G54SOD (Spring 2018)

Lecture 02

Simulation Study Life Cycle

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Motivation

- Introduce different life cycles used for simulation studies
- Provide a complete example of a simulation study

Three Factors to Consider for the Choice of the Simulation Study Approach

Factor 1: Purpose of Study

- Exploratory
  - Seeks to define research questions of a subsequent study or to determine the feasibility of research procedures
    - Supports initial research into a hypothetical or theoretical idea

- Explanatory
  - Seeks to determine how events occur and which ones may influence particular outcomes (establish cause-and-effect relationships)
    - Can only be applied once we have accumulated enough knowledge to make predictions with some accuracy

Factor 2: Drivers of Model Formulation

- Theory driven
  - Theory for model formulation
  - Data (or expert opinion) for model validation

- Data driven
  - Data for model formulation (qualitative or quantitative)
  - Data (or expert opinion) for model validation

- Logic driven
  - Logic for model formulation
  - Data (or expert opinion) for model validation

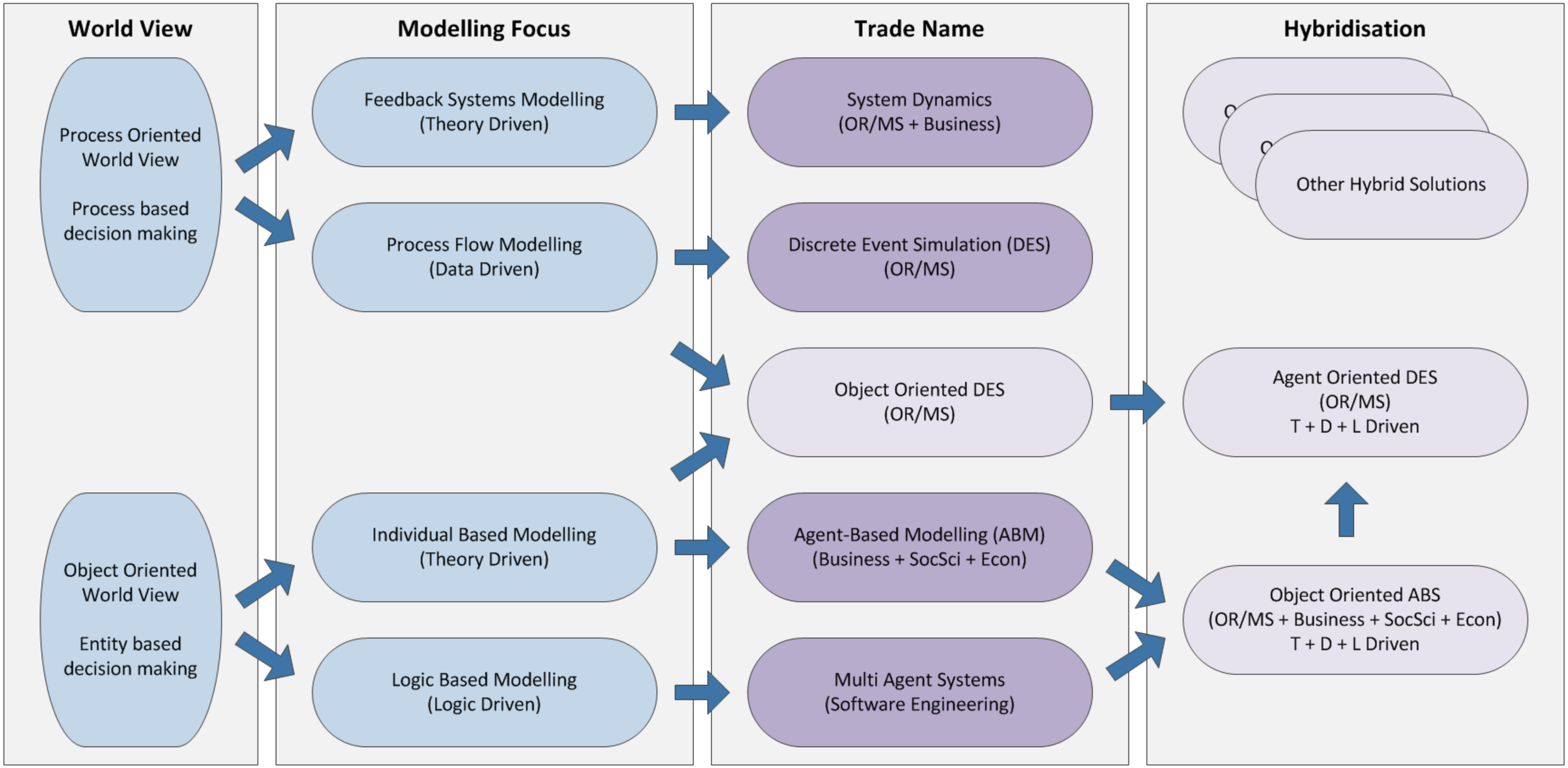
Factor 3: Domain

- Typical simulation study characteristics in different domains

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)

Simulation Modelling Framework



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

Simulation Study Life Cycle Overview

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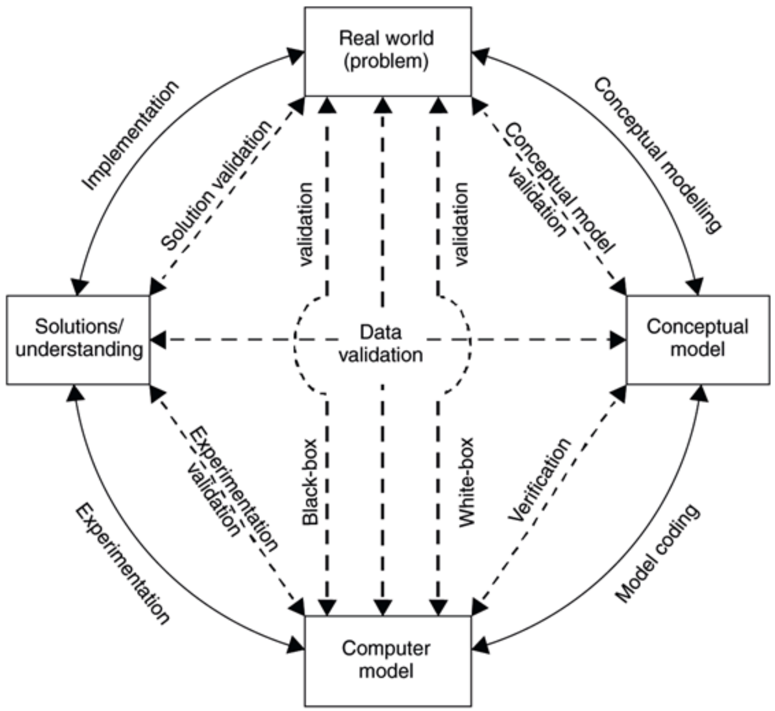
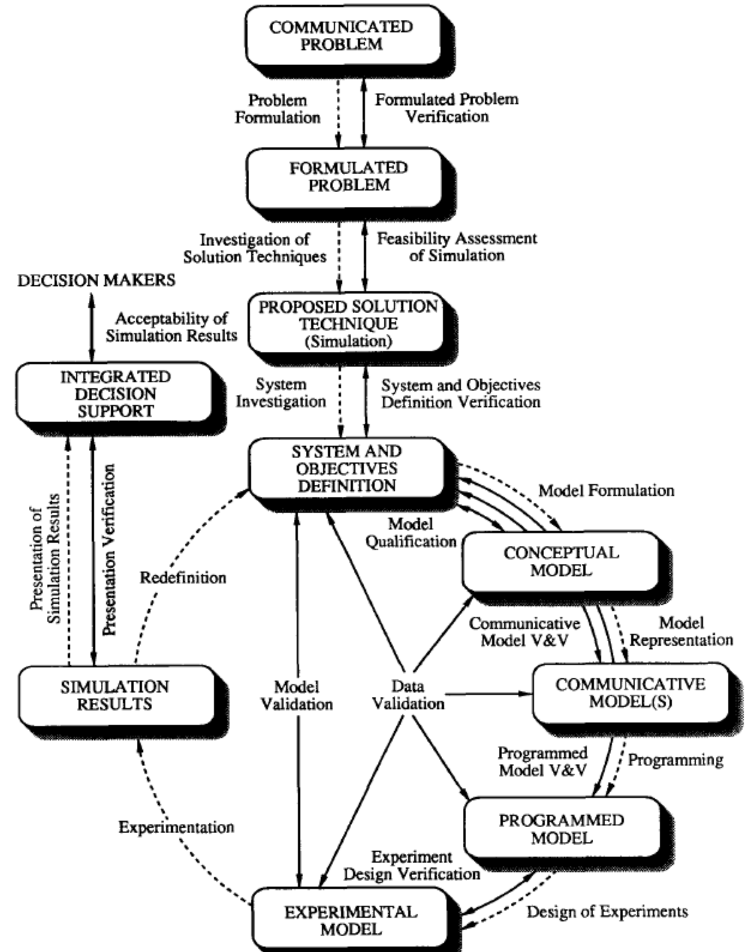
Life Cycle of a Simulation Study

- Operations Research
  - Data driven



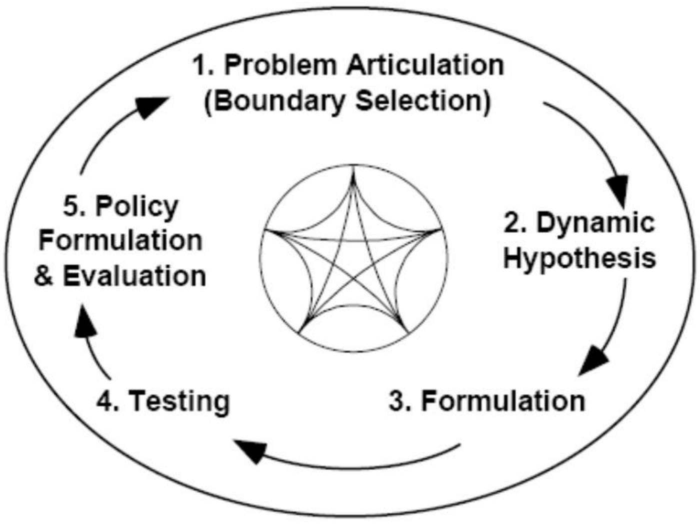
Robinson (2004)



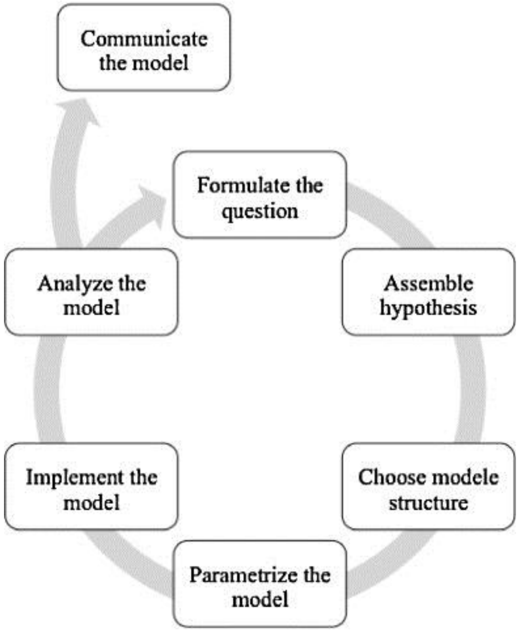
Balci (1990)

Life Cycle of a Simulation Study

- Business + Economics + Social Science
  - Theory driven



Sterman (2000)



Grimm and Railsback (2005)

How does Optimisation fit into this?

