Aachen Summer Simulation Seminar 2014

Lecture 02

Simulation Studies - An Overview

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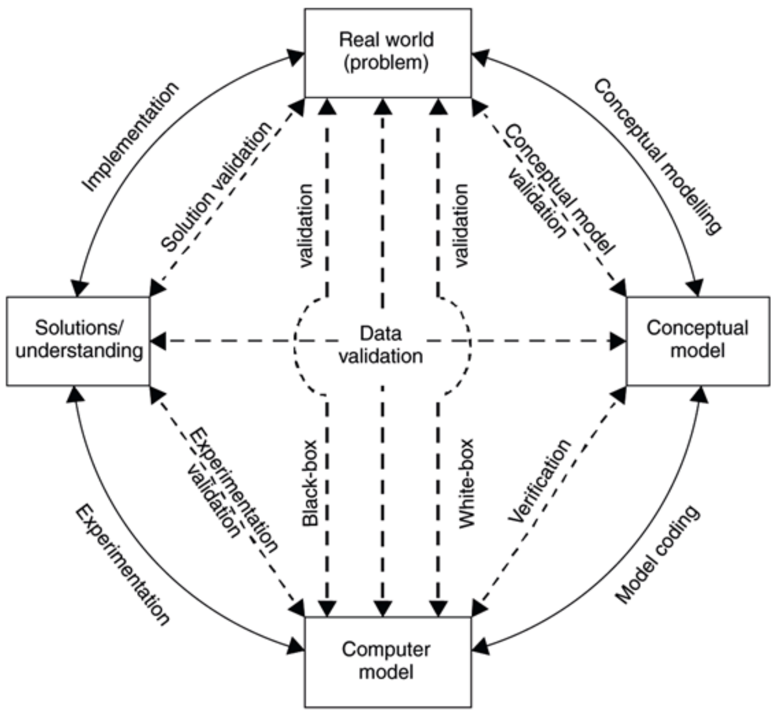
Motivation

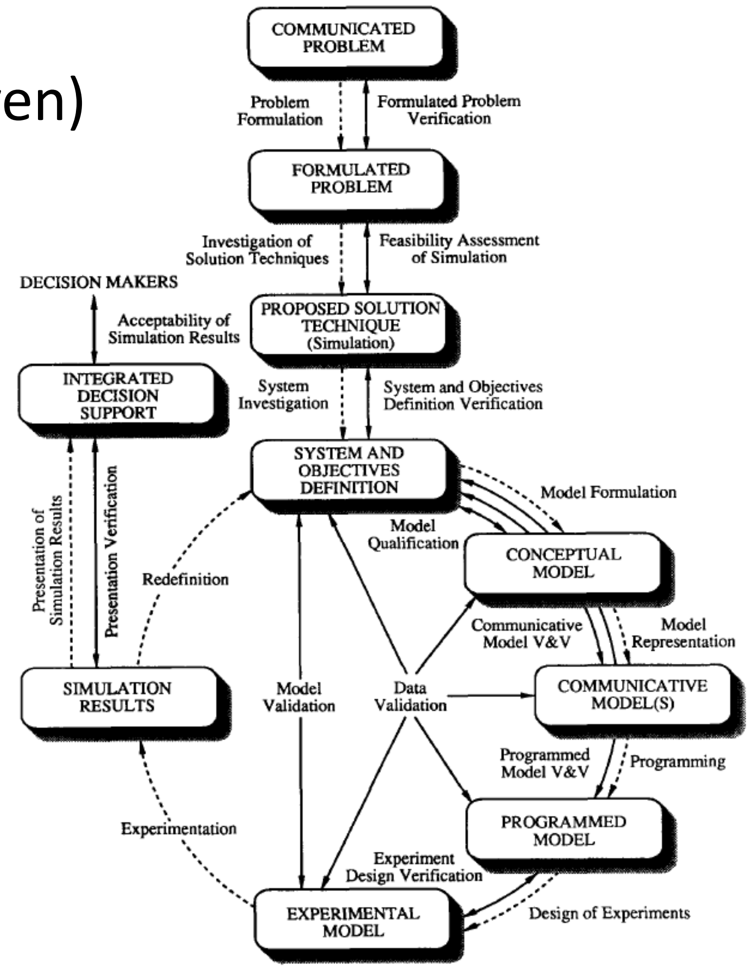
- Introduce different life cycles used for simulation studies (for data and theory driven simulation)
- Further distinguish simulation paradigms in data and theory driven approaches
- Provide a complete example of a simulation study

Life Cycle of a Simulation Study

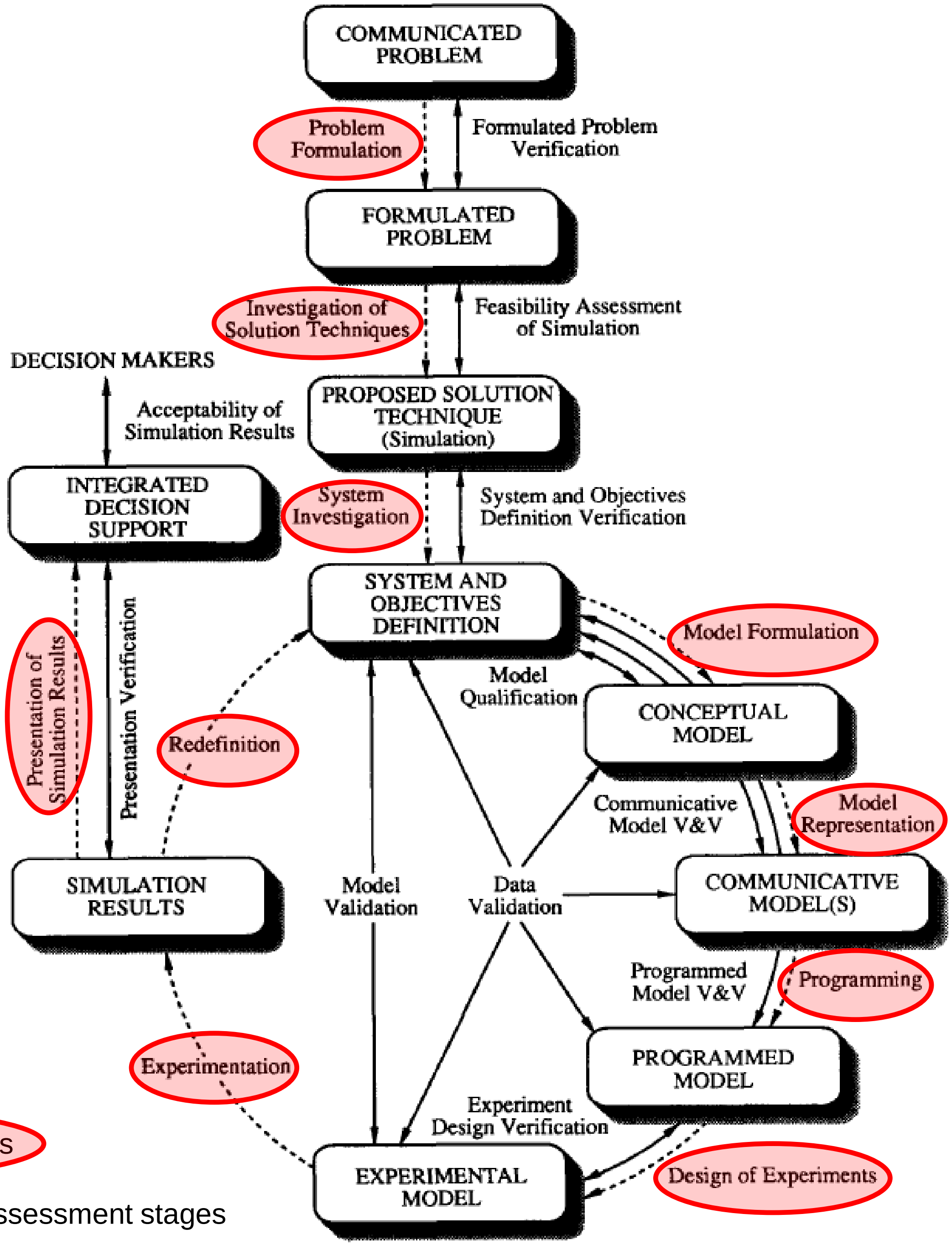
- Operations Research (data driven)
  - Discrete Event Simulation



Robinson (2004)



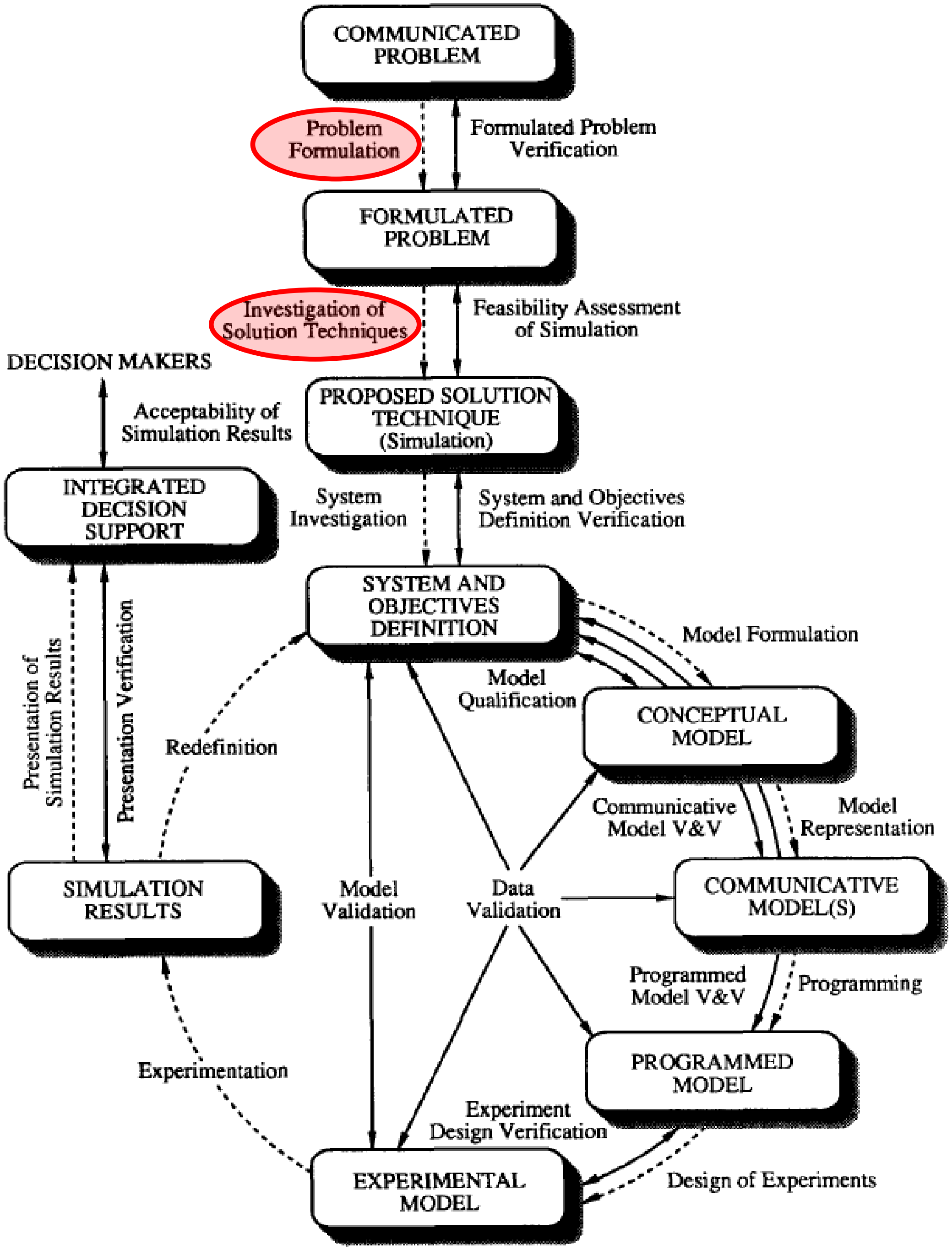
Balci (1990)



