World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:6, No:4, 2012

The Role of Object Oriented Simulation Modeling in Maintenance Processes

Abdulsalam A. Al-Sudairi

***Abstract*—**Object-oriented simulation is considered one of the most sophisticated techniques that has been widely used in planning, designing, executing and maintaining construction projects. This technique enables the modeler to focus on objects which is extremely important for thorough understanding of a system. Thus, identifying an object is an essential point of building a successful simulation model. In a maintenance process an object is a maintenance work order (MWO). This study demonstrates a maintenance simulation model for the building maintenance division of Saudi Consolidated Electric Company (SCECO) in Dammam, Saudi Arabia. The model focused on both types of maintenance processes namely: (1) preventive maintenance (PM) and (2) corrective maintenance (CM). It is apparent from the findings that object-oriented simulation is a good diagnostic and experimental tool. This is because problems, limitations, bottlenecks and so forth are easily identified. These features are very difficult to obtain when using other tools.

***Keywords*—**Object oriented, simulation, maintenance, process, work orders

I. Introduction

FOCUSING on processes and improving them has led to great benefits in terms of cost and time reduction and adding value to the customer. Many researchers used different tools and techniques in improving processes. This study argues that object-oriented simulation is one of the sophisticated tools that can be used for analysis and evaluation. To demonstrate the potentiality of simulation, a maintenance system for Saudi Consolidated Electric Company (SCECO), a leading company in Saudi Arabia, was selected as a case study. The maintenance division of SCECO is responsible for maintaining all administrative buildings, which consist of 30 buildings of different sizes and functions, and about 2000 employees are daily working in these buildings. An object-oriented program is considered so if it supports three concepts: (1) objects, (2) classes and (3) inheritance. An *object* is the basic component of the object-oriented program. Each object is characterized by its own set of attributes and by a set of operations that it can perform [1]. A *class* is a set of objects that share a common conceptual basis. All objects in a given class have matching attributes and operations. *Inheritance* is a technique for using existing definitions as the basis for new definitions. That is, inheritance means that if one define a new object type (sometimes called a *child*) in terms of an existing object type (the *parent*), then the *child* type inherits all the characteristics of the *parent* type [2]. In addition to the three concepts offered in object-oriented program, it is believed that this technique best suits the nature of maintenance processes due to uncertainty associated with them. Uncertainty may arise due to the arrival of a maintenance job request, the maintenance job content, the time to complete the job as well as the availability of equipment and spare parts [3].

Professor, College of Architecture & Planning, University of Dammam, P. O. Box: 2397, Dammam 31451, Saudi Arabia, Email: aalsudairi@ud.edu.sa.

Also, the flexibility and accuracy inhered in today's simulation packages are another reason that justifies the use of such a tool.

II. The Maintenance Simulation Models

Field surveys and interviews aimed at collecting data necessary for building two types of models: static and dynamic models. Static model, on one hand, is a two dimensional representation of the process by mapping it using flow chart techniques. A flow chart will show the logic, the activities and the decisions involved in performing maintenance work orders.

Out of the 60 employees working at the maintenance division, 23 were interviewed. Selection of interviewees was based on their: 1) occupation and participation in the process, 2) experience and knowledge of the process (5 years of work experience is the minimum). Foremen and craftsmen constitute the majority because they are more involved in the maintenance process.

Figure (1) shows the interrelationship between PM and CM processes and the minor processes underneath them. For example under the PM process there are prepared batches of work orders and material acquisition sub-processes. For micro maintenance process maps, readers are advised to refer to reference [4].

PM work orders are generated in batches once a week. The PM engineer prepares the weekly batch, allocates work orders according to each maintenance unit, and submits work orders to each unit whereby they go through the normal PM process. There are five maintenance units under the Head Quarter of Maintenance Division. Each unit is responsible for operating a certain type of service. Under each unit there are several workshops that differ in size from one unit to another. In this study only units that are related to building maintenance are included. The selected units are: (1) Electrical Repair Unit (ERU), (2) Air Condition Repair Unit (ACRU), and (3) Facility Maintenance Unit (FMU).