Life Cycle of an Optimisation Study

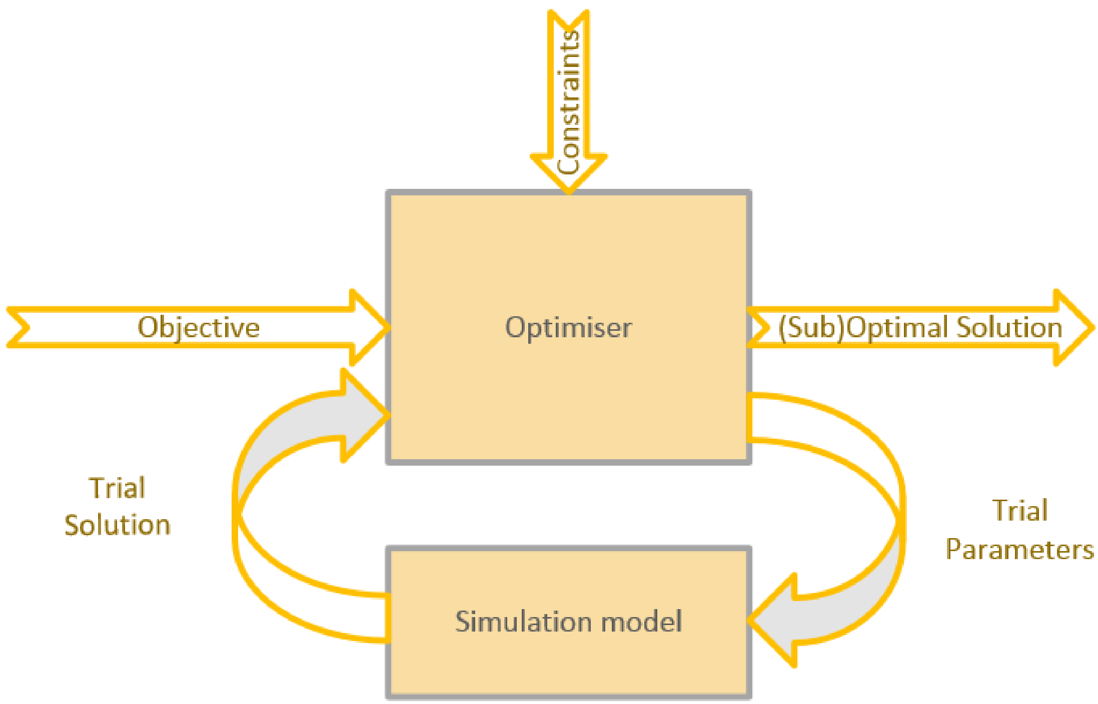
- Optimisation goal
  - Choosing a decision alternative that either minimising or maximising an evaluation function while considering certain constraints

- Steps
  - Recognising the problem
  - Defining the problem
  - Constructing a model for the problem
    - Describe the decision variables and the relationship between them
    - Describe the structure of an evaluation function
    - Consider additional parameters > Often determined by using simulation

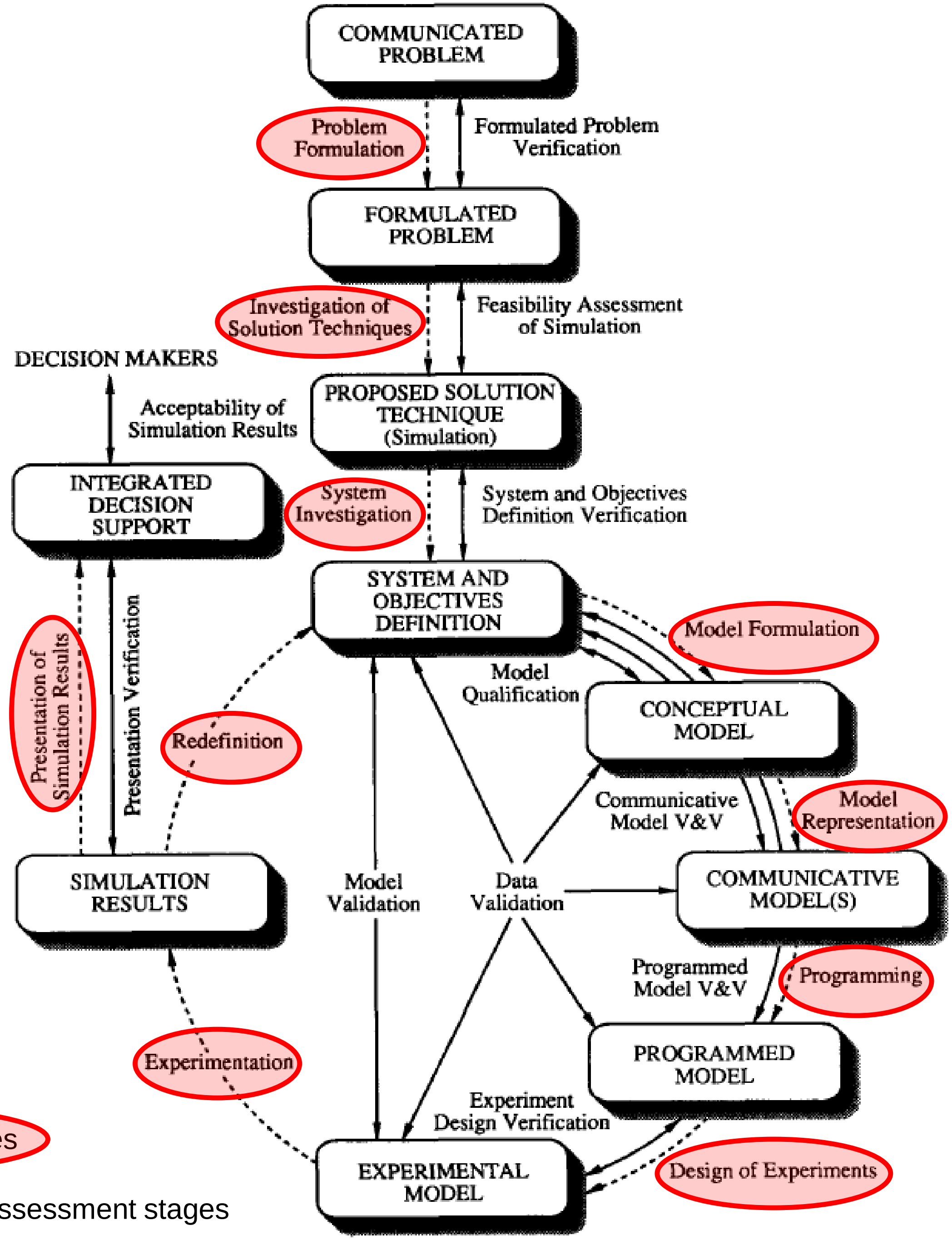
Life Cycle of an Optimisation Study

- Steps (cont.)
  - Solving the model
    - Using algorithms > classical methods or modern heuristics
  - Validating the obtained solutions
    - Often using sensitivity analysis (to see how the optimal solution depends on variations of the model)
  - Implementing one solution
    - Validated solution is implemented once
    - Model is used and solved repeatedly (real time optimisation)

Life Cycle of an Optimisation Study



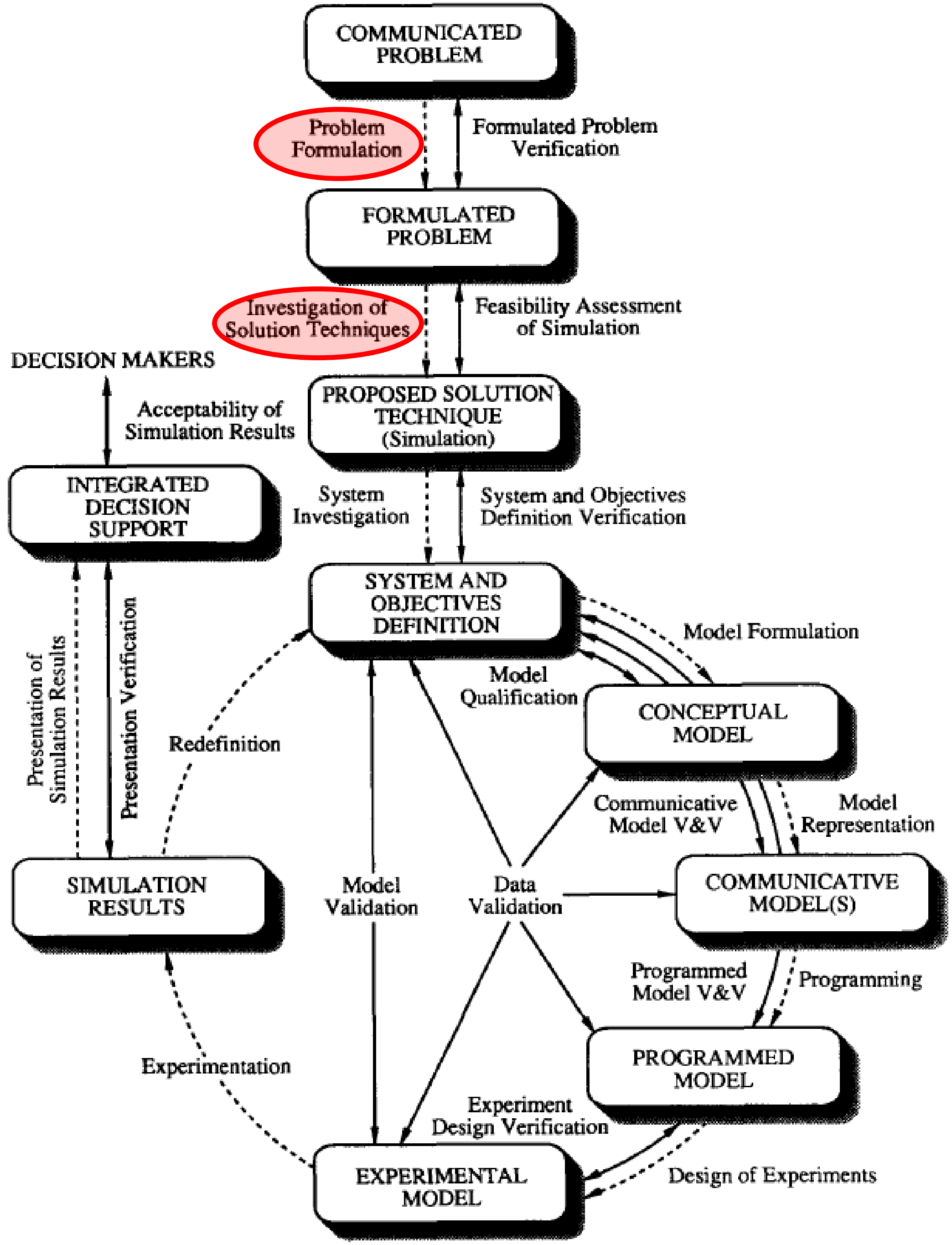
A more detailed walk-through the Operations Research Study Simulation Life Cycle