Oval symbols: Phases

Dashed arrows: Processes

Solid arrows: Credibility assessment stages


COMMUNICATED PROBLEM
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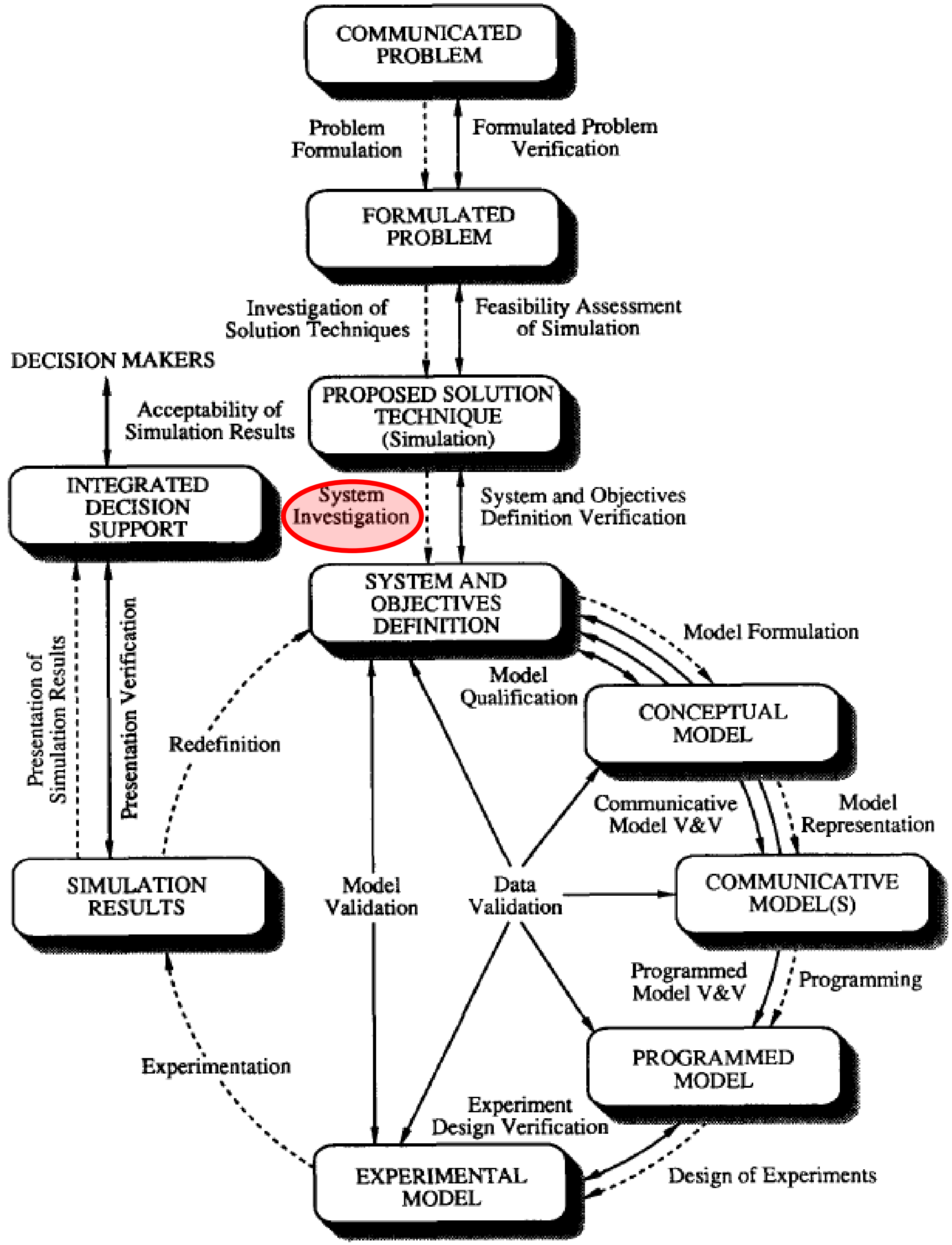
Processes

- Problem formulation (problem structuring / definition)
  - Communicated problem is rarely clear, specific, or organized
  - Initially communicated problem is translated into a formulated problem sufficiently well defined to enable specific research action

- Investigation of Solution Techniques
  - Sometimes communicated problem is formulated under the influence of a solution technique in mind
  - Important to identify all alternative techniques that can be used in solving the formulated problem
  - Chosen technique needs to be a sufficiently credible one which will be accepted and used by the decision maker(s)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Processes

- System investigation
  - Process of investigating the characteristics of the system that contains the formulated problem (for consideration in system definition and modelling)
    - **Change characteristics:** How often and how much the real system will change during the course of a simulation study
    - **Environment characteristics:** Consists of all input variables that can significantly affect its state
    - **Counterintuitive behaviour characteristics:** Some systems may show counterintuitive behaviour which we should try to identify for consideration in the model

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Processes

- System investigation (cont.)
    - **Drift to low performance characteristics:** A system may show a drift to low performance due to the deterioration of its components over a period of time
    - **Interdependency and organisation characteristics:** In a complex system, many activities or events take place simultaneously and influence each other; needs to be examined before abstracting the real system for the purpose of modelling; decomposing the system into subsystems and subsystems into sub-subsystems

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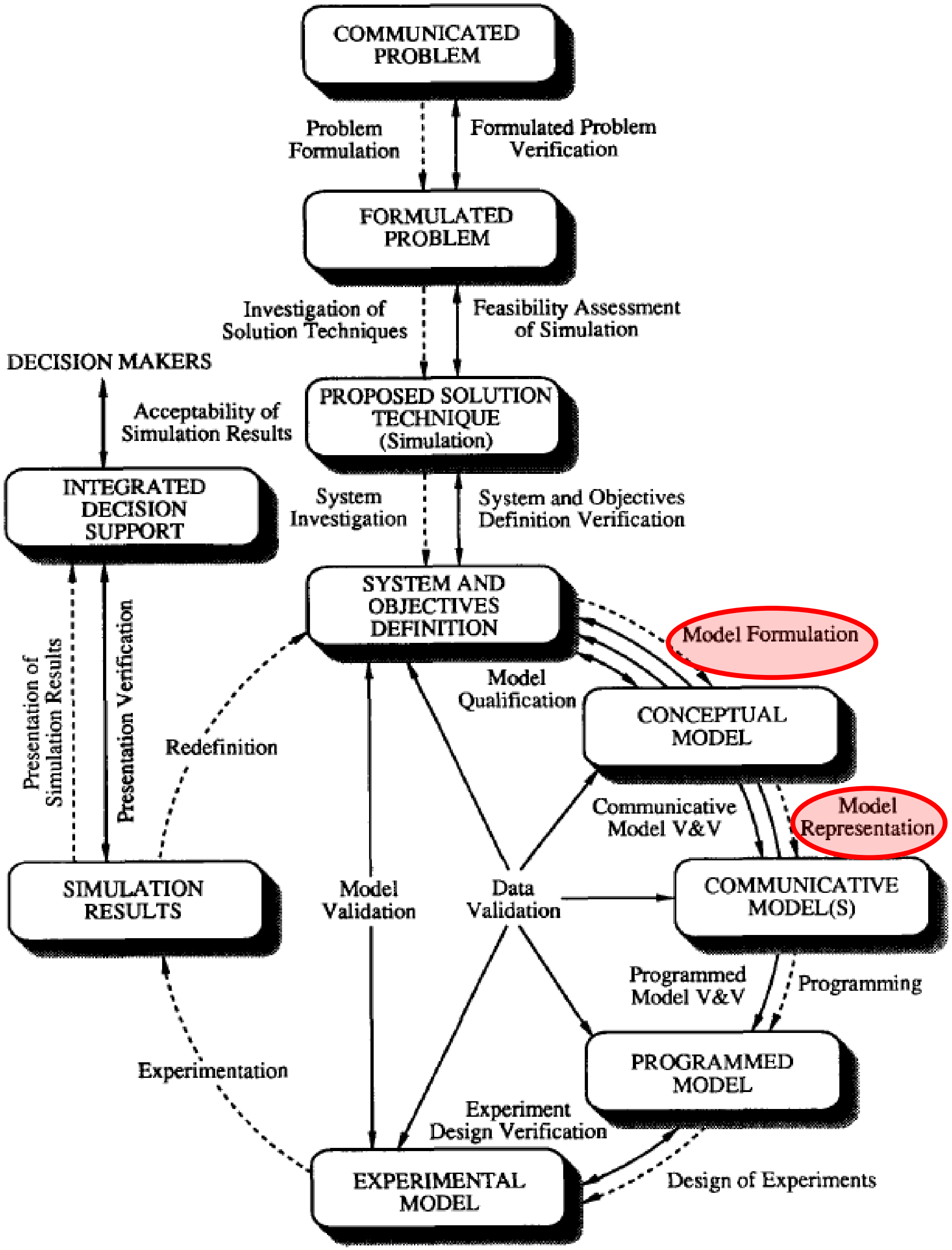
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Processes

- Model formulation
  - Process by which a conceptual model is envisioned to represent the system under study
  - Robinson (2004): "The conceptual model is a non-software specific description of a simulation model describing the objectives, inputs, outputs, content, assumptions and simplification of the model"
  - Input data analysis and modelling
    - SDS: Model driven by rate changes defined through differential equations
    - DES and ABS: Model driven by input values obtained via sampling from probability distributions

