Aachen Summer Simulation Seminar 2014

Lecture 03

Introduction to Conceptual Modelling

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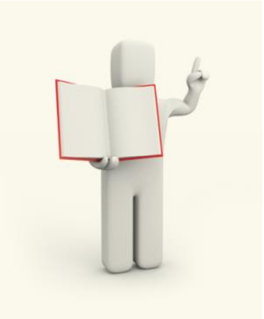
Motivation

- Define what a conceptual model is and how to communicate such a model
- Demonstrate how to develop a conceptual model

Introduction



- Importance of conceptual modelling (or model design)
  - The modeller along with the clients determines the appropriate scope and level of detail to model, a process known as conceptual modelling
  - Model design impacts all aspects of the study
  - A high proportion of the benefits of a simulation study is obtained just from the development of the conceptual model
    - For the development of the conceptual model we often seek answers to questions that have not previously been ask
    - Effective conceptual modelling may even lead to the identification of a suitable solution without the need for any further simulation work

Introduction

- What about the following argument:
  - The emergence of modern simulation software has reduced or even removed the need for conceptual modelling?
    - The modeller can move straight from developing an understanding of the real world problem to creating a computer model
    - The software allows rapid model development and prototyping but it does not reduce the level of decision making about the model design
- What about the following argument:
  - Power and memory of modern hardware and the potential of distributed software has increased the need for conceptual modelling?
    - Increase in complexity of simulation models; modellers build more complex models because software/hardware allows them to do so
    - Models are being developed that are far more complex than they need to be; careful model design is increasing in importance

What is a conceptual model?

- Definition (Robinson 2008a):
  - The conceptual model is a ***non-software specific description*** of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model.

- Conceptual modelling is more an art than a science; therefore it is difficult to define methods and procedures

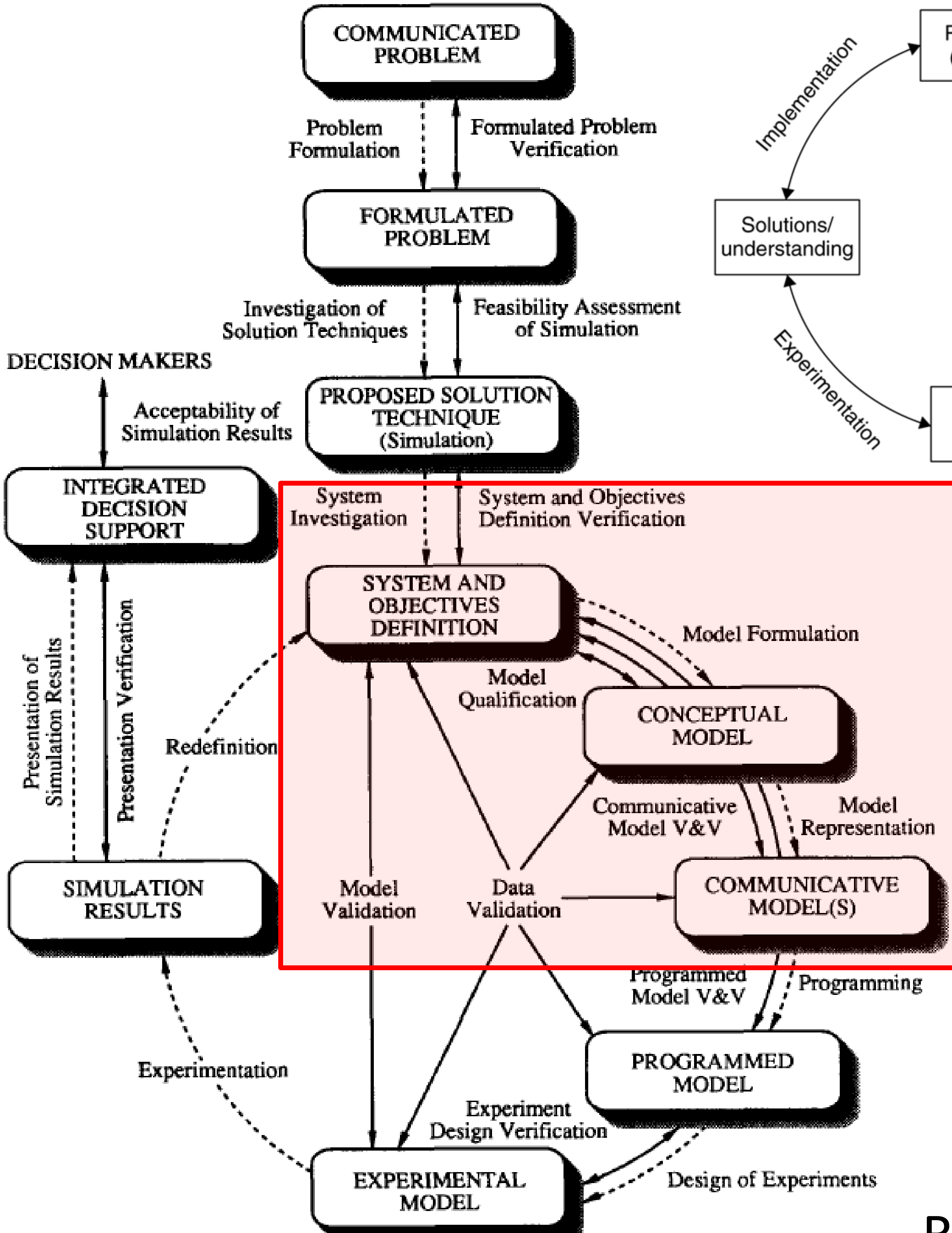
What is a conceptual model?

