A Methodology to Adapt and Understand a Manufacturing System and Operations using Discrete-Event Simulation

D. Phanindra Kshatra, P. Ratna Prasad, S. Akhil, B.L.N.S.S. Charan Raghavendra, S.V.S. Prakash

Abstract: Discrete-Event Simulation (DES) is concerned with system and modeling of that system, where the state of the system is transformed at different discrete points from time to time, and several event occurs from time to time and the changes in state variables will transform then activities/attributes connected to these state variables changes according to the event. It is a robust methodology in the manufacturing industry for strategic, tactical, and operational applications for an organization, and yet organizations ignore to use simulation and do not rely on it. Moreover, companies that are using DES are not using the potential benefits but merely used as a short-hand basis for problems like bottlenecks, optimization, and in later stages of production like PLM, this paper aims to apply and analyze Discrete-Event Simulation through a Manufacturing System. The work describes here is to understand the concept of simulation for a system and to practice Discrete Event methodology.

Keywords: Manufacturing System, Operations, Simulation, Discrete-Event Simulation, Computer Simulation, Discrete-Event Methodology, Dynamic Demand.

I. INTRODUCTION

The Manufacturing industry is in constant pressure to meet customers' demands in time and focus on improving their production performance and simultaneously eliminating the bottlenecks, thus improving their processes efficiency. There are specific ways to study a system. Figure-1 explains the method for simulation [1]. Simulation is one of the vital and powerful tools to design and analyze the complex processes in the manufacturing industry [2]. Simulation mimics the current real-time system. With the help of modeling a wide range of experiments can be performed and evaluate the results. Optimizing and implement them for the best possible outcome, so that these iterations will apply to the real system for improvement of overall production [3], with the help of DES and computers a model is built with the help of the real-world system, and the simulation represents the dynamic characteristics of that system.
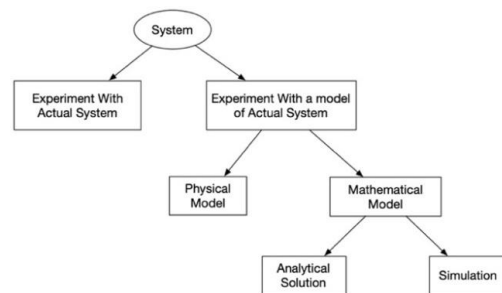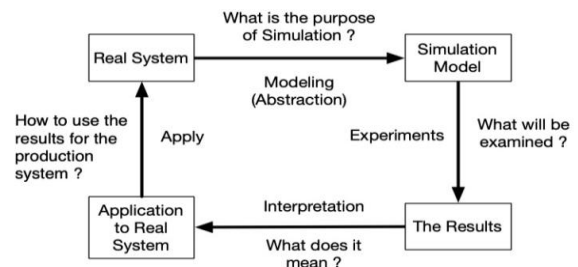

Figure 1: System Study [1]

Figure 2: Principle of computer simulation [3]

II. PROBLEM STATEMENT

A. *How to Develop a simulation model for a system of Interest?*

It is essential to choose a particular system of Interest where the simulation is necessary, and there is a need for it, then identifying the steps and its methodology to conduct the simulation, once the method is defined then it is crucial to develop a model, design of experiments, and perform analysis, validate and verify the results and check if the simulation results are according to the satisfactory level, then documentation and implementation to the system and see how the system is performing. This must be a continuous process, and the model update should be done according to the data collected [4], [5].

D.Phanindra Kshatra, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Vijayawada, India,

P.Ratna Prasad*, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Vijayawada, India,

S.Akhil, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Vijayawada, India.

B.L.N.S.S. Charan Raghavendra, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Vijayawada, India.

S.V.S. Prakash, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Vijayawada, India.

B. *What is the process to select a Simulation Software?*

Once the methodology is proposed, the next step is how simulation should be performed, and there is a wide range of software's developed for computer simulation to design different production and process aspects and their operations. Some software's are free available, but most of the software's require professional licenses. A model is built based on the real-time system with the help of programming language or through Object-Oriented Programming (OOP) that are present in different simulation platforms and are implemented through these packages. It is crucial to identify these computer simulation programs and packages and compare these programs for the use of academia and industry [4],[6].