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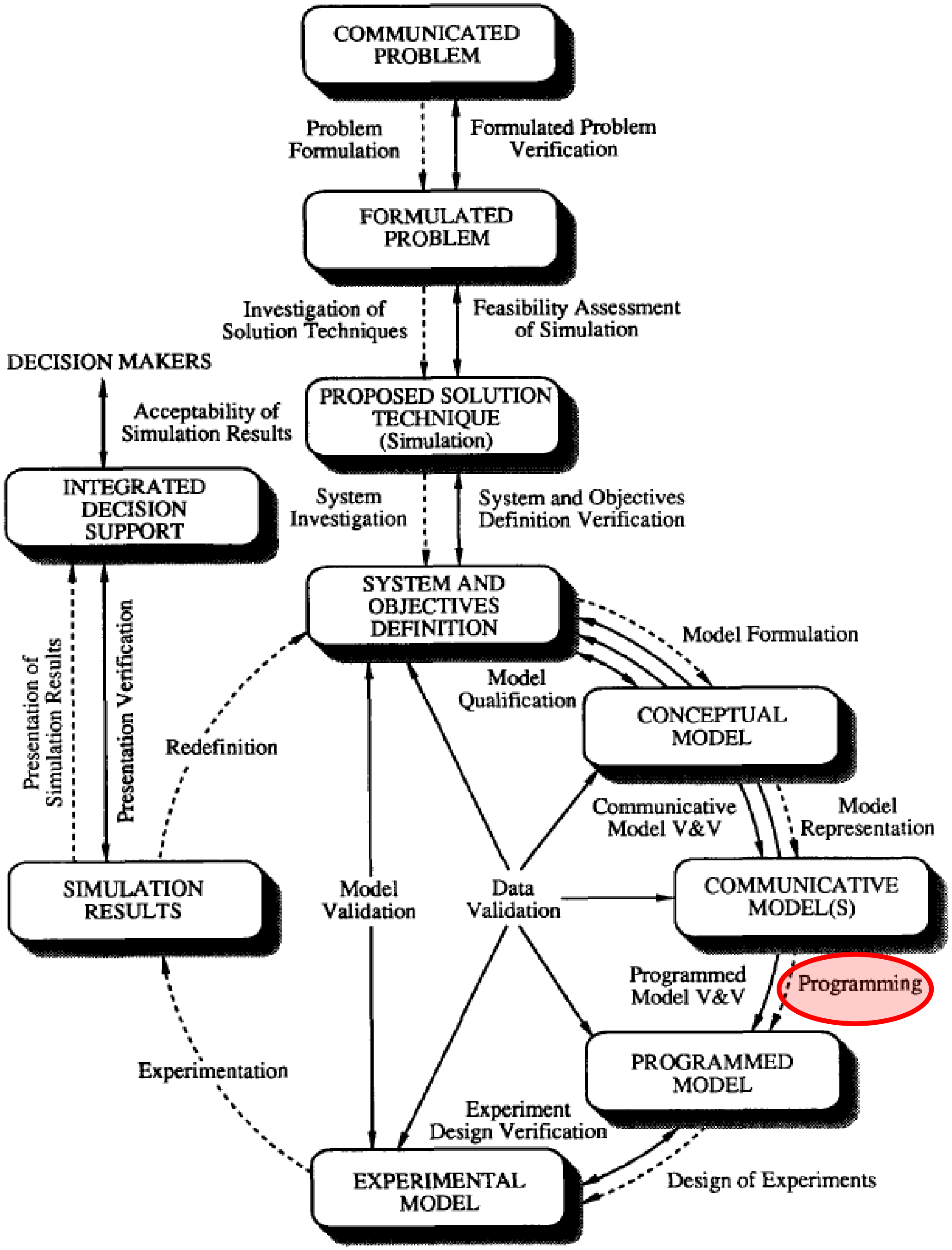
Processes

- Model Representation
  - Process of translating the conceptual model into a communicative model (representation which can be communicated to other humans)
  - Typical representation formats:
    - SDM: Causal loop diagrams, stock and flow diagrams
    - DEM: Flow charts, activity cycle diagrams
    - ABM: UML + AgentUML
    - Specific mechanisms: Pseudo-code
  - Criteria for selection:
    - Applicability for describing the system under study
    - Technical background of the people to whom the model is communicated
    - Translatability into a programmed model



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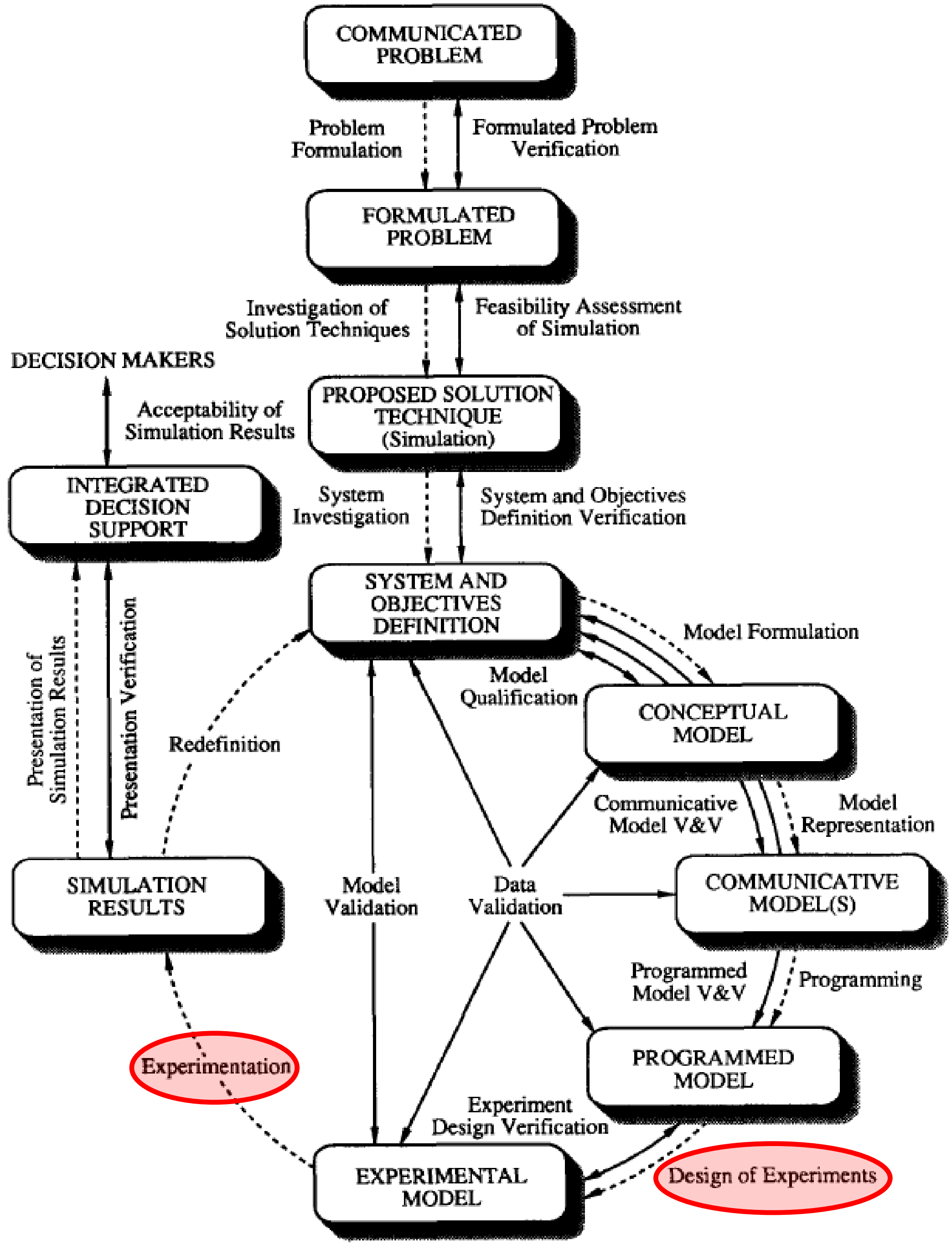
Processes

- Programming
  - Nowadays mainly Visual Interactive Modelling Systems (VIMS)
  - Software:
    - SDS: Dynamo, iThink/Stella, PowerSim, Vensim, ...
    - DES: Arena, SimIO, Simul8, Witness, ProModel, Extend, FlexSim, ...
    - ABS: AnyLogic, many academic tools focusing on specific research areas
    - Programming languages: GPSS, SIMAN, SIMSCRIPT, SIMULA, SLAM, ...
  - Survey available at OR/MS website (latest version from October 2013)
    - http://www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html



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Processes

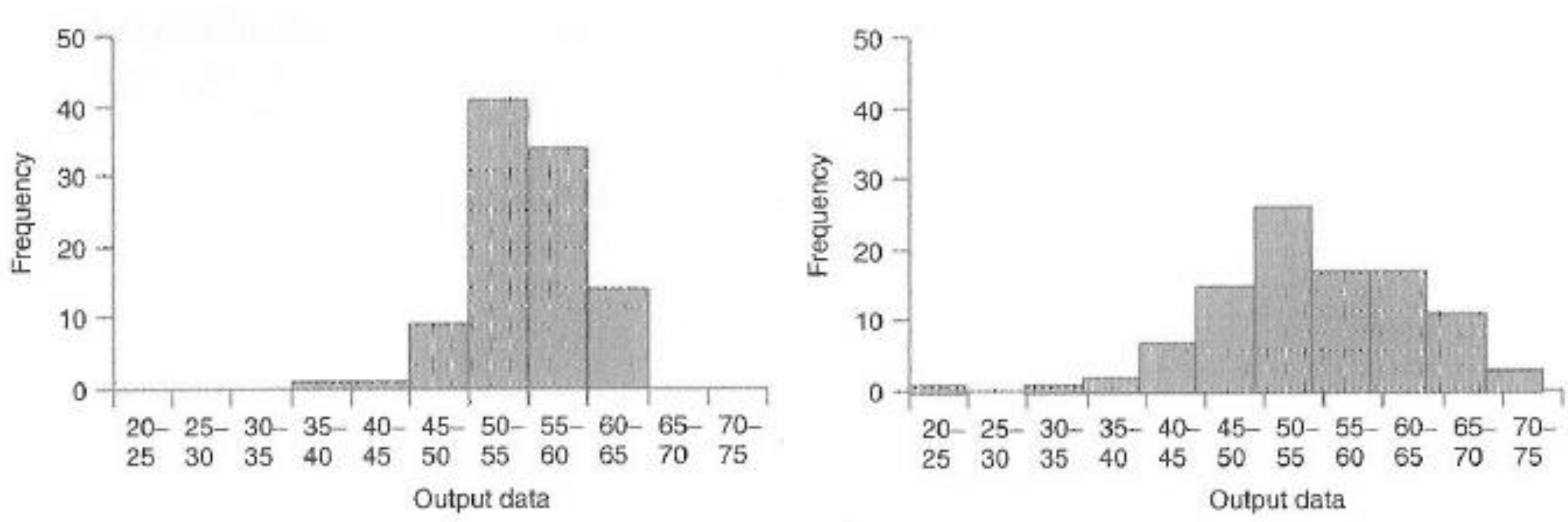
- Design of experiment
  - Process of formulating a plan to gather the desired information at minimal cost and to enable the analyst to draw valid inferences
    - Obtaining accurate results
      - Run conditions: Warm up period, number of replications, run length
      - Variance reduction techniques: Obtain greater statistical accuracy for the same amount of simulation runs
    - Searching the solution space
      - Response-surface methodologies: Find the optimal combination of parameter values which maximize or minimize the value of a response variable
      - Factorial designs: Determine the effect of various input variables on a response variable
      - Ranking and selection techniques: comparing alternative systems

