Module 1: MODELLING AND SIMULATION CONCEPTS

Module Introduction

This module is divided into six (6) units

Unit 1: Basics of Modelling and Simulation

Contents

1.0 Introduction

The ability of man to define what may happen in the future and to choose among alternatives lie at the heart of contemporary societies. Our knowledge of the way things work, in society or nature are trailed with clouds of imprecision, and vast harms have followed a belief in certainty. To reduce the level of disparity between outcome and reality,

we require a decision analysis and support tool to enable us to evaluate, compare and optimize alternative. Such a tool should be able to provide explanations to various stakeholders and defend the decisions. One such tool that has been successfully employed is simulation which we use to vary the parameter of a model and observe the outcome.
Simulation has been particularly valuable:

a. When there is significant uncertainty regarding the outcome or consequences of a particular alternative under consideration. It allows you to deal with uncertainty and imprecision in a quantifiable way.
b. When the system under consideration involves complex interactions and requires input from multiple disciplines. In this case, it is difficult for any one person to easily understand the system. A simulation of the model can in such situations act as the framework to integrate the various components in order to better understand their interactions. As such, it becomes a management tool that keeps you focused on the "big picture" without getting lost in unimportant details.
c. when the consequences of a proposed action, plan or design cannot be directly and immediately observed (i.e., the consequences are delayed in time and/or dispersed in space) and/or it is simply impractical or prohibitively expensive to test the alternatives directly.

2.0 Intended Learning Outcomes (ILOs)

After studying this unit, you should be able to:

- Define a model and modelling.
- Explain when to and why we use models
- Describe the modelling process
- Describe different types of Models.

3.0 Main Content

Modelling and Simulation Concepts

Modern science would be inconceivable without computers to gather data and run model simulations. Whether it involves bringing back pictures of the surface of the planet Mars or detailed images to guide brain surgeons, computers have greatly extended our knowledge of the world around us and our ability to turn ideas into engineering reality. Thus modelling and computer simulation are important interdisciplinary tools.

3.1 Definitions

a. **Modelling** is the process of generating abstract, conceptual, graphical and/or mathematical models. Science offers a growing collection of methods, techniques and theory about all kinds of specialized scientific modelling.
   Modelling also means to find relations between systems and models. Stated otherwise, models are abstractions of real or imaginary worlds we create to

understand their behaviour, play with them by performing "what if" experiments, make projections, animate or simply have fun.

b. A **model** in general is a pattern, plan, representation (especially in miniature), or description designed to show the main object or workings of an object, system, or concept.
c. A **model** (physical or hypothetical) is a representation of real-world phenomenon or elements (objects, concepts or events). Stated otherwise a model is an attempt to express a *possible structure of physical causality*.
   Models in science are often theoretical constructs that represent any particular thing with a set of variables and a set of logical and or quantitative relationships between them. Models in this sense are constructed to enable reasoning within an idealized logical framework about these processes and are an important component of scientific theories.
d. **Simulation -**is the manipulation of a model in such a way that it operates on time or space to compress it, thus enabling one to perceive the interactions that would not otherwise be apparent because of their separation in time or space.
e. Modelling and Simulation is a discipline for developing a level of understanding of the interaction of the parts of a system, and of the system as a whole. The level of understanding which may be developed via this discipline is seldom achievable via any other discipline.
f. A **computer model** is a simulation or model of a situation in the real world or an imaginary world which has parameters that the user can alter.

For example Newton considers movement (of planets and of masses) and writes equations, among which $f = ma$ (where f is force, m mass and a acceleration), that make the dynamics intelligible. Newton by this expression makes a formidable proposition, that force causes acceleration, with mass as proportionality coefficient. Another example, a model airplane is a physical representation of the real airplane; model of airplanes are useful in predicting the behaviour of the real airplane when subjected to different conditions; weather, speed, load, etc. Models help us frame our thinking about objects in the real world. It should be noted that more often than not we model dynamic (changing) systems.

3.2 What is Modelling and Simulation?

Modelling is a discipline for developing a level of understanding of the interaction of the parts of a system, and of the system as a whole. The level of understanding which may be developed via this discipline is seldom achievable via any other discipline.

A simulation is a technique (not a method) for representing a dynamic real world system by a model and experimenting with the model in order to gain information about the system and therefore take appropriate decision. Simulation can be done by hand or by a computer. Simulations are generally iterative in their development. One develops a model, simulates it, learns from the result, revises the model, and continues the iterations until an adequate level of understanding is attained.

Modelling and Simulation is a discipline, it is also very much an art form. One can learn about riding a bicycle from reading a book. To really learn to ride a bicycle one must become actively engaged with a bicycle. Modelling and Simulation follows much the same reality. You can learn much about modelling and simulation from reading books and talking with other people. Skill and talent in developing models and performing simulations is only developed through the building of models and simulating them. It is very much –learn as you go‖ process. From the interaction of the developer and the models emerges an understanding of what makes sense and what doesn't.