The PM work orders are either closed after completion or transferred to the CM process. That is, the PM work orders are already planned and scheduled in the maintenance system. On the other hand, CM work orders enter the maintenance system by a request of a technician or a complaint from a customer. During the routine check, a technician who is performing PM work order can't continue the job because it requires major repairs. Thus, this PM work order will be converted into a CM work order or, in many cases, a CM dispatcher receives a complaint from a customer. This complaint will enter the maintenance system as a CM work order.

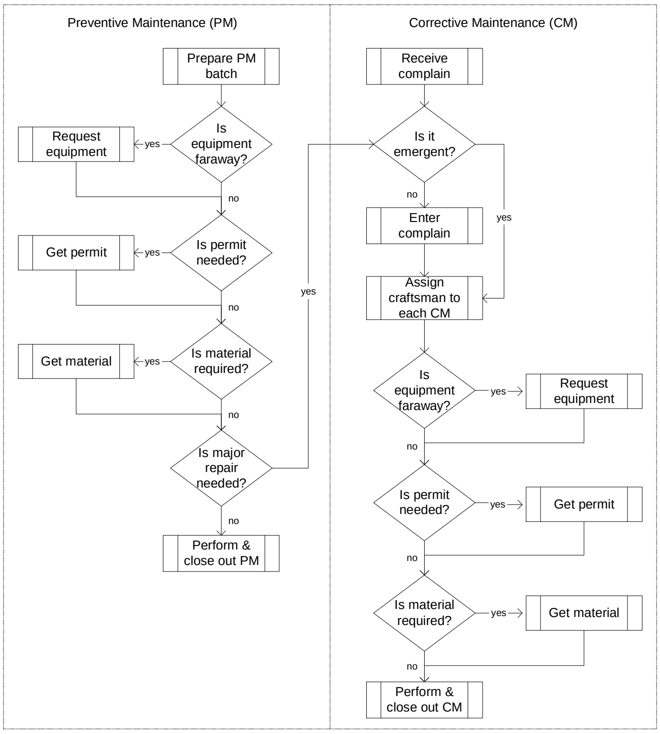
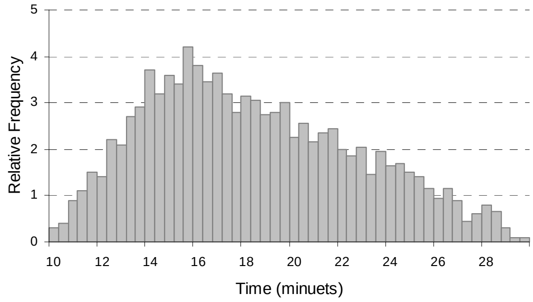
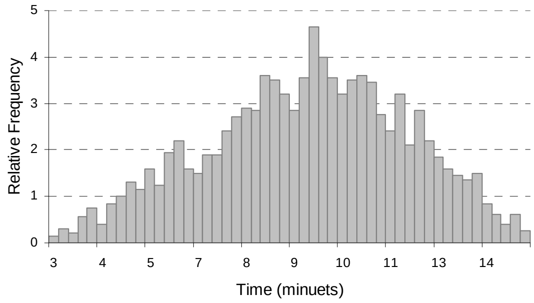


Fig. 1 a macro process map for both preventive and corrective maintenance processes



(a) PM Activity: *Get Equipment* distribution



(b) CM Activity: *Enter Complaint* distribution

Fig. 2 Two examples of activities' time distributions in both PM and CM processes

After having the logic of process flow diagram completed, it is time to determine quantitative data related to each activity and decision. Measuring activities' durations is one of the critical inputs to the validity of simulation models. The activities' duration were estimated by experts who were asked to give three times (most likely, maximum, and minimum) for each activity. The three time estimates were entered for each activity in the simulation model. Figure 2 (a & b) shows an example of one PM activity and another CM activity in which Extend+BPR, which is the simulation package used in this study, converts such estimates into distributions. The same procedure was done for all activities. According to Cassady *et al.* probability distributions of activities in simulation models ensure a more realistic portrayal of real systems [5].