Processes

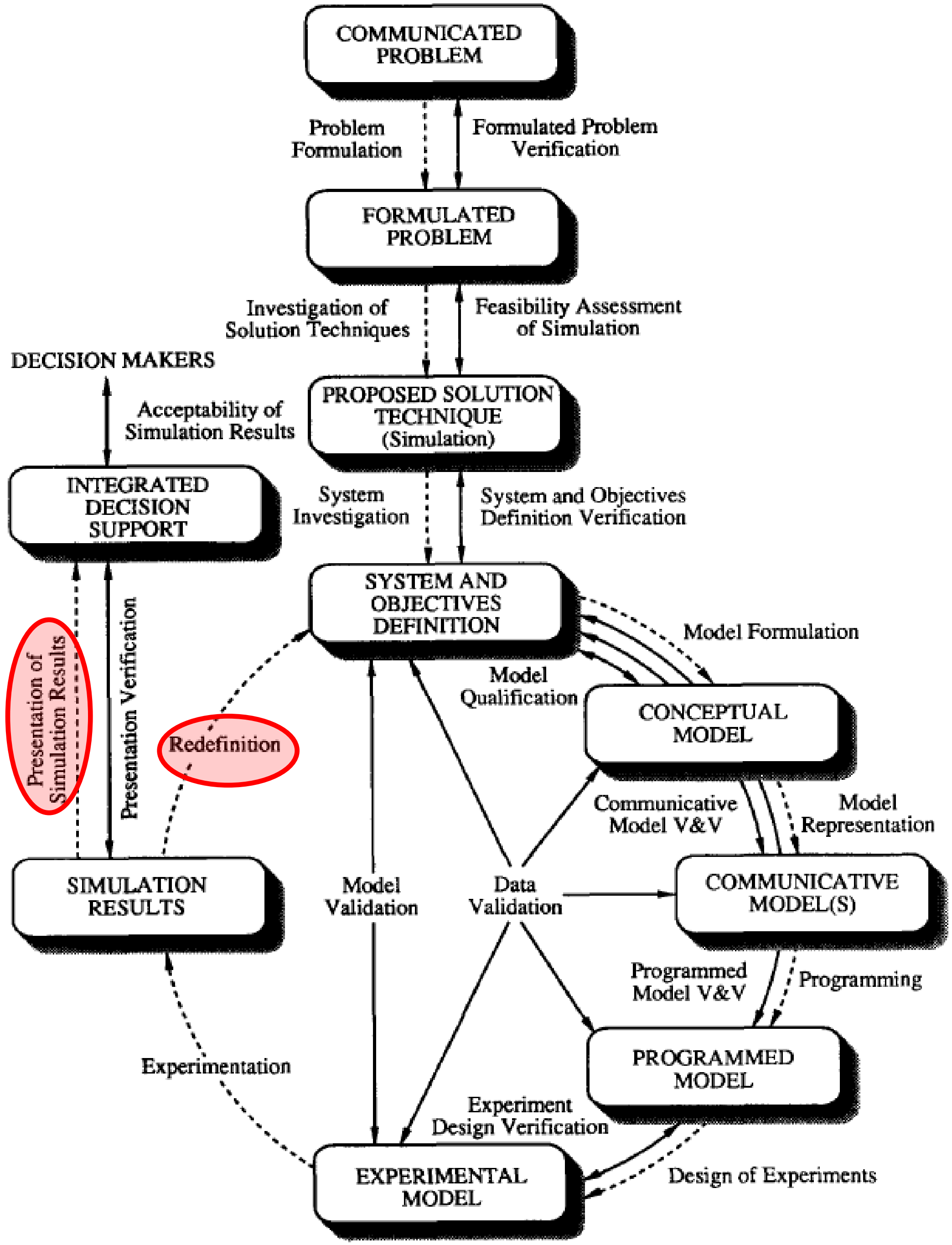
- Experimentation
  - What-if analysis
    - Making changes to the model's inputs, running the model, inspecting the results, learning from the results, making changes to the model's inputs ...
  - Different purposes of experimentation
    - Comparison of different operating policies, evaluation of system behaviour, sensitivity analysis, forecasting, optimisation, determination of functional relations
  - Output analysis (for stochastic simulation)
    - Analysis of results from single scenario (mean and standard deviation)
    - Comparing alternative scenarios (using confidence intervals to test difference between results from two scenarios)

Processes

- Histograms of the same mean but different levels of variability



Robinson (2004)



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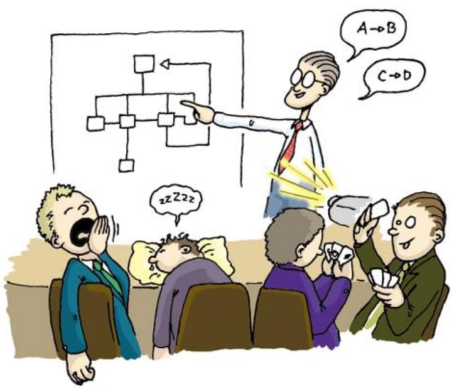
Processes

- Redefinition
  - Maintaining the model for further use
    - Updating the model so that it represents the current form of the system
    - Altering it for obtaining another set of results

- Presentation of simulation results
  - Process of interpreting simulation results and presenting them to the decision makers for their acceptance and implementation
  - Implementation:
    - Putting the solution into practice
    - Implementing the model
    - Implementation as a learning aid



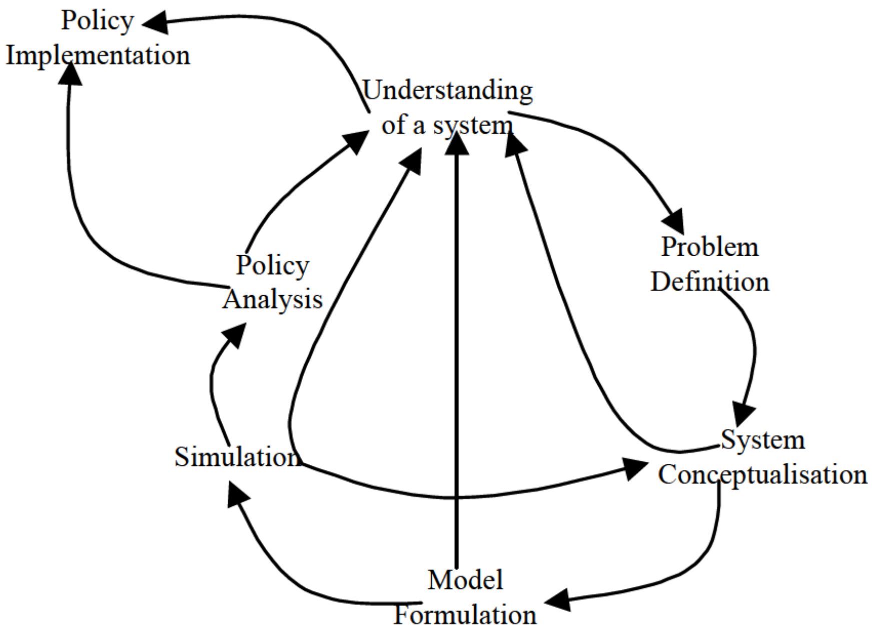
Verification and Validation

- Verification and validation are continuous processes that are performed throughout the life cycle of the simulation study

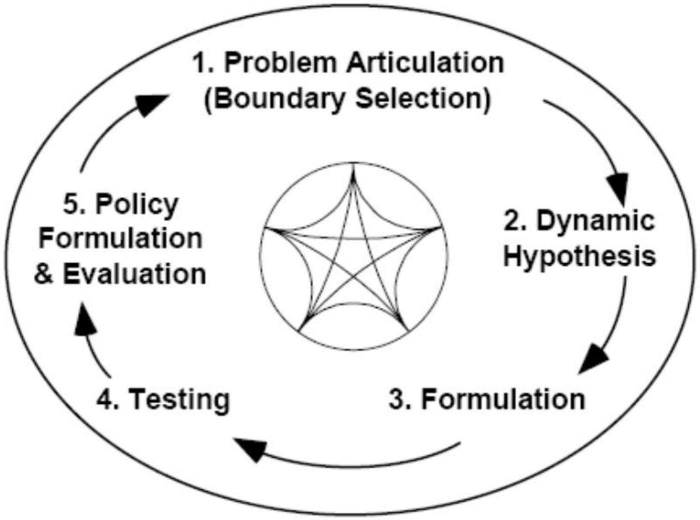
- Verification
  - Substantiating that the simulation model has been transformed from one form into another as intended with sufficient accuracy
  - Deals with "building the model right"
- Validation
  - Substantiating that the simulation model, within its domain of applicability, behaves with satisfactory accuracy consistent with the study objectives
  - Deals with "building the right model"

Life Cycle of a Simulation Study

- Business + Economics + Social Science (theory driven)
  - System Dynamics Simulation and Agent-Based Simulation



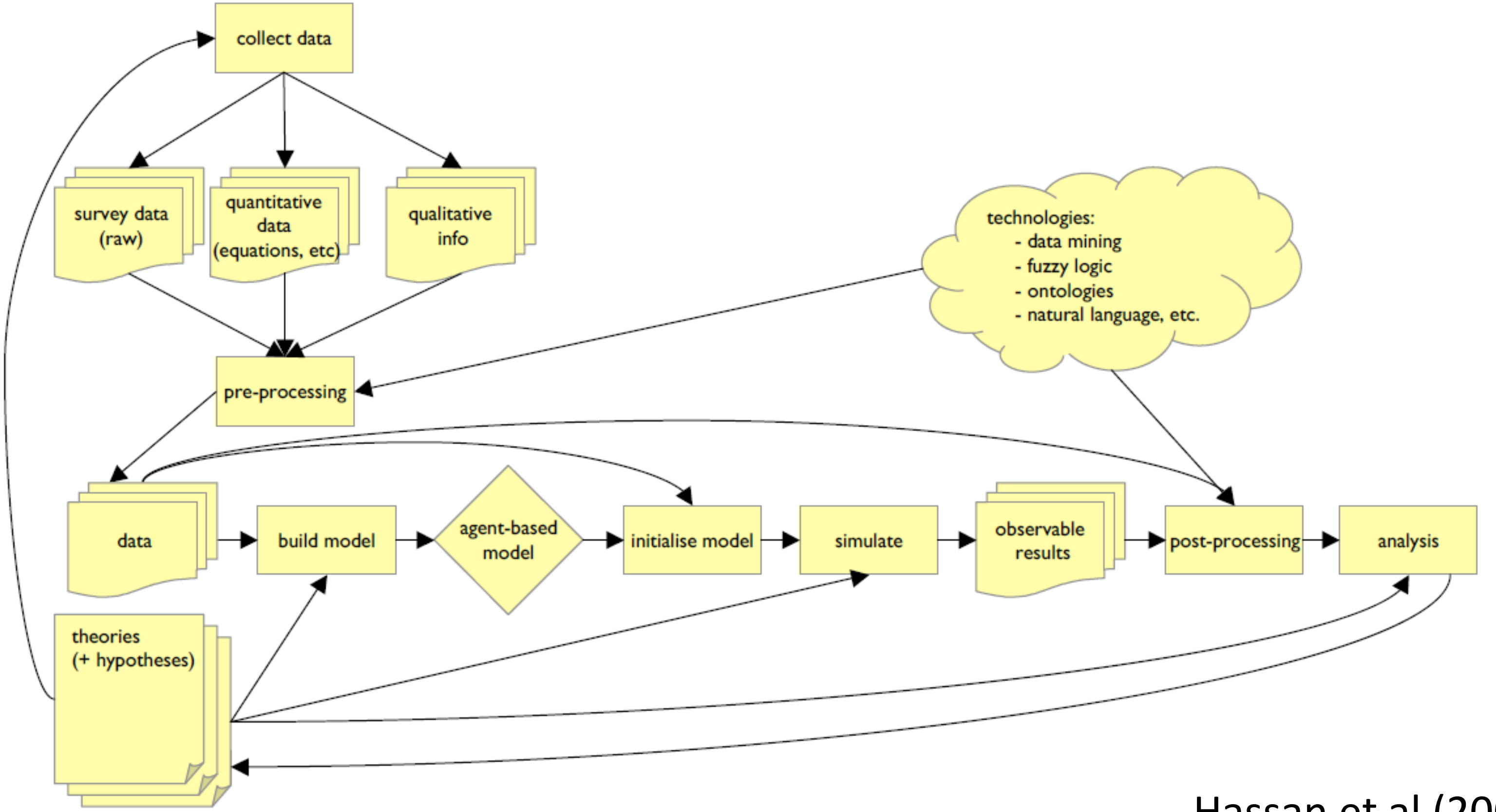
Richardson and Pugh (1981)



Sterman (2000)

Life Cycle of a Simulation Study

- Data driven agent-based simulation



Hassan et al (2008)

