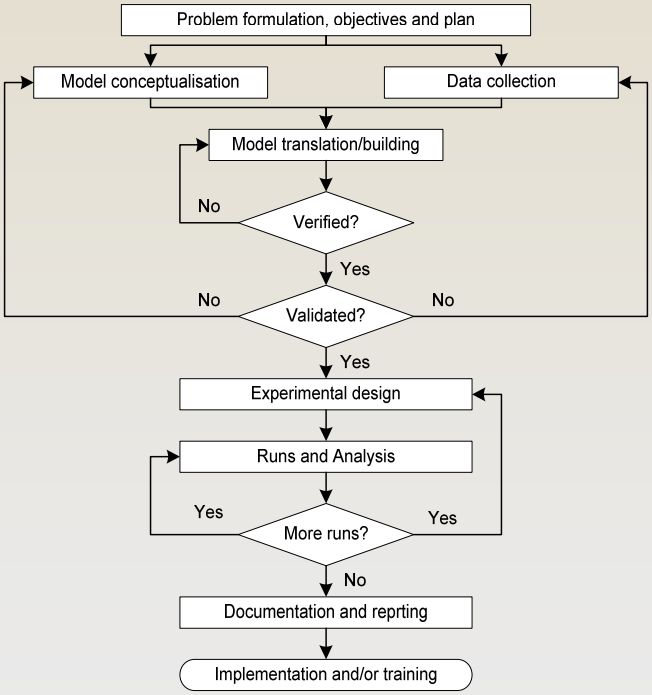
## Application Types:

- Design and Operation of Queuing Systems
- Managing Inventory Systems
- Estimating the Probability of Completing a Project by the Deadline
- Design and Operation of Manufacturing & Distribution Systems
- Financial Risk Analysis
- Health Care Applications
- Applications to Other Service Industries
  - Government service, banking, hotels, restaurants, educational institutions, disaster planning, the military, amusement parks, …

## Simulation Packages:

- Arena, AutoMOD, Extend, ProModel, Quest, Simul8, Witness, etc.

# The Steps in a Simulation Study








# Advantages of Simulation (1/2)

## Advantages:

- Interaction of random events: e.g. random occurrence of machine breakdowns
- Non-standard distributions: Only simulation gives you the flexibility to describe events and timings as they occur in real life
- Communication tool (visualisation, animation). Lets you clearly describe your proposal to others
- It is able to show the behaviour of a system (how the system develops over time) rather than just the end result.
- Makes you think: Simulation provides a vehicle for a discussion about all aspects of a process
- Most simulation packages have some optimisation add-ons; once a valid simulation model exists it can also be used for optimisation

# Advantages of Simulation (2/2)

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## Advantages (continued):

- Basic concept of simulation is easy to comprehend and hence easier to justify to customer.
- Requires fewer simplifying assumptions and hence captures more of the true characteristic of the system under study.
- Allows us to gain insight into how a modelled system actually works and understanding of which variables are most important to performance.





# Disadvantages of Simulation

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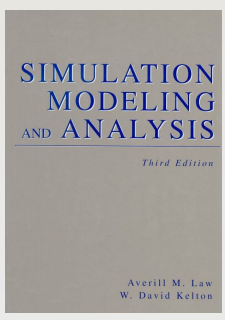
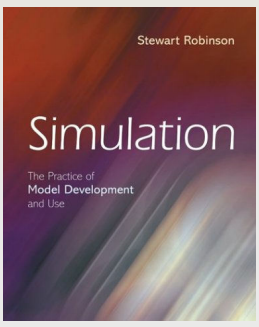
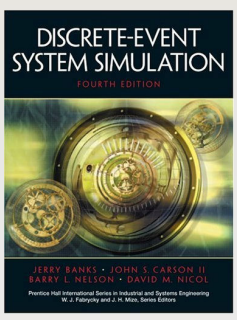
## Disadvantages:

- Utility of the study depends upon the quality of the model and the skills of the modeller.
- Gathering highly reliable input data can be time consuming and therefore expensive.
- Simulation models do not yield an optimal solution, rather they serve as a tool for analysis of the behaviour of a system under conditions specified by the experimenter.