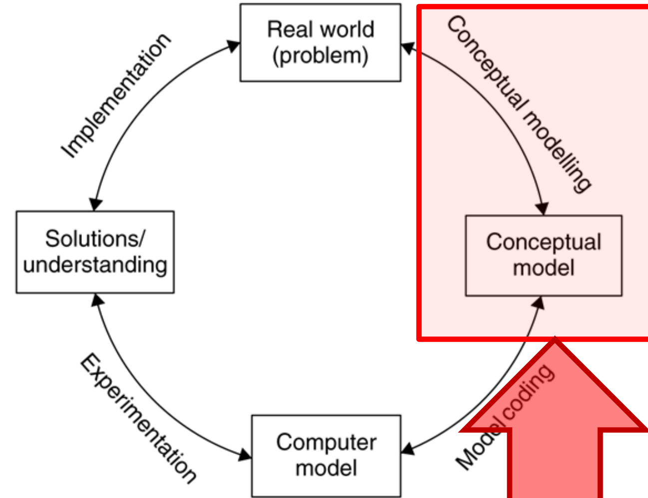
- Key components of a conceptual model:
  - *Objectives:* The purpose of the model
  - *Inputs:* Elements of the model that can be altered
  - *Outputs:* Measures to report the results from the simulation runs
  - *Content:* Components represented in the model and their interconnections
  - *Assumptions:* Uncertainties and believes about the real world to be incorporated into the model
  - *Simplifications:* Reduction of the complexity of the model

What is a conceptual model?

- Basic conceptual model for booking clerk @ theatre:
  - ***Objectives:*** Serve 95% of customers in less than 10 minutes
  - ***Inputs:*** Arrival rates, service rates, number of clerks
  - ***Outputs:*** % of customers queuing for less than 10 minutes; histogram of waiting time for each customer in the queue; clerk utilisation
  - ***Content:*** Personal enquirers; phone callers; inter arrival time distribution; service time distribution; queuing priority
  - ***Assumption:*** Unlimited queues (we do not know space availability)
  - ***Simplifications:*** Queuing discipline (no jockeying, balking, leaving)
- Remember:
  - Assumptions are a facet of limited knowledge or presumptions
  - Simplifications are a facet of the desire to create simple models

Balci (1990)





Oval symbols: Phases
Dashed arrows: Processes
Solid arrows: Credibility assessment stages

Robinson (2004)

What is a conceptual model?

