SIMULATION PRINCIPLES AND STRATEGIC APPLICATIONS IN BUSINESS MANAGEMENT: A STRATEGIC DISCOURSE

JOHN E. CHIKWE PhD.
Department of Management
Faculty of Management Sciences
University of Port Harcourt
Port Harcourt.

ABSTRACT

Simulation as a term or concept may have different meanings depending on the usage and applicability. Generally it may refer to the usage of computer to perform certain experiments on a model of a real system. This study investigates into simulation methodology and its major phases and as a tool for evaluating ideas. Included in the study are investigation of scope of simulation applications, simulation programs and languages, desirable features of simulation software, Monte Carlo simulation as well as advantages and disadvantages of simulation. The study noted that a simulation model seeks to duplicate the behavior of the system under investigation by studying the interactions among its components. The output of a simulation model is normally presented in terms of selected measures that reflect the performance of the system. The study therefore recommends that simulation principles and models should be used where applicable in business policy and strategy model building and with care.

Key works: Simulation; Principles, Strategic applications; Business management; Computer simulation.

Introduction

In contemporary business world, the concept of simulation and its principles have become a standard tool, in organizational business operations. It is important to note that definitional problems abound in simulation concepts as is applicable in some other management concepts. Simulation as a term may have different meanings depending on the usage and application in business world. It refers to the use of a numerical model, which represents relationships in a business system, in order to predict what will happen in the future (Urieto, Umoh and Chikwe, 2011). It generally refers to using computer to perform experiments on a model of a real system. Simulation can be used in manufacturing. Simulation is a common tool for manufacturing planning problems modeling such as complex material flow problems in the factory. It can also be used to determine production schedules, inventory levels, as well as the maintenance of procedures. Simulation principle can be used to plan capacity, resource requirements and processes.

In reality, in services operations, simulation is noted to be widely used to analyze waiting lines and scheduling operations. Simulation application in business offers a ready tool for applicability in business when a mathematical technique fails. This simply implies that when a problem is too complex to model mathematically, simulation is a popular alternative. Under such situation and by returning the program under different starting conditions and/or different scenarios one can, by a kind of trial- and – error process, discover the best strategy for managing the system. Concisely, simulation is a model or a re-creation of a real situation that allows the user to examine different scenarios in laboratory environment. Examples of simulation principles and applications abound. As noted by Nahmias (1997), wind tunnels simulate conditions under which planes fly, allowing an airplane designer to test different wing configurations without crashing planes. Flight simulators are valuable teaching tools. In this context, "fatal" errors in a simulator could save related real world situation and people will live and may not talk about it.

Other examples of types of simulation include video games and virtual reality animation (Chase, Aquilano and Jacobs, (2001). Simulation experiments may be undertaken before a real system is operational, to aid in its design, to see how the system might reach to changes in its operating rules, or to evaluate the systems response to changes in its structure. In situations in which the size or complexity of problems makes the use of optimizing techniques difficult or impossible, it is of note that simulation application is particularly very appropriate. In view of this, Chase, Aquilano and Jacobs (1997), reveal that, job shops, which are characterized by complex queuing problems, have been studied extensively via simulation, as have certain types of inventory, layout, and maintenance problems (to name but a few). Relatedly, simulation is useful in training managers and workers in how the real system operates, in demonstrating the effects of changes in system variables, in real-time control, and in developing new ideas about how to run the business. In a related development, simulation can also be used in conjunction with traditional statistical and management science techniques.

Production planning applications utilize computer-based simulators. It is important at this point to note that, a computer simulator is a computer program that accurately reflects a real – world situation. As applicable in mathematical model, variables are defined to represent real quantities and expressions developed to describe the relations among these variables. However, both deterministic and stochastic problems are amenable to simulation. It is noted that the method has been applied more in problems with some elements of randomness. Simulators are particularly noted to be valuable for modeling uncertainty. In contemporary business world, computer scientists have expended substantial efforts in developing so called random generators (Nahmias, 1997). In essence, these are mathematical recursions that create strings of numbers that appear to be completely random (i.e. drawn from a uniform distribution). Random numbers can be transformed into observations on random variables having almost any desired distribution using relationships from probability theory. Simulations that include some elements of uncertainty are referred to as Monte Carlo simulations.