# PhD Research - Background (1/2)

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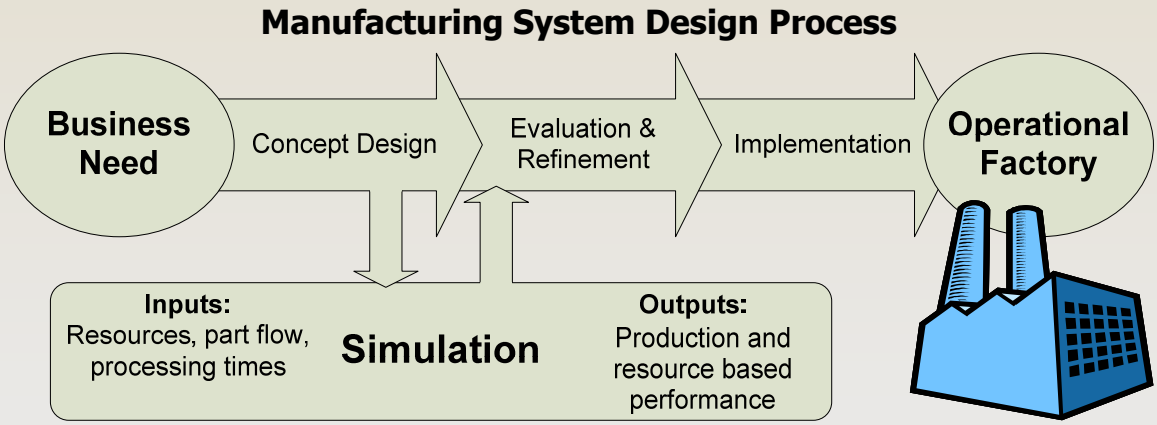






# PhD Research - Background (2/2)

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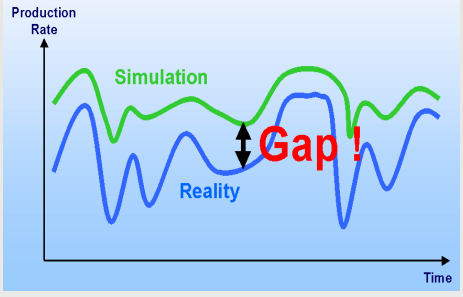
## Statement:

- Discrete Event Simulation (DES) is now a standard tool used for the design of manufacturing systems within the automotive industry.

## Common Observations:

- A gap exists between the performance prediction of a system model and the performance of the real system.
- The magnitude of the gap is bigger when simulating non existing systems.
- The magnitude of the gap is bigger when simulating manual lines.
- A standard way of taking workers into account is to model them as deterministic resources.



# PhD Research - Aim and Method

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## Research Aim:

- To demonstrate the importance of incorporating Human Performance Variation (HPV) models into manufacturing system simulation models.

## Research Method:

- Examination of the level of randomness inherent in HPV for different tasks.
- Design of representative HPV models.
- Sensitivity analysis to identify the impact that HPV has on the accuracy of manufacturing systems DES models.
- Literature review for more advanced methods of representing the human element within simulation models.





# Step 1: Examination of Level of Randomness

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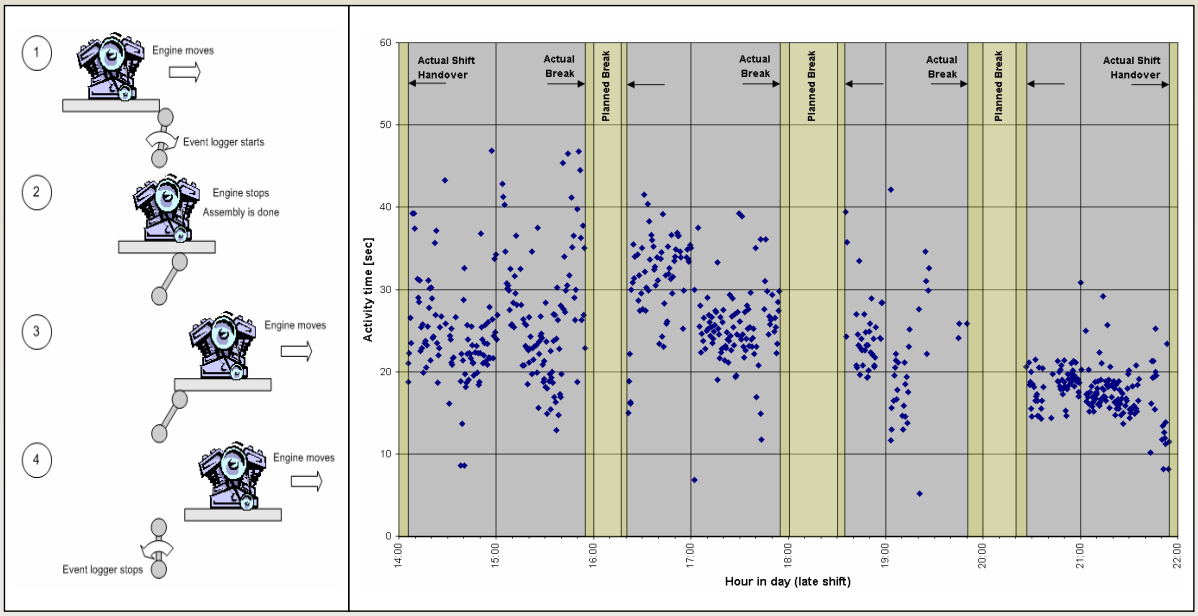