- Requirements of a conceptual model:
  - *Validity*
  - *Credibility*
  - *Utility*
  - *Feasibility*

- What do these terms mean?

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What is a conceptual model?

- Requirements of a conceptual model (Robinson 2004):
  - ***Validity:*** A perception, on behalf of the modeller, that the conceptual model will lead to a simulation model that is sufficiently accurate for the purpose at hand
  - ***Credibility:*** A perception, on behalf of the clients, that the conceptual model will lead to a simulation model that is sufficiently accurate for the purpose at hand
  - ***Utility:*** A perception, on behalf of modeller and clients, that the conceptual model will lead to a simulation model that is useful as an aid to decision making within the specified context
  - ***Feasibility:*** A perception, on behalf of modeller and clients, that the conceptual model will lead to a simulation model

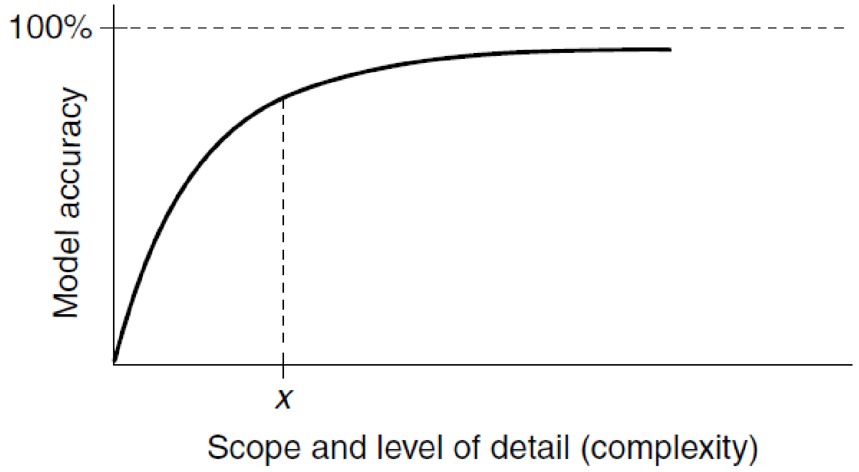
Model complexity and accuracy

- Aim: Keep the model as simple as possible to meet the objectives of the simulation study

- Advantages of simpler models:
  - They can be developed faster
  - They are more flexible
  - They require less data
  - They run faster
  - Results are easier to be interpreted

Model complexity and accuracy

- 80/20 Rule
  - 80 percent of accuracy is gained from only 20% of complexity; beyond this there is diminishing returns from increasing levels of complexity
  - Increasing the complexity (scope and level of detail) too far might even lead to a less accurate model since the data and information are not available to support the detail being modelled



Model complexity and accuracy

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  - Increasing the complexity (scope and level of detail) too far might even lead to a less accurate model since the data and information are not available to support the detail being modelled
- It is important to consider both, constructive simplicity and transparency.
  - Constructive simplicity: Attribute of the model
  - Transparency: Attribute of the client

Methods of model simplification

- Simplification entails reducing the scope and the level of detail in a conceptual model
  - Scope reduction: Removing components and interconnections that have little effect on model accuracy
  - Detail reduction: Representing more simple components and interconnections while maintaining a satisfactory level of model accuracy

- Remember:
  - Most effective approach to simplification is to start with the simplest model possible and gradually add to its scope and level of detail; once a point is reached in which the study objectives can be addressed, then no further details should be added

Methods of model simplification

- Methods (*scope or level of detail reduction?*)
  - Aggregation of model components
    - Black box modelling
    - Grouping entities
  - Excluding components and details
  - Replacing components with random variables
  - Excluding infrequent events
  - Reducing the rule set
  - Splitting models

