IMPORTANCE OF SIMULATION IN TODAY'S LIFE

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ABSTRACT

The purpose of the paper is to take a comprehensive look at Simulation, which is a popular term for the reoptimization of organizational processes and structures after the implementation of new information technologies into an organization. We have stirred beyond the Industrial Age and into the Information Age, but manufacturing remains an essential part of the global economy. Numerous efforts have been made to use modeling and simulation tools and techniques to improve manufacturing efficiency over the last three decades. While much development has been made and an increasing number of manufacturing system decisions are being made based on the use of models, their use is still sporadic in many manufacturing environments. We believe that there is a need for pervasive use of modeling and simulation for decision support in current and future manufacturing systems. There are several problems that need to be addressed by the simulation community to realize this dream. The main goal of the paper is to present and discuss the level of information system modeling and simulation modeling. The paper also stressed the necessity for integrating simulation modeling and information system modeling.

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1.1 SIMULATION

With the development of computer technology, simulation has been more and more widely used in many fields of our society. Simulation techniques not only play very important role in scientific study, but also occupy very important places in education, military, entertainment and almost any fields that we can imagine. The following section presents some of the important definitions of simulation.

The *Oxford English Dictionary* gives the following definition of simulation: The technique of imitating the behavior of some situation or process (whether economic, military, mechanical, etc.) by means of a suitably analogous situation or apparatus, especially for the purpose of study or personnel training. And *Glossary of Geology (Third Edition, AGU)* gives a definition of simulation especially appropriate for scientific simulations: The representation of a physical system by a device such as a computer or model that imitates the behavior of the system. Simulation, according to Robert E. Shannon (1975), is "the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies for the operation of the system."

Simulation is an indispensable problem-solving methodology for the solution of many real-world problems. Simulation is used to describe and analyze the behavior of a system, ask "what if" questions about the real system, and aid in the design of real systems. Both existing and conceptual systems can be modeled with simulation.

There is no unifying theory of computer simulation. Learning simulation does not consist of learning a few fundamental theorems and then using them and their various corollaries to solve problems. There are no universally acceptable principles guiding the formulation of simulation models. Each application of simulation is adhoc to a great extent. In this sense simulation is an art.

1.2 SIMULATION AND EXPERIMENT

Simulation is basically an experimental technique. It is a fast and relatively inexpensive method of doing an experiment on the computer. Consider, for example, the inventory-control problem. Instead of trying out in the actual store the different replenishment policies, each for a period of six months and then selecting the best one, the same experiment can be conducted on the computer and results can be obtained within a few minutes at a very small cost. This is why computer simulation is often referred to as performing an experiment.

1.3 WHEN TO SIMULATE

All of us in our daily lives encounter problems, which although mathematical in nature, are too complex to lend themselves to exact mathematical analysis. The performance of such a system (say, weather or traffic jam) may be difficult to predict, either because the system itself is complex or the theory is not yet sufficiently developed. The difficulties in handling such problems (by means of classical mathematical tools) may also arise due to the effect of uncertainties or due to dynamic interactions between decisions and subsequent events or due to complex interdependencies among variables in the system, or due to some combination of these. Before the days of computer simulation, in such situations either an intuitive decision was made or if the stakes were too high to rely on intuition, elaborate laboratory experiments had to be conducted which were usually expensive and time-consuming. Simulation provides a third alternative which is cheap and fast and thus fills the gap between exact analysis and physical intuition. Occasionally, simulation is also used even when an exact analytic solution is possible but it is too expensive in terms of computation time.

It is impossible to give a full list of applications for which simulation might be used. It is, however, useful to give some indication of the range of systems that can be modeled. Banks *et al*. (1996) suggest the following list:

- Manufacturing systems
- Public systems: health care, military, natural resources
- Transportation systems
- Construction systems
- Restaurant and entertainment systems
- Business process reengineering/management
- Food processing
- Computer system performance

1.4 SIMULATION IN SCIENCE AND ENGINEERING RESEARCH

Simulation has changed, in a very fundamental sense, the way in which research is conducted today. Earlier most experiments were carried out physically in the laboratories. Thousands and even millions were spent on physical models (e.g. wind tunnels, river basin models, network analyzers, aircraft flight simulators) and expensive experiments. Today a majority of these experiments are simulated on a computer. 'Computer Experiments' besides being much faster, cheaper and easier, frequently provide better insight into the system than laboratory experiments do. Not all laboratory experiments, of course, can be replaced with computer simulations. Typically, a few key experiments are performed in the laboratory after, say, 80-90 percent of the experimenting has been done on the computer.