Scope of Simulation Applications

As expressed by Taha (1982), simulation has been used to analyze problems of two distinct types:

- Theoretical problems in basic science areas such as mathematics, physics, and chemistry.
  - Estimation of the area enclosed by a curve, including the evaluation of multiple integrals
  - Matrix inversion
  - Estimation of the constant π (=3.14159) in mathematics
  - Solution of partial differential equations
  - Study of movement of particles in plane
  - Study of particle diffusion
  - Solution of simultaneous linear equations.
- Practical problems in all aspects of real life
  - Simulation of industrial problems (e.g design of chemical processes, inventory control, design of distribution systems, maintenance scheduling, design of queuing systems, job-shop scheduling, deign of communication systems).
  - Simulation of business and economic problems (e.g operation of total firm, consumer behavior, evaluation of proposed capital expenditures, price determination, market processes, study of national economies under problems of recession and inflation, development plans and balance-of –payments policies in underdeveloped economics, economic forecasting).
  - Behavioural and social problems (e.g. population dynamics, individual and group behaviour).

- Simulation of biomedical systems (field balance and electrolyte distribution in the human body, modeling of the brain, blood cell proliferation).
- Simulation of ware strategies and tactics.

Simulation Methodology

Notably, simulation is a tool for evaluation ideas. Methodologically, the process of developing a systems simulation is a substantial and onerous undertaking that has been made clear with the availability of modeling software such as Service Model (Fitzsimmons and Fitzsimmons, 2001). The experimental nature of systems simulation is as shown in the systems simulation process figure below .

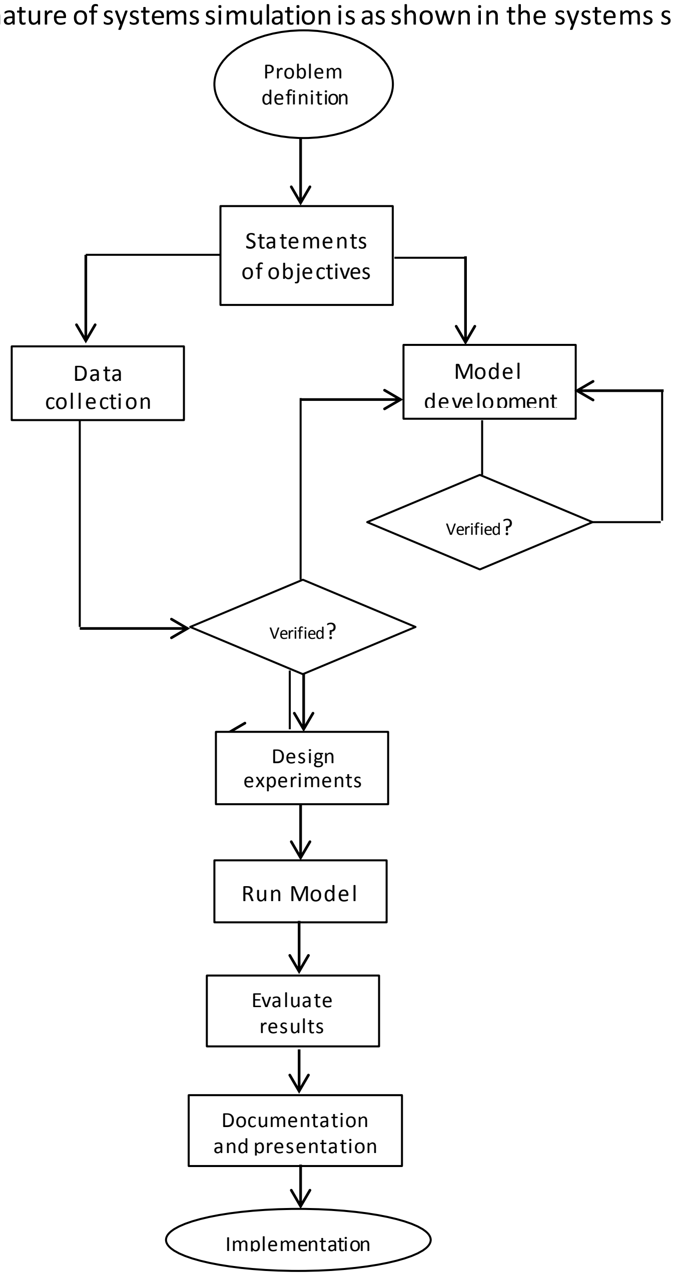

Fig. 1: The Process of System Simulation

Source: Adapted from Fitzsimmons and Fitzsimmons (2001); Service Management. McGraw-Hill, Higher Education, New York.

