Aachen Summer Simulation Seminar 2014

Lecture 05

Simulation Methods: Discrete Event Simulation

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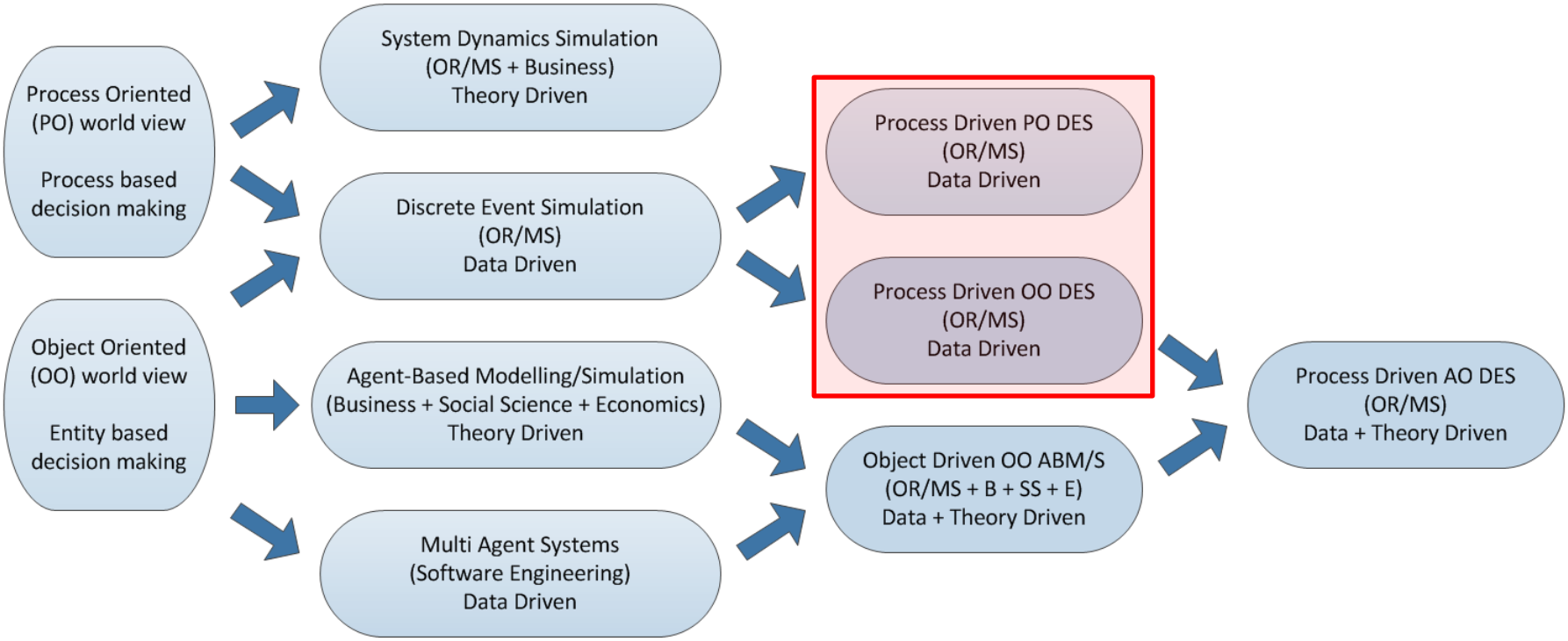
Motivation

- Introduce Discrete Event Modelling (DEM)
- Introduce the Discrete Event Simulation (DES) execution cycle
- Show how DES can be applied in real world projects

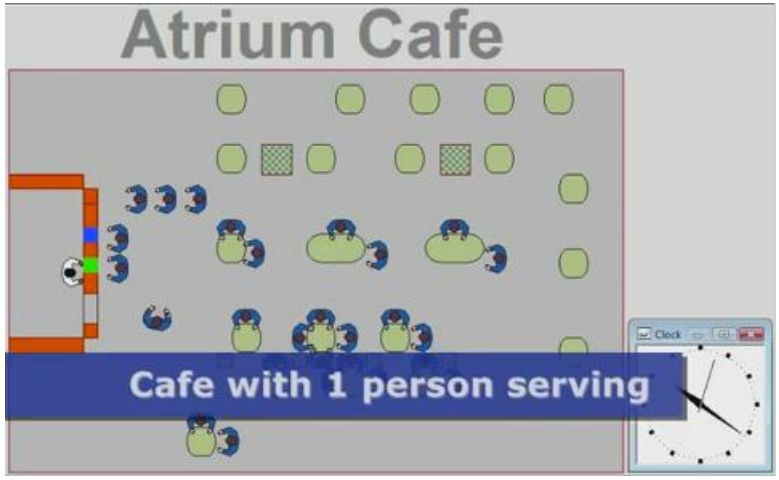
Simulation Paradigms: Update

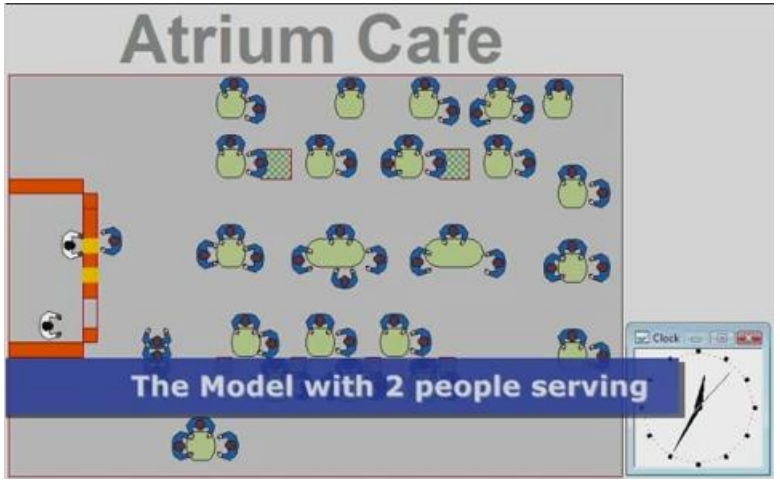


Data Driven: Data for model formulation (in Social Sciences can be quantitative and qualitative); data for model validation
Theory Driven: Theories for model formulation; data for model validation

Discrete Event Simulation Demo

- Coffee Shop Discrete Event Simulation Demo (Witness)