1.5 SIMULATION IN SOFT SCIENCES

Simulation can be expected to play even a more vital role in biology, sociology, economics, medicine, psychology etc. where experimenting could be very expensive, dangerous or even impossible. In these areas, the mathematical theories are even less developed than in physical sciences. Moreover, in fields such as biology and economics the problems are truly large, involving tens of thousands of variables. The complications caused by uncertainty are also greater in these areas than in physical sciences. Thus simulation has become an indispensable tool for a modern researcher in most social, biological and life sciences.

1.6 SIMULATION FOR BUSINESS EXECUTIVE

There are many problems faced by management that cannot be solved by standard operations research tools like linear and dynamic programming, inventory and queueing theory. Therefore, a business executive had to make decisions based solely on his intuition and experience. Now he can use computer simulation to make better and more meaningful decisions. Utilizing the power of a digital computer, he can build and study a simulation model containing arbitrarily high-order complexities and a huge number of interdependencies as well as uncertainties. Simulation has been used widely for inventory control, facility planning, production scheduling and the like.

1.7 SIMULATION VERSUS EXPERIMENTATION WITH THE REAL SYSTEM

Rather than develop and use a simulation model, experiments could be carried out in the real system. For instance, additional check-in desks could be placed in an airport departure area, or a change in the flow around a factory floor could be implemented. There are some obvious, and less obvious, reasons why simulation is preferable to such direct experimentation.

1. ***Cost:*** Experimentation with the real system is likely to be costly. It is expensive to interrupt day-to-day operations in order to try out new ideas. Apart from the cost of making changes, it may be necessary to shut the system down for a period while alterations are made. Added to this, if the alterations cause the operation’s performance to worsen, this may be costly in terms of loss of custom and customer dissatisfaction. With a simulation, however, changes can be made at the cost of the time it takes to alter the model and without any interruption to the operation of the real world system.

2. ***Time:*** It is time consuming to experiment with a real system. It may take many weeks or months (possibly more) before a true reflection of the performance of the system can be obtained. Depending on the size of the model and speed of the computer, a simulation can run many times faster than real time. Consequently, results on system performance can be obtained in a matter of minutes, may be hours. This also has the advantage that results can be obtained over a very long time frame, maybe years of operation, if required. Faster experimentation also enables many ideas to be explored in a short time frame.
3. ***Control of the experimental conditions***: When comparing alternatives it is useful to control the conditions under which the experiments are performed so direct comparisons can be made. This is difficult when experimenting with the real system. For instance, it is not possible to control the arrival of patients at a hospital. It is also likely that experimentation with the real system will lead to the Hawthorne effect, where staff performance improves simply because some attention is being paid to them. In some cases the real system only occurs once, for example, a military campaign, and so there is no option to repeat an experiment. With a simulation model the conditions under which an experiment is performed can be repeated many times. The same pattern of patient arrivals can be generated time and time again, or the events that occur during a military campaign can be reproduced exactly as often as is required.
4. ***The real system does not exist:*** A most obvious difficulty with real world experimentation is that the real system may not yet exist. Apart from building a series of alternative real world systems, which is unlikely to be practical in any but the most trivial of situations, direct experimentation is impossible in such circumstances. The only alternative is to develop a model.

1.8 SIMULATION VERSUS OTHER MODELING APPROACHES

Simulations are not the only models that can be used for understanding and improving the real world. Other modeling approaches range from simple paper calculations, through spreadsheet models, to more complex mathematical programming and heuristic methods (e.g. linear programming, dynamic programming, simulated annealing and genetic algorithms). Queuing theory provides a specific class of model that looks at similar situations to those often represented by simulations, arrivals, queues and service processes (Winston 1994). There are some reasons why simulation would be used in preference to these other methods.

1. ***Modeling variability:*** It has already been stated that simulations are able to model variability and its effects. If the systems being modeled are subject to significant levels of

variability, then simulation is often the only means for accurately predicting performance. Some systems cannot be modeled analytically. This is illustrated by Robinson and Higton (1995) who contrast the results from a ‘‘static’’ analysis of alternative factory designs with a simulation. In the static analysis the variability, largely resulting from equipment failures, was accounted for by averaging their effects into the process cycle times. In the simulation, the variability was modeled in detail. Whilst the static analysis predicted each design would reach the throughput required, the simulation showed that none of the designs were satisfactory. It is vital that variability is properly accounted for when attempting to predict performance.