As could be seen in Fig.1 above, the development of an accurate and concise problem definition is of necessity very important. This is so because this activity involves the client in the process and facilitates implementation of results. Immediately after that follows the statement of objectives which naturally aids in providing a framework for the scope of the model and system performance measures. For instance, a problem might involve improving customer service in a bank with the objective of reducing waiting times. The collection of data and model development are often accomplished concurrently to save time, in the area of an ongoing systems, historical data may be obtainable from similar systems. The model development starts with a conceptual abstraction of the system. This could be in the form of process flowchart. It is of note that as event processing and relationships between events are defined, the conceptual model becomes a logic model.

As the preliminary model gets developed, the checking and verification of the model ascertain the workability in the way intended comes up. In this case, it is noted that verification is accomplished by running the model step by step to be sure that the intended logic is being followed (Fitzsimmons and Fitzsimmons, 2001). Another method as expressed is to perform a few hand calculations as to ascertain if they agree with the computer output. It is important to note that most complex models will require some "debugging" to fix the shortcomings in the logic. Another level of methodological operation is validation. Validation makes sure that the model reflects the operations of the real system under study in sufficient detail to address the problem. At this level of operation, data collected on the real system are compared with results generated by the model. For example, in the validation of an emergency ambulance for example, the historical distribution of response time is compared to the model's prediction of this distribution. In this context, the prediction of response times is important, because the study is interested in how different ambulance deployments would affect response time. The validation stage as noted is also an excellent time to involve the client because of his or her familiarity with the system and the need to be convinced of the model credibility.

The validation phase: In this process, simulation model is followed by the simulation experiments. These are then designed with the aid of the preliminary idea about alternatives that are to be evaluated. The formulation of procedures and tests for analyzing the comparing alternative comes on board. Fitzsimmons and Fitzsimmons, (2001). Noted that studies involving stochastic elements need to be controlled to ensure that each experiment is subjected to some randomness by designating a common stream of random numbers that produces an identical sequence of events. This control of inputs to the simulation will guarantee that results observed are due to the "treatment" and not confounded by variations in the environment, they further expressed. In addition, the model is run for a certain number of replications and the warm-up time is considered before statistics are recorded.

It is important to note that results of the simulation run often suggest additional experiments. In the case of the emergency ambulance study cited earlier, Fitzsimmons and Fitzsimmons, (2001) reported that the identification of which hospitals would receive patients was found to be important, in addition to staffing levels, to match simulation of demand fluctuation during the day and night. All this stage, each configuration of the model and its associated output is therefore advised to be documented for future reference. It is of note that graphic presentation capabilities found in simulation software produce an effective visual representation of model results that can be self-explanatory. The implementation of the results is advised to be assured when the client for instance, is involved from the beginning and during the simulation process. On a final note, it is expressed that a post-mortem of the simulation study could generate ideas for improving the next project.

Flowchart of the Major Phases in Simulation Study Methodology

The flow chart below show how the development of each phase in a simulation study is derived, with particular reference to the note associated key factors. Which are subsequently therein analyzed.