3.3 Type of Models

There are many types of models and different ways of classifying/grouping them. For simplicity, Models may be grouped into the following – Physical, Mathematical, Analogue, Simulation, Heuristic, Stochastic and Deterministic models.

a. <u>Physical Models</u>

These are call iconic models. Good examples of physical models are model cars, model railway, model airplane, scale models, etc. A model railway can be used to study the behaviour of a real railway, also scale models can be used to study a plant layout design. In simulation studies, iconic models are rarely used.

b. <u>Mathematical Models</u>

These are models used for predictive (projecting) purposes. They are abstract and take the form of mathematical expressions of relationships. For examples:

1. $x^2 + y^2 = 1$ (mathematical model of a circle of radius 1)

2. $$\text{Interest} = \frac{\text{Principal x Rate x Time}}{100}$$

3. Linear programming models and so on.

Mathematical models can be as simple as interest earnings on a savings account or as complex as the operation of an entire factory or landing astronauts on the moon. The development of mathematical models requires great deal of skill and knowledge.

c. <u>Analogue Models</u>

These are similar to iconic models. But here some other entities are used to represent directly the entities of the real world. An example is the analogue computer where the magnitudes of the electrical currents flowing in a circuit can be used to represent quantities of materials or people moving around in a system. Other examples are; the gauge used to check the pressure in a tyre. The movement of the dial represent the air pressure in the tyre. In medical examination, the marks of electrical current on paper, is the analogue representation of the working of muscles or organs.

d. <u>Simulation Models</u>

Here, instead of entities being represented physically, they are represented by sequences of random numbers subject to the assumptions of the model. These models represent (emulate) the behaviour of a real system. They are used where there are no suitable mathematical models or where the mathematical model is too complex or where it is not possible to experiment upon a working system without causing serious disruption.

e. Heuristic Models

These models use intuitive (or futuristic) rules with the hope that it will produce workable solutions, which can be improved upon. For example, the Arthur C Clerk‘s heuristic model was the forerunner of the communications satellite and today‘s international television broadcast.

f. Deterministic Models

These are models that contain certain known and fixed constants throughout their formulation e.g., Economic Order Quantity (EOQ) for inventory control under uncertainty.

g. Stochastic models

These are models that involve one or more uncertain variables and as such are subject to probabilities.

3.4 Advantages of Using Models

- They are safer.
- They are less expensive. For example, Practical Simulators are used to train pilots.
- They are easier to control than the real world counterparts.

3.5 Applications

One application of scientific modelling is the field of "Modelling and Simulation", generally referred to as "M&S". M&S has a spectrum of applications which range from concept development and analysis, through experimentation, measurement and verification, to disposal analysis. Projects and programs may use hundreds of different simulations, simulators and model analysis tools

3.6 Modelling Procedure

In modelling we construct a suitable representation of an identified real world problem, obtain solution(s) for that representation and interpret each solution in terms of the real situation. The steps involved in modelling are as follows:

1. Examine the real world situation.
2. Extract the essential features from the real world situation.
3. Construct a model of the real (object or system) using just the essential features identified.
4. Solve and experiment with the model.
5. Draw conclusions about the model.
6. If a further refinement necessary, then re-examine the model and readjust parameters

and continue at 4, otherwise continue at 7.

7. Proceed with implementation.

Explanation of the Steps

Begin with the real world situation, which is to be investigated with a view to solving some problem or improving that situation.

The first important step is to extract from the real world situation the essential features to be included in the model. Include only factors that make the model a meaningful representation of reality, while not creating a model, which is difficult by including many variables that do not have much effect. Factors to be considered include ones over which management has control and external factors beyond management control. For the factors included, assumptions have to be made about their behaviour.

Run (simulate) the model and measure what happens. For example, if we have simulation of a queuing situation where two servers are employed, we can run this for hundreds of customers passing through the system and obtain results such as the average length of the queue and the average waiting time per customer. We can then run it with three servers, say, and see what new values are obtained for these parameters. Many such runs can be carried out making different changes to the structure and assumptions of the model.

In the case of a mathematical model we have to solve a set of equations of some sort, e.g. linear programming problem where we have to solve a set of constraints as simultaneous equations, or in stock control – where we have to use previously accumulated data to predict the future value of a particular variable.

When we have solved our mathematical model or evaluated some simulation runs, we can now draw some conclusions about the model. For example, if we have the average queue length and the average waiting time for a queuing situation varied in some ways, we can use this in conjunction with information on such matters as the wage-rates for servers and value of time lost in the queue to arrive at decisions on the best way to service the queue.

Finally, we use our conclusions about the model to draw some conclusions about the original real world situation. The validity of the conclusions will depend on how well our model actually represented the real world situation.

Usually the first attempt at modelling the situation will almost certainly lead to results at variance with reality. We have to look back at the assumptions in the model and adjust them. The model must be rebuilt and new results obtained. Usually, a large number of iterations of this form will be required before acceptable model is obtained. When an acceptable model has been obtained, it is necessary to test the sensitivity of that model to possible changes in condition.

The modelling process can then be considered for implementation when it is decided that the model is presenting the real world (object or system) sufficiently well for conclusions drawn from it to be a useful guide to action.

The model can be solved by hand, especially if it is simple. It could take time to arrive at an acceptable model. For complex models or models which involve tremendous amount of data, the computer is very useful.

4.0 Self-Assessment Exercise(s)

Answer the following questions:

1. Differentiate between Model, Modelling, Simulation and Computer model.
2. What are the steps followed in modelling?
3. State why we use models

5.0 Conclusion

In this unit we took a look at an overview of major concepts that underlie models to prepare us for the work in this course simulation and modelling.

6.0 Summary

In introducing this unit, it was stated that simulation is a decision support tool which enable us to evaluate, compare and optimize alternative ways of solving a problem and the following were discussed:

- Modelling was defined
- The concepts of modelling were outlined
- Why we use models
- The application of models especially for simulations
- The types of modelswhich include: Physical, Mathematical, Analogue, Simulation, Heuristic, Stochastic and Deterministic models were highlighted.

7.0 Further Readings

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