2. ***Restrictive assumptions***: Simulation requires few, if any, assumptions, although the desire to simplify models and a shortage of data mean that some appropriate assumptions are normally made. Many other modeling approaches require certain assumptions. Queuing theory, for instance, often assumes particular distributions for arrival and service times. For many processes these distributions are not appropriate. In simulation, any distribution can be selected.
3. ***Transparency*****:** A manager faced with a set of mathematical equations or a large spreadsheet may struggle to understand, or believe, the results from the model. Simulation is appealing because it is more intuitive and an animated display of the system can be created, giving a non-expert greater understanding of, and confidence in, the model. Of course, there are occasions when another modeling approach is appropriate and simulation is not required. Because simulation is a time consuming approach, it is recommended that it is used as a means of last resort, rather than the preferred option (Pidd 1998). Indeed, surveys of modeling practice demonstrate that simulation is one of the most commonly used modelling techniques (Jeffrey and Seaton 1995; Fildes and Ranyard 1997; Clark 1999**).**

1.9 TYPES OF SIMULATION

1.9.1 Continuous System Simulation

Continuous system simulation can be used to model systems that are continuous in nature i.e. in which the predominant activities cause smooth changes in the attributes of the system entities. In continuous system simulation, the relationships describe the rates at which attributes change so that the model consists of differential equations. The simplest differential equation models have one or more linear differential equations with constant coefficients.

For example, the water level in a reservoir with given in and outflows may change all the time. In such cases "continuous simulation" is more appropriate. Other application areas range from aircraft flight dynamics, nuclear reactors, chemical processes, and physiological dynamics to a wide variety of control systems, civil engineering, mechanical engineering, systems biology.

1.9.2 Discrete Event Simulation

Discrete event simulation is one of the better known simulation types. It can be used to model systems that are dynamic, stochastic and discrete. In discrete event simulation, time plays an important role (dynamic model) and it was created for systems with random input components (stochastic models) In addition, discrete event simulation is a discrete model because it models a system in which the states of entities in the system are changed at separated (discrete) moments in time. In other words, discrete event simulation models the process of state variable changes for an entity at discrete points in time **(Carson, 2005)**. A simple example for this type of simulation is the student registration process. To complete the overall process, each student will have their own arrival time, waiting time, service time and service completion time. These chronological sequence of events shows that, every student has their own time for each activity and these random times are known as event times.

1.9.3 Examples of Applications

According to **Law and McComas (1998),** the potential of DES was firstly discovered in manufacturing areas since 1960. It is often needed in manufacturing, especially where a large amount of investment is involved, or to simulate complex manufacturing processes. For instance, if one company wishes to build a new production line, the line should be first simulated in order to assess whether the line is practical and efficient enough to be implemented. This can be considered as sufficient way to receive a good result without having to conduct real experiments.

Since its introduction, the usage of DES has spread out to various applications. The common types of DES applications are design and operation in queuing system, manufacturing and distribution systems, managing inventory systems, fleet management, business games, government services, banking, hotels, restaurant, educational institution, disaster planning, military and many more. Among the famous examples of simulation packages are Arena, AutoMod, Extend, ProModel, Quest, Simul8 and Witness.

1.10 STEPS IN SIMULATION

Figure 1 shows a set of steps to guide a model builder in a thorough and sound simulation study. Similar figures and their interpretation can be found in other sources such as Pegden, Shannon, and Sadowski (1995) and Law and Kelton (2000).

1. Problem Formulation

Every simulation study begins with a statement of the problem. If the statement is provided by those that have the problem (client), the simulation analyst must take extreme care to insure that the problem is clearly understood. If a problem statement is prepared by the simulation analyst, it is important that the client understand and agree with the formulation. It is suggested that a set of assumptions be prepared by the simulation analyst and agreed to by the client. Even with all of these precautions, it is possible that the problem will need to be reformulated as the simulation study progresses.

2. Setting of Objectives and Overall Project Plan

Another way to state this step is “prepare a proposal”. This step should be accomplished regardless of location of the analyst and client, viz., as an external or internal consultant.