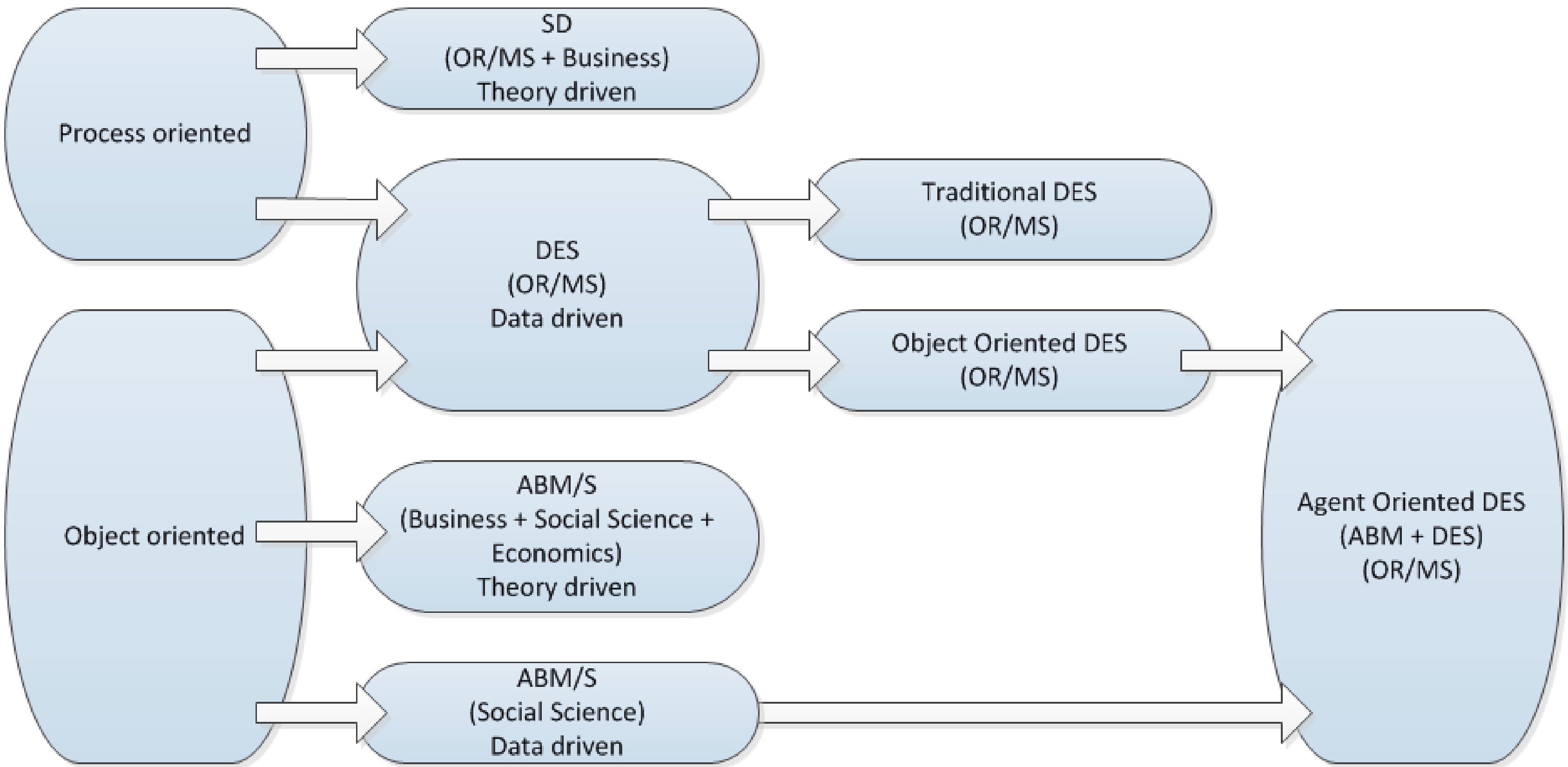
Life Cycle of a Simulation Study

- Comparing data driven and theory driven approaches

Operations Research	Business, Economics, Social Science
Empirical basis	Theoretical basis
Improving the real world	Thinking about the real world
Data collection and analysis	Dynamic hypothesis
Validation: Sufficient accuracy for purpose	Plausibility: Seeming reasonable or probable
Implementing findings	Learning + understanding

after Robinson (2011)

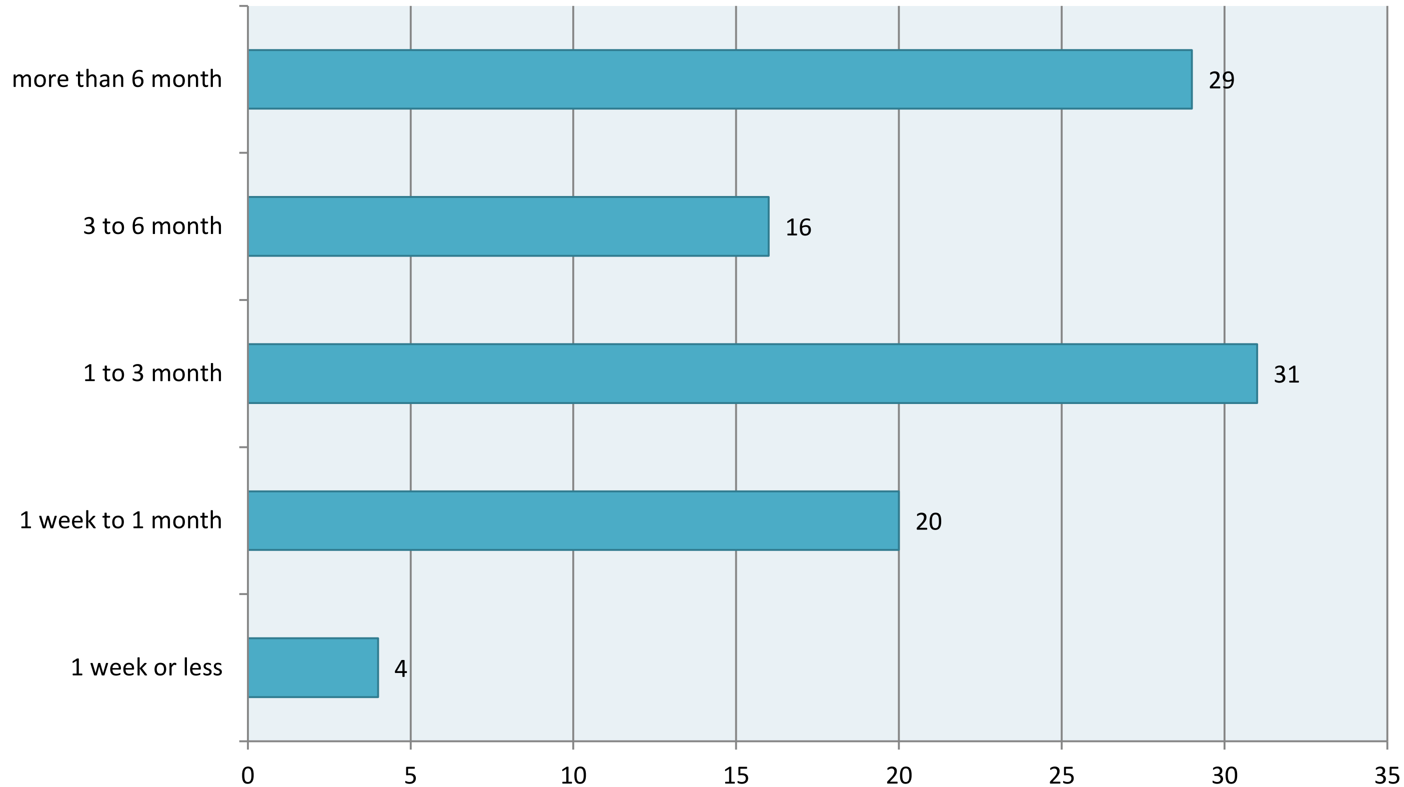
Paradigms: Update



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

Simulation Project Time-Scales

- Cochran et al. (1995):
  - Surveyed: Simulation users in industrial settings



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Case Study

Modelling the Cargo Screening Process
at the Ferry Port in Calais

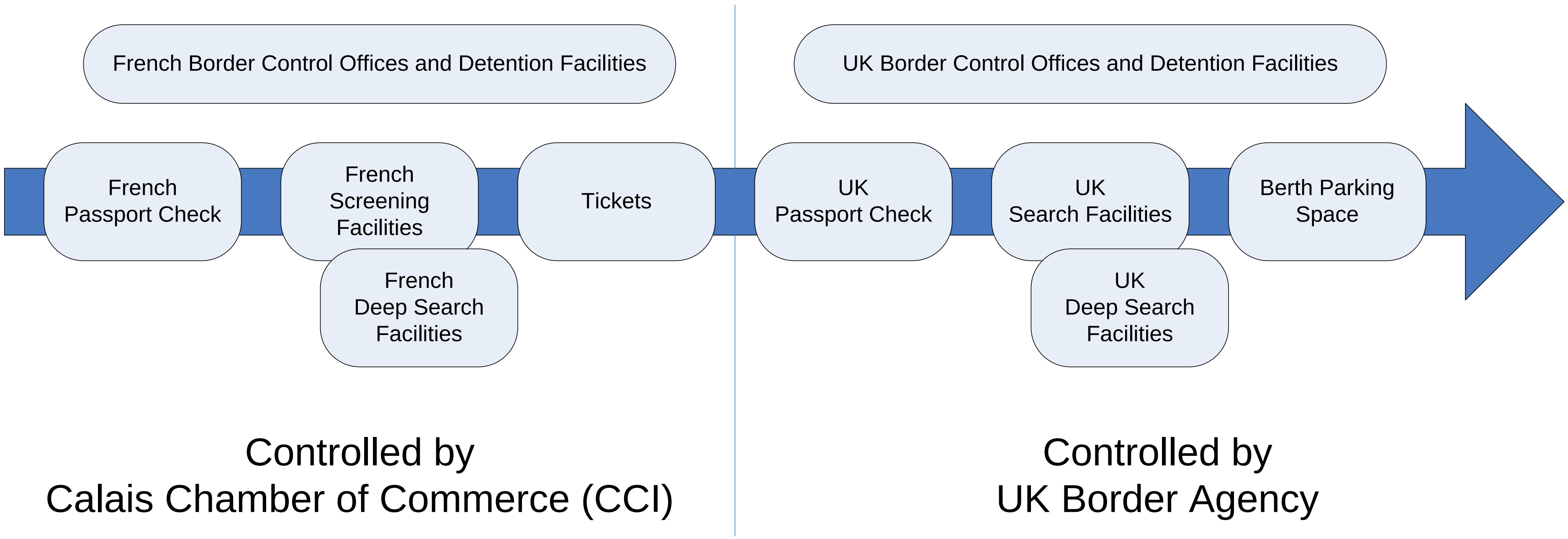
Problem Formulation

- Location: Calais Ferry Port (France)
- Problem: Illegal immigration
- 900.000 lorries/year
- 3500 positive lorries ~ 0.4%