Methods of model simplification

- Methods
  - Aggregation of model components [detail reduction]
    - Black box modelling
    - Grouping entities
  - Excluding components and details [scope reduction]
  - Replacing components with random variables [detail reduction]
  - Excluding infrequent events [scope reduction]
  - Reducing the rule set [detail reduction]
  - Splitting models [advantage: individual models run faster]

- Remember: Over-simplification can make a model less transparent and thereby reducing its credibility

Communicating the conceptual model

- Representing the conceptual model (examples):
  - System Dynamics (SD)
    - Causal loop diagrams; stock and flow diagrams
  - Discrete Event Simulation (DES)
    - Component list; process flow diagram; logic flow diagram; activity cycle diagram; combining Petri net and UML static structure diagrams (Pels and Goossenaerts 2007); class diagram to support OO DES
  - Agent Based Simulation (ABS)
    - UML + AgentUML (class, component, sequence, deployment, state chart, use cases, and activity diagrams) (Bommel and Müller 2008); coloured Petri nets (Jensen et al 2007)

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Communicating the conceptual model

- DES Example: M/M/1/n Queue
  - A single server system with ...
    - A queue capacity of n
    - An infinite calling population
    - Poisson (random) arrival process (inter-arrival times are exponentially distributed) and service times are also exponentially distributed

Communicating the conceptual model

- DES Example: M/M/1/n Queue
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    - Poisson (random) arrival process (inter-arrival times are exponentially distributed) and service times are also exponentially distributed

Component	Detail
Customers	Inter-arrival time (exponentially distributed)
Queue	Capacity
Service	Service time (exponentially distributed)

Component list

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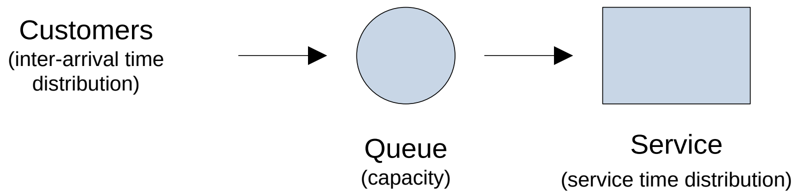
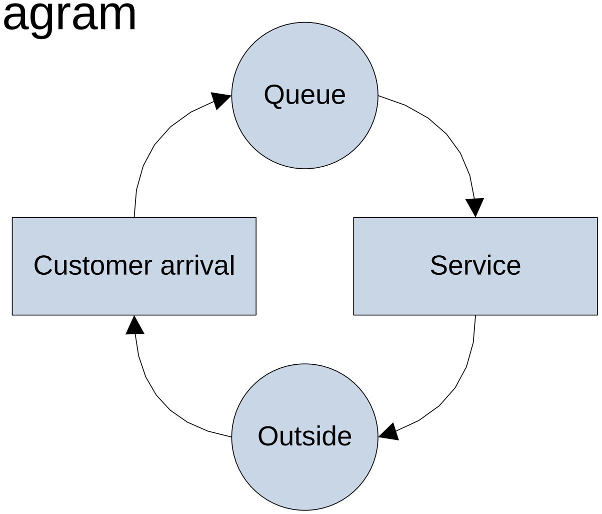
Communicating the conceptual model