Oval symbols: Phases

Dashed arrows: Processes

Solid arrows: Credibility assessment stages



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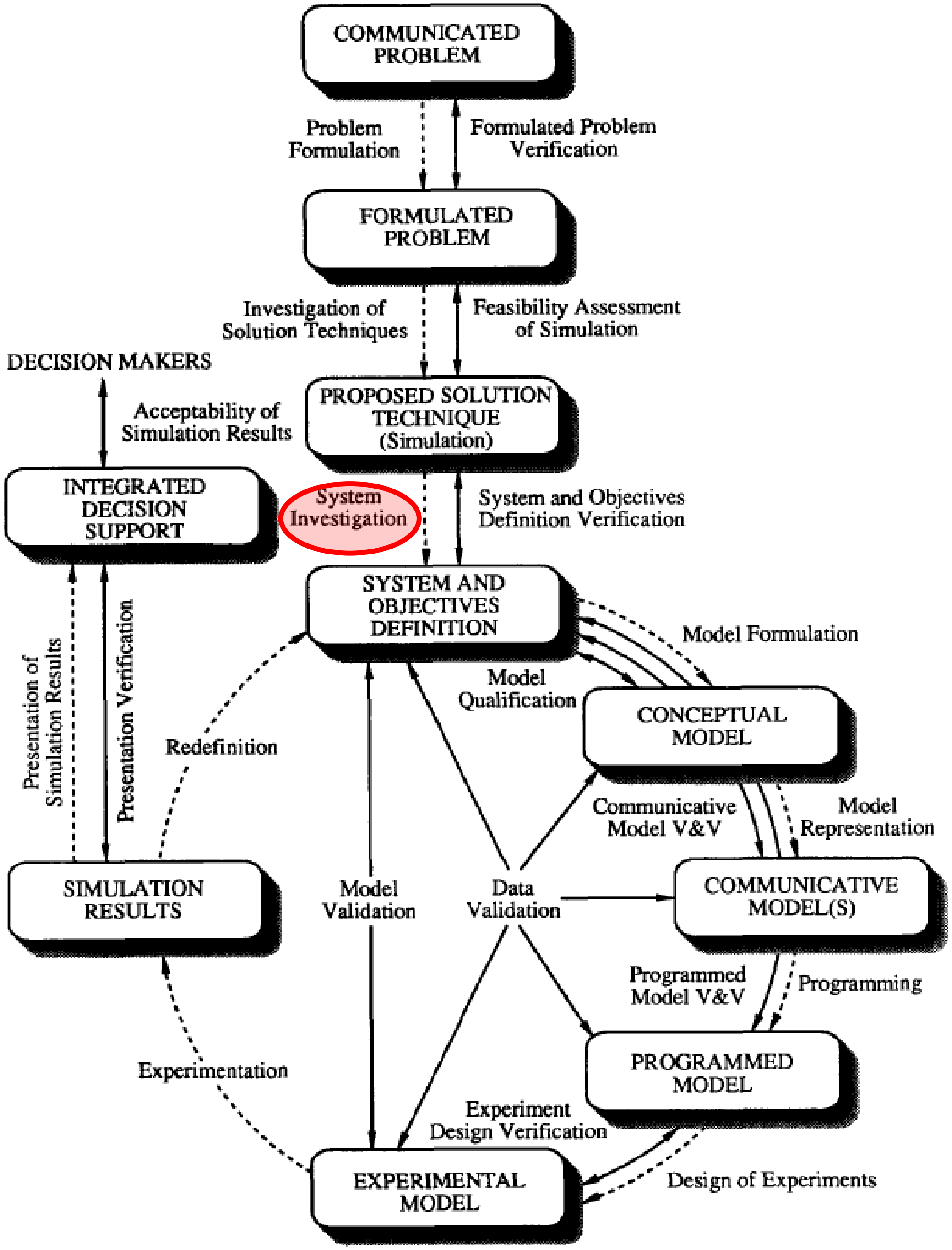
Processes

- Problem formulation
  - Communicated problem is rarely clear, specific, or organised
  - Initially **communicated problem is translated into a formulated problem** sufficiently well defined to enable specific research action

- Investigation of Solution Techniques
  - Often 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
    - **Change characteristics:** How often and how much the real system will change during the course of a simulation study
      - Changes require model updates and may even change study objectives
    - **System's environment:** Consists of all input variables that can significantly affect its state with regards to the study objective
      - E.g. for a traffic intersection system arrival rate of vehicles would be an input variable whereas pedestrian arrival rate might be omitted
    - **Counterintuitive behaviour characteristics:** Some systems may show counterintuitive behaviour which we should try to identify for consideration in the model
      - Requires people who have expert knowledge about the system

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 (leading to cycle time increase, machine breakdown, etc.)
  - **Interdependency and organisation characteristics:** Many activities or events take place simultaneously and influence each other
    - This needs to be examined before abstracting the real system for the purpose of modelling

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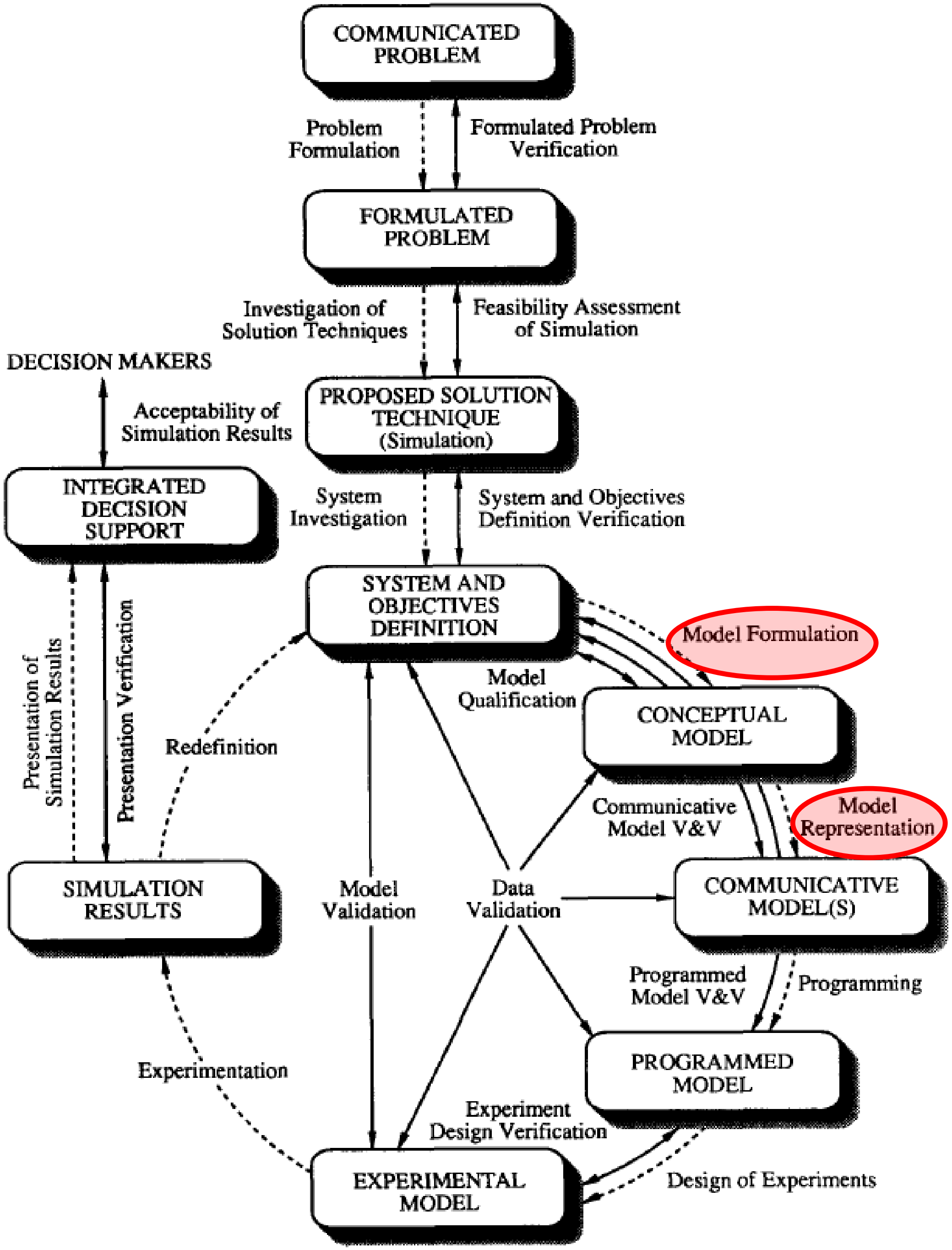

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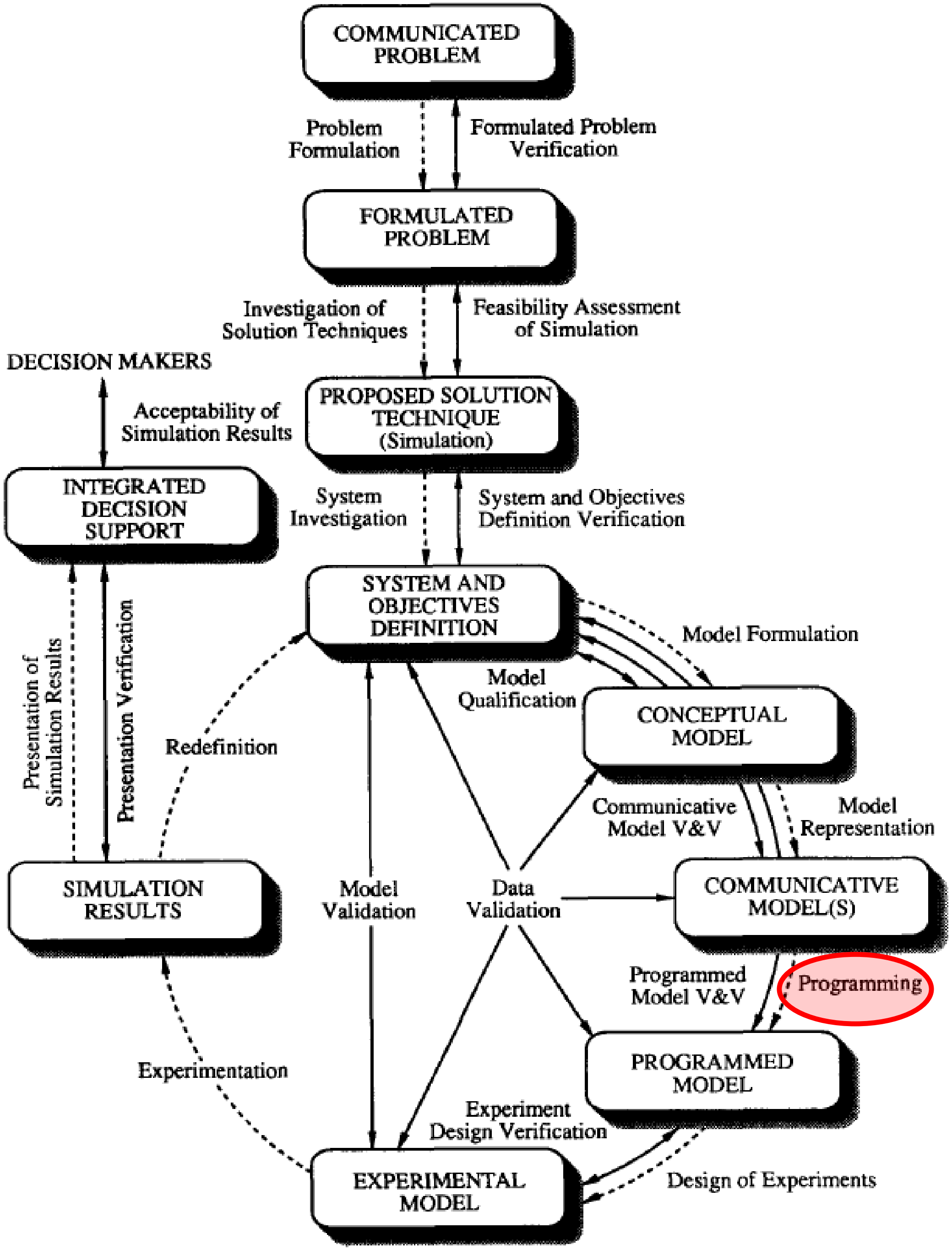
Processes

