G54SOD (Spring 2018)

Workshop 02 (reduced to 1 hour)
Introduction to Conceptual Modelling

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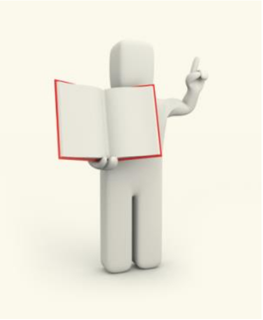

Introduction

- 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
    - 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 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?
    - 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
    - Assumptions are a facet of limited knowledge or presumptions
  - ***Simplifications:*** Reduction of the complexity of the model
    - Simplifications are a facet of the desire to create simple models

Hands-On Example [Pidd 1998]

- Booking clerk at theatre:
  - 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.
  - Constraints
    - 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

Hands-On Example [Pidd 1998]

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Hands-On Example [Pidd 1998]

- 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)

How do we develop such a conceptual model?

- Prerequisite: You need to understand the problem situation
  - Clients might not have a good understanding of the cause and effect relationships within the problem situation
  - Clients have different world views; 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 and understanding of it will both be changing during the simulation study

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How do we develop such a conceptual model?

1. Determine the modelling objectives
   - Modelling objectives are used ...
     - to determine the nature of the model
     - to determine level of abstraction and simplification
     - as a reference point for model validation
     - to guide experimentation

   - The purpose of the modelling exercise 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, i.e. models that are looking for a problem to solve

How do we develop such a conceptual model?

1. Determine 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 do we develop such a conceptual model?

2. Determine simulation 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 do we develop such a conceptual model?

2. Determine simulation 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 do we develop such a conceptual model?

3. Decide about 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 do we develop such a conceptual model?

3. Decide about the model content (cont.)
   – Use rapid prototyping throw away models to decide about scope and level of detail

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

How do we develop such a conceptual model?

4. Capture information/decisions about model content
   - S+LOD table to capture information in a structured way
   - Rapid prototype drawing to support understanding of S+LOD table

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		

What do people expect from a conceptual model?

- Requirements of a conceptual model (Robinson 2004):
  - *Validity*
  - *Credibility*
  - *Utility*
  - *Feasibility*

- What do these terms mean?

What do people expect from a conceptual model?

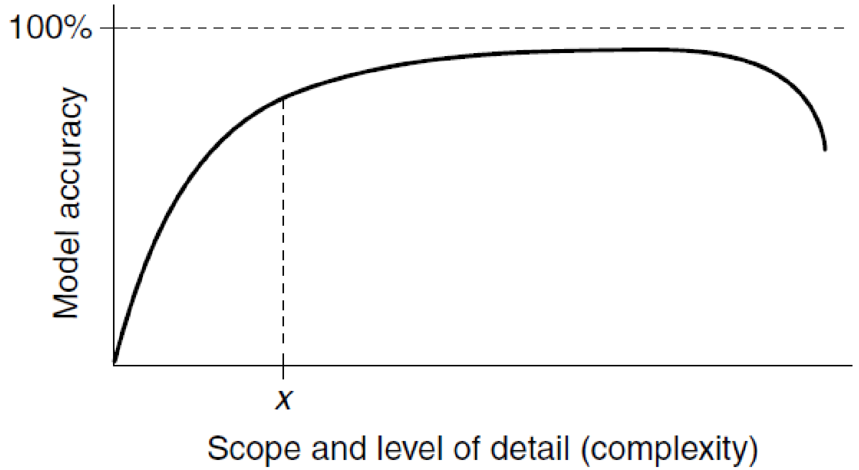
- Requirements of a conceptual model (Robinson 2004):
  - ***Validity:*** A perception, on behalf of the modeller, that the conceptual model will lead to a simulation model that is sufficiently accurate for the purpose at hand
  - ***Credibility:*** A perception, on behalf of the clients, that the conceptual 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



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

The 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 no further details should be added

Methods of model simplification

- Methods: (*scope or level of detail reduction?*)
  - 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 [workload sharing (individual models run faster)]