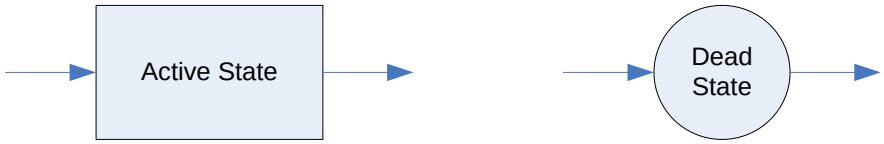


Discrete Event Modelling

- Terminology:
  - 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)

Discrete Event Modelling

- Terminology (cont.)
  - 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



Discrete Event Modelling

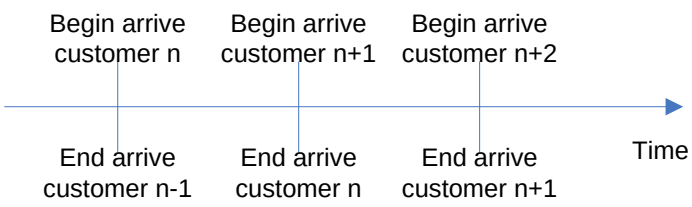
- Hands-On Example:
  - The plot (Pidd, 1998)
    - A theatre booking clerk is employed to sell tickets and answer enquiries. Enquiries can come from someone at the box office or someone phoning the theatre.
    - The clerk is instructed to give priority to the personal customers. Customer and phone calls queue on a FIFO basis. Phone callers never hang up!
  - Classes:
    - Personal customers
    - Phone customers

Discrete Event Modelling

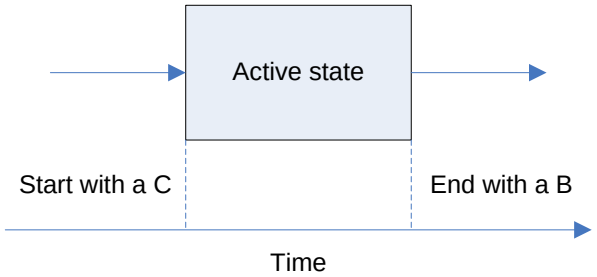
- Hands-On Example:
  - Sets:
    - Personal customers queuing
    - Phone customers queuing
  - Attributes:
    - Type of customer
  - Resources:
    - Booking clerk

Discrete Event Simulation (DES)

- Three-Phase Approach
  - In this simulation approach events are classified into two types
    - **B (bound or booked) Events:** State changes that are scheduled to occur at a point in time. In general B events relate to arrivals or the completion of an activity.
    - **C (conditional) Events:** State changes that are dependent on the conditions in the model. In general C events relate to the start of some activity



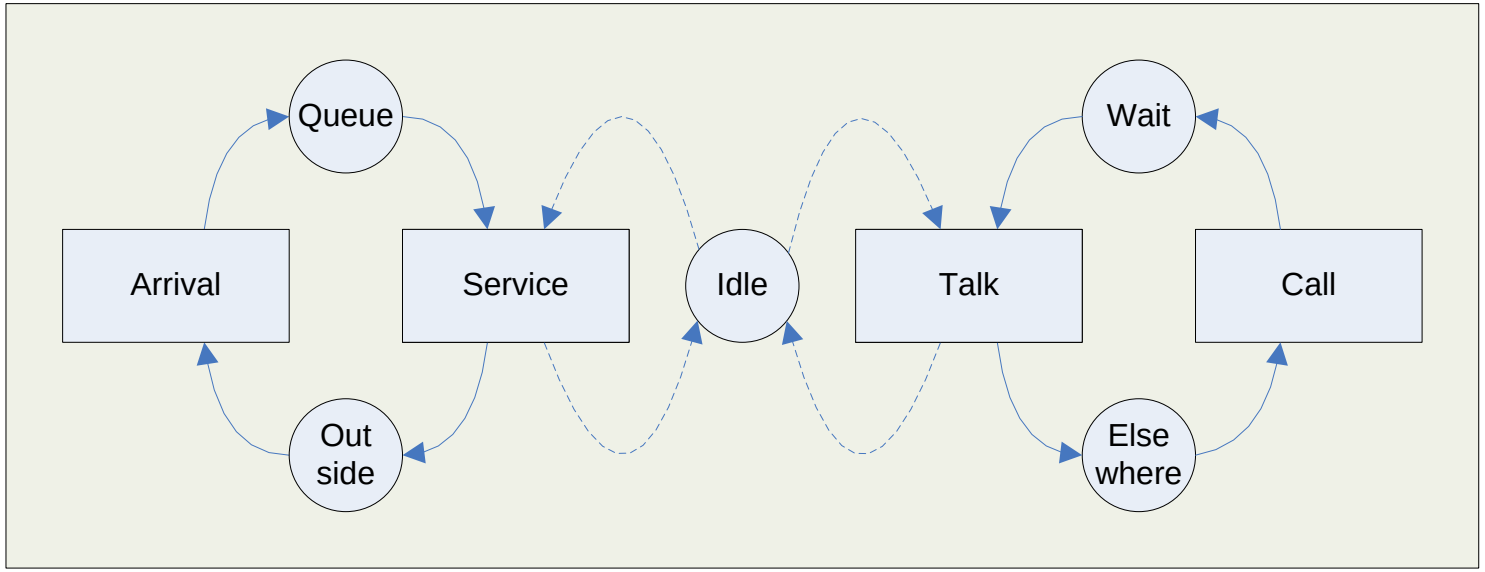
Arrival process



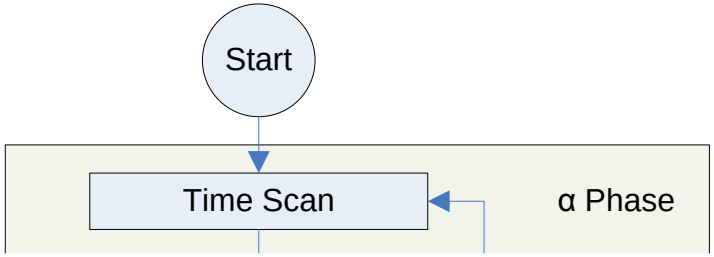
Activity

Discrete Event Simulation

- Three-Phase Approach
  - Booking Clerk Bs and Cs
    - B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk
    - C1: BeginService ... C2: BeginTalk