Problem Formulation

System Investigation

System Investigation



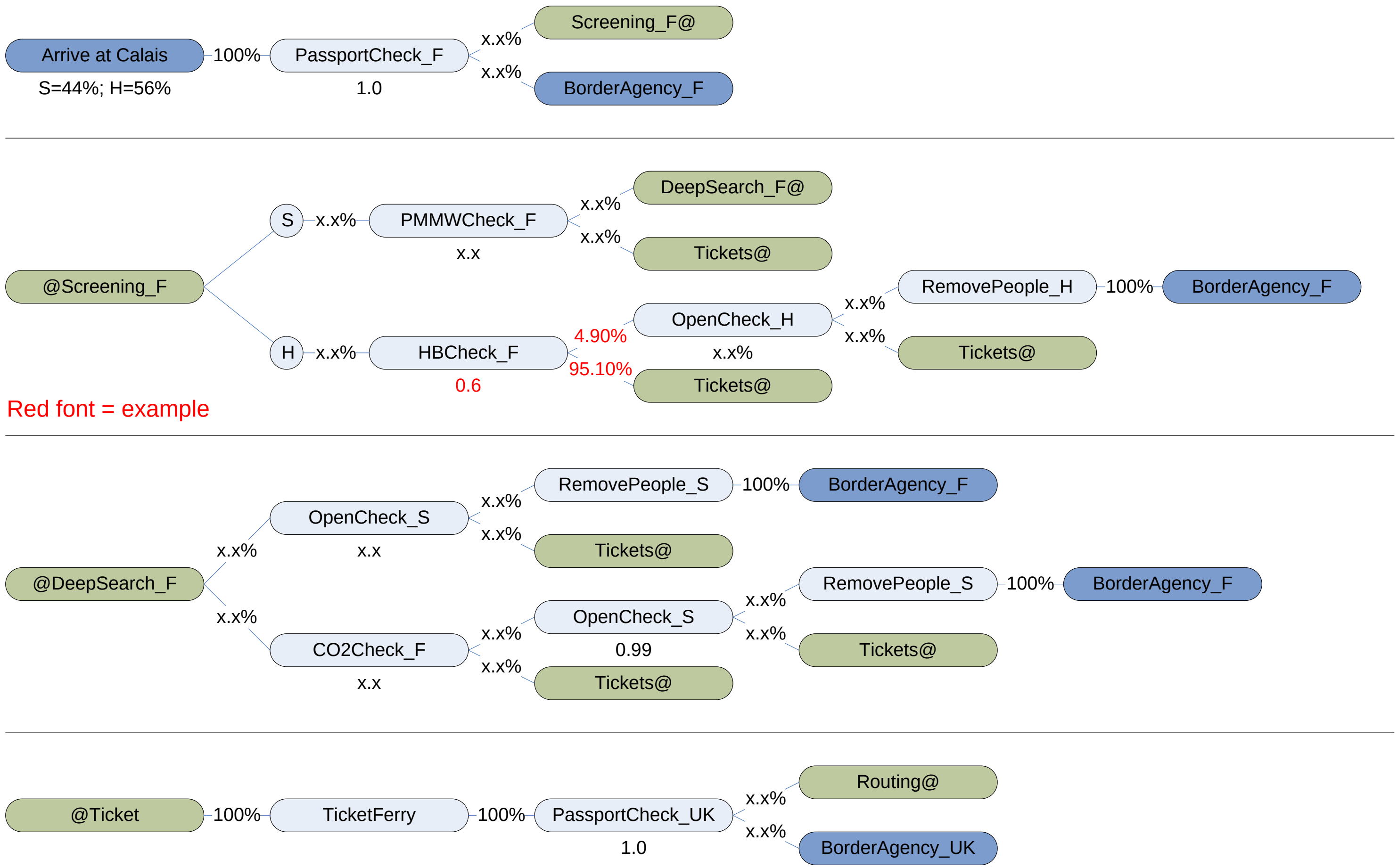
System Investigation

- Inspection Sheds
  - Heartbeat Detector
  - CO2 Probe
  - Visual Inspection
  - Canine Sniffers
- Drive Through
  - Passive Millimetre Wave Scanner

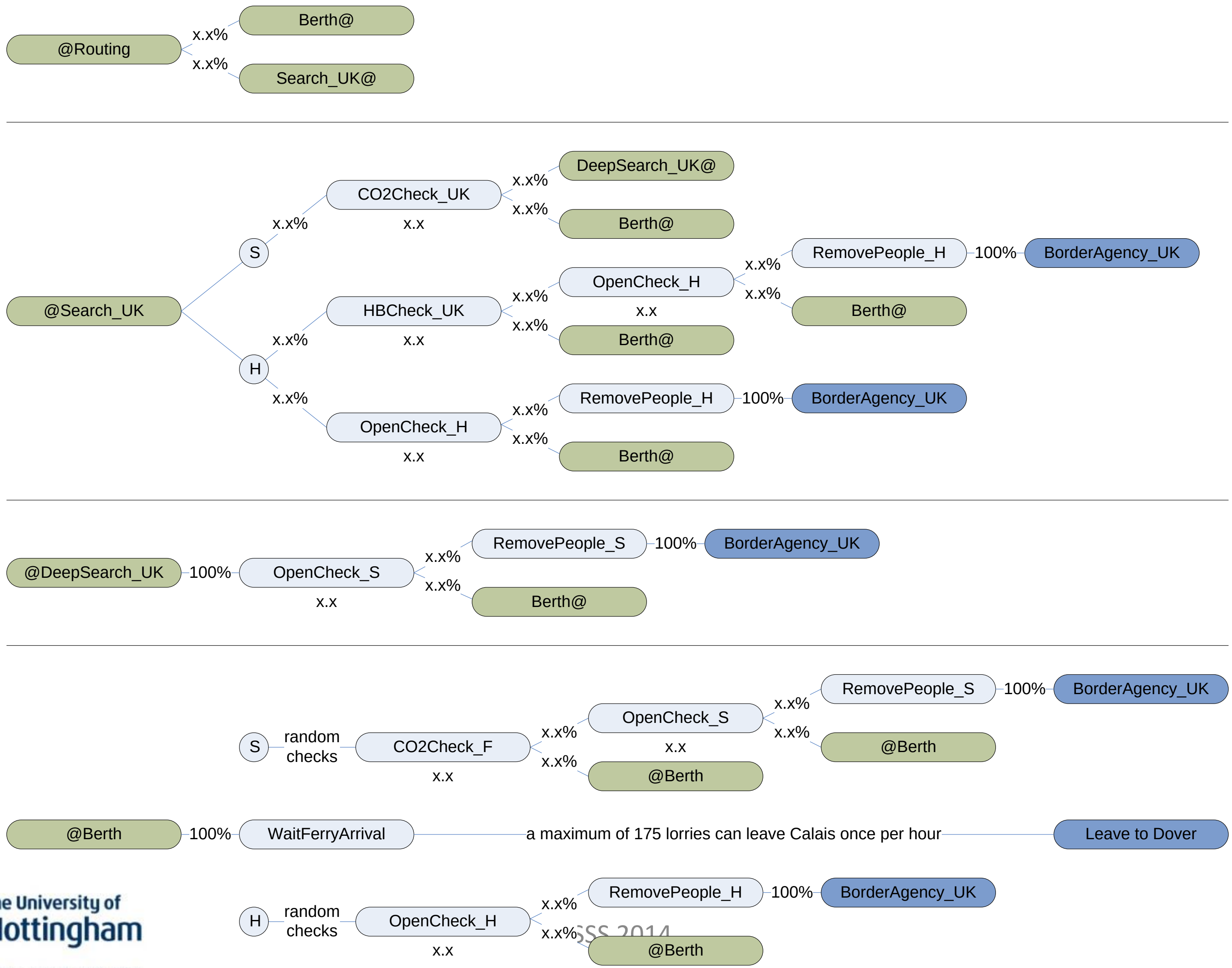
System Investigation

Statistic	Value
Total number of lorries entering Calais harbour	900,000
Total number of positive lorries found	3474
Total number of positive lorries found on French site	1,800
Total number of positive lorries found on UK site	1,674
… In UK Sheds	890
… In UK Berth	784

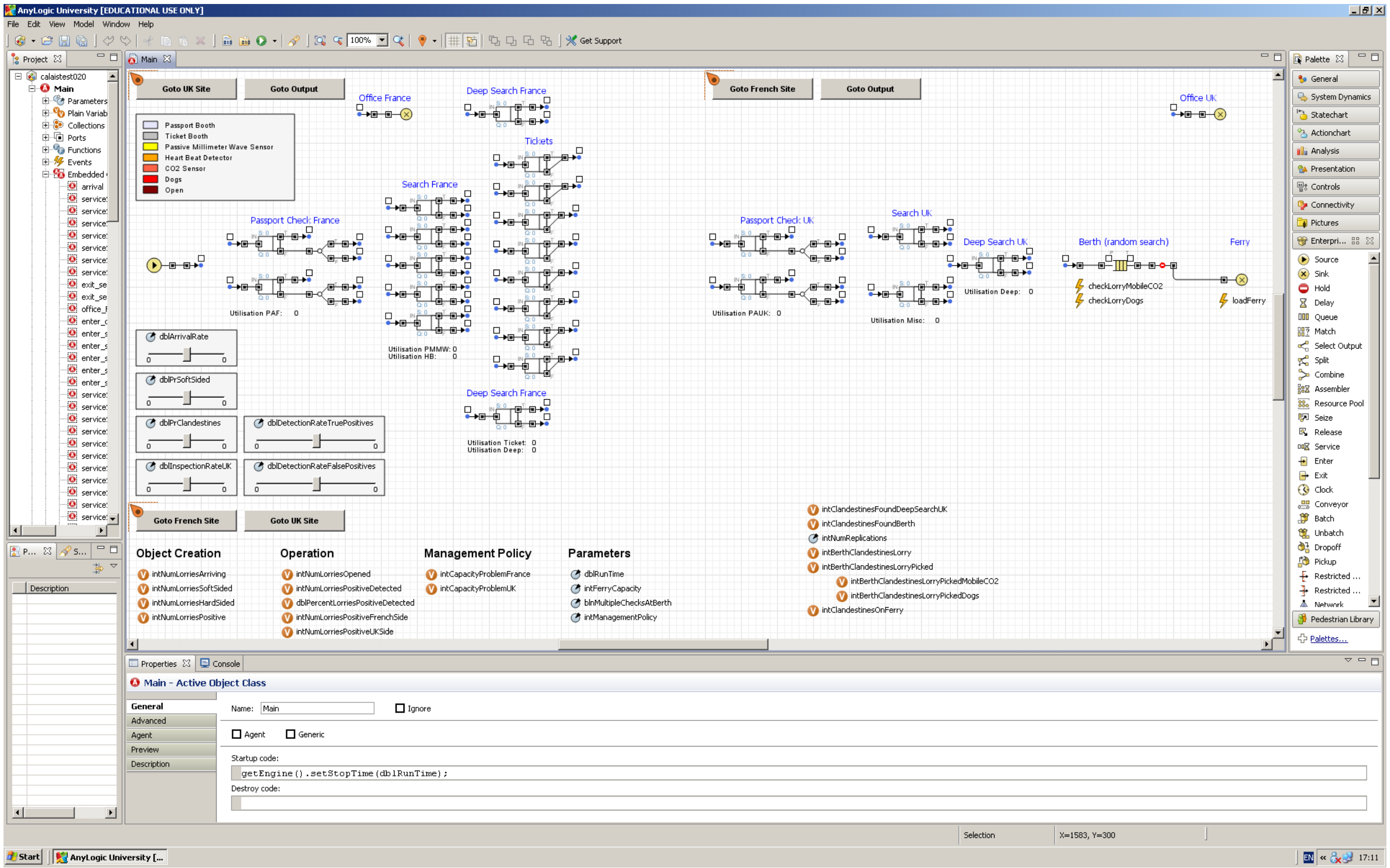
Model Representation (French Side)



Model Representation (UK Side)