# Step 2: Design of HPV Models

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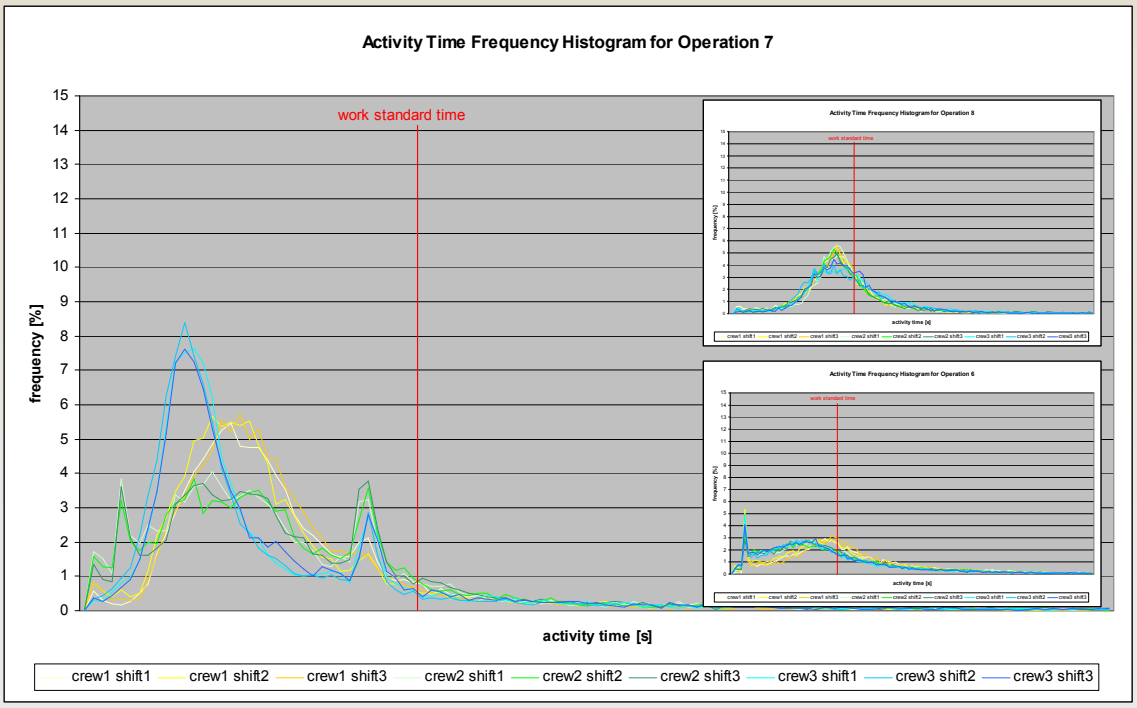