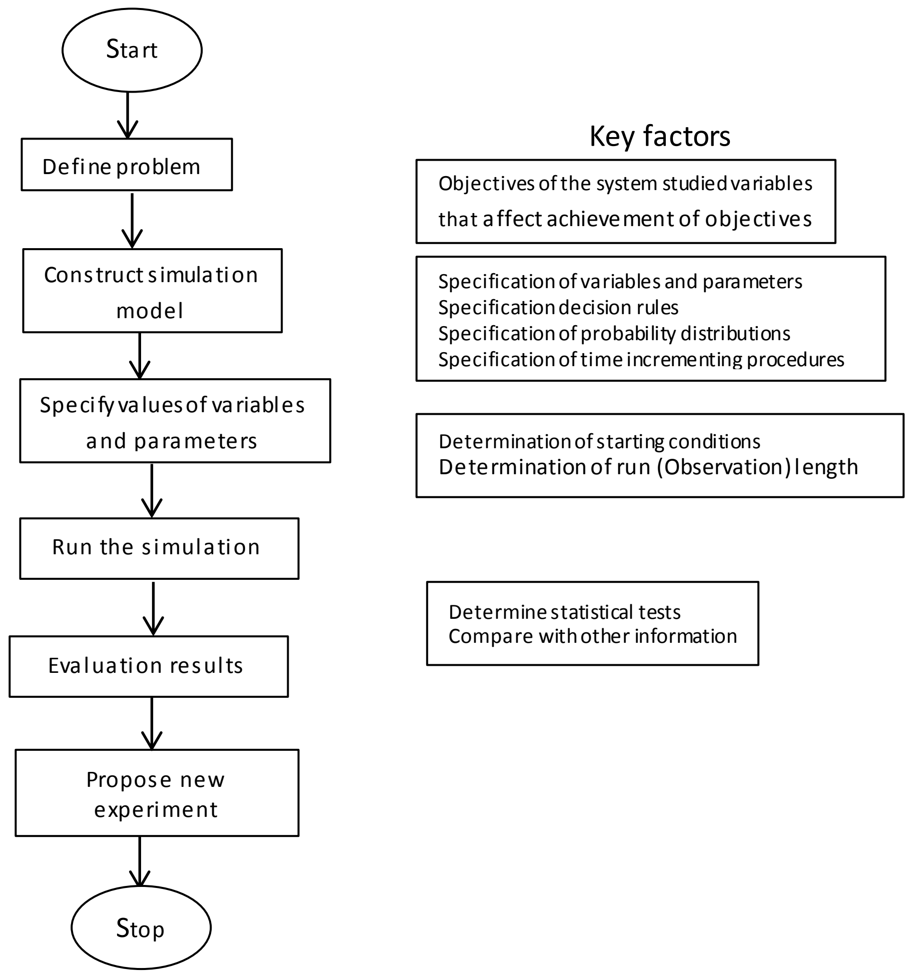

Fig. 2: Major Phases of Simulation Study Methodology

Source: Adapted form Chase, Aquilano and Jacobs (2001), Operations Management for Competitive Advantage. McGraw-Hill Higher Education Company, New York.

Computer Simulation: A valuable Scheduling Tool

Real world scheduling problems are often too complex to be amenable to mathematical analysis. Computer-based simulation is a valuable tool for comparing various scheduling strategies and scenarios. Some of the earliest applications of computer-based operations research application involved simulation (Nahmias, 1997). Computer simulation provides management an experimental laboratory in which to study a model simulation provides management an experimental laboratory in which to study a model of a real system and to determine how the system might respond to change in policies, resource levels, or customer demand. A system for out purposes here, is defined as a combination of elements that interact to accomplish an objective. Systems simulation as noted can be used to answer “what - if” questions about existing or proposed systems. For instance, what if another bank teller is added in a bank passage way or lobby? What if some bank teller handle only depositors? It is revealed that, a simulation model generates estimates of system performance, such as average customer waiting time, for each scenario of interest. Relatedly, an animated simulation running on a personal computer allows decision makers to view the activity of system (e.g. flow of customers) in accelerated time.

As expressed by Rivett (1980), there are in general three main reasons for using simulation. The first relates to a situation where the technical problem, either mathematical or statistical, is too complex to be solve. The second domain where simulation is used covers those problems where the research worker needs to gain some understanding of a complex real situation is that in which the researcher is dealing with problems which do not exist in the real world and where one has to anticipate in advance how one should deal with them should they arise.

Table1: Examples of Simulation Application in Services

Application	Simulation Objective
Staffing bank tellers, queening model	Consider the waiting time of customers when determining the number of tellers to staff a workshift.
Emergency ambulance location	Analyze the response to implication of location options
Hospital patient flows	Develop procedures to manage patient flows and resource utilization.
Order processing	Analyze order processing procedures to support just – in –time shipments
Aircraft maintenance	Determine the impact on downtime of preventive maintenance schedules.
Hazardous waste handling	Analyze capability of recycling facilities and transportation needs.
Scheduling of police patrols	Investigate the impact of targeting crime areas on crime prevention
Project management	Determine the project completion time distribution when activity times are uncertain
Recreational facilities	Predict the impact upon facilities under different operating policies.