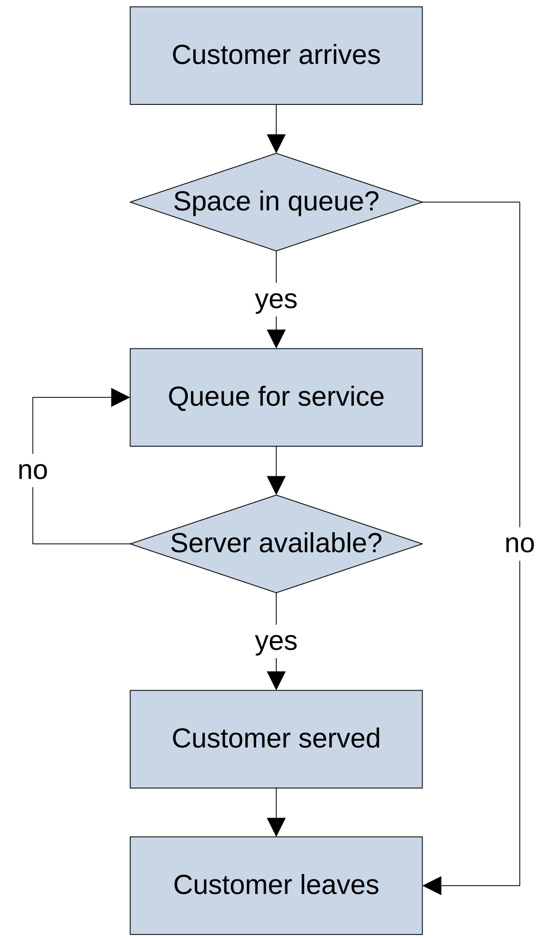
- DES Example: M/M/1/n Queue



Process flow diagram



Activity cycle diagram



Logic flow diagram

How to develop a conceptual model

- Framework for conceptual modelling
  - Four key elements
    1. Develop an understanding of the problem situation
    2. Determine the modelling objectives
    3. Design the conceptual model: Inputs and outputs
    4. Design the conceptual model: The model content
- Remember that conceptual modelling is an iterative process!

- For more examples see Robinson (2004) Appendix 1+2
  - Online version available from the library catalogue

How to develop a conceptual model

1. Develop an understanding of the problem situation
   - Clients might not have a good understanding of the cause and effect relationships within the problem situation
   - Clients have different world view
   - While learning from clients the modeller needs to play an active role
   - Modeller needs to confirm his/her understanding by providing a description of the problem situation for the client

- Problem situation and understanding of it will both be changing during the simulation study

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How to develop a conceptual model

- Case Study: Fast-Food Restaurant (Robinson, 2004):
  - A fast-food restaurant is experiencing problems with one of its branches in its network. Customers regularly complain about the length of time they have to queue at the service counters.
  - It is apparent that this is not the result of shortages in food, but a shortage of service personnel.

How to develop a conceptual model

2. Determining the modelling objectives
   - Modelling objectives determine the nature of the model
   - Modelling objectives determine level of abstraction and simplification
   - Modelling objectives are a reference point for model validation
   - Modelling objectives guide for experimentation

- The purpose of the modelling study is not the development of the model itself but to develop a tool to aid decision making

- Bad practice: Developing models that do not serve any useful purpose, e.g. models that are looking for a problem to solve

How to develop a conceptual model

2. Determining the modelling objectives (cont.)
   - Forming the objectives:
     - By the end of the study what do we hope to achieve?
       - What does the client want to achieve?
       - What level of performance is required?
       - What constraints must the client (modeller) work within?
     - Modeller should be willing to suggest additional objectives and to redefine or eliminate objectives suggested by the clients
     - It is important that the clients understands what a simulation model can and cannot do for them; managing the expectations of the client

How to develop a conceptual model

- Case Study: Fast-Food Restaurant
  - What does the client want to achieve?
  - What level of performance is required?
  - What constraints must the client (modeller) work within?
- Objective:
  - The number of service staff required during each period of the day to ensure that 95% of customers queue for less than 3 minutes for service.
- Constraint:
  - Due to space constraints, a maximum of six service staff can be employed at any one time.

How to develop a conceptual model

3. Design the conceptual model: Inputs and outputs
   – Experimental factors (inputs):
     - Often, they are the means by which it is proposed that the modelling objectives are to be achieved
     - They can be either qualitative or quantitative
     - They are often under control of the clients; however, also factors that are not under control of the client should be considered as this improves the understanding of the real system

- Remember: If possible, the range over which experimental factors are to be varied as well as the method of data entry should be defined

How to develop a conceptual model

3. Design the conceptual model: Inputs and outputs (cont.)
   – Responses (outputs):
     - Measures used to identify whether the objectives have been achieves
     - Measures used to identify reasons for failure to meet objectives (e.g. bottlenecks)

- During the course of the simulation study review the experimental factors and responses when objectives are changing!