- Model formulation
  - Process by which a conceptual model is envisioned to represent the system under study
    - A **conceptual model** is a non-software specific description of a simulation model describing objectives, inputs, outputs, content, assumptions, and simplifications of the model (Robinson 2004)
    - Model needs to be **formulated before the implementation** rather than building it ad-hoc and evolving it (in particular in bigger projects)

  - Input data analysis and modelling
    - Start collecting data
    - Identify distributions and estimate their parameters

Processes

- Model representation
  – Process of translating the conceptual model into a more communicative model
    - Typical representation formats:
      – SDM: Causal Loop Diagrams + Stock and Flow Diagrams
      – DEM: Activity Cycle Diagrams (deprecated) + Flow Charts
      – ABM: Equations or UML
      – 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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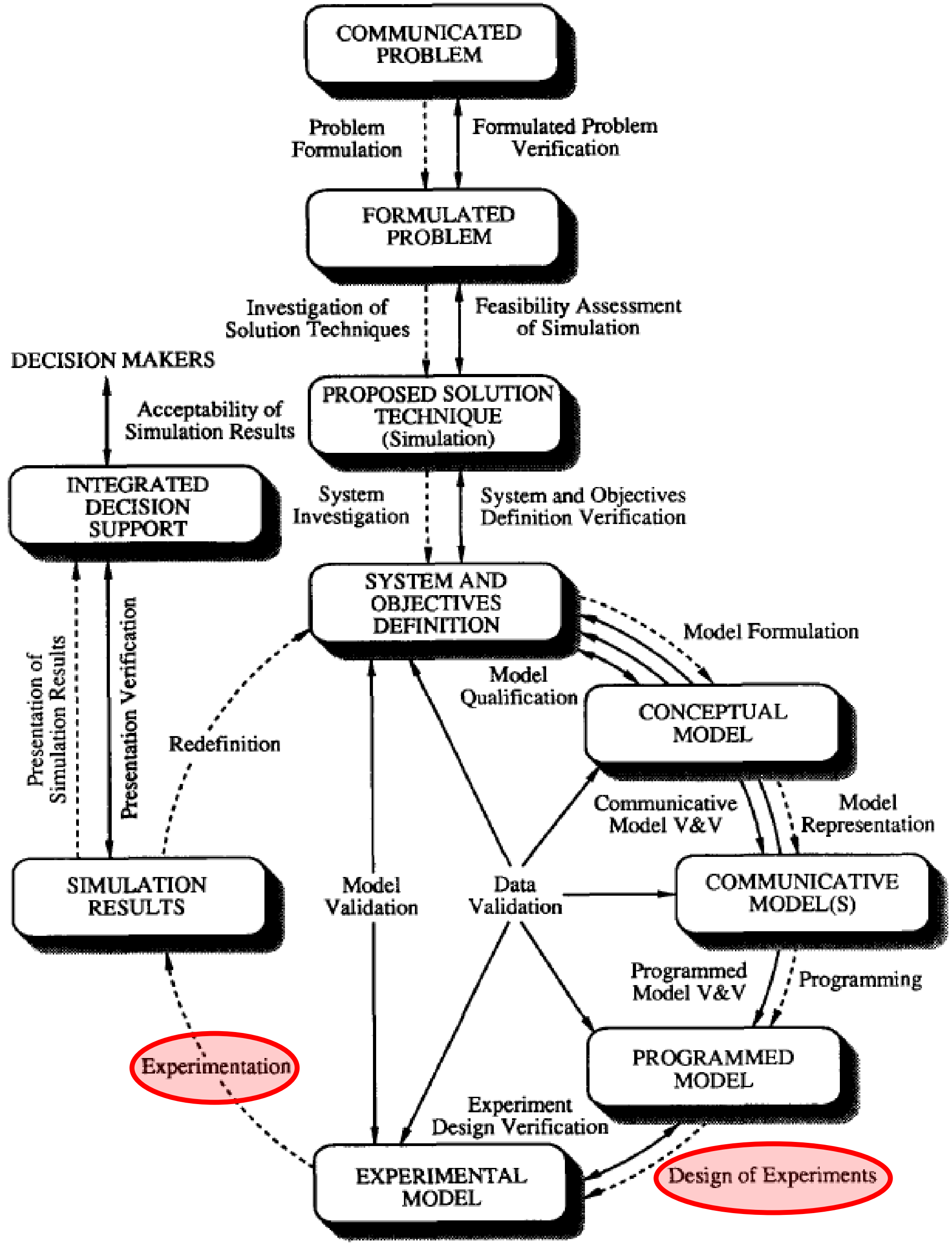
Processes

- Programming
  - Nowadays mainly Visual Interactive Modelling Systems (VIMS)
    - SDS: Dynamo, iThink/Stella, PowerSim, Vensim, ...
    - DES: Arena, SimIO, Simul8, Witness, ProModel, Extend, FlexSim, ...
    - ABS: AnyLogic, many academic tools focusing on specific research areas
  - Specific programming languages
    - GPSS, SIMAN, SIMSCRIPT, SIMULA, SLAM, ...

Survey available at OR/MS website [url]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Processes

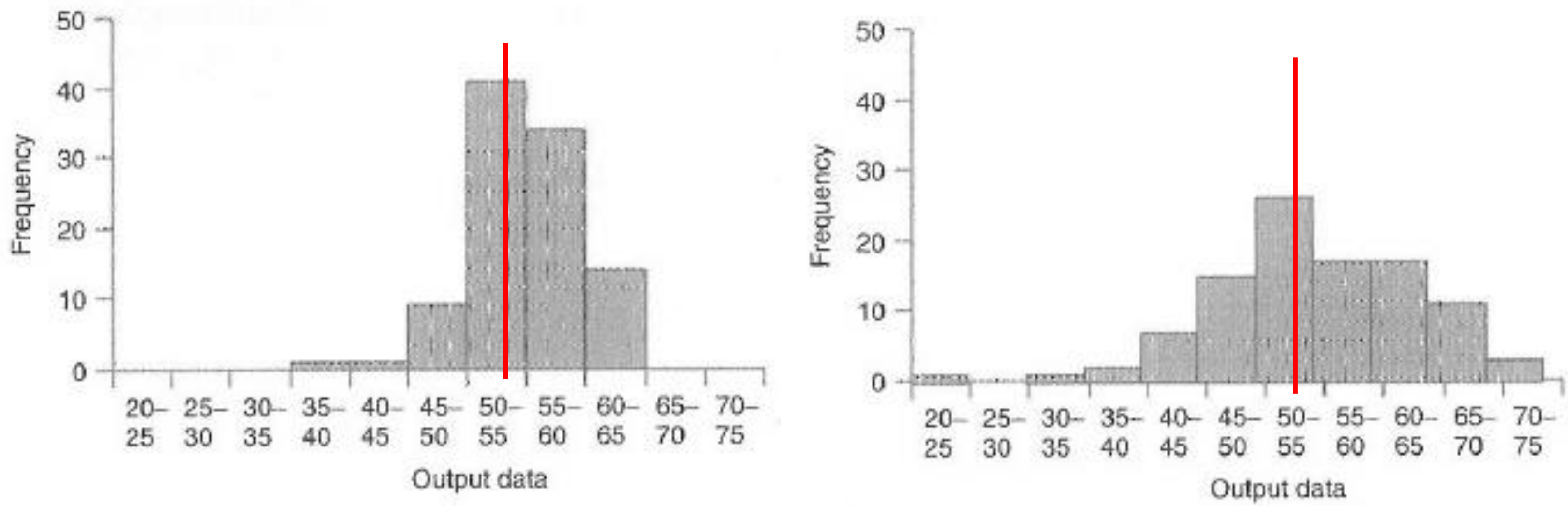
- Design of experiment
  - Process of formulating a plan to gather the desired information at minimal cost and to enable the analyst to draw valid inferences
    - Obtaining accurate results
      - **Run conditions**: Warm up period, number of replications, run length
      - **Variance reduction techniques**: Obtain greater statistical accuracy for the same amount of simulation runs
    - Searching the solution space
      - **Response-surface methodologies**: Finding the optimal combination of parameter values which maximise or minimise 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