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

Communicating the conceptual model

- Representing the conceptual model graphically (examples):
  - System Dynamics (SD)
    - Causal loop diagram; stock and flow diagram
  - Discrete Event Simulation (DES)
    - Component list; process flow diagram; logic flow diagram; activity cycle diagram (deprecated); class diagram (to support OO DES)
  - Agent Based Simulation (ABS)
    - Use case diagram; class diagram; sequence diagram; state machine diagram; activity diagram

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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

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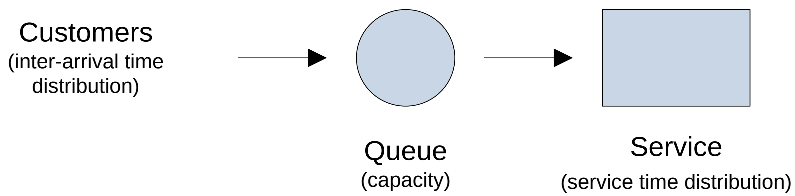
Component	Detail
Customers	Inter-arrival time (exponentially distributed)
Queue	Capacity
Service	Service time (exponentially distributed)

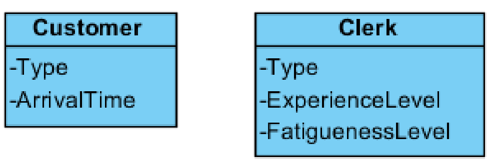
Component list

Communicating the conceptual model

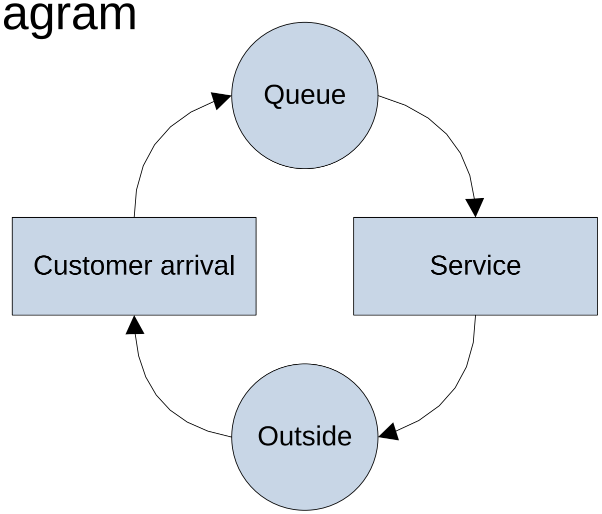
- DES Example: M/M/1/n Queue



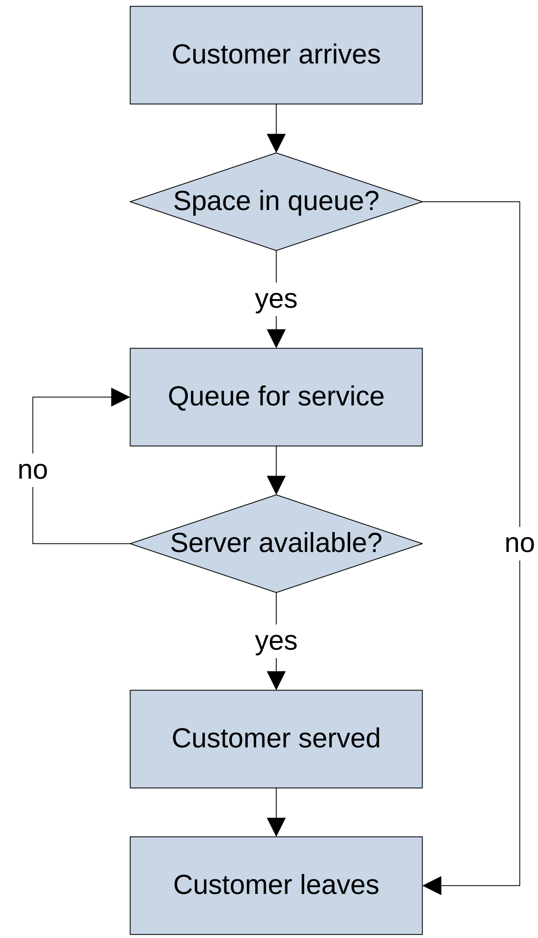
Process flow diagram



Classes



Activity cycle diagram



Logic flow diagram

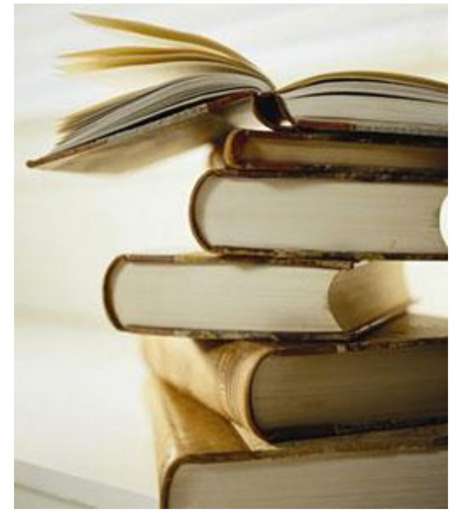
The role of data in conceptual modelling

- 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

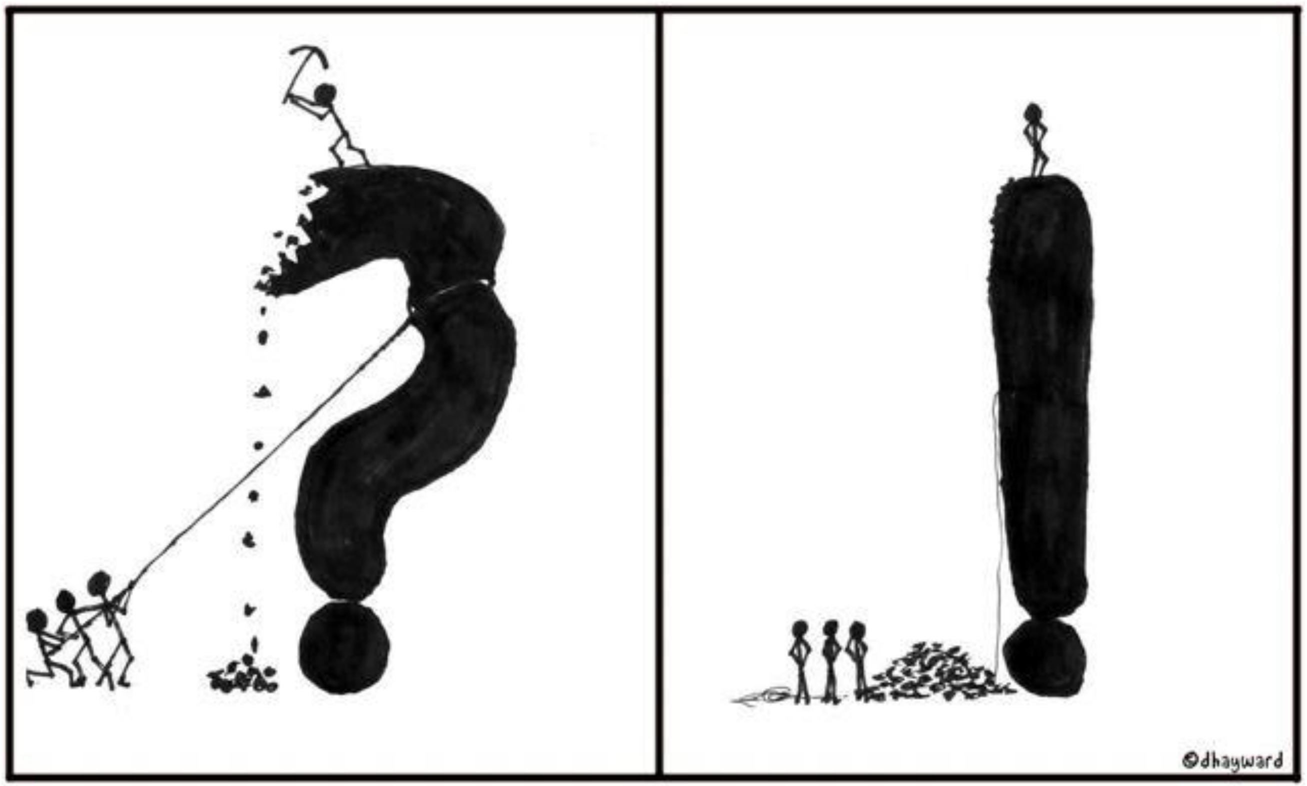
Further Reading

- 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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