III. LITERATURE OVERVIEW

Simulation can be used to an existing system or a new build system, and this is used to study the behavior of the system. Simulation is used to evaluate the performance and outcomes of the system for different inputs and a different time. By this, it enables us to find the rate of failure and to identify the bottlenecks present in the system. So, by using simulation, we will able to optimize the performance of the system.[4]

A simulation is a flexible tool which is used to design and analysis of the given system. But without a systematic approach, simulation can provide improper results. With a proper systematic approach or methodology, we can apply simulation to any real-world system.[11]

Simulation helps to reduce the bottlenecks and increase in efficiency in manufacturing products. Most of the simulation process is done by the layout without layout. There is no perfection in the process of simulation [17].

According to the [1] Law, A.M., and Kelton, W.D. (1991) in the Manufacturing industry, the simulation plays a significant role to meet the customers need time in society.

Simulation is an approximate limitation of the operation of a process or a system. There are many methods in simulation for developing the manufacturing process [2]. As the technology is updating the simulation software is also updating in order to make the steps easily by the analyzer for the analysis [3]. A model is an abstraction form the reality used to help understand the system.

The methodology also plays an important one for the simulation. The methodology also includes data collection. This data helps the software to do the simulation in real-time appliances. According to the Onur M. Ulgen, John J. Black, the methodology of simulation is based on the steps that are defined for the problem statement [5]. It is essential to choose a particular system of interest where the system needs the necessary. The model should be updated for the simulation is based on the data collection because of data collection changes according to the customer requirements or the industrial requirements. The documentation of the model and problem statement made it easy for the results of the simulation and helping to develop the simulation model [6], [7].

With an example of a health care setting, conceptual modeling has been clearly explained through which the best model can be built by the abstraction of the simulation model from a real-world system. Decision making for the
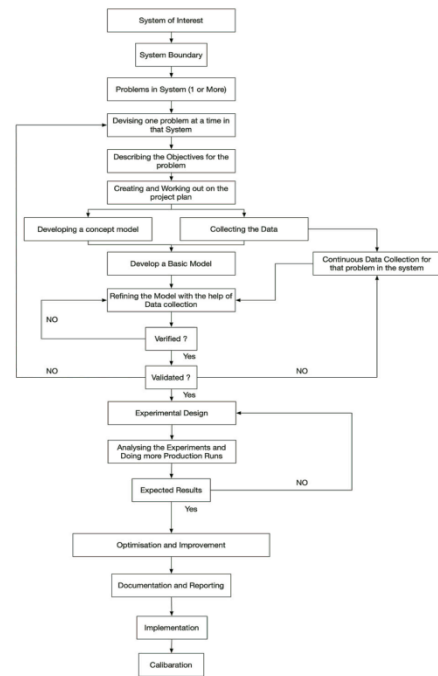
inclusions, along with the maintenance of complexity in the model were also furnished.[13]

This paper described and validated an application method for detecting bottlenecks on a discrete event simulation model, which will be helpful in the automation of bottleneck analysis [6].

True System performances can be measured when we are provided with model assumptions and gathered observations by using discrete-event simulation through numerical methods which employ computational procedures to solve the models. DES can also act as a strengthening tool for the improvement of system performance.[7]

IV. METHODOLOGY

The methodology developed here is the combination of Banks [7], and Skoogh's [9] DES methodology, here the description for each step in the methodology is done, and a thorough analysis is conducted.

Figure 3: Steps for Discrete-Event Simulation [7],[9]

The steps involved are as follows
Step 1. System of Interest
Step 2. System Boundary
Step 3. Identification of problems in the system
Step 4. Devising one question or problem at a time
Step 5. Objectives of the problem
Step 6. Developing the Project plan
Step 7. Conceptual Model
Step 8. Collecting the Data
Step 9. Develop a Basic Model of the system
Step 10. Continuous Data Collection
Step 11. Refining the Model with continuous Data Collection
Step 12. Verification
Step 13. Validation
Step 14. Design of

Experiments or Experimental Design
Step 15. Analyzing the Experiments and Production Runs
Step 16. Results
Step 17. Optimization and Improvement
Step 18. Documentation and Reporting
Step 19. Implementation
Step 20. Calibration

Before the start of the simulation, it is vital to understand the concept of a system for a manufacturing environment, A pre-study about the facility is very important before any simulation to understand the dynamic behavior of the situation. Qualitative analysis of the environment is critical to understand the complexity, flexibility, dynamic demand patterns, variety of product mix and variable product volumes for that environment with the help of physical configuration by visiting the manufacturing facility [10].