Source: Adapted from Fitzsimmons and Fitzsimmons (2001) Service Management.
McGraw – Hill Higher Education Publ. New York

Some other related application of simulation as argued by Urieto, et al (2011) include;

- Ambulance and fire-fighting equipment location and dispatching
- Assembly –line balancing
- Design of parking lots, harbours, communication systems.
- Design of distribution systems
- Scheduling aircraft
- Job-shopping scheduling
- Manpower – living decisions
- Personnel scheduling
- Traffic –light timing
- Inventory analysis

Simulation Programs and Languages

Chase, Aquilano and Jacobs (2001), expressed that simulation models can be classified as continuous or discrete. Continuous models, they noted, are based on mathematical equations and therefore are continuous, with values for all points in time. Relatedly in contrast, discrete simulation occurs only at specific points. Examples of discrete simulation abound. For example, customers arriving at a particular product's corner in a supermarket store would be discrete simulation. The simulation jumps from point to point the arrival of a customer, the start of a service, the ending of service, the arrival of the next customer, and so on. Discrete simulation can also be triggered to run units of time (daily, hourly, minute by minute). This type of simulation as noted is called event simulation. Operations Management applications almost exclusively use discrete (event) simulation (Chase, Aquilano and Jacobs, 2001).

Simulation programs they noted, can also be categorizes as general-purpose and special-purpose. General-purpose software is really language that allows programmers to build their own models. On the other, hand, special applications. In a specialized simulation for manufacturing, for example, provisions in the model allow for specifying the number of work centres, their description, arrival rates, processing time, batch sizes, quantities of work in progress, available resources including labour, sequences, and so on. Additionally, as revealed, the program may allow the observer to watch the animated operation and see the quantities and flows throughout the system as the simulation is running. Under this context data are collected, analyzed, and presented in a form most suitable for that type of application.

Desirable Features of Simulation Software

As is noted in course of this work, simulation software takes a while to learn to use. Once specific software is learned, the tendency is to stay with it for a long time, so the choice must be made carefully.

Under this context, Raider and Banks (1986) opined that, simulation software should:

- Be capable of being used interactively as well as allowing complete runs
- Be user-friendly and easy to understand.
- Allow modules to be built and then connected. In this way, models can be worked on separately without affecting the rest of the system.

- Allow users to write and incorporate their own routines; no simulation program can provide for all needs.
- Have building blocks that contain built-in commands (such as statistical analysis or decision rules for where to go next).
- Have macro capability. Operations involve the movement of material and people; the program should be able to model trucks, cranes, conveyors, and so on.
- Output standard statistics such as cycle times, utilizations, and wait times.
- Allow a variety of data analysis alternatives for both input and output data
- Have animation capabilities to display graphically the product flow through the system.
- Permit interactive debugging of the model, so the user can trace flows through the model and more easily find errors.

Monte Carlo Simulation

Simulations that include some elements of uncertainty (of probability) are referred to as Monte Carlo simulations. Typically, systems simulation is used to analyze complex models that cannot be solved practically by means of analytical methods. These models often are stochastic to account for the realities of the system. Monte Carlo simulation is a method that enables us to model random variables with their associated probability distributions. Monte Carlo simulation relies upon sampling values form the probability distributions associated with the random variables. Values of the random variables are selected at random from the appropriate distributions and then are used in the simulation. It is noted that these observations of the random variables are made repeatedly to imitate the behavior of the variables. Fitzsimmons and Fitzsimmons (2001), expressed that there are several methods that can be used to select observations of random variables from their probability distributions, but all are based on the use of random numbers. It is important to note that a random number is a special random variable that is uniformly distributed between 0 and 1. This means that all values in the interval (0,1) have equal likelihood of being selected.

It is also noted that computer-based simulations actually use pseudo-random numbers. These as expressed are values that behave like random numbers, although they are generated using a mathematical function. While pseudo-random are not truly random, as further expressed, they have the appearance of being random. Pseudo-random numbers are noted to have the advantage of not requiring large amounts of file space in the computer. As a result and more important, they permit the exact replication of experimental conditions by allowing the same stream of numbers to be realized from a “seed” value (Fitzsimmons and Fitzsimmons 2001).