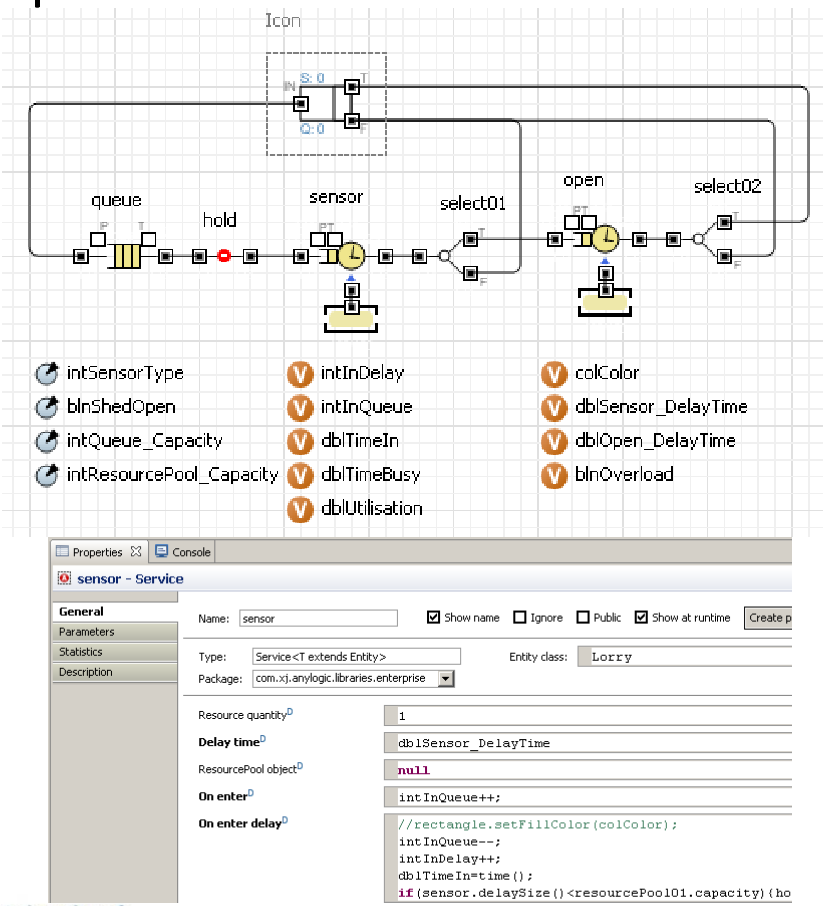


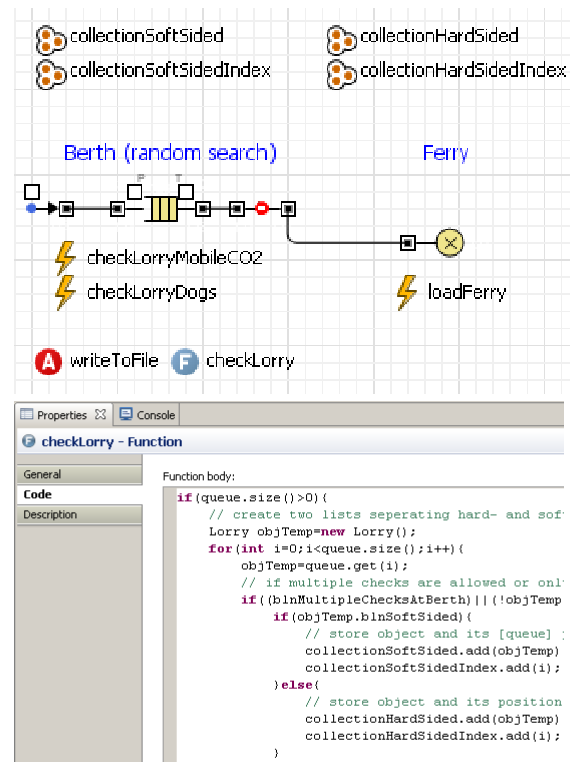
Programming



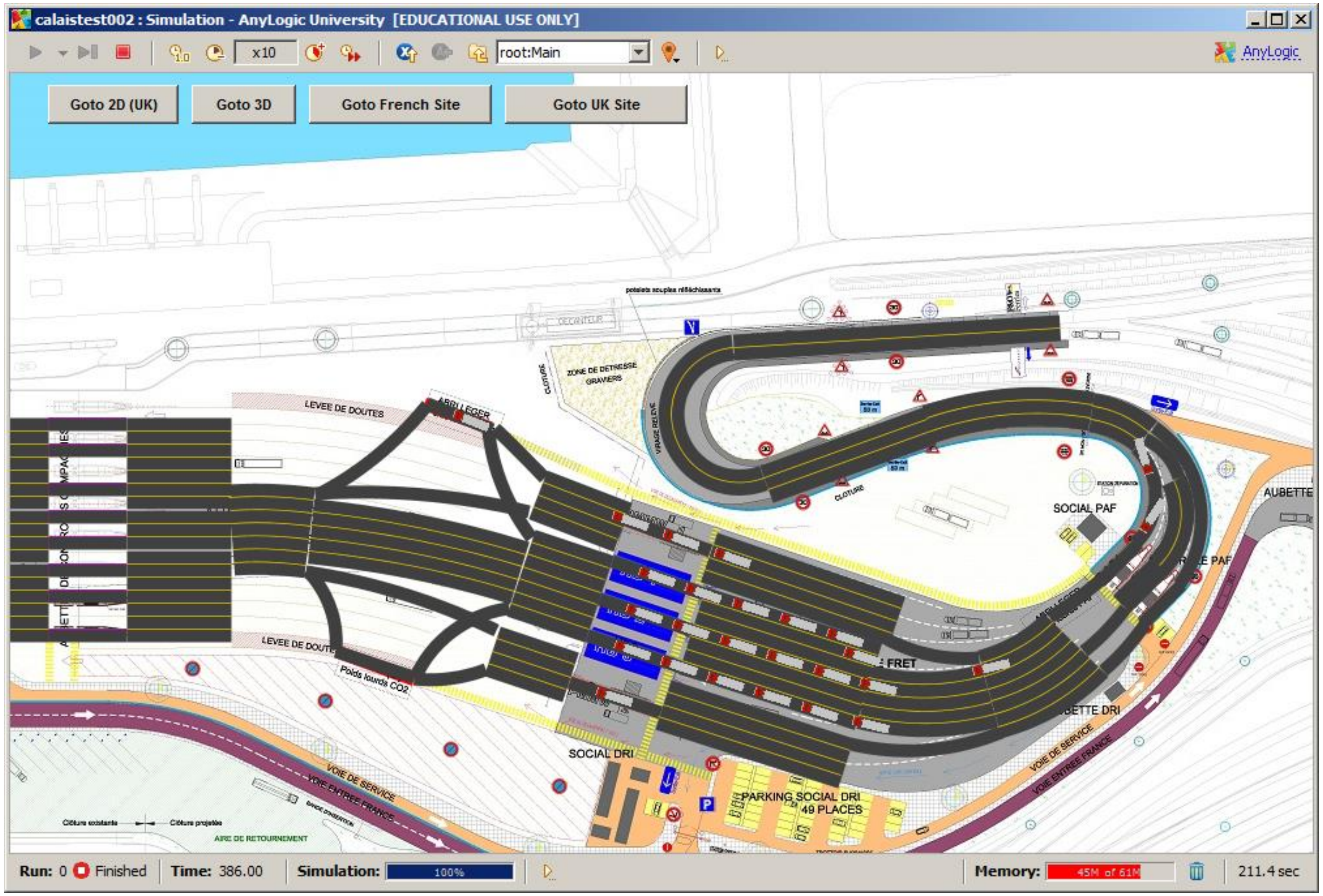
Programming

- Inspection sheds and berth activities





Presentation



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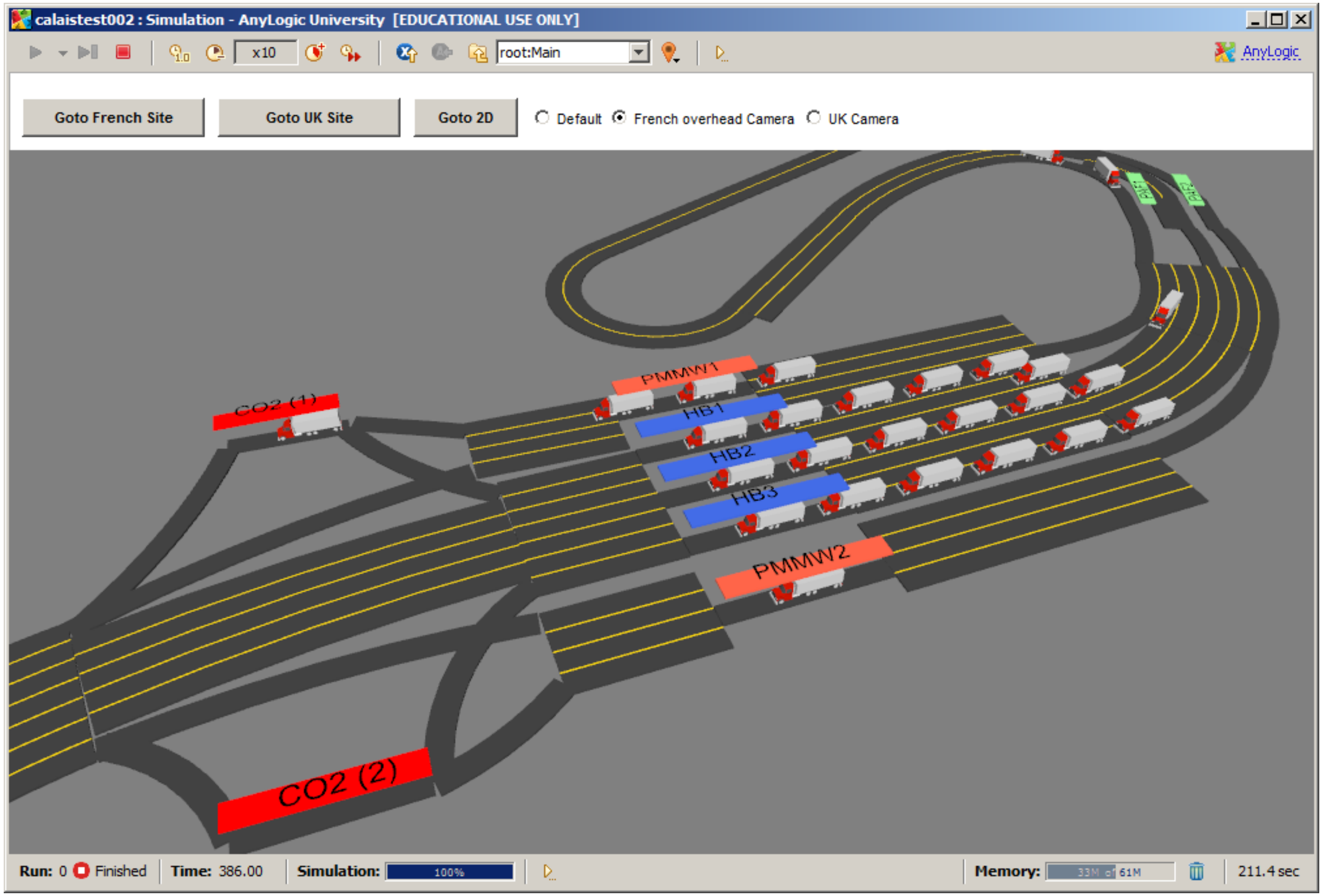