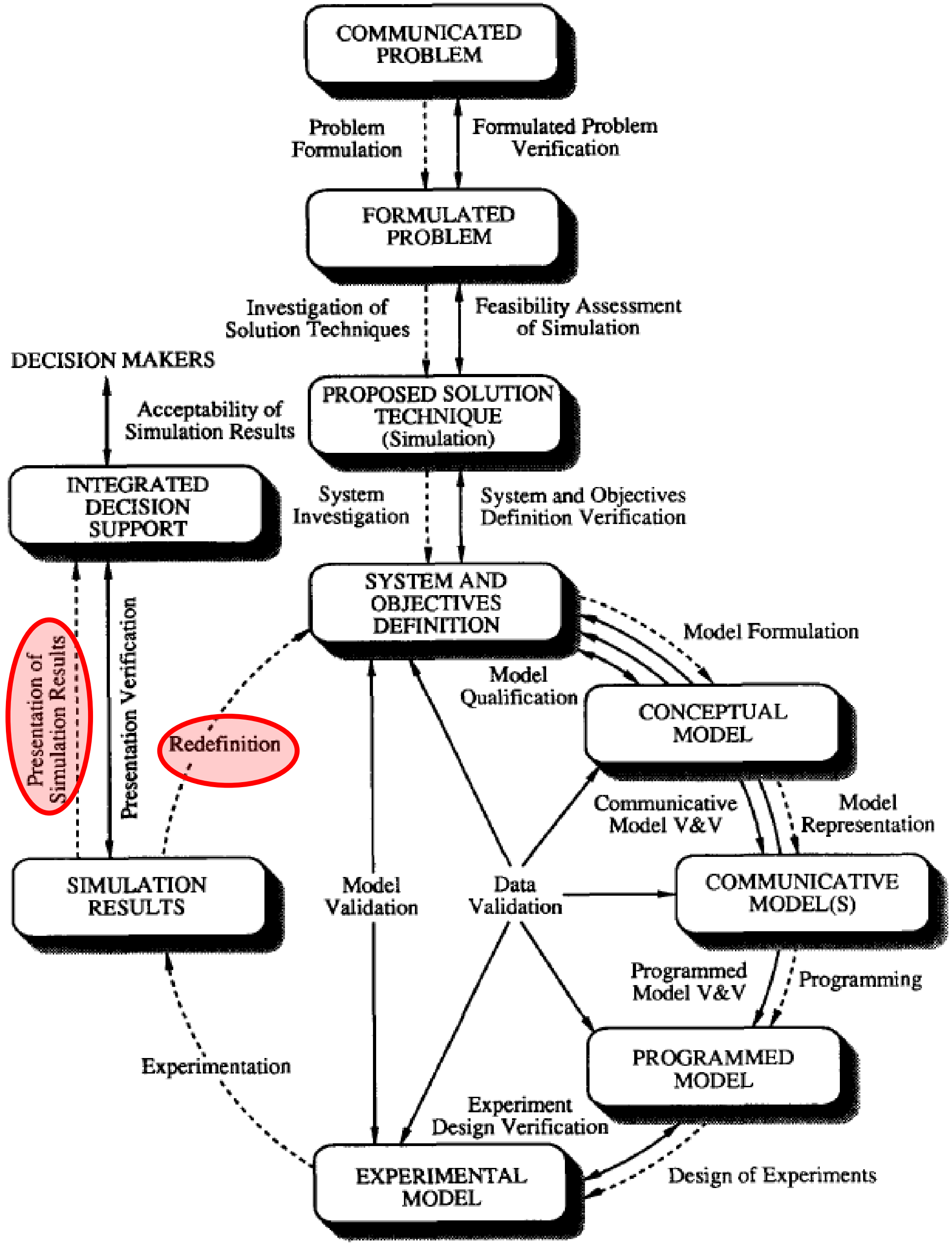
- Experimentation
  - What-if analysis
    - Making changes to the model's inputs, running the model, inspecting the results, learning from the results, making changes to the model's inputs ...
  - Different purposes of experimentation
    - Comparison of different operating policies; evaluation of system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

Processes

– Output analysis (for stochastic simulation) cont.
  - Why is it not enough to provide the mean value only?



Robinson (2004)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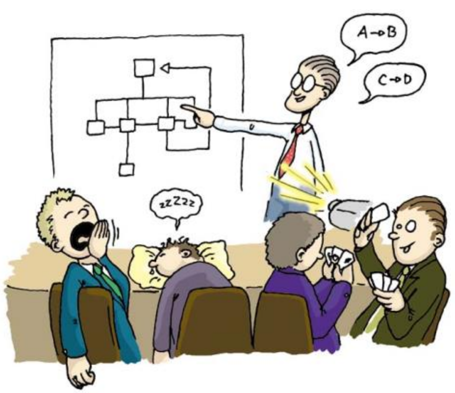
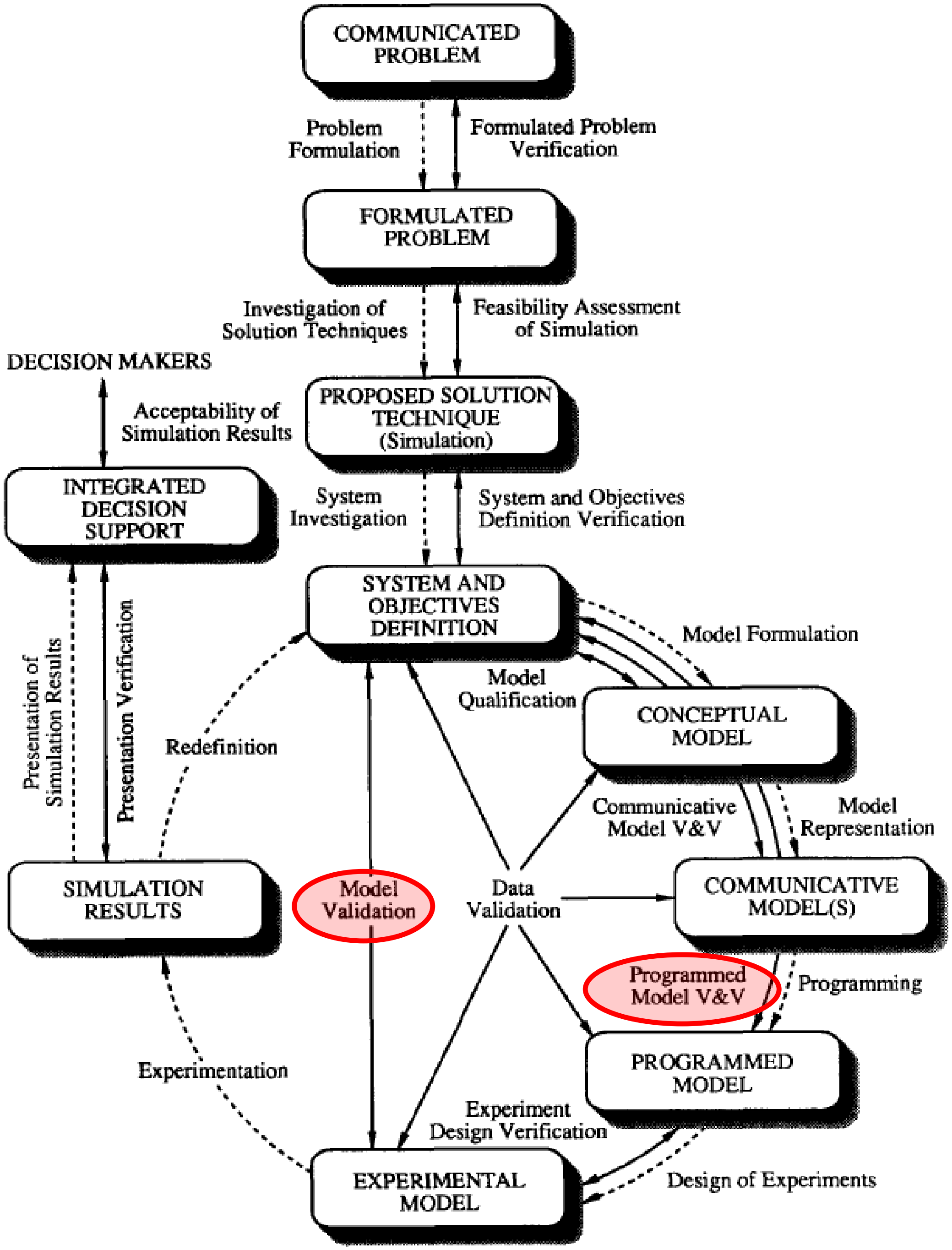
Processes

- Redefinition
  - Process of 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





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Verification and Validation

- Verification and validation are continuous processes that are performed throughout the life cycle of the simulation study
  - Model Verification
    - The process of ensuring that the model design has been transformed into a computer model with sufficient accuracy
      - Deals with "building the model right"
  - Model Validation
    - The process of ensuring that the model is sufficiently accurate for the purpose at hand
      - Deals with "building the right model"

Case Study: Modelling the Cargo Screening Process at the Ferry Port in Calais

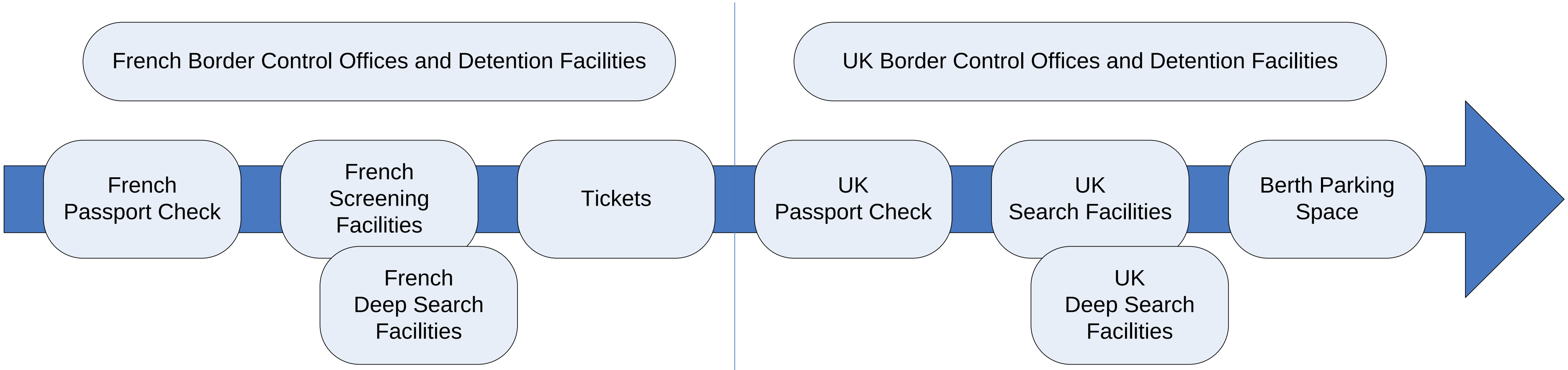
Problem Formulation

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

Problem Formulation

System Investigation

System Investigation

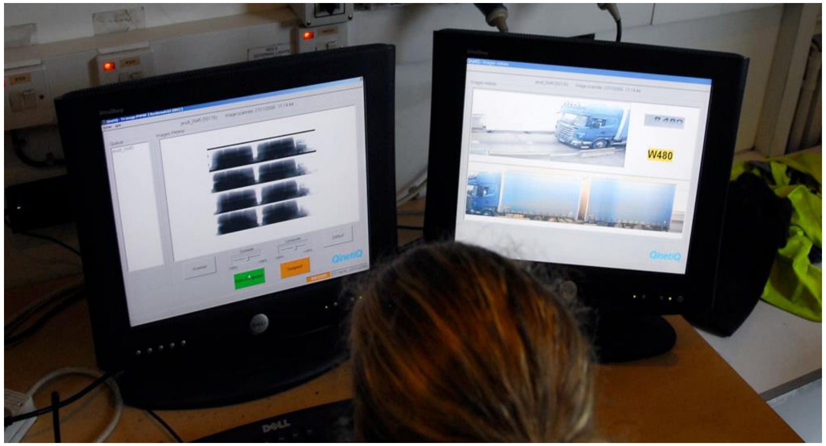


Controlled by
Calais Chamber of Commerce (CCI)