# Step 3: Sensitivity Analysis

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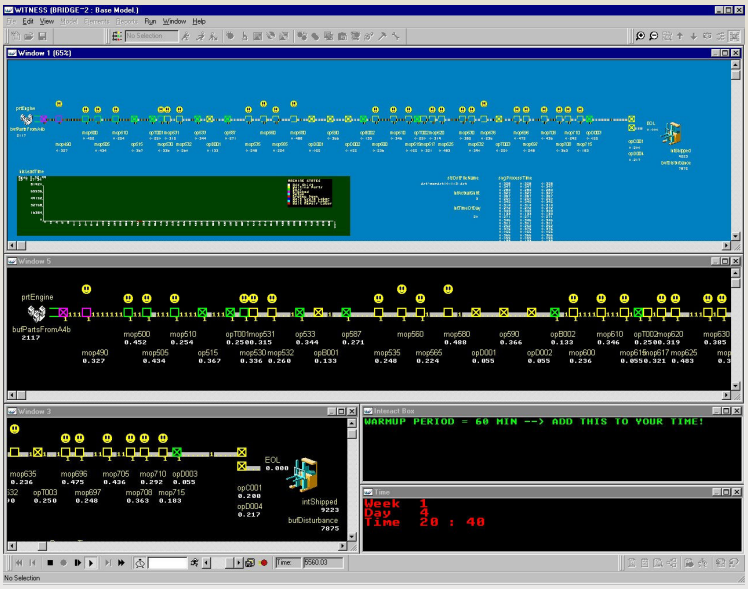


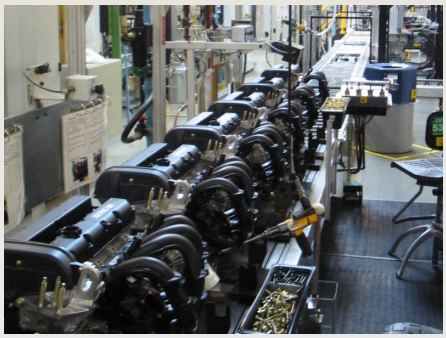

# PhD Research - Conclusions

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## Key Findings about HPV:

- Differences in activity times when workers repeat a task, between different workers, and between different work crews.
- Form of activity time distributions is dependent on the nature of the task.
- Variation of break start and duration is not dependent on the break length.

## Key Findings from Sensitivity Analysis:

- Representation of HPV can have a significant effect on the behaviour of manufacturing system simulation models.
- The magnitude of impact depends on the type of variation to be represented as well as on the system to be modelled.

## Main Limitation of Current HPV Modelling Approach:

- Independent representation of sources of randomness.





# PhD Research - Outlook

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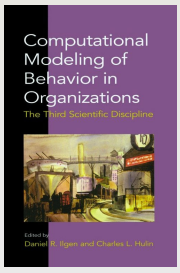
## Possible Solution:

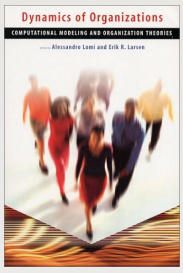
- Using Computational Organisation Theory as a methodological approach and multi-agent based simulation as a technique.

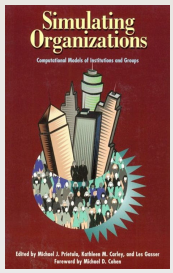
## Issues:

- Complexity of the task
- Concept of pro-activeness

| System Engineering Modelling of Human Performance |
|---|
| Bio mechanical models |
| Information sensing and processing models |
| Knowledge based/cognitive modelling approaches |
| Optimal control theory models |
| Task network models |
| Anthropometric models |
| Workload prediction models |
| Situational awareness models |
| Human reliability models |
| Micro models |
| Integrated models |
| |
| **Social Science Modelling of Human Behaviour** |
| Artificial Society modelling |
| - Microsimulation |
| - Cellular automata |
| - Production systems |
| - Multi-Agent Modelling |
| - Learning and adaptive models |
| Descriptive human performance modelling |
| Emergency simulation |



# Agent-Based Modelling and Simulation (1/2)

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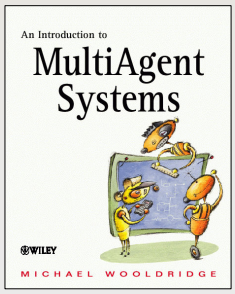
## What is ABMS?