The objectives indicate the questions that are to be answered by the simulation study. The project plan should include a statement of the various scenarios that will be investigated. The plans for the study should be indicated in terms of time that will be required, personnel that will be used, hardware and software requirements if the client wants to run the model and conduct the analysis, stages in the investigation, output at each stage, cost of the study and billing procedures, if any.

3. Model Conceptualization

The real-world system under investigation is abstracted by a conceptual model, a series of mathematical and logical relationships concerning the components and the structure capabilities. Finally, add the special features. Constructing an unduly complex model will add to the cost of the study and the time for its completion without increasing the quality of the output. Maintaining client involvement will enhance the quality of the resulting model and increase the client’s confidence in its use.

4. Data Collection

Shortly after the proposal is accepted, a schedule of data requirements should be submitted to the client. In the best of circumstances, the client has been collecting the kind of data needed in the format required, and can submit these data to the simulation analyst in electronic format. Oftentimes, the client indicates that the required data are indeed available. However, when the data are delivered they are found to be quite different than anticipated. For example, in the simulation of an airline-reservation system, the simulation analyst was told we have every bit of data that you want over the last five years. When the study commenced, the data delivered were the average talk time of the reservationists for each of the years. Individual values were needed, not summary measures.

Model building and data collection are shown as contemporaneous in Figure 1. This is to indicate that the simulation analyst can readily construct the model while the data collection is progressing.

5. Model Translation

The conceptual model constructed in Step 3 is coded into a computer recognizable form, an operational model.

6. Verification

Verification concerns the operational model. Is it performing properly? Even with small textbook sized models, it is quite possible that they have verification difficulties. These models are orders of magnitude smaller than real models (say 50 lines of computer code versus 2,000 lines of computer code). It is highly advisable that verification take place as a continuing process. It is ill advised for the simulation analyst to wait until the entire model is complete to begin the verification process. Also, use of an interactive run controller, or debugger, is highly encouraged as an aid to the verification process.

7. Validation

Validation is the determination that the conceptual model is an accurate representation of the real system. Can the model be substituted for the real system for the purposes of experimentation? If there is an existing system, call it the base system, then an ideal way to validate the model is to compare its output to that of the base system. Unfortunately, there is not always a base system. There are many methods for performing validation.

8. Experimental Design

For each scenario that is to be simulated, decisions need to be made concerning the length of the simulation run, the number of runs (also called replications), and the manner of initialization, as required.

9. Production Runs and Analysis

Production runs, and their subsequent analysis, are used to estimate measures of performance for the scenarios that are being simulated.

10. More Runs?

Based on the analysis of runs that have been completed, the simulation analyst determines if additional runs are needed and if any additional scenarios need to be simulated.