Another important piece of information is the percentage of occurrence of the decisions associated with both maintenance processes as shown in figure 1. For instance, a work permit is required whenever a WO is associated with hazardous equipment/material or it is located in a restricted area. To quantify this information, previous WOs for 52 weeks were surveyed to identify WOs that needed permits where one can then calculate their percentage of occurrence. This method of quantifying decisions is the one most used by several researchers [6 and 7].

With respect to maintenance work orders, it is also important to know whether they are preventive or corrective and to what maintenance unit they belong to. Figure 3 summarizes the classification and frequency of maintenance WO for 52 weeks which indicates that most work orders are handled by ACRU (45% of PM WO) while FMU got the least (14% of PM WO). These percentages are useful in simulating the flow and type of WO. To model maintenance processes, data collected in previous steps requires transfer into simulation notation. For this study, Extend+BPR was selected as the simulation modeling package because of its flexibility and adaptability in modeling lengthy complex processes [8].

Fig. 3 Average weekly percentages with respect to type and frequency for both types of WOs

Objects vary according to the system they belong to. In the model presented in this study, the object is a maintenance work order whether preventive or corrective and their classes as in figure (3). Thus, the simulation models created for this study are designed to examine the flow of maintenance work orders for both PM and CM. This feature of object-oriented simulation packages allow the determination of how long each WO stays in a process that includes both processing time and waiting time. In doing so, one can accurately determine process efficiency.

Figure 4 shows a small portion of the maintenance model that was built on Extend+BPR. The most important part of any Extend+BPR model are the blocks, the libraries where blocks are stored, the dialogs associated with each block, the connectors on each block, and the connections between blocks (Krahl 2002). A block specifies an action or process; it is used to represent an activity, an event or a function of a model. Some blocks may simply represent sources of information. Others may modify information as it passes through them. In other words, a block is a high-level modeling element accompanied with window that allows a modeler to enter specific data and identify certain parameters (Hansen 1997). Information comes into the block and is processed by the program that is embodied in the block. The block then transmits information out of the block to the next block in the simulation.

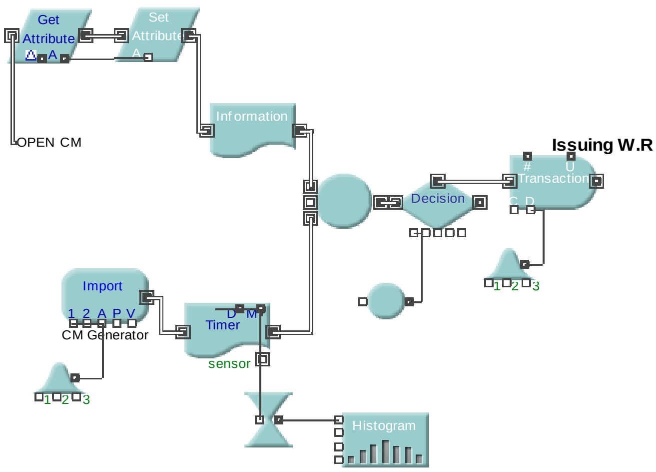


Fig. 4 Portion of the maintenance simulation model that mimics issuance of CM WO

Verifying and validating the models of this study went through two steps. First, several interviews with maintenance practitioners and experts were conducted to ensure the correctness of the logic of the models. Second, a comparison of the model outcomes and the data gathered from both processes on site was made as shown in table 1 to ensure the validity of the model. Table 1 shows two sets of data, actual and empirical, for the total cycle time to close out one work order of either PM or CM and the number of completed work orders per week. Notice how close the two sets of data which proves that the simulation models are valid and ready for evaluation. The verified-validated traditional model was used as a reference point to measure the performance of the studied processes in terms of cycle time and crew utilization.