Discrete Event Simulation



- **α:** Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list
- **β:** Execute activities of entities in the *DueNow* list
- **γ:** Executive must attempt each C in turn by checking if the condition in the test heads are satisfied

Discrete Event Simulation

- Required information about each entity
  - **Time cell:** Time when entity is next due to change state, if this is known; only meaningful if entity is committed to some B in the future
  - **Availability:** Boolean field showing whether the entity is committed to some B in the future; if **TRUE** entity is uncommitted and its time cell is meaningless; if **FALSE** time cell indicates when entity will next change state
  - **Next activity:** only meaningful if the availability is FALSE and it indicates the B in which the entity is due to engage at the time shown by the time cell
- Reminder
  - B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk;
  - C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - **Initialisation:** Clerk is idle; first personal enquirer due to arrive at time 4 and first phone call due to arrive at time 6; time is 0; all queues are empty; no personal enquirers or phone calls have arrived
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of Init.: Clock=0; Queue=0; Wait=0; PersIn=0; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	4	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

Discrete Event Simulation

- Three-Phase Approach
  - **First α-Phase:** Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list (at t=4 entity 1 is due to arrive)
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of α: Clock=4; Queue=0; Wait=0; PersIn=0; PhoneIn=0; DueNow=1

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	4	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

Discrete Event Simulation

- Three-Phase Approach
  - **First β-Phase:** Execute activities of entities in the *DueNow* list; remember that the service does not start in the β-Phase (brings first persEnq into the system and schedules next persEnq (to arrive 5 min later); entity is put in queue and counter for persEnq is increased)
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of β: Clock=4; Queue=1; Wait=0; PersIn=1; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

Discrete Event Simulation

- Three-Phase Approach
  - **First γ-Phase:** Executive must attempt each C in turn by checking if the condition in the test heads are satisfied (beginServ requires persEnq in queue and clerk to be idle; fulfilled; service takes 5 min)
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of γ: Clock=4; Queue=0; Wait=0; PersIn=1; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

Discrete Event Simulation

- Three-Phase Approach
  - **Second α-Phase:** Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of α: Clock=6; Queue=0; Wait=0; PersIn=1; PhoneIn=0; DueNow=2

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

Discrete Event Simulation

- Three-Phase Approach
  - **Second β-Phase:** Execute activities of entities in the *DueNow* list; remember that the service does not start in the β-Phase
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of β: Clock=6; Queue=0; Wait=1; PersIn=1; PhoneIn=1; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	9	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

Discrete Event Simulation

- Three-Phase Approach
  - **Second γ-Phase:** Executive must attempt each C in turn by checking if the condition in the test heads are satisfied
  - **Random number stream:** 4,6,5,5,3,3,6,4,8

End of γ: Clock=6; Queue=0; Wait=1; PersIn=1; PhoneIn=1; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	9	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

Discrete Event Simulation

- Three-Phase Approach
  - Third Round?

Discrete Event Simulation

- Three-Phase Approach

End of α3: Clock=9; Queue= ; Wait= ; PersIn= ; PhoneIn= ; DueNow=1,2,3

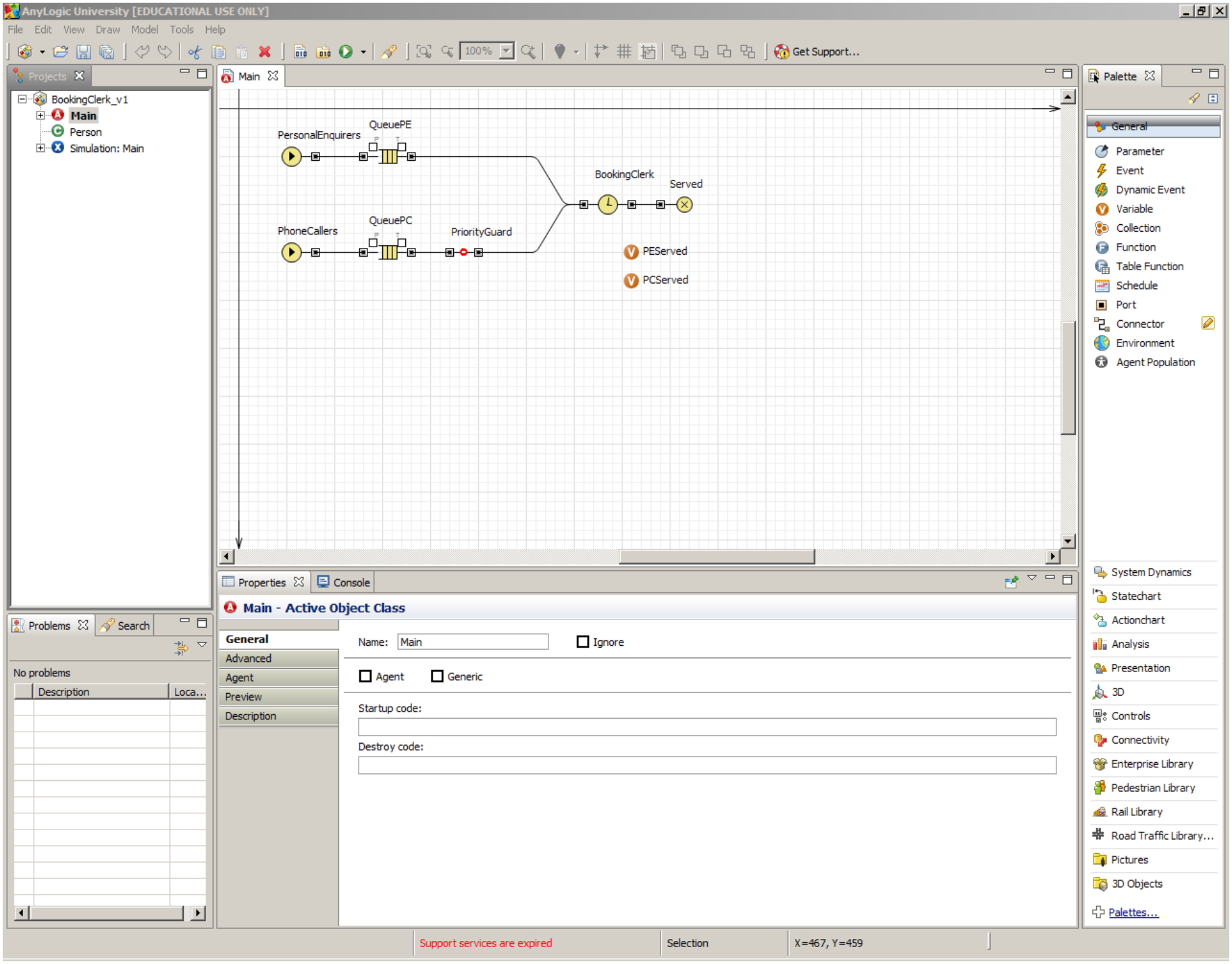
Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine			Personal Arrival
(2) Phone call arrival machine			Phone Call
(3) Clerk			EndService