Controlled by
UK Border Agency

System Investigation

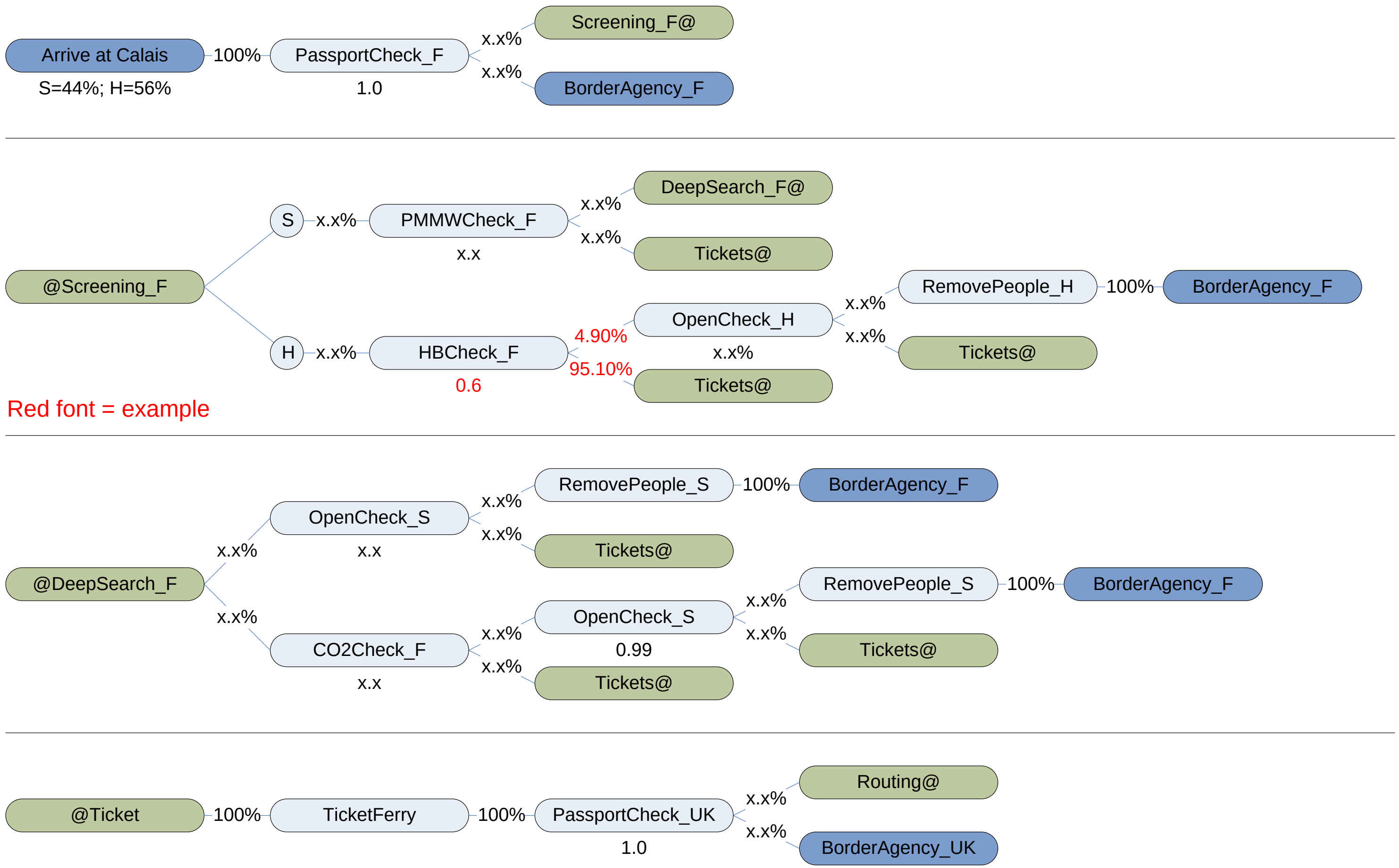
- Inspection Sheds
  - Heartbeat Detector
  - CO2 Probe
  - Visual Inspection
  - Canine Sniffers
- Drive Through
  - Passive Millimetre Wave Scanner



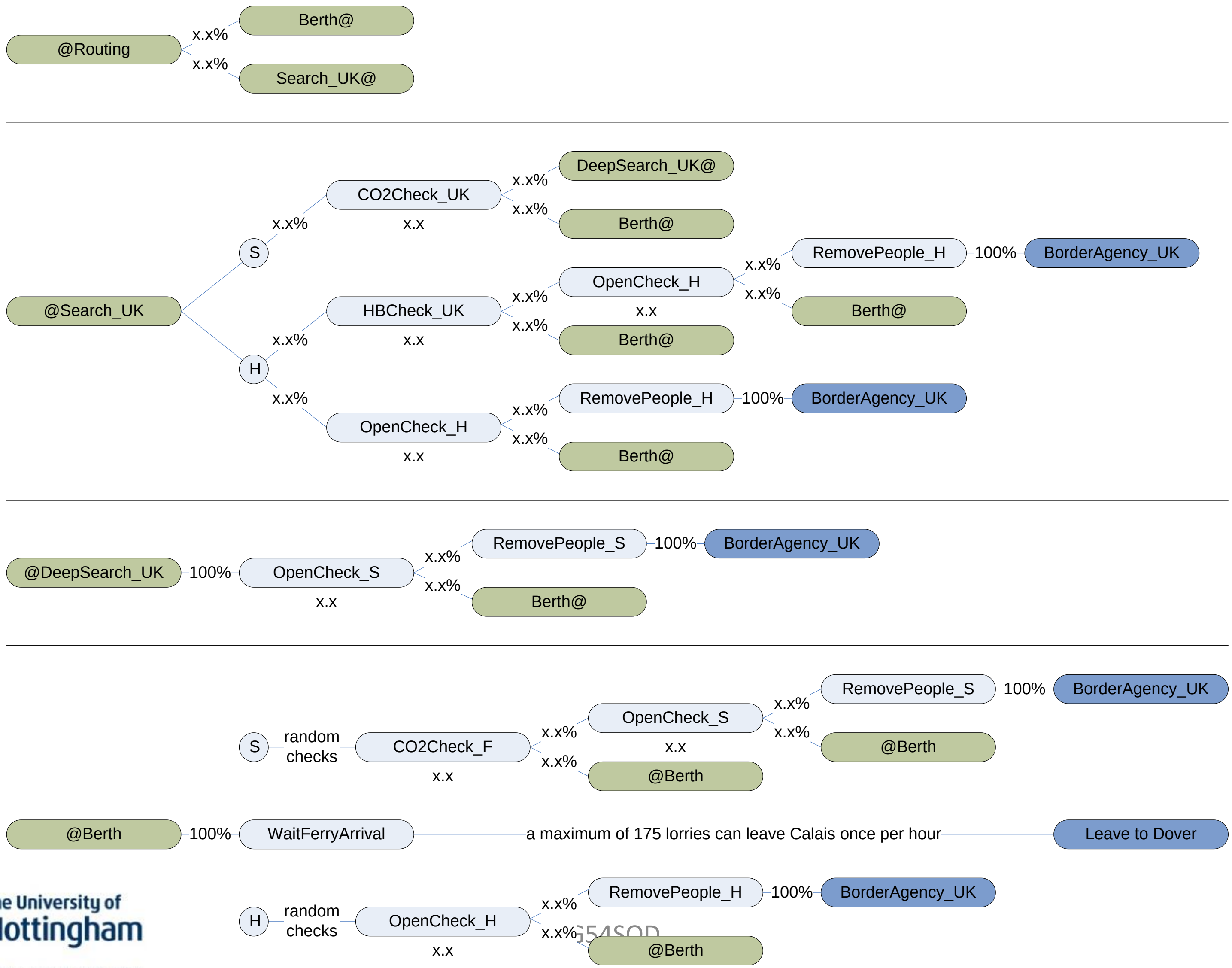
System Investigation

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

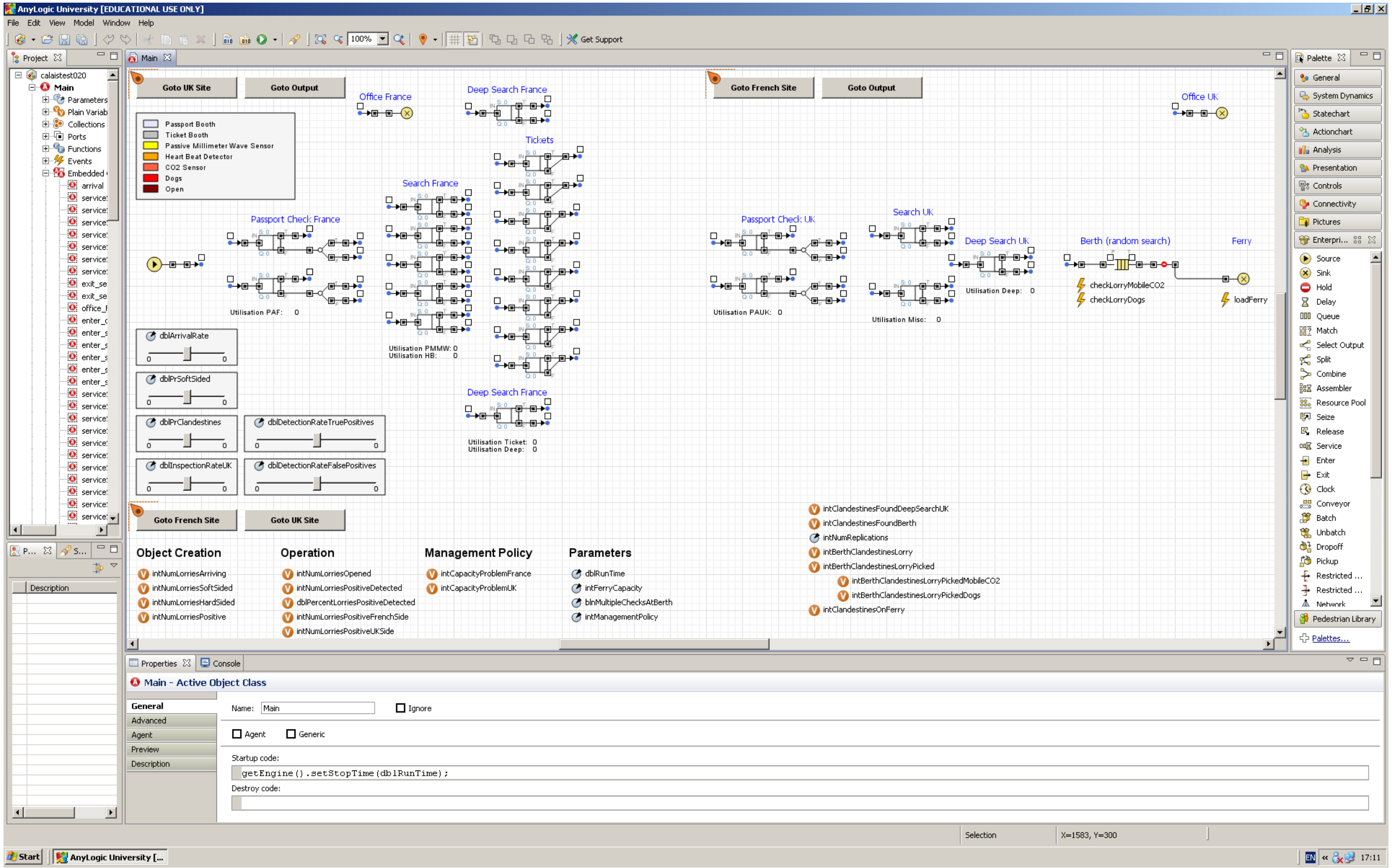
Model Representation (French Side)