TABLE I
COMPARING THE OUTCOMES OF THE SIMULATION MODEL WITH THE ACTUAL DATA

	Cycle Time (hours)		**Throughput (WO/week)**	
	Actual	**Empirical**	**Actual**	**Empirical**
PM	16	15	110	115
CM	22	20	80	76

III. FINDINGS AND DISCUSSIONS

From figure 5 one may notice that crew utilization in the maintenance process is very low. It is as low as 34% in facility maintenance unit (FMU). Being specific and detailed in terms of measuring a system is one of the significant advantages of object-oriented modeling. That is object-oriented modeling provided crew utilization with respect to the different types of maintenance units.

The low crew utilization may be caused by the fact that work orders have to go through long paper work before they get assigned to a specific maintenance unit. Once these work orders reach their units, the superintendent checks the availability of his craftsmen who may be busy in other work orders, which means that most of the crew time was spent on non-value adding activities. This necessitates a responsive and adaptable system that can meet most maintenance work orders. One way is to provide more skilled technicians that can handle most maintenance services. By doing so, maintenance processes will be more flexible; being flexible is one of the major indicators of proactive management [9].

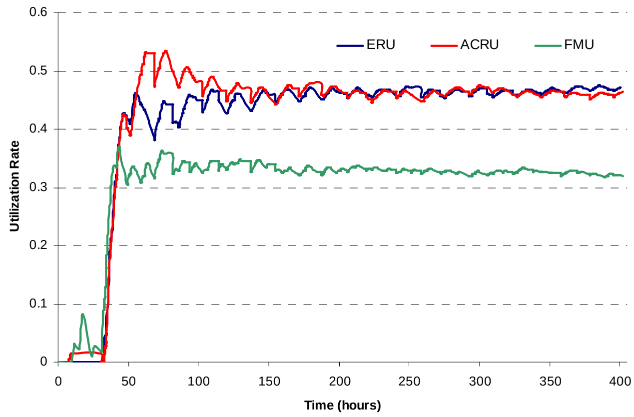
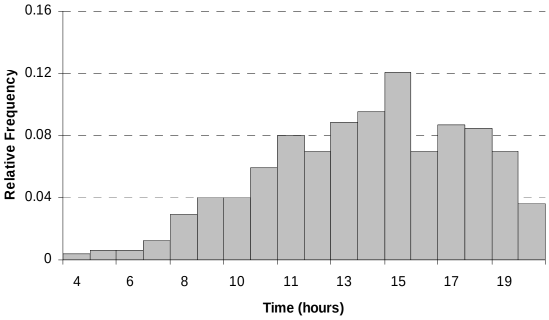
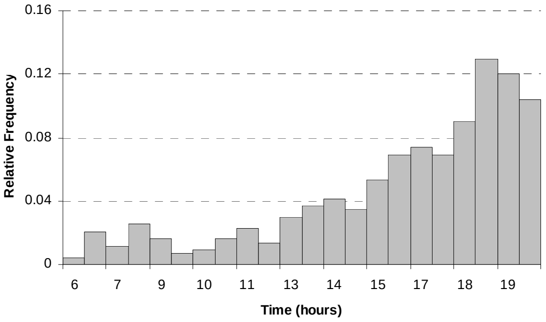


Fig. 5 The different technician utilization rates in the traditional maintenance model

Figures (6) (a, b) presents cycle time distribution of work orders for both PM and CM processes. The work orders take longer to be completed where it takes an average of 15 hours. Besides the long time of WO, one may notice the huge variability in both distributions. There is a 16-hour difference in the preventive maintenance process, which is almost the same in the corrective maintenance process. The huge variability indicates a weakness in the existing process. In fact, Narayan (1998) concluded that process variability is a major source of cost increase [10].



(a) PM cycle time distribution



(b) CM cycle time distribution

Fig. 6 Cycle time distribution for 2000 runs of the maintenance process

Understanding a process is a key principle in improvement programs. Inefficiencies and their sources are manifested more when management has a clear picture of its process, that is; non-value-adding activities, queues and decisions and their paths and low crew utilization are easily identified and measured using object-oriented modeling. Improving the efficacy of the studied processes were beyond the scope of this study.