Step 1. *System of Interest*
It is essential to identify the mode of Interest because the system should not be the continuous system and the changes that the system occur at discrete points in time. The method of Interest can have multiple entity types, and event types, Examples of such systems can be Departments in Manufacturing Plants of Product and Process types. The entities for such systems can be either permanent or temporary depends on the lifetime of the system [11].

Step 2. System Boundary
Once the system of Interest is chosen, its essential to consider the boundaries for the system these boundaries include are machines in that system and their capabilities, product data, number of workers, and Material Handling Systems (MHSs), Management system, Distribution of facilities in the system [3], [12].

Step 3. Identification of problems in the system
Once the system boundary is defined, it is essential to compute or count the problems that are present in the existing system, and this includes looking at the issues in the current system like throughput, bottlenecks, buffer size, a sequence of production, batch size, etc. [4].

Step 4. Devising one problem at a time
After problem identification, It is essential that one problem is defined and solve it, due to nature of the issues present in the system it is better to act with one question or problem at a time, solve it and move on to the next challenge in the system [5].

Step 5. Objectives of the problem
From the selected issue in the system it is essential that the goal is well defined, the client and the administrator should work together and set all the objectives for the problem, it is to determine the level of details needed to study the system and see if the problem is highlighted for the targets that are developed [11].

Step 6. Developing the Project plan
It's essential to create a project plan with, keeping the system lifecycle in mind, list all the assumptions for the system, estimate the number of models required for simulation, select the appropriate simulation tool, establish the level of data available and what data is needed for simulation of system, categorize the deliverables and set the system specifications [5],[11].

Step 7. Conceptual Model
The Model is the abstraction of the real system to understand what is really happening in a system, the most important for the modeler in the model what to include and what to exclude, it is his choice and an important decision to make which best model development, Making the model too complicated will not be possible to complete it on time, with the gained knowledge and may confuse the simulation results of what is essential and what is not. Making it too simple may not have accurate and sufficient results. This process of determining what should be included in the model is known as conceptual modeling [13].

Step 8. Collecting the Data
Once the conceptual model is designed and developed, it is essential to collect the data for simulation and perform experiments, the necessary data for the simulation includes, Type of machines and their capacities, equipment's data, personnel, Products and its Variants Data, Data about Facility, Data about availability of Machines and Equipment and Data about management system [3].

Step 9. Develop a Basic Model of the system
After the Data collection, it is essential to Build, Verify and Validate the simulation model, the first and most important objective is to construct the flow diagram of the system of interest with the help of available data, the next step is to include what the management aims from the system, next step is to describe each and every process in the system and their connection within that system, next step is to gather all the data that is available for each and every process in the system, if some information is missing make appropriate assumptions, next is to specify each and every parameter and functional specifications about the system and lastly validate the model, with the real system and compare the model, and make conclusions [5],[11].
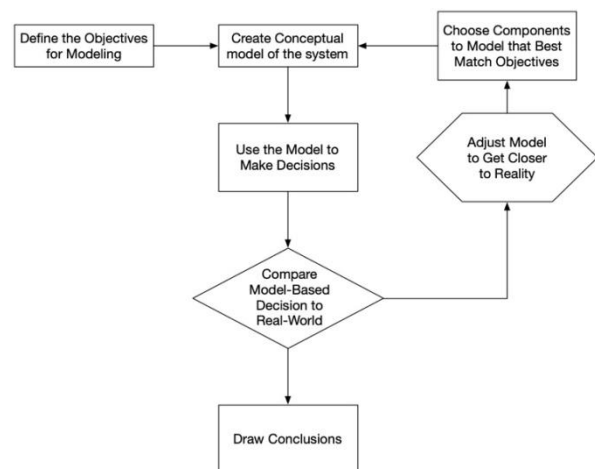

