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Improvement of medical device's maintenance System through simulation- A case study in Jordan

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Abstract: Medical devices utilization has been major points of interest for many hospitals due to their direct impact on performance and patient safety. Achieving the highest possible utilization will improve the performance and patient safety. There are many variables that affect the performance of hospital staff and medical devices maintenance schedule is one of them. In this paper a simulation method was implemented to improve the maintenance processes of medical devices. To demonstrate the implementation process a hospital in Jordan was used as a case study.

Key words: Medical Devices Maintenance System (MDMS); Medical Devices Maintenance Department (MDMD); Queen Alia Military Hospital (QAMH).

Introduction

Medical devices maintenance is an integral aspect of an efficient health system. Preventive maintenance policies have been studied for decades. These policies consider the timing of two types of maintenances: preventive maintenance and corrective maintenances. Corrective maintenance is more costly and time intensive than preventive maintenance, but only occurs when a machine fails. A good preventive maintenance policy considers the trade-offs between more frequent preventive maintenances and the more expensive corrective maintenances [1].

The medical industry is becoming quite complex with a huge capital investment being incurred on process automation to enhance the reliability of system. Invariably, the proper maintenance of such systems and the frequency of maintenance are some of the issues that are gaining importance in industry [2].

A hospital is an integrated complex system comprising of various system: logistics, health care delivery system and maintenance systems like MDMS.

The production suffers due to failure of any intermediate system even for small interval of time. The cause of failure may be due to system complexity, poor design or maintenance, defective planning or lack of expertise.

Thus, to run a process plant highly skilled experienced maintenance personnel are required. For efficient functioning, it is essential that various systems of the plant remain in upstate as far as possible. However, during operation they are liable to fail in a random fashion.

The failed subsystem can however be inducted back into service after repairs/replacements. The rate of failure of the subsystems in the particular system depends upon the operating conditions and repair policies used.

Newer technological developments have enabled the use of simulation models to test the performance of the Medical Devices Maintenance System (MDMS).

A simulation analysis of the system under given operative conditions is helpful in forecasting the device behavior which further helps in design to

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achieve minimum failure in the system i.e. to optimize the system working.

The construction and the validation of the simulation model presented in this paper are based on expert knowledge and statistical data on medical devices work orders.

The effectiveness of MDMS is mainly influenced by the availability, reliability and maintainability of the plant. The present paper provides an Arena simulation model for MDMS in Queen Alia Military Hospital (QAMH) to analyze system performance and to achieve the maximum availability.

Literature review

The simulation studies for the staff planning and measurement of service efficiency have presented in production systems, health service systems, shopping centers, education and finance facilities, traffic systems etc. in service systems [2] .

Duffuaa et al. [3] have devised a conceptual model for repair and maintenance systems which is based upon the concept of simulation and facilitates operations of the repair and maintenance systems.

Arya et al. [3] in identifying the probability distribution of the repair time concluded that the average timing failure, average outage duration, and average annual downtime are the basic indices whose distribution function is exponential. This leads to justification for assuming constant failure rates and repair rates for each distributor segment. In effect, they suggest analytical methods for a reliable evaluation of a distribution network. Since repair time is much larger than failure times, approximate relations are expensed for obtaining reliability indices of series parallel systems. Average reliability indices are evaluated via analytical techniques, whereas simulation techniques are employed to generate the distribution of these indices.

Prasertrungruang and Hadikusumo [3] have also introduced a model for identifying significant factors affecting the repair time by exerting the simulation.

Kaufman and Lewis [1] examine M/G/1 single-machine systems where process time may increase as the machine deteriorates. The machine deteriorates one state at a time in random time intervals. Two models are evaluated: repair and replacement. The repair model has random repair times with a positive mean. The replacement model has an instantaneous repair time. It is shown that the optimal policy is monotone in the machine state. However, the optimal policy is not necessarily monotone in the WIP level.

Some research has been presented for staff planning with alternative structures of simulation models and performance measures [4]. In maintenance engineering, a simulation model has been developed by using Arena for MDMS to improve medical devices reliability and availability.

The historical roots of simulation for the practice of skills, problem solving, and judgment are evident. Medical simulation in primitive forms has also been practiced for centuries; Physical models of anatomy and disease were constructed long before the advent of modern plastic or computers.

Medical education evolved during the 1900s from a simple apprenticeship to incorporating the learning of scientific principles. The introduction of human patient simulation toward the end of the 20th century was a major step in the evolution of health sciences education [2].

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About preventive maintenance, a study at a distribution warehouse has been presented for a conveyor system. The integrating predictive maintenance strategies with production planning strategies have been used to reduce of downtime for the management of device breakdown and failure conditions by simulation with Arena. For instance, the downtime was reduced more than 50 % and work in process inventory was reduced more than 65 % [5].

Hence, for successful implementation of any simulation project, it is particularly important to have a right approach to the requirement collection and the experimentation phases. This paper intends to provide an integrated framework for those two phases in a simulation project.

The Case Study: Analysis of MDMS in QAMH by Simulation

The purpose of this study is to Use simulation modeling to study the maintenance activity of QAMH. We use the arena module to capture the operation of the system at an appropriate level of detail. We will establish alternative scenarios to enhance the efficiency of the MDMS .