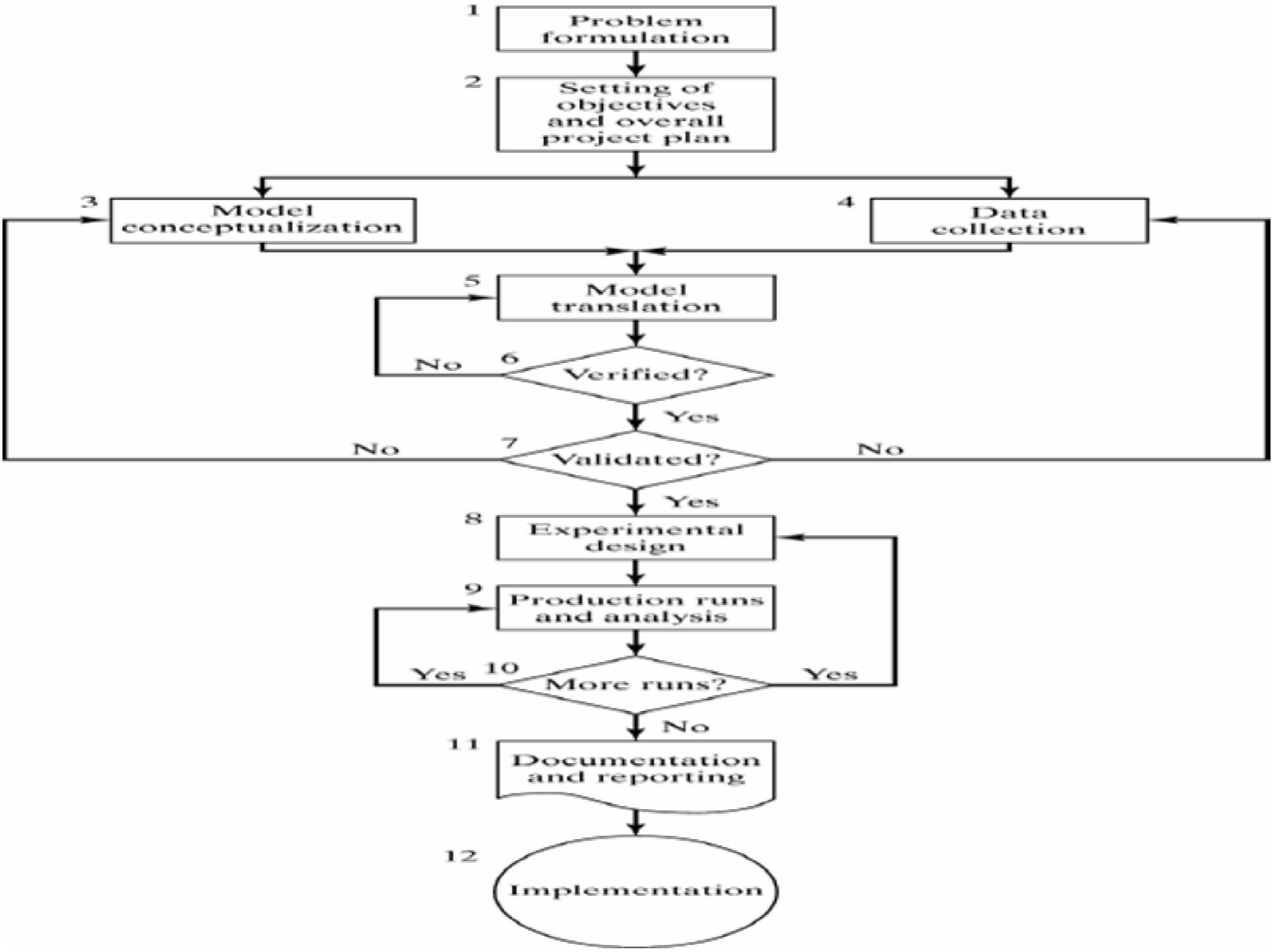
11. Documentation and Reporting

Documentation is necessary for numerous reasons. If the simulation model is going to be used again by the same or different analysts, it may be necessary to understand how the simulation model operates. This will enable confidence in the simulation model so that the client can make decisions based on the analysis. Also, if the model is to be modified, this can be greatly facilitated by adequate documentation.

The result of all the analysis should be reported clearly and concisely. This will enable the client to review the final formulation, the alternatives that were addressed, the criterion by which the alternative systems were compared, the results of the experiments, and analyst recommendations, if any.

12. Implementation

The simulation analyst acts as a reporter rather than an advocate. The report prepared in step 11 stands on its merits, and is just additional information that the client uses to make a decision. If the client has been involved throughout the study period, and the simulation analyst has followed all of the steps rigorously, then the likelihood of a successful implementation is increased.



1.11 PRINCIPLES USED IN MODELING

It is not possible to provide rules by which mathematical models are built but a number of guiding principles can be stated. They do not describe distinct steps carried out in modeling a model but describe different viewpoints from which to judge the information to be included in the model.

1. Block-Building

The description of the system should be organized in a series of blocks. The aim in constructing the blocks is to simplify the specification of the interactions within the system. Each block describes a part of the system that depends upon a few input variables and results in a few output variables. The system as a whole can then be described in terms of the interconnections between the blocks. Correspondingly, the system can be represented graphically as a simple block diagram.

2. Relevance

The model should only include those aspects of the system that are relevant to the study objectives. While irrelevant information in the model may not do any harm, it should be excluded because it increases the complexity of the model and causes more wok in solving the model.

3. Accuracy

The accuracy of the information gathered for the model should be considered. For e.g. If we consider the example of an aircraft system, an engineer responsible for estimating the fuel consumption may be satisfied with the simple representation. Another engineer responsible for considering the comfort of the passengers needs to consider vibrations and will want the detailed description of the airframe.

4. Aggregation

A further factor to be considered is the extent to which the number of individual entities can be grouped together into larger entities.