- A new approach to modelling systems comprised of autonomous interacting agents

## What is an Agent?

- Any type of independent component
- … must be adaptive (learn and change behaviour in response)
- … has to contain both, base level and higher level rule sets
- … fundamental feature is the capability of the component to make independent decisions




## Object or Agent?

- An agent is a self directed object with additional capability of action choice





# Agent-Based Modelling and Simulation (2/2)

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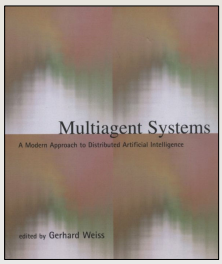
## ABMS Application Areas:

- Business & Organisations (manufacturing; consumer markets; supply chains)
- Economics (artificial financial markets; trade networks)
- Infrastructure (electric power markets; hydrogen economy; transportation)
- Crowds (human movement; evacuation modelling)
- Society and Culture (ancient civilizations; civil disobedience)
- Terrorism (social determinants; organisational networks)
- Military (command & control; force-on-force)
- Biology (ecology; animal group behaviour; cell behaviour)




## In Applications of ABMS to Social Processes:

- Agents represent people or groups of people
- Agent relationships represent processes of social interactions
- Simple rules result in emergent organisation and complex behaviour

# Current Research Project

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## Project Partners:

- Aston, Sheffield, and Cambridge

## Project Aim:

- Investigating the role of management practices in closing the productivity gap that exists between the UK and its major international competitors.

## Project Objectives:

- Assess the role of management practices
- Identify key aspects of management activity for productivity
- **Develop multi-level models of relevant variables to understand and predict practice**
- Generate ideas on good practice for productivity improvement





# Results from Initial Literature Review

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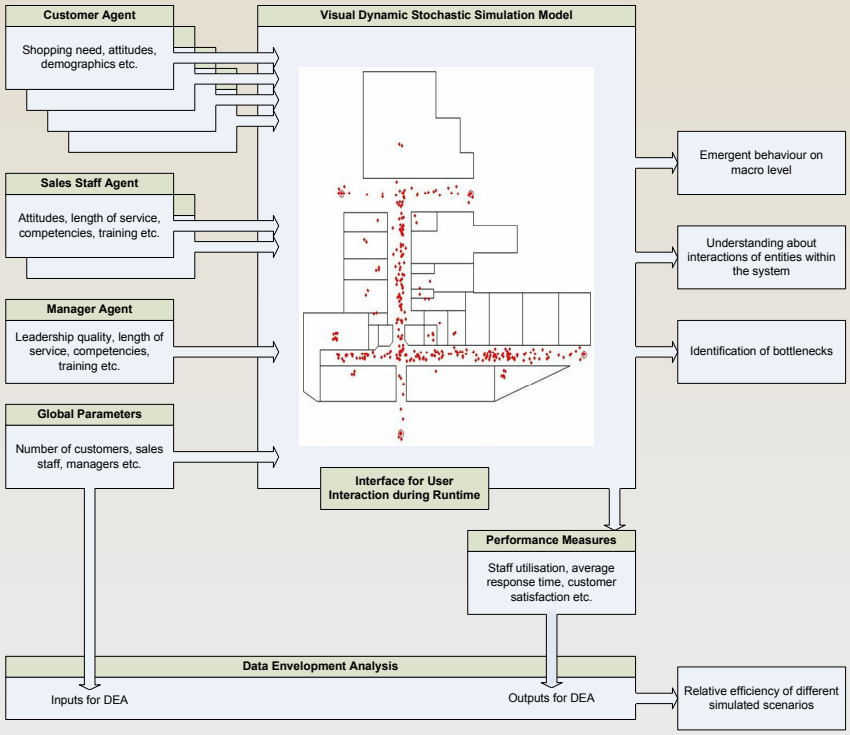
## Initial Literature Review Results:

- Multi-Agent Simulation for gaining insight into the system/operation.
  - Examining social and economic processes by studying the emergence of complex behaviour from relative simple activities.
- Data Envelopment Analysis for comparative efficiency evaluation.
  - Access the relative efficiency of a variety of homogeneous decision making units (e.g. retail stores) using a variety of input and output data

## Current Working Aim:

- The application of Multi-Agent Simulation in combination with DEA to understand and predict the impact of management practices on the productivity of UK/US retail stores.

# Conceptual Tool Design








# Summary & Conclusions

## Summary:

- Discrete Event Simulation as OR technique to support decision making
- Problems involved when modelling human oriented systems
- ABMS as a possible solution to worker modelling
- ABMS as a possible solution to model the impact of management practices on productivity

## Conclusion:

- Decision about the method to be used has been made
- Next steps:
  - Definition of required data/format
  - Begin with design of simple agents based on theoretical models