Figure 4: The Modeling Process [5],[11]

Step 10. Continuous Data Collection

For most of the modelers who are performing the simulation methods, it is essential to continuously monitor the data that is collected and should be used in the model accordingly, The first type of Data is **Event** type where it is the frequency of incident occurring over a period of time, the second type of Data is **Rate** where it is the frequency of incident expressed in a Ratio, the third type is **Interval** where it calculates the approximate number of times an incident occurs, the fourth type is **Duration** where it states the length of time the incident happens, and finally the fifth type is **latency** where it describes how long it takes for an event to start an incident once requested. All these five types of data are present in the system, and it's essential to monitor this data from time to time and does the modifications in the simulation accordingly [14],[15].

Step 11. Refining the Model with continuous Data Collection

This is a most critical process where refining of the model is significant according to that data collected, one has to verify the model and continuously update the model with the Data collection process, majority of percent in the simulation process take place at this step and has to be repeated for each significant alternate model that has developed considered in the study [5].

Step 12. Verification

Experimentation with the model should be conducted and test the model by simulation runs with the determine the data, the most crucial aspect in this step is considering the necessary variables that must be inputted in the model and eliminate the unnecessary variables from the system and once this is done now see how the model is behaving with the available data, walk through the logic developed in the model, and perform the input-output validation for the model so that necessary changes can be done for the model to predict as required [5],[11].

Step 13. Validation

Once the verification is done thoroughly, it is essential to compare the model with the actual system, with the help of gathered data it is essential to test the model with verification runs, it is also essential to understand the logic behind the model and what happens in the actual system and have to calibrate the model along with the Data gathered [7].
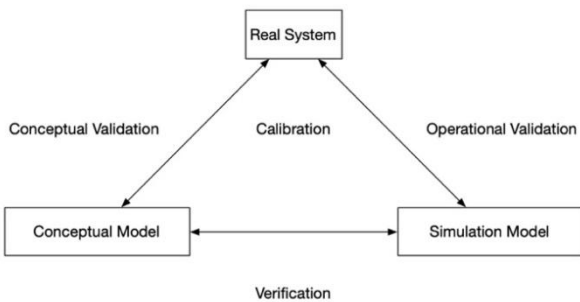

Figure 5: Validation and verification in Simulation [7]

Step 14. Design of Experiments or Experimental Design

Once the model is verified, validated and necessary calibration is done, it is essential to identify the significant variables which are essential for the system and eliminate the unimportant variables from the system, once this is done design of experiments (DOE) is conducted in detail, once the results are obtained, it is essential to identify the new paraments to be tested on the system and this cycle is continued till the best results are expected from the simulation [5],[11].

Step 15. Analyzing the Experiments and Production Runs

Once the complete analysis for DOE is done on the system, with the help of simulation software's like AutoMod, Tecnomatix Plant Simulation, Any-Logic, FlexSim, with the help of simulation make a pilot test, with the variable change one by one, it's easy to determine time for different scenarios, use the DOE and so the simulation runs and Analyzing the results and classify the causes and effects for the variables that are used in the input and the output and modify the inputs according to the Data that is gathered until the results reached the expectation, if additional runs are required it's crucial to design these experiments accordingly [5], [7].

Step 16. Results

The results obtained can be of bottleneck detection, optimization, reduction in setup times etc. the results phase is crucial because in the first step it helps in the identification of potential outcome from the problems, and once this is done these problems can be solved by giving the exact parameters so that the in-depth outcome analysis will be done and proposal for improvements can be carried out, and through checking of results will be done by varying the parameters and once everything is set out its essential to act on these solutions, the following figure 6 will help to understand the details of the results are being used to improve the system and this process continuous [16].
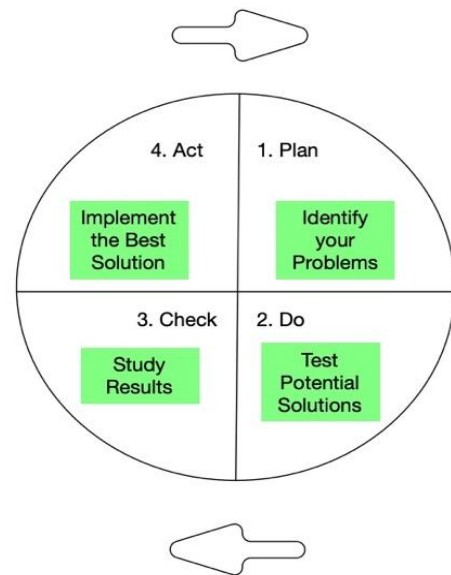