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How to develop a conceptual model

- Case Study: Fast-Food Restaurant
  - Objective:
    - The number of service staff required during each period of the day to ensure that 95% of customers queue for less than 3 minutes for service.
  - Constraint:
    - Due to space constraints, a maximum of six service staff can be employed at any one time.
  - Experimental factors?
  - Responses?

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How to develop a conceptual model

- Case Study: Fast-Food Restaurant
  - Objective:
    - The number of service staff required during each period of the day to ensure that 95% of customers queue for less than 3 minutes for service.
  - Constraint:
    - Due to space constraints, a maximum of six service staff can be employed at any one time.
  - Experimental factors:
    - Staff roster
  - Responses:
    - % of customers queuing for less than 3 minutes
    - Histogram of waiting time for each customer in the queue
    - Time series of mean queue size by hour
    - Staff utilisation

How to develop a conceptual model

4. Design the conceptual model: The model content
   - Model must be able to accept the experimental factors and to provide the required responses
   - Scope of the model must be sufficient to provide link between the experimental factors and responses
   - Scope of the model must also include any other processes that have a significant impact on the response
   - Level of detail must be such that it represents the components defined within the scope and their interconnections with sufficient accuracy

How to develop a conceptual model

4. Design the conceptual model: The model content (cont.)
   - Use rapid prototyping throw away models to decide about scope and level of detail

- Keep a record of all assumptions that are made during the design of the model content!!!

Methods of model simplification

- Case Study: Fast-Food Restaurant

Model Scope	Detail	Decision	Justification
Customers			
Staff	Service		
	Food preparation		
	Cleaning		
Queue at service counter			
Tables			
Kitchen			

Model Level of Detail	Detail	Decision	Comments (Details)
Customers	Inter-arrival time		
	Size of order		
Service staff	Service time		
	Staff rosters		
	Absenteeism		
Queues	Queuing		
	Capacity		
	Queue behaviour	-	-
	- jockey, balk, leave		
	- join shortest queue		