Model Representation (UK Side)

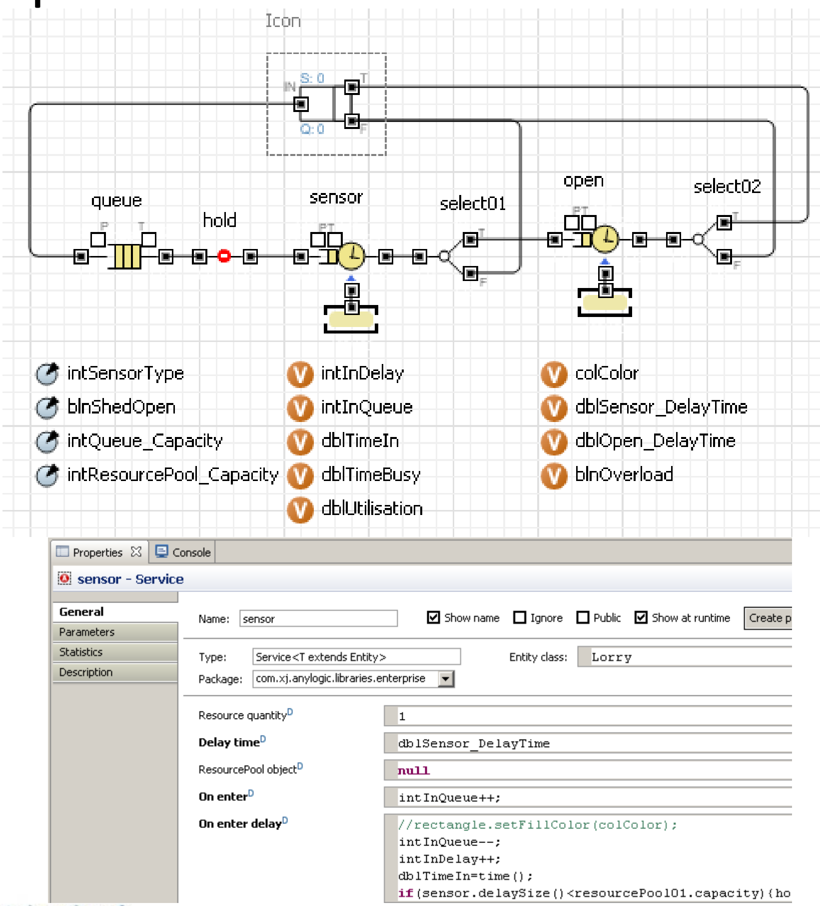


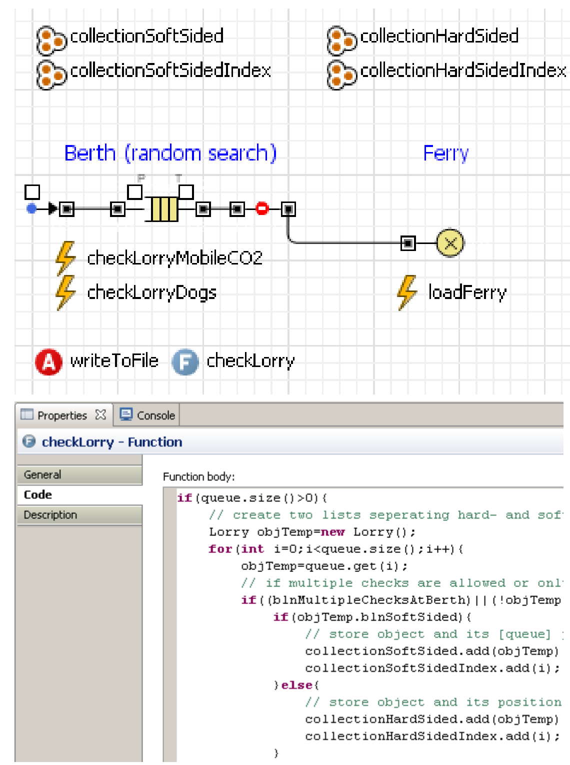
Programming



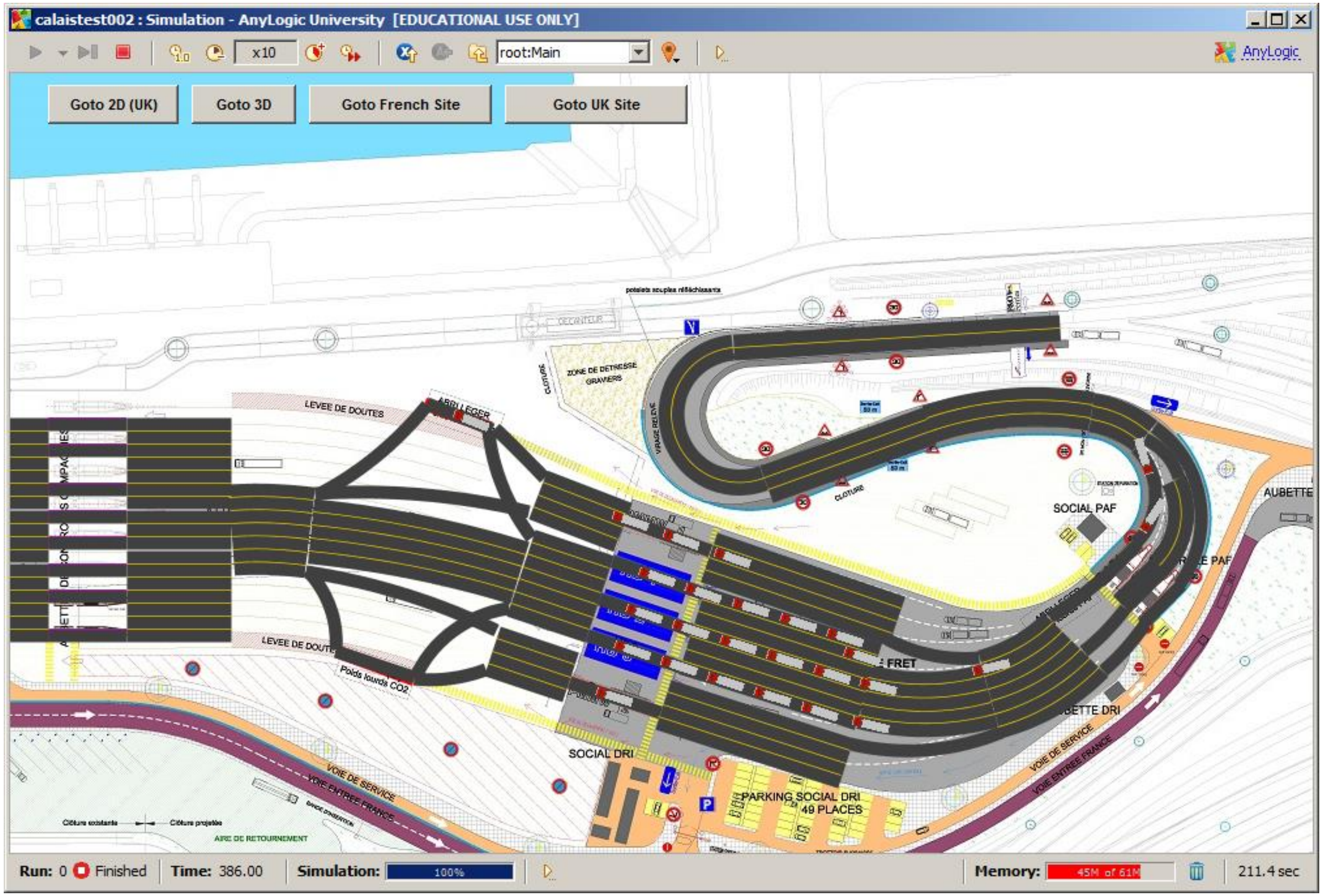
Programming

- Inspection sheds and berth activities





Presentation



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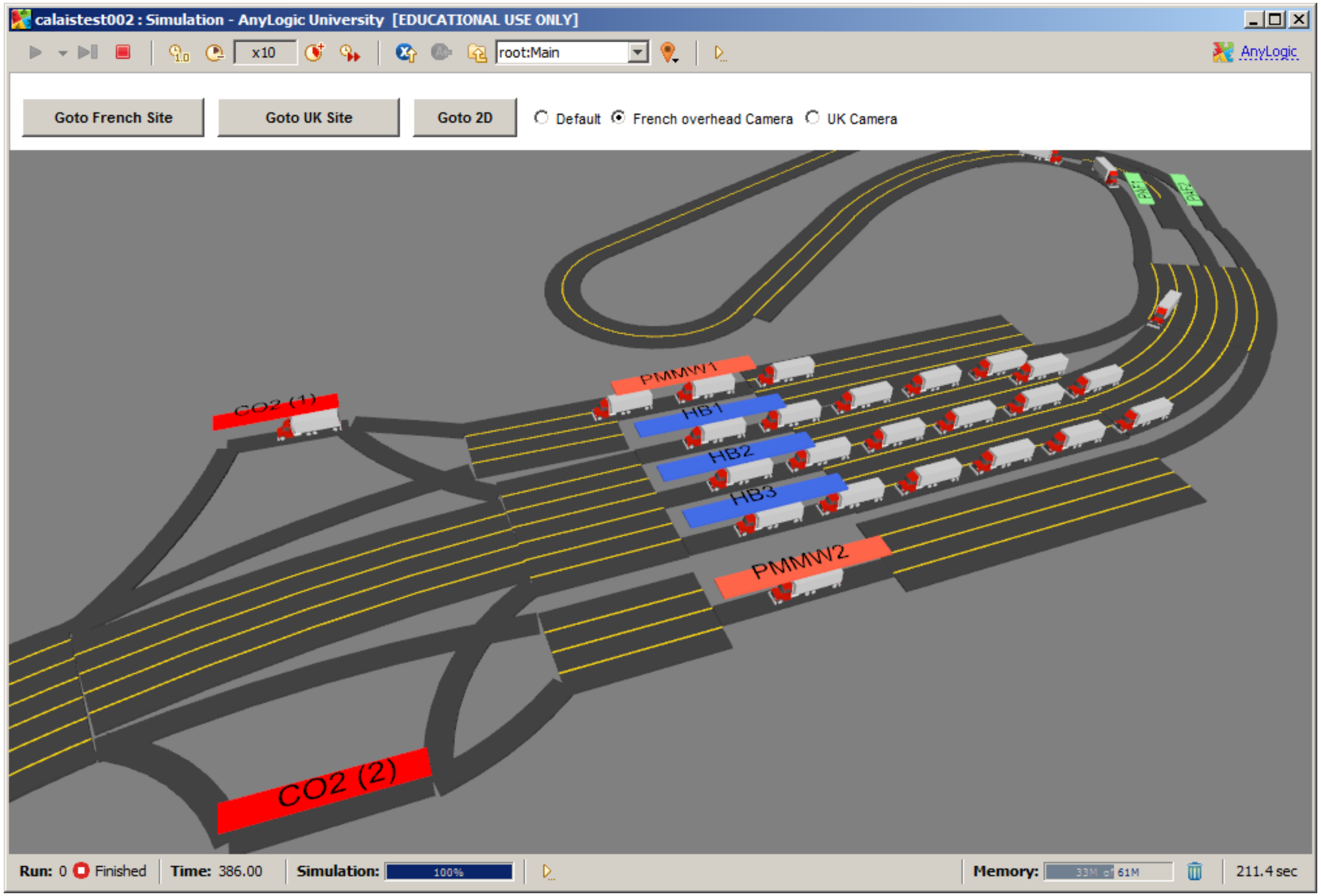
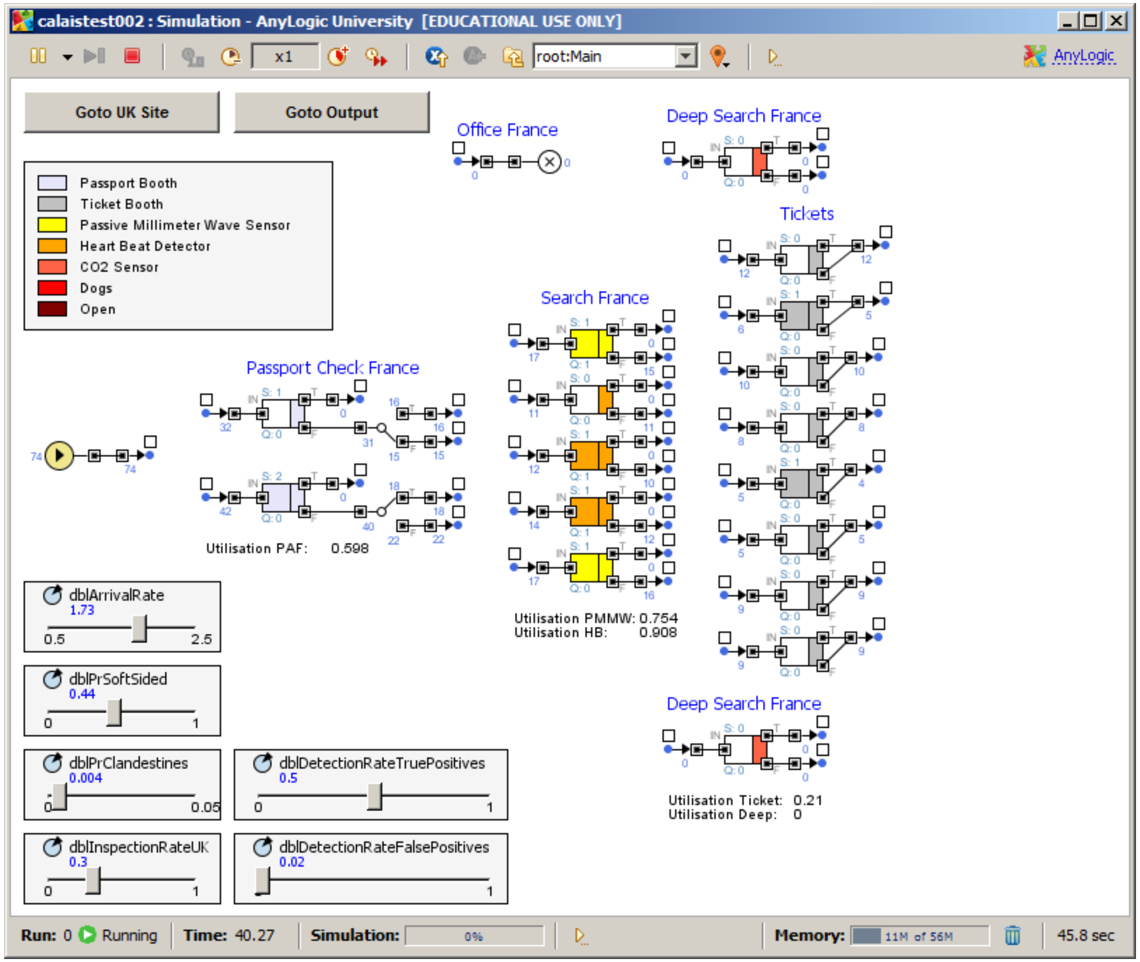
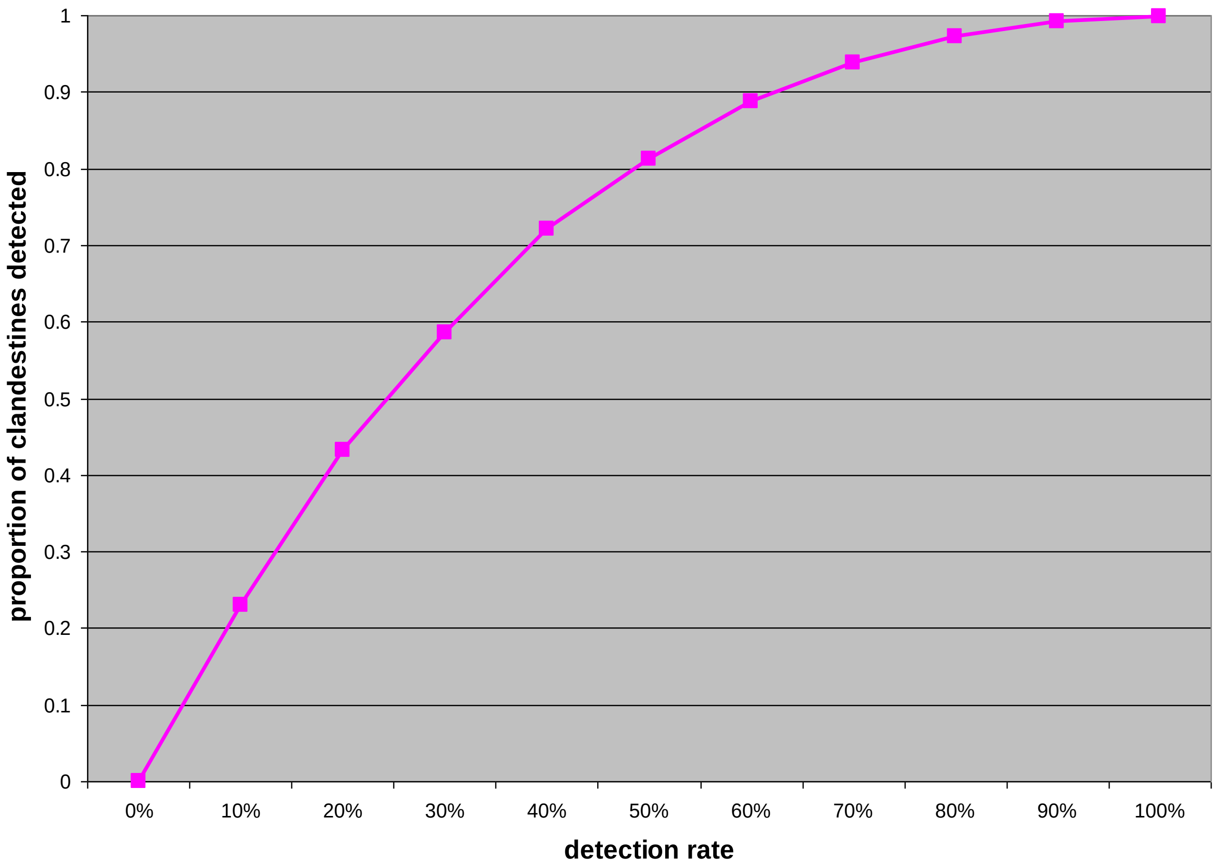