IV. Conclusion

This study advocates the use of object-oriented simulation modeling as an essential tool for analyzing and evaluating maintenance processes. The maintenance process presented in this study is very difficult to analyze with traditional tools. Indeed, simulation is a superior tool due its numerous advantages as being dynamic, beneficial through all project phases, and enabler of a system approach.

Identifying objects and system that governs them is very critical in simulating maintenance processes using object-oriented modeling tools. The complicated case study presented in this study was easily evaluated using this tool. One may argue that modeling with simulation takes time and effort and very difficult to verify and validate. This is truly a misconception about simulation because object-oriented models do not need sophisticated programming background, easy to construct, and flexible to change.

Acknowledgment

The author would like to express his thanks and appreciations to Professor Omar M. Al-Amro Al-Akloby for the time and support in editing this paper.

References

[1] McGregor, J. and Sykes, D. (1992). Object-Oriented Software Development: Engineering Software Reuse. International Thomson Computers Press, Boston, MA, USA.
[2] Law, A. and Kelton, D. (2000). Simulation Modeling and Analysis. 3rd Edition, McGrrow-Hill, Boston, USA.
[3] Mjema, E. (2002). An Analysis of Personnel Capacity Requirement in the Maintenance Department by Using a Simulation Method. Journal of Quality in Maintenance Engineering, Vol. 8, No. 3, pp. 253-273.
[4] Al-Sudairi, A. (2010). Lean Management Models for Facility Maintenance. University of Dammam, Deanship for Scientific Research, Report # 91009.
[5] Cassady C., Pohl, E. and Murdock, W. (2001). Selective Maintenance Modeling for Industrial Systems. Journal of Quality in Maintenance Eng., Vol. 7, No. 2, pp. 104-117.
[6] Hansen, G. (1997). Automating Business Process Reengineering: Using the Power of Visual Simulation Strategies to Improve Performance and Profit, Prentice Hall PTR, New Jersey, USA.
[7] Laguna, M. and Marklund, J. (2005). Business Process Modeling, Simulation and Design. Prentice Hall, Upper Saddle River, New Jersey, USA.
[8] Krahl, D. (2002). The Extend Simulation Environment. Proceedings of the 2002 Winter Simulation Conference, pp. 205-213.
[9] Organ, M., Whitehead, T. and Evans, M. (1997). Availability-Based Maintenance within an Asset Management Program. Journal of Quality in Maintenance Eng., Vol. 3, No. 4, pp. 221-232.
[10] Narayan, V. (1998). The Raison *D'etre* of Maintenance. Journal of Quality in Maintenance Engineering, Vol. 4, No. 1, pp. 38-50.

Abdulsalam A. Al-Sudairi was born in Dammam Saudi Arabia. He obtained his bachelor degree in Architecture and Planning in 1989 from King Faisal University. He was appointed as demonstrator in 1990 in the same University he graduated from, which is known now as Dammam University. He finished his master degree in 1993 from the same university and was promoted as lecturer in 1994. He earned his Ph. D. of Architectural Engineering from University of Colorado, Boulder, USA in September 2000. He was promoted as assistant professor in November 2000. In 2006 he was promoted to the rank of associate professor. He was the head of Interior Design Department from 2005 to 2006. Dr. Al-Sudairi was appointed as Vice Dean for Academic Affairs from 2007 to 2006. In January 2011 he was appointed Dean of College of Architecture and Planning and in June 2011 he was promoted to the rank of Full Professor. He published various articles in several peer reviewed international, regional and local journals. He is a reviewer for several journals. He is actively participating in teaching of undergraduate and graduate courses. He supervised several master dissertations and examined some since he joined the college of Architecture and Planning. He is currently involved as a member and head of various committees in the college and the university. He is actively participating in scientific conferences as a speaker, chairing sessions and organizer both internationally and locally. Currently he is the Dean of College of Architecture and Planning University of Dammam, Saudi Arabia.