Figure 6: PDCA Cycle

Step 17. Optimization and Improvement

Once the results are set out, verifying them and changing the parameters according to the problem in the system is essential, computing the numerical estimates with the actual system for the desired performance measure for each system setup, and continuous monitoring of the system also helps for the optimization and improvement of the system is necessary [4].

Step 18. Documentation and Reporting

Documentation of the work plays a significant role in the simulation study where it is used for the long-term use of the models that are used for the simulation type where, the system, the functional specification of the system that is to be considered, problem definition and the objective of the problem Documentation of model input, the program for the model, and output all are documented for the present use and also useful for the future prospectus. The next important use of documenting and reporting is that discussion and explanation of model results are briefed in it so that if the model parameters change the output changes and this behavior is well described in the documentation, Relating the output values with the input values are also described in the documentation, final important information is the project is not repeated again and again and time is not wasted in un useful task because of documenting the previous work [5], [7].

Step 19. Implementation

The final and most crucial step in DES is implementing the work that is done to the real system so that the expected output can be achieved, and the success of the simulation depends on how all the previous steps have been performed. All the steps must be carefully conducted, and then a through trial and error procedure must be followed before the final implementation to the system [7].

Step 20. Calibration

The last and final step is essential because, once the implementation starts it's important to check the system from time to time about the performance, what has happened before implementation and what has changed after implementation and the behavior of the system should be monitored [4].

V. RESULT

Discrete Event Simulation (DES) has major impact in the complex systems of a manufacturing environment, the result here is the presentation of developed methodology for DES and explanation of methodology step-by-step with detailed description included, the work carried out here will be implemented in the future studies for the complex system analysis.

VI. CONCLUSION AND DISCUSSION

Simulation is the most crucial methodology but often forgotten in the industry, yet it benefits the manufacturing industry in achieving the accuracy and elimination of waste within the system, in order to apply simulation to a real-system many benchmarking methods need to be followed, and a lot of prior work needs to be carried out ever before modeling of the system, In this paper we described the methodology step-by-step for application of simulation to answer real-time system problems.

VII. FUTURE SCOPE

The work presented in this paper will be used in the future projects where there will be a need to implement DES in complex systems like Automotive manufacturing industry, and through the accomplishment of 2nd problem, the statement is not considered in this paper and would like to accomplish this in the further study.

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AUTHORS PROFILE

Mr. D. Phanindra Kshatra, working as Assistant Professor in the Department of Mechanical Engineering of Koneru Lakshmaiah Educational Foundation of Andhra Pradesh state in India. He has published many international journals in various reputed Journals. His area of interests is in Discrete Event Simulation, DES in Lean, Lean Flow, Kanban Systems, and Simulation methodologies. At present, his area of research is going on Discrete Event Simulation for Automobile Manufacturing.

Mr. P. Ratna Prasad, working as Assistant Professor in the Department of Mechanical Engineering of Koneru Lakshmaiah Educational Foundation of Andhra Pradesh state in India. He has published many international journals in various reputed Journals. His area of interests is Discrete Event Simulation, Robotics, Human Exoskeleton methodologies, Gait analysis. At present, his area of research is going on Applications of Simulation in Medical and Automobile Field.

S. Akhil is an IV Year, B-Tech Mechanical Engineering Student at Koneru Lakshmaiah Educational Foundation, Vaddeswaram, Guntur (DT)

B.L.N.S.S. Charan Raghavendra is an IV Year, B-Tech Mechanical Engineering Student at Koneru Lakshmaiah Educational Foundation, Vaddeswaram, Guntur (DT)

S.V.S. Prakash is an IV Year, B-Tech Mechanical Engineering Student at Koneru Lakshmaiah Educational Foundation, Vaddeswaram, Guntur (DT)