Experimentation



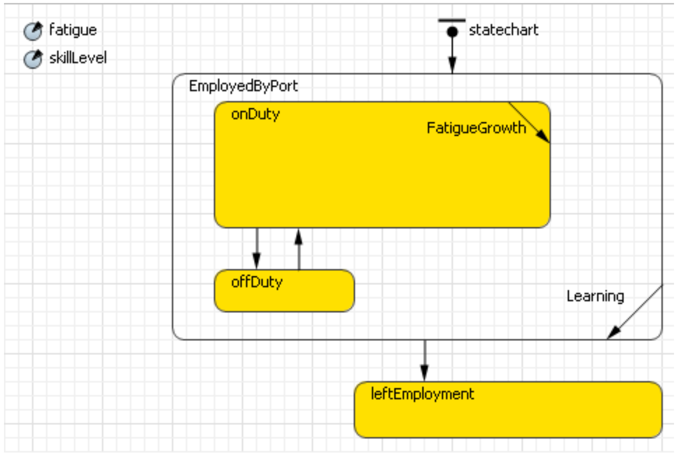
Validation Experiment

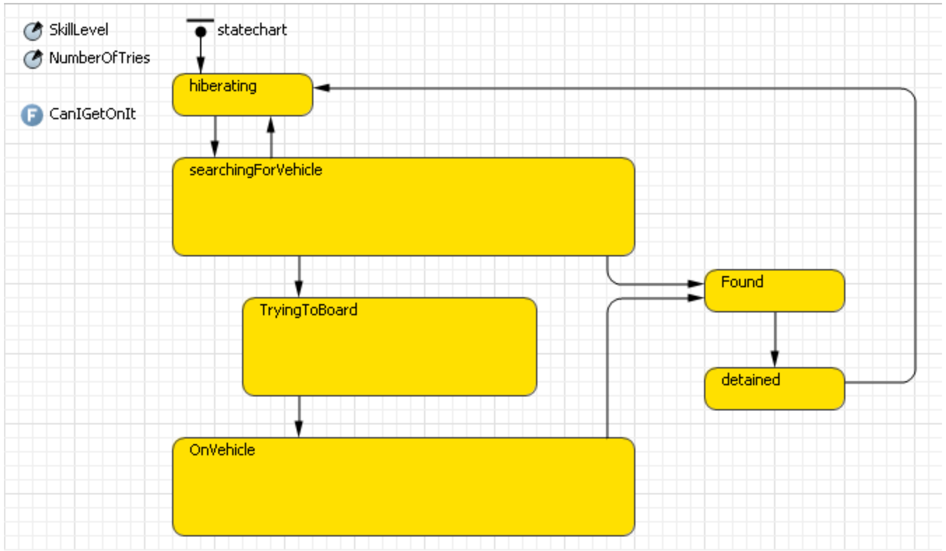
- Detection Rate vs. Clandestines Detected



Alternative Modelling Approach

- Develop a combined DES/ABS version of the model





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Comments or Questions?

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