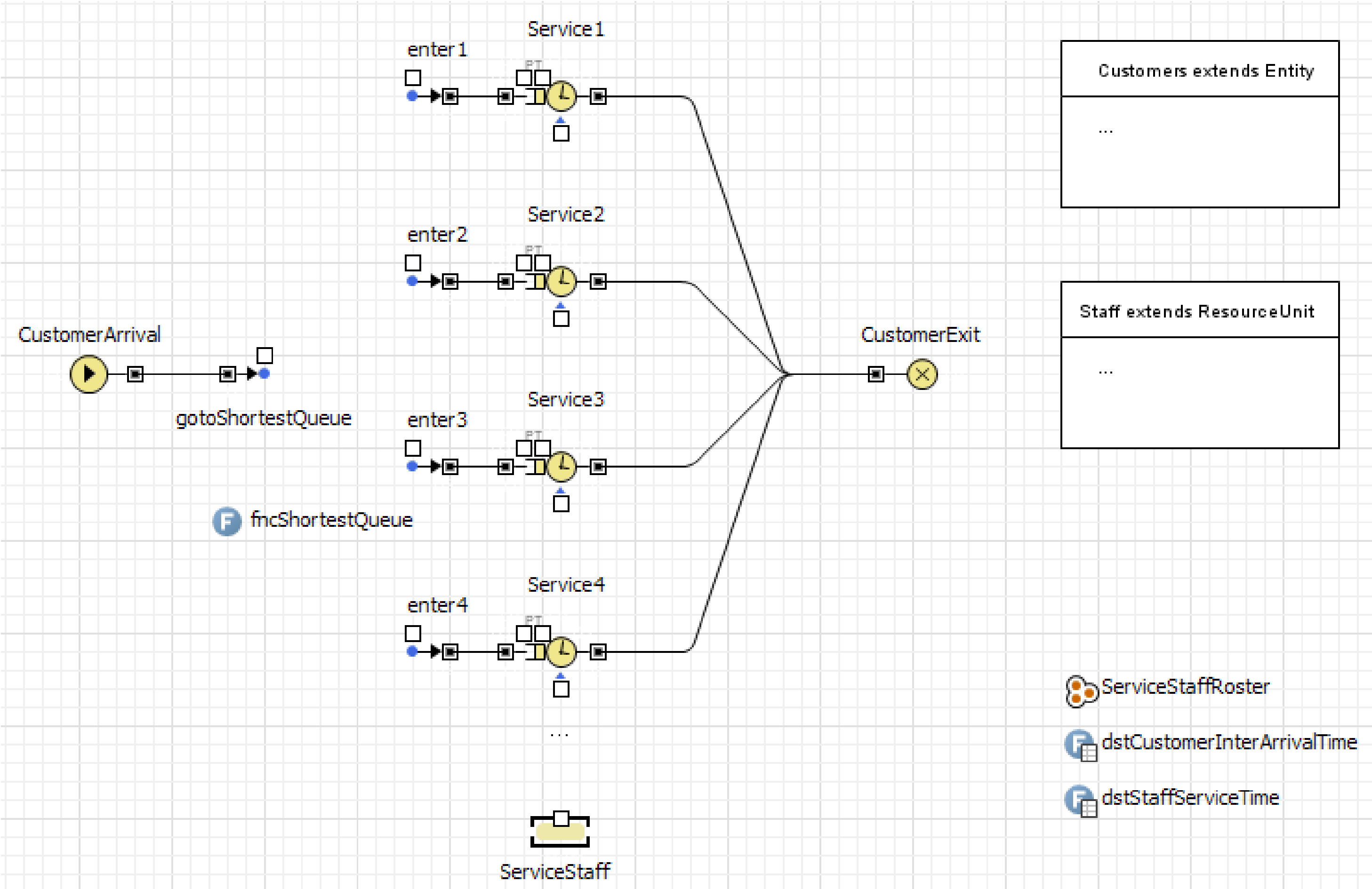
Methods of model simplification

- Case Study: Fast-Food Restaurant

Model Scope	Detail	Decision	Justification
Customers		Include	Flow through service process
Staff	Service	Include	Required for response
	Food preparation	Exclude	Material shortage not significant
	Cleaning	Exclude	Not related to speed of service
Queue at service counter		Include	Required for response
Tables		Exclude	Not related to customers waiting
Kitchen		Exclude	Material shortage not significant

Model Level of Detail	Detail	Decision	Comments (Details)
Customers	Inter-arrival time	Include	Distribution
	Size of order	Exclude	Represented in service time
Service staff	Service time	Include	Distribution
	Staff rosters	Include	Experimental factor
	Absenteeism	Exclude	Could be represented in staff rosters
Queues	Queuing	Include	Required for responses
	Capacity	Exclude	Assumption: unlimited
	Queue behaviour	-	-
	- jockey, balk, leave	Exclude	Not well understood
	- join shortest queue	Include	Well understood

Graphical Representation



The role of data in conceptual modelling

- Data for model realisation are not required for conceptual modelling, but are identified by the conceptual model
- Sometimes it is difficult or even impossible to obtain adequate data making the proposed conceptual model problematic!
- What can you do in these cases?
  - Redesign the conceptual model and leave out the troublesome data
  - Estimate the data
  - Treat data as an experimental factor rather than a fixed parameter

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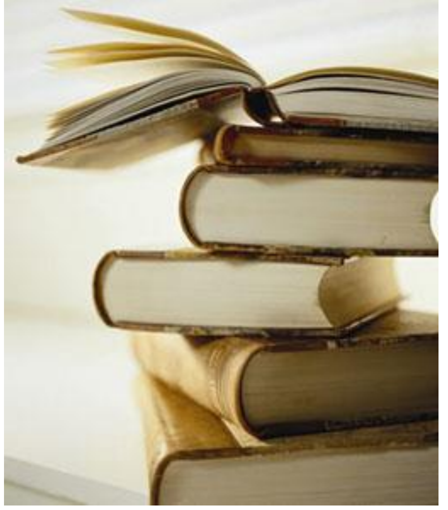
Summary

- What did you learn?