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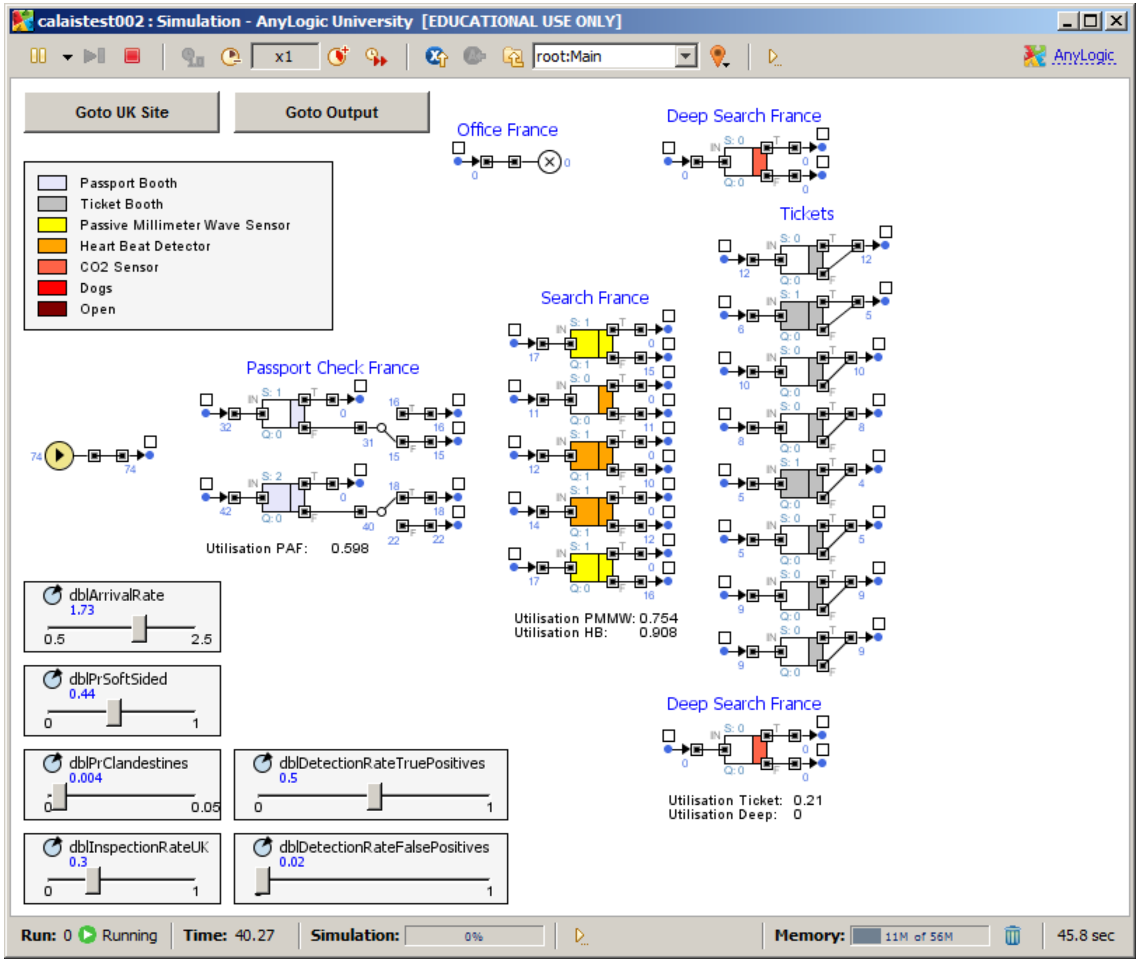
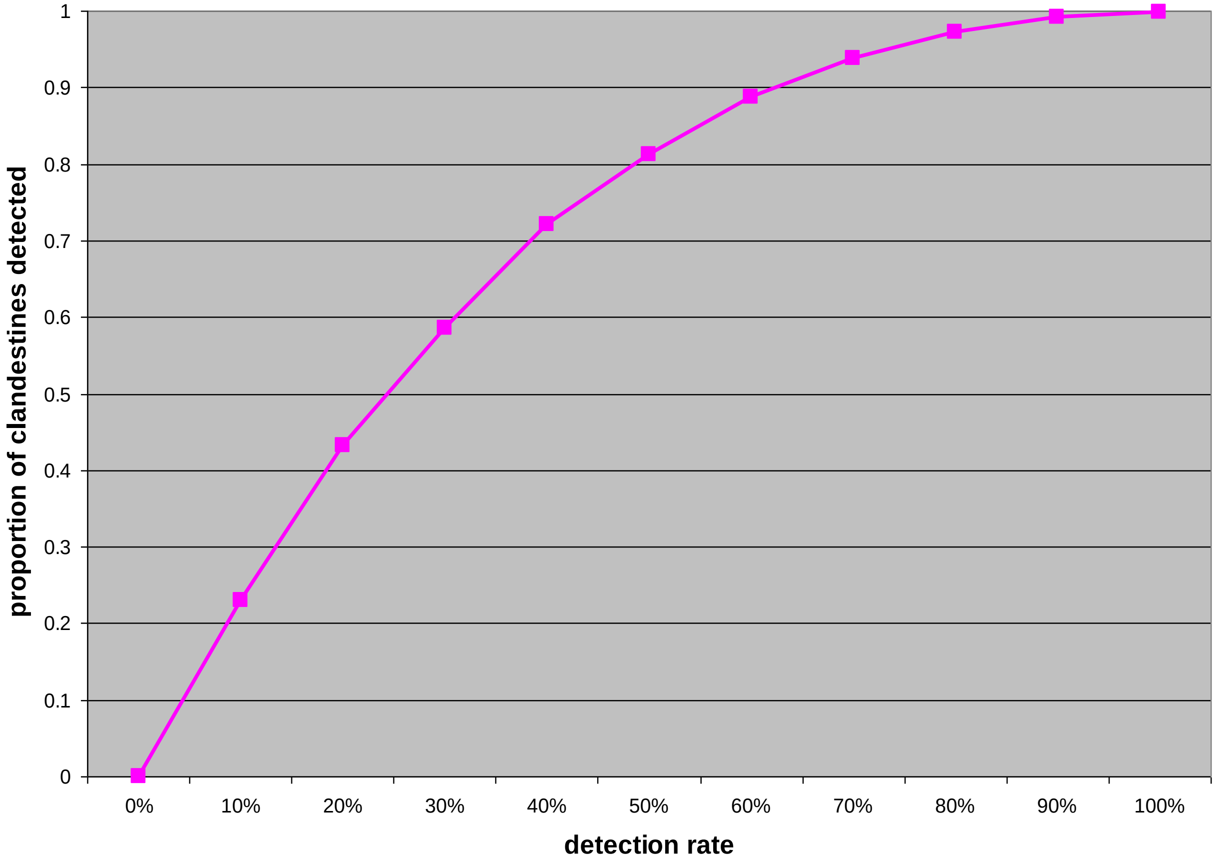
Experimentation



Experiment 1

- Detection Rate vs. Clandestines Detected



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Experiment 2

- Objectives (service standards)
  - Less than 5% of lorries should spend more than 27.01 minutes in the system
  - The base detection rates should not be compromised

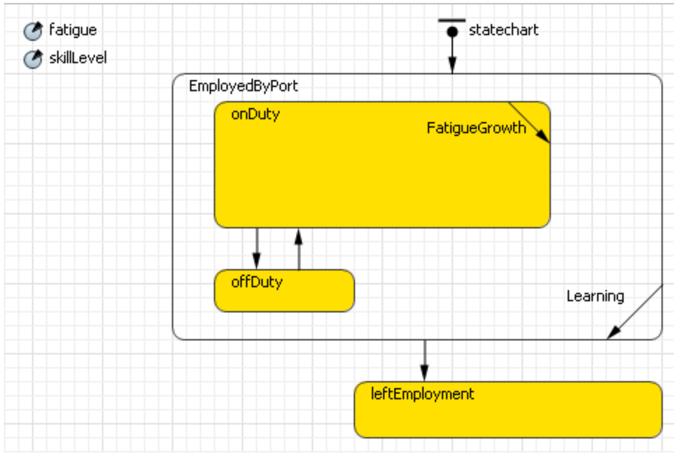
- Possible intervention
  - Allow lorries to pass without inspection when queues in front of the UK sheds are getting too long

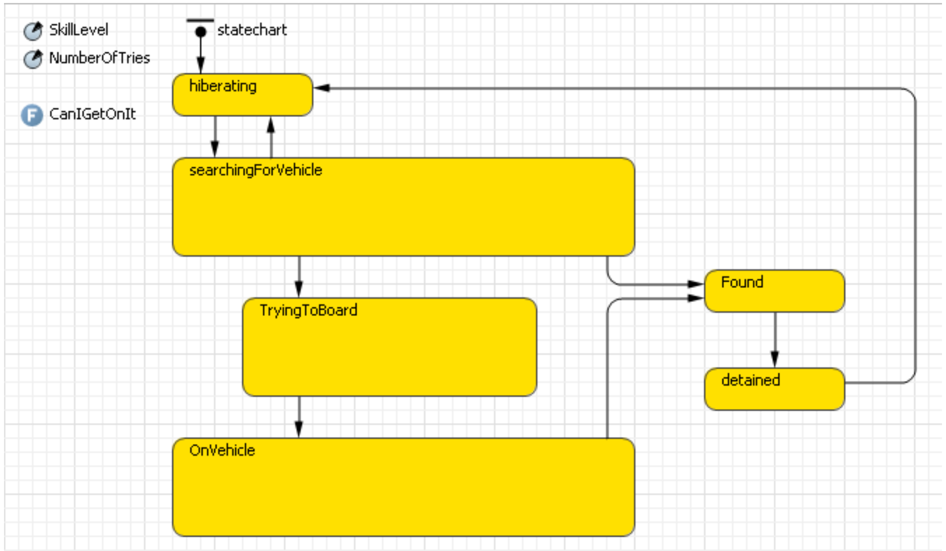
Experiment 2

Scenarios		1	2	3	4	5	6	7
Traffic Growth (TG)		0%	10%	20%	0%			
Search Growth (SG)		0%			10%	20%		
Lorries	Arrivals	900000	990000	1080000	900000			
	Soft-sided	0.44						
	Positive	0.00550	0.00500	0.00458	0.00550			
Search rate	UK Sheds	0.330	0.300	0.275	0.363	0.396		
	UK Berth	0.600	0.545	0.500	0.660	0.720		
Detection Rates	France	0.41						
	UK Sheds	0.80						
	UK Berth	0.95						
Queue size restriction	UK Sheds	off					10	9
Results		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Waiting times (avg)[*1)]	France	0.858	1.019	1.268	0.863	0.859	0.860	0.863
	UK Sheds	2.612	2.474	2.321	3.452	5.046	3.940	3.763
	Overall	1.831	1.783	1.856	2.439	3.620	2.901	2.788
Time in system (avg)		18.099	18.085	18.155	18.517	19.274	18.893	18.834
Service problem		0.019	0.019	0.020	0.036	0.068	0.052	0.049
Resource utilisation	UK Sheds	0.676	0.676	0.677	0.744	0.812	0.803	0.801
	UK Berth	0.808	0.808	0.809	0.868	0.915	0.914	0.914
Positive lorries	France	1774.9	1765.5	1745.9	1780.5	1774.3	1757.5	1769.7
	UK Sheds	900.8	814.0	733.8	981.2	1078.0	1061.2	1042.8
	UK Berth	699.9	658.4	630.7	715.9	743.0	746.5	746.8
	Missed	1590.1	1697.2	1797.0	1480.7	1365.7	1361.7	1358.1

Next Step

- Develop a combined DES/ABS version of the model





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Summary

- What did you learn?

Comments or Questions?

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References

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