End of β3: Clock= ; Queue=1; Wait=2; PersIn=2; PhoneIn=2; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	12		Personal Arrival
(2) Phone call arrival machine	15		Phone Call
(3) Clerk	9	TRUE	-

End of γ3: Clock= ; Queue=0; Wait=2; PersIn=2; PhoneIn=2; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine			Personal Arrival
(2) Phone call arrival machine			Phone Call
(3) Clerk	13	FALSE	EndService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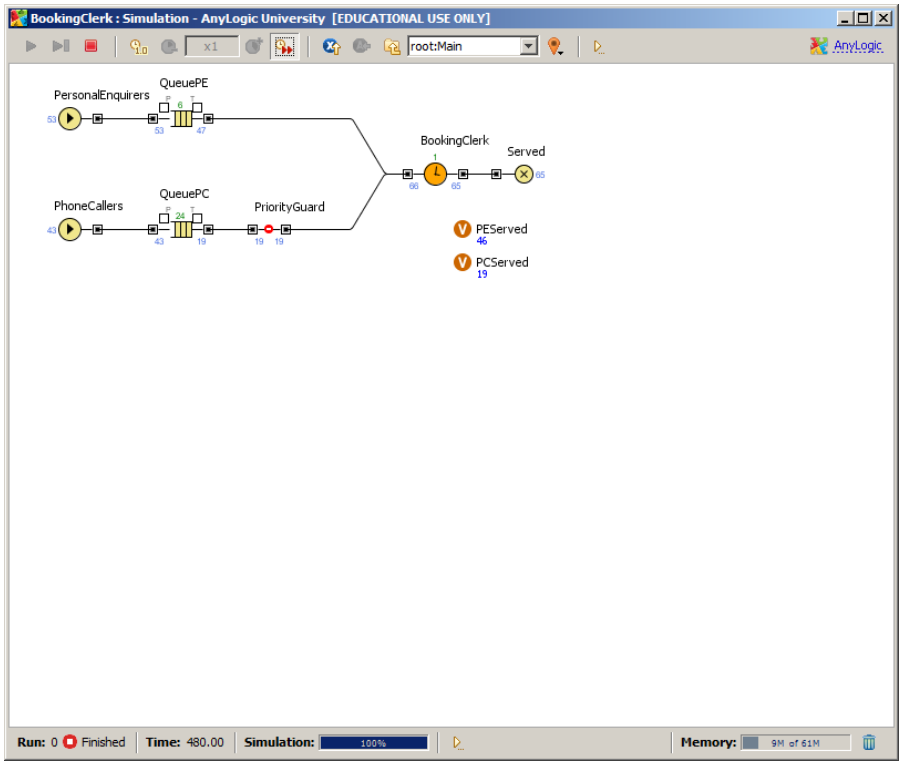
File Edit View Draw Model Tools Help
Get Support...
Projects
BookingClerk_v1
Main
Person
Simulation: Main
Main
PersonalEnquirers
QueuePE
PhoneCallers
QueuePC
PriorityGuard
BookingClerk
Served
PEServed
PCServed
Palette
General
Parameter
Event
Dynamic Event
Variable
Collection
Function
Table Function
Schedule
Port
Connector
Environment
Agent Population
System Dynamics
Statechart
Actionchart
Analysis
Presentation
3D
Controls
Connectivity
Enterprise Library
Pedestrian Library
Rail Library
Road Traffic Library...
Pictures
3D Objects
Palettes...
Properties
Console
Main - Active Object Class
General
Advanced
Agent
Preview
Description
Name: Main
Ignore
Agent
Generic
Startup code:
Destroy code:
Problems
Search
No problems
Description
Loca...
Support services are expired
Selection
X=467, Y=459

Discrete Event Simulation

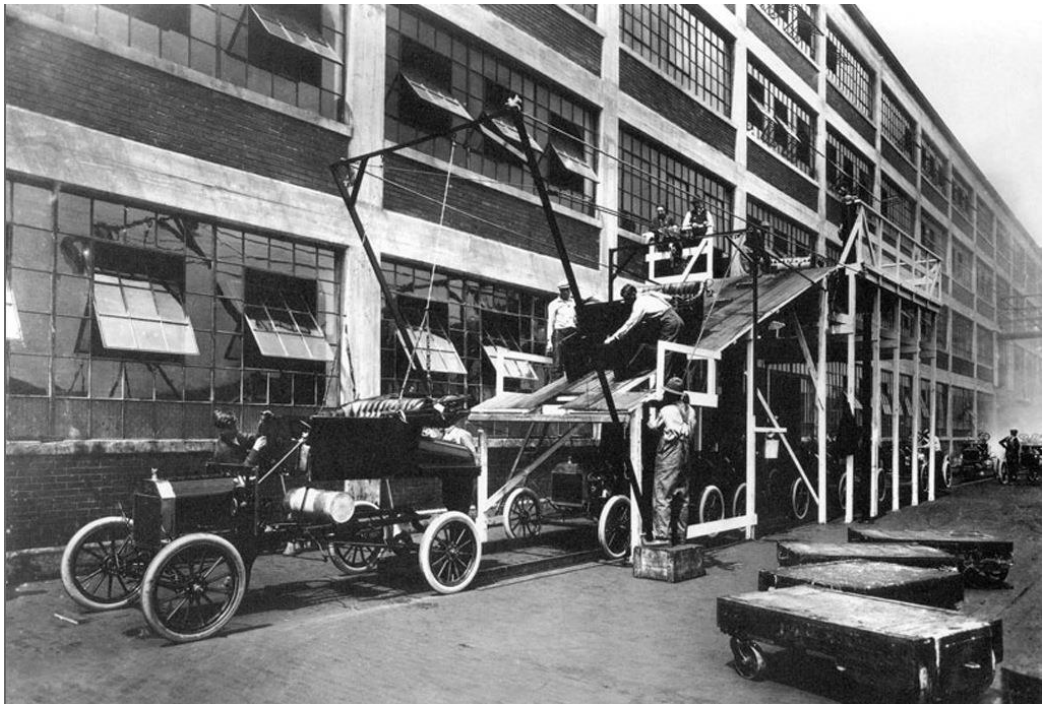
- Simulation Output (single run)