3.1 The Arena Model of Maintenance Process in QAMH

The Arena model of maintenance process workflow for a MDMS in QAMH is presented. We categorized the medical devices maintenance process in 13 steps as follows:

Step 1: Three Create module as a part arrival ,they characterize the type if maintenance need in " Lab ,Field or Contract" . The input for this module is the service order from Hospital or Clinical center "it is start time for maintenance".

Step 2 : Three Assign modules and we defined an attribute arrive Time , which is used to record the arrival time of the device .

Step 3: Three Process modules to represent where the repair is made (it is the time for starting the maintenance process).

Step 4 : The decide module to specify whether if the maintenance process is needed or not.

Step 5: The process module represents the time needed for purchase and logistic department to deliver the spare part needed.

Step 6: The process module represents the time needed to probability to repair the device.

Step 7:The decide module represents the decision between the completion of repairing or the need to be set the device as scrapped.

Step 8: The process module represents the quality control and assurance.

Step9: Process module for store stage.

Step 10 and 10 : Tow decide modules to type of maintained device (Lab ,Field or Contract).

Step 12: four Record modules to record statistical information for cycle time separated by Lab ,Field or Contract, Scrap.

Step 13: four Dispose modules.

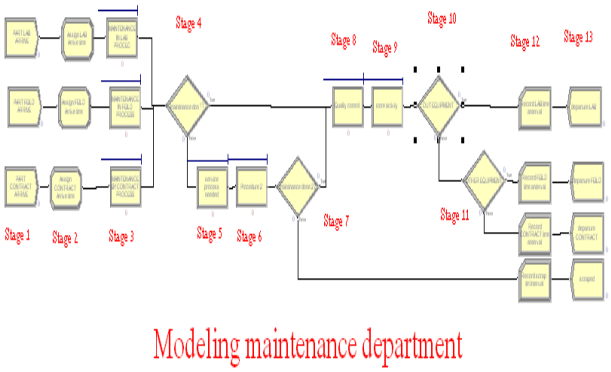

Figure1:The Workflow Diagram for MDMS

3.2 Initial and Alternative Staff Structures in MDMS

Three different scenarios are developed and evaluated for customer requirements. The entities are classified in two classes which are field , lab and contracted failed medical devices.

Regarding the lab failed medical devices, we collected data over two years (1/1/2009-31/12/2010). The percentages of arrivals to the system have an exponential distribution with parameters of 12 and 1 days for lab failed medical devices respectively . The percentages of inter arrivals to the system have a Lognormal distribution and its expression:3.2+LOGN (4.20,1.11) .

Process times are determined in two different ways. The arrival time of work orders from the field and lab are determined from a historical data of Medical Devices Maintenance Department (MDMD) in QAMH. The other process times are determined from brainstorming and interviewing the expertise of MDMD in QAMH. The Process distribution was found to be Gamma type with Expression 0.001+GAMM (2.41,1.52).

Regarding the Field failed medical devices, we collected data over two years (1/1/2009-31/12/2010). The percentages of arrivals to the system have an exponential distribution with parameters of 11 and 2 days for Field failed medical devices respectively . The percentages of inter arrivals to the system have a Lognormal distribution and its expression:-12+LOGN (13.0,1.51) . The Process distribution was found to be Weibul type with Expression - 0.001+WEIB(5.66, 0.664).

Regarding the Contracted failed medical devices, we collected data over two years (1/1/2009-31/12/2010). The percentages of inter arrivals to the system have is Beta distribution and it is Expression : -0.5+BETA(0.610,6.49)for Field failed medical devices. The Process distribution was found to be Weibul type with Expression - 0.001 + WEIB(8.48, 0.490).

Experimental Results

The initial model is simulated and then the alternative scenarios are developed to find the better enhancement of productivity. The results are evaluated to reduce waiting times in queues.

The simulation models answered the questions that arisen in the beginning of the study. The all results of the simulation are illustrated in the following Figures (2-7). The simulation results showed that some improvements are necessary to have better efficiency of the medical Devices need service, number of medical devices need to be repaired and The time needed to repair

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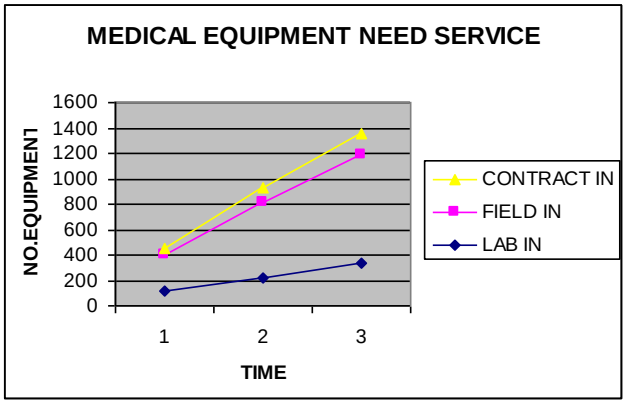

Figure2:Medical Devices needing service versus number of devices