Advantages and Disadvantages of Simulation

The under listed is not however, intended to be a comprehensive list of reasons why we should select to use or not to use simulation as a management technique. Instead, will in as much as possible state some of the generally accepted advantages and disadvantages as relatedly noted by Chase, Aquilano and Jacobs. (2001). One of the major advantages of simulation is that it determines the result of a particular decision (In a sort of laboratory fashion) before from the tries to actually implement it. In this way, a manager can ask a series of "what if" questions about the system, test several alternatives and choose the one that provided the best results. Computer simulation allows the very rapid testing of many options and has advanced the popularity of this approach to problem solving (Urieto, Umoh and Chukwe, 2011).

- The development of the model often leads to a better understanding of the real system.
- Time as a very important scarce resource can be compressed in simulation; similarly, years of experience in the real system can be compressed into seconds or minutes.
- Simulation does not disrupt ongoing activities of the real system.
- Simulation is far more general than mathematical models and the aid can be used where conditions are not suitable for standard mathematical analysis.
- Simulation can be used as a game for training experience
- Simulation provides a more realistic replication of a system than mathematical analysis.
- Simulation can be used to analyze transient conditions, whereas mathematical techniques usually cannot.
- Many standard packaged models, covering a wide range of topics, are available commercially.
- Simulation answers what- if questions

Disadvantages

- Irrespective of the fact that a great deal of time and effort may be spent to develop a model for simulation, there is no guarantee that the model will in fact, provide good answers.
- There is no way to prove that a simulation model's performance is completely reliable. Simulation involves numerous repetitions of sequences that are based on randomly generated occurrences. An apparent stable system can, with the right combination of events – however unlikely-explode.
- Depending on the system to be simulated, building a simulation model can take anywhere from an hour to 100 worker years. In the same vein, complicated systems can be very costly and take a long time.
- Simulation may be less accurate than mathematical analysis because it is randomly based. With this understanding, if a given system can be represented by a mathematical model. It may be better to use than simulation.
- A significant amount of computer time may be needed to run complex models
- The technique of simulation. While making progress, still lacks a standardized approach. This therefore means that models of the same system built by different individuals may differ widely.

Conclusions and Recommendations

Simulation is a powerful technique for tackling complex problems. A computer simulation is a description of a problem reduced to a computer program. The program is therefore designed to recreate the key aspects of the dynamics of a real situation. From our study of simulation principles, it is noted that when a problem is too complex to model mathematically, simulation is a popular alternative. In the processes of running the program under different starting conditions and/or different scenarios, one can, by trial- and – error process, discover the best strategy for managing a system, subject to the situation. We also conclude that simulation is a common tool for modeling manufacturing planning problems such as complex material flow problems in the plant. In applying simulation principles and models in business management, it is important to note that simulation, however, has nothing fixed and that there are no boundaries to building a model or making assumptions about a system. This is so because expanding computer power and memory have pushed out the limits of what can be simulated

When there is a sample error, optimization of simulation models becomes all the more difficult, and care is recommended to be taken in its usage and application. Nevertheless, simulation principles are recommended to be used in business management in view of its simplicity and applicability.

References

Chase, R. B: Aquilano, N. J, & Jacobs, F.R. (2001). Operations Management Competitive Advantage. New York, McGraw – Hill Higher Education.

Fitzsimmons, J. A. and Fitzsimmons, M.J. (2001), Service Management: Operations, Strategy and Information Technology. New York: Mc Graw – Hill Higher Education.

Nahmias, S. (1997). Production and Operations Analysis. USA, McGraw – Hill Company Inc.

Raider, S. W. and Banks, J. (1986). “Simulation Software Products for Analyzing Manufacturing System”. Industrial Engineering 18, (7): 98 – 103, July.

Rivett, P. (1980). Model Building for Decision analysis. England. Page Bros (Norwich) Ltd.

Taha, H.A. (1982). Operations Research: An Introduction. New York: Macmillan Publishing Co, Inc.

Urieto, J. E.: Umoh, G.I and Chikwe, J. E. (2011). Production and Operations Management: A self –study Approach. Port Harcourt: Divine Project Publishers.