Case Study (my PhD)

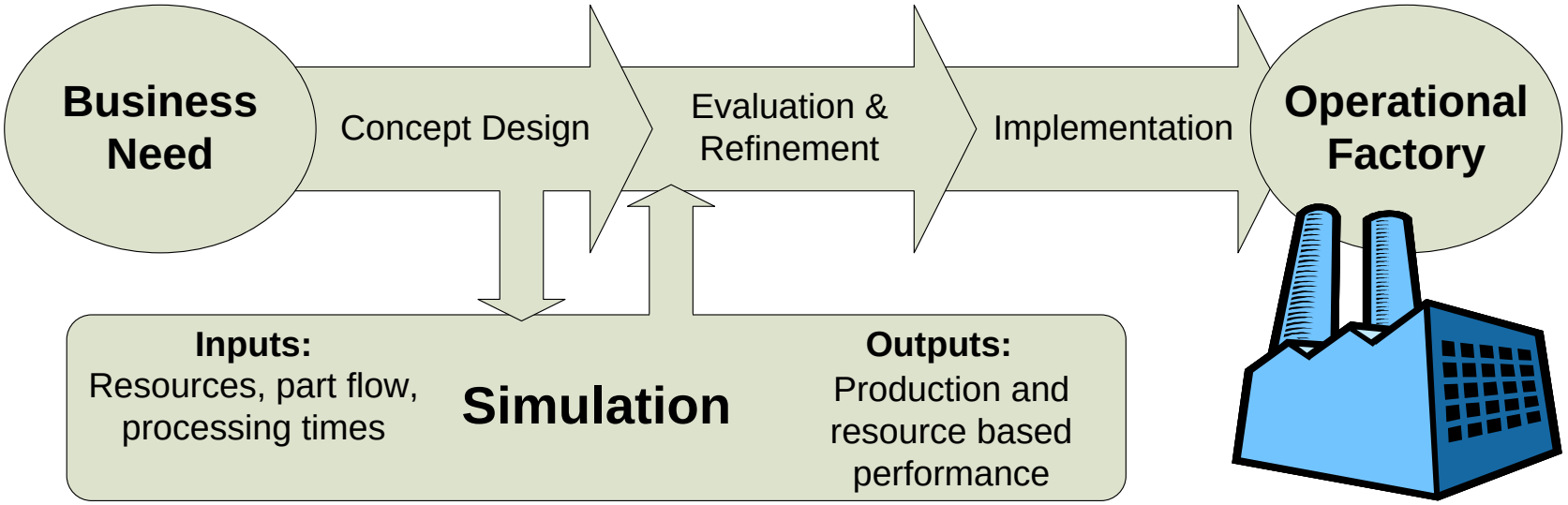
Case Study

- The Impact of Human Performance Variation on the Accuracy of Manufacturing Systems Simulation Models (Siebers 2004)



Case Study

- Manufacturing System Design Process



Case Study

- 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
  - Magnitude of the gap is bigger when simulating non existing systems
  - 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