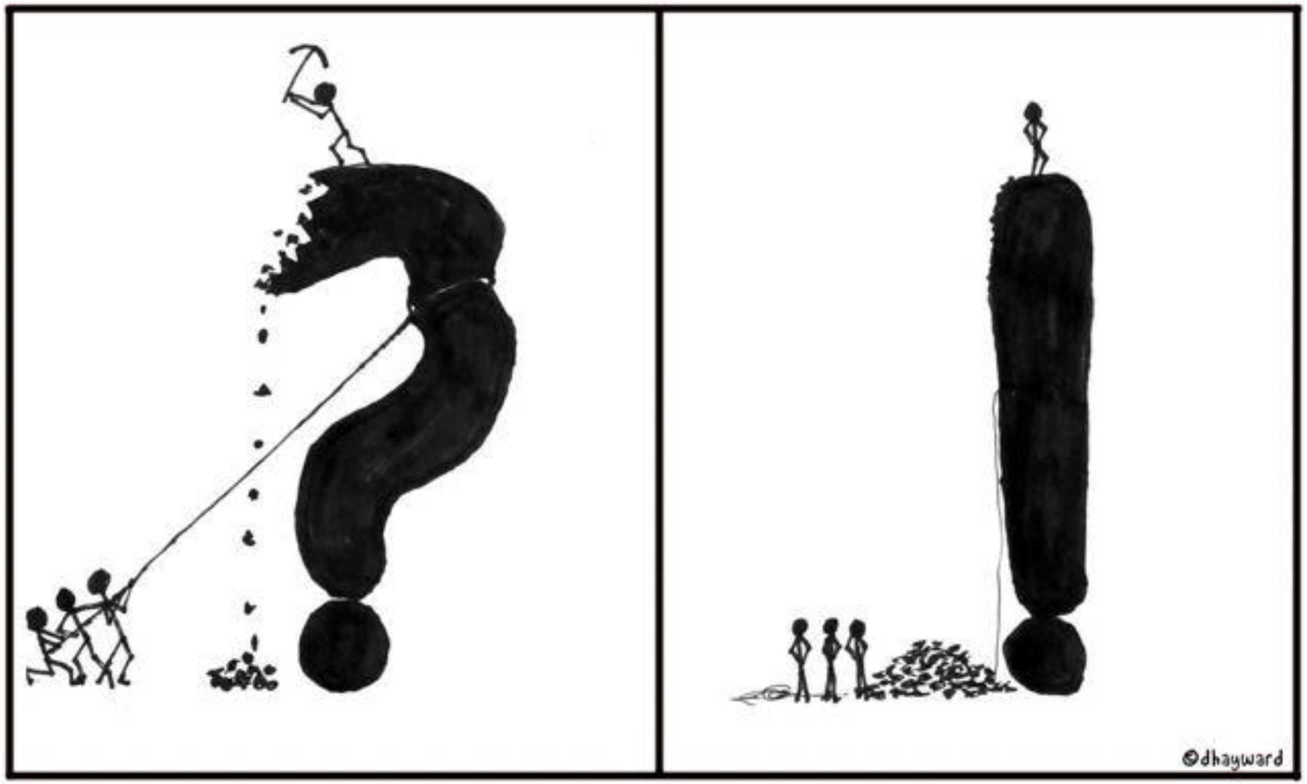
Further Reading

- Further Reading
  - Robinson (2008a; 2008b)
  - Bommel and Müller (2008)
  - Robinson et al. (2010)



- Acknowledgement
  - The content of this presentation is a summary of Robinson (2004) chapter 5 and 6

Questions / Comments



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