1.12 SOME SPECIFIC AREAS OF APPLICATION OF SIMULATION

"*Anything can be simulated and everything has been simulated*"-Anonymous

Simulation is a modeling technique that can be applied in almost every aspect of business functioning but some of the specific areas where simulation can be used are:

- Manufacturing Applications
- Semiconductor Manufacturing
- Construction Engineering and project management
- Military application
- Logistics, Supply chain and distribution application
- Transportation modes and Traffic
- Business Process Simulation
- Health Care
- Automated Material Handling System (AMHS)
- Test beds for functional testing of control-system software
- Risk analysis (Insurance, portfolio)
- Computer Simulation (CPU, Memory)

- Network simulation (Internet backbone, LAN, Wireless)
- Inventory control
- Scheduling of flexible manufacturing systems
- National economy
- Physics
- Telecommunication systems

1.13 ADVANTAGES OF SIMULATION

1. Helps in decision making

Simulation lets you test every aspect of a proposed change or addition without committing resources to their acquisition. This is critical, because once the hard decisions have been made, the bricks have been laid, or the material-handling systems have been installed, changes and corrections can be extremely expensive. Simulation allows to test designs without committing resources to acquisition.

2. Time Compression and Expansion

By compressing or expanding time, simulation allows to speed up or slow down phenomena so that one can thoroughly investigate them. Entire shift can be examined in a matter of minutes if required, or two hours can be spend examining all the events that occurred during one minute of simulated activity.

3. Understand "Why?"

Managers often want to know why certain phenomena occur in a real system. With simulation, the answer to the "why" questions can be determined by reconstructing the scene and taking a microscopic examination of the system to determine why the phenomenon occurs. It cannot be accomplished with a real system because it cannot be seen or control it in its entirety.

4. Explore Possibilities

One of the greatest advantages of using simulation software is that once a valid simulation model have been developed; new policies, operating procedures, or methods can be explored without the expense and disruption of experimenting with the real system. Modifications are incorporated in the model, and the effects of those changes can be observed on the computer rather than the real system.

5. Diagnose Problems

The modern factory floor or service organization is very complex--so complex that it is impossible to consider all the interactions taking place in one given moment. Simulation allows us to better understand the interactions among the variables that make up such complex systems. Diagnosing problems and gaining insight into the importance of these variables increases understanding of their important effects on the performance of the overall system. The last three claims can be made for virtually all modeling activities, queueing, linear programming, etc. However, with simulation the models can become very complex and, thus, have a higher fidelity, i.e., they are valid representations of reality.

6. Identify Constraints

Production bottlenecks give manufacturers headaches. It is easy to forget that bottlenecks are an effect rather than a cause. However, by using simulation to perform bottleneck analysis, it is possible to discover the cause of the delays in work-in-process, information, materials, or other processes.

7. Develop Understanding

Many people operate with the philosophy that talking loudly, using computerized layouts, and writing complex reports convinces others that a manufacturing or service system design is valid. In many cases these designs are based on someone's thoughts about the way the system operates rather than on analysis. Simulation studies aid in providing understanding about how a system really operates rather than indicating an individual's predictions about how a system will operate.

8. Visualize the Plan

Taking designs beyond CAD drawings by using the animation features offered by many simulation packages allows us to see facility or organization actually running. Depending on the software used, it is possible to view operations from various angles and levels of magnification, even 3-D. This allows to detect design flaws that appear credible when seen just on paper on in a 2-D CAD drawing.

9. Build Consensus

Using simulation to present design changes creates an objective opinion. We avoid having inferences made when we approve or disapprove of designs because we simply select the designs and modifications that provided the most desirable results, whether it be increasing production or reducing the waiting time for service. In addition, It is much easier to accept reliable simulation results, which have been modeled, tested, validated, and visually represented, instead of one person's opinion of the results that will occur from a proposed design.

10. Prepare for Change

We all know that the future will bring change. Answering all of the "what-if" questions is useful for both designing new systems and redesigning existing systems. Interacting with all those involved in a project during the problem formulation stage gives an idea of the scenarios that are of interest. Then the model is constructed so that it answers questions pertaining to those scenarios.

11. Wise Investment

The typical cost of a simulation study is substantially less than 1% of the total amount being expended for the implementation of a design or redesign. Since the cost of a change or modification to a system after installation is so great, simulation is a wise investment.

1.14 Limitations of Simulation

1. A simulation model can, at best, provide only **estimates** of the system's performance
2. All alternative answers must be known **before** the simulation experiments are carried out
3. The chosen "best" solution is restricted to the set of alternatives
4. There may be an extremely large number of possible answers to be evaluated: this may make determination of the best answer difficult or impossible