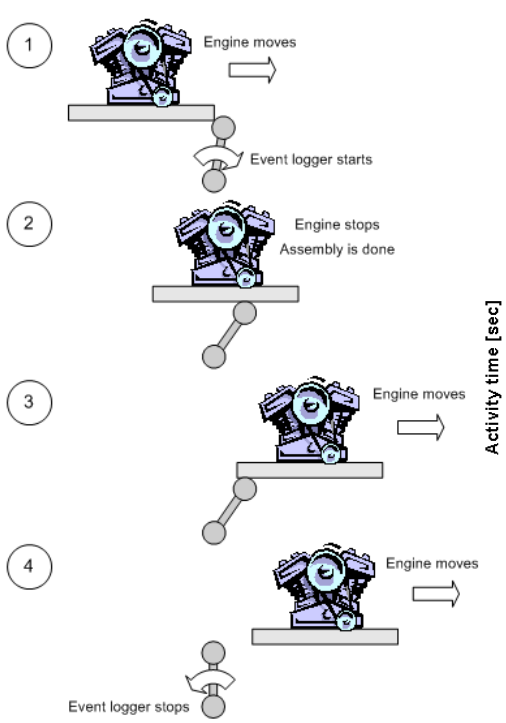
Case Study

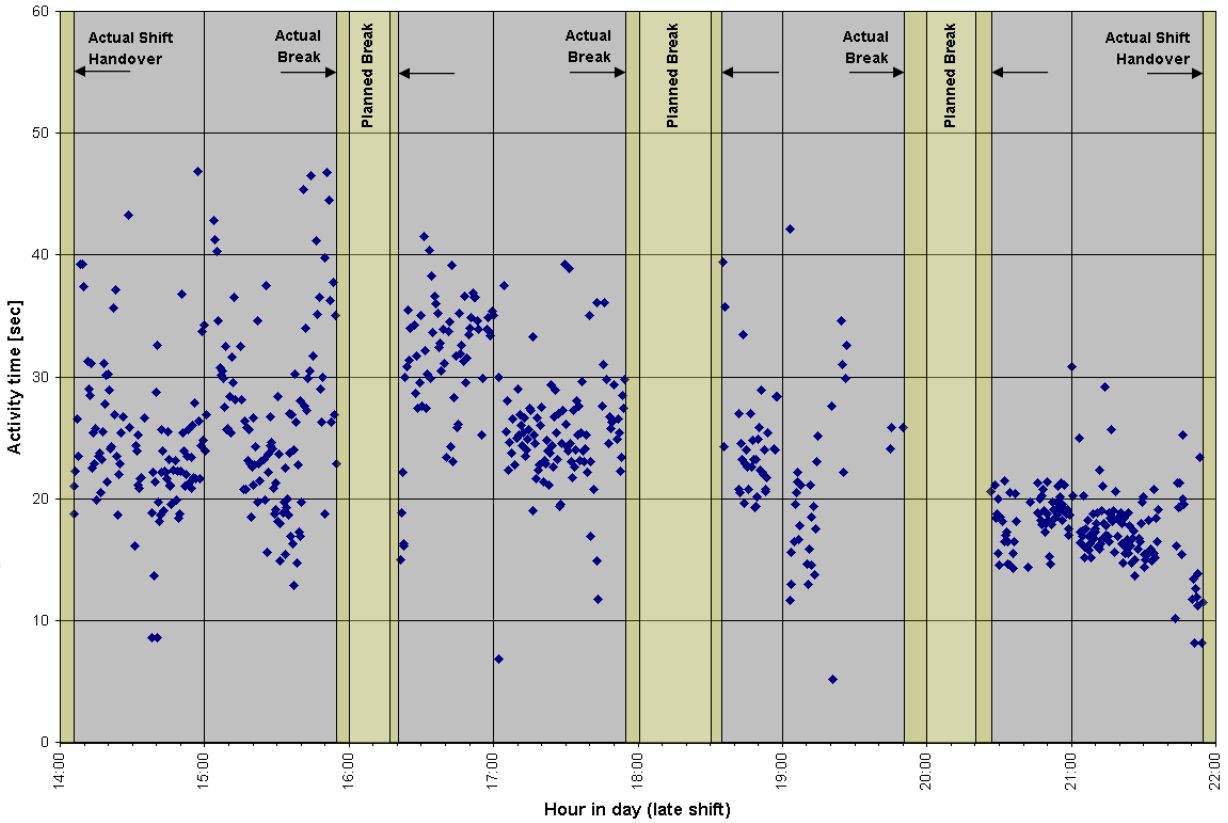
- Research Aim:
  - To demonstrate the importance of incorporating Human Performance Variation (HPV) models into manufacturing system simulation models

- Research Method:
  - Examine 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

Case Study

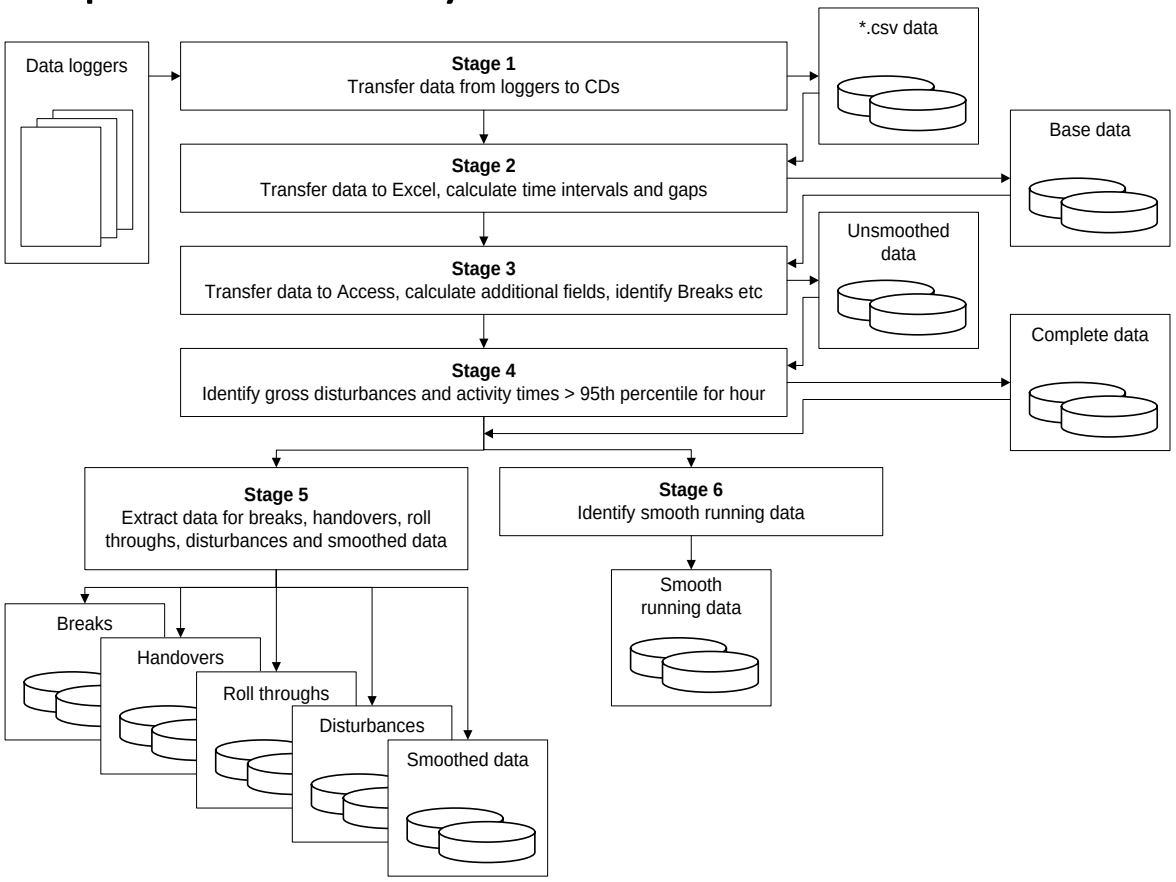
- Step 1: Examining the level of randomness





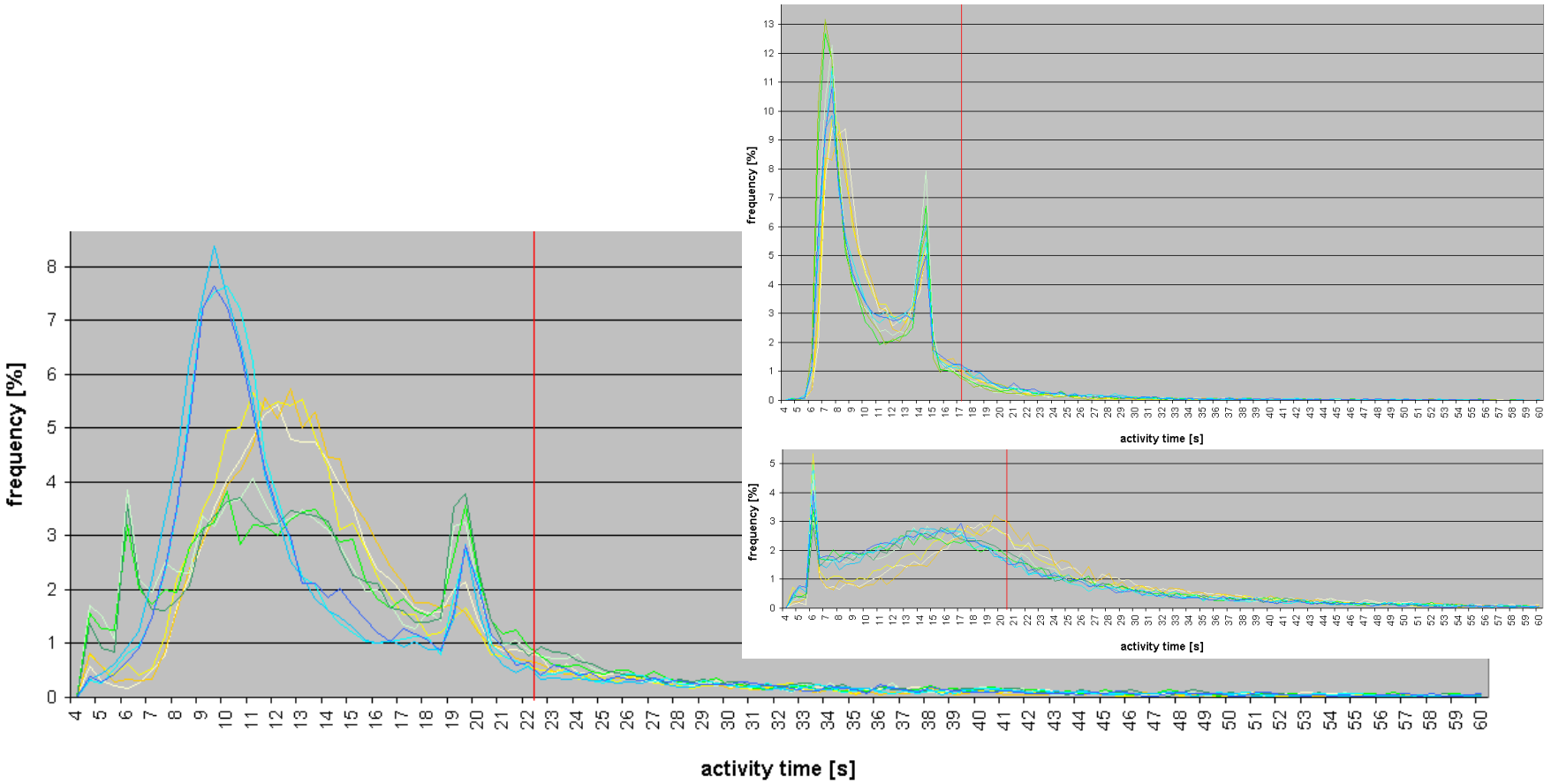
Case Study

- Step 2: Data analysis



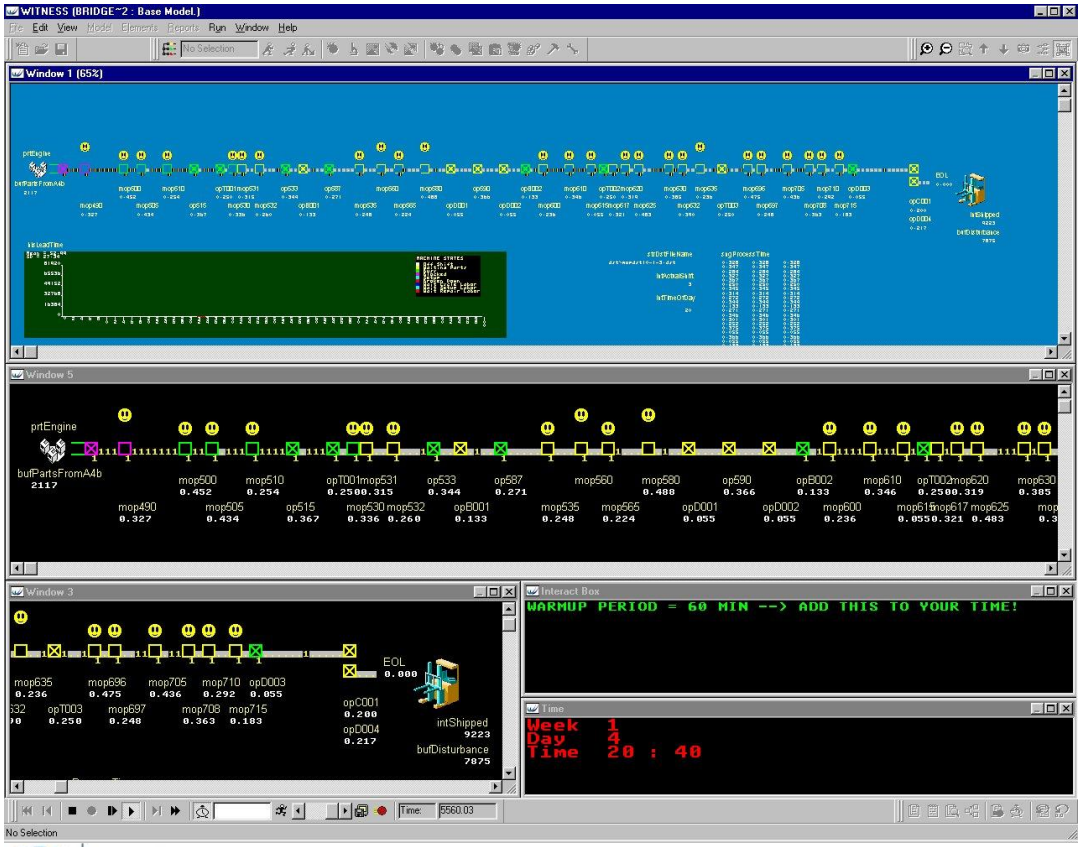
Case Study

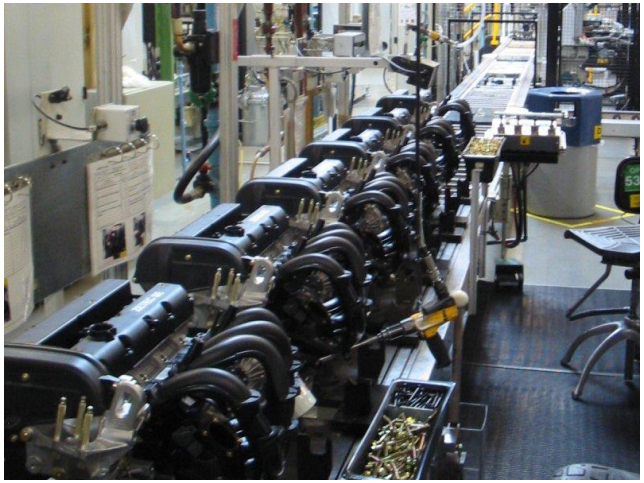
- Step 3: Designing HPV models



Case Study

- Step 4: Conducting sensitivity analysis





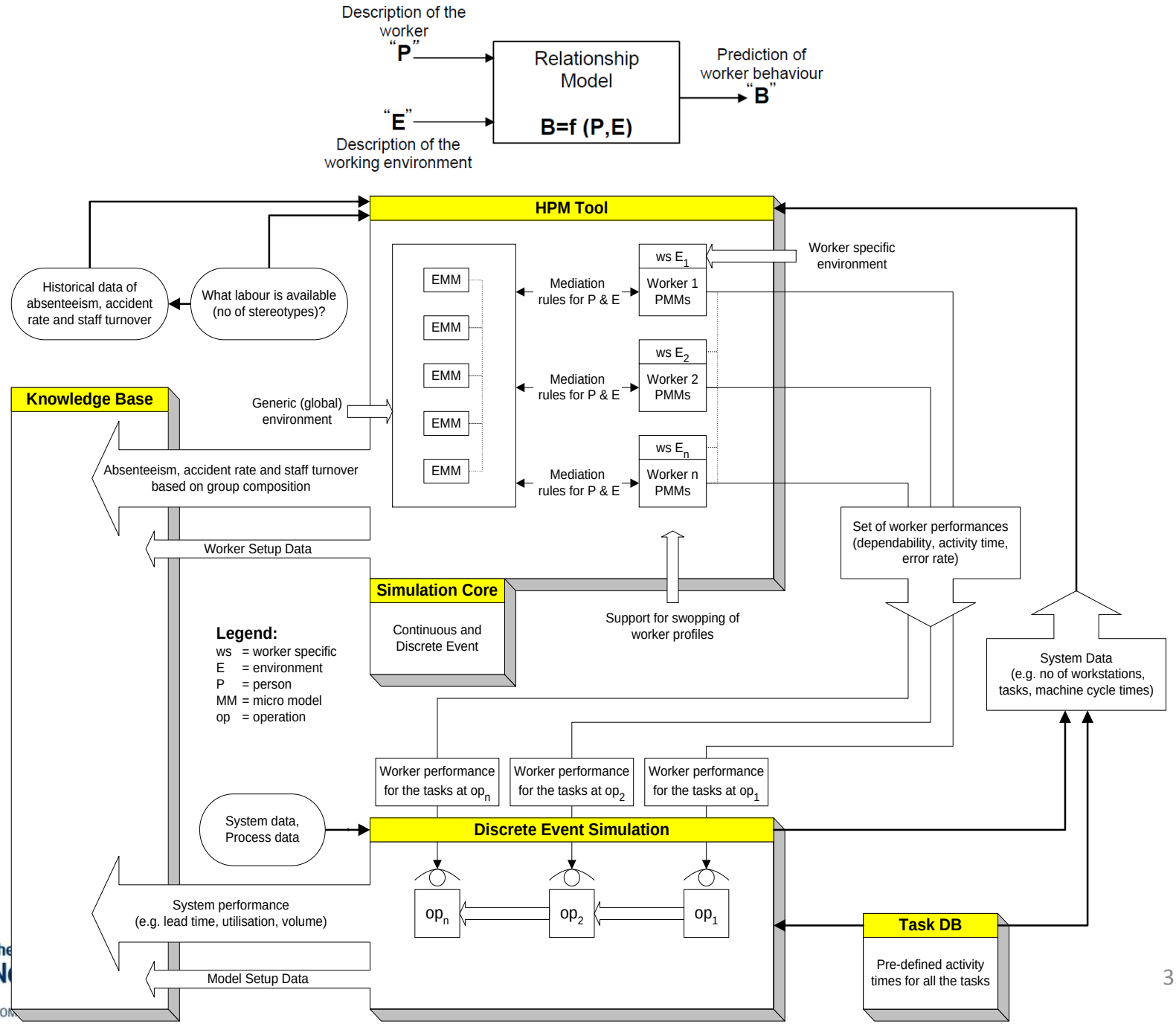
Case Study

- 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 depends on the nature of the task
  - Variation of break start and duration does not depend on the 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

Case Study

- Main limitation of current HPV modelling approach:
  - Independent representation of sources of randomness
- 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


Description of the worker "P"
"E" Description of the working environment
Relationship Model
B=f (P,E)
Prediction of worker behaviour "B"
HPM Tool
Historical data of absenteeism, accident rate and staff turnover
What labour is available (no of stereotypes)?
Knowledge Base
Generic (global) environment
EMM
EMM
EMM
EMM
EMM
Mediation rules for P & E
Mediation rules for P & E
Mediation rules for P & E
ws E1
Worker 1 PMMs
ws E2
Worker 2 PMMs
ws En
Worker n PMMs
Worker specific environment
Absenteeism, accident rate and staff turnover based on group composition
Worker Setup Data
Simulation Core
Continuous and Discrete Event
Support for swopping of worker profiles
Set of worker performances (dependability, activity time, error rate)
System Data (e.g. no of workstations, tasks, machine cycle times)
Legend:
ws = worker specific
E = environment
P = person
MM = micro model
op = operation
Worker performance for the tasks at opn
Worker performance for the tasks at op2
Worker performance for the tasks at op1
System data, Process data
Discrete Event Simulation
opn
op2
op1
System performance (e.g. lead time, utilisation, volume)
Model Setup Data
Task DB
Pre-defined activity times for all the tasks

Summary

- What did you learn?

Questions / Comments

References

- Pidd M (1998). Computer Simulation in Management Science.
- Robinson S (2004). Simulation: The Practice of Model Development and Use.
- Siebers PO (2004). The Impact of Human Performance Variation on the Accuracy of Manufacturing System Simulation Models. PhD Thesis. Cranfield University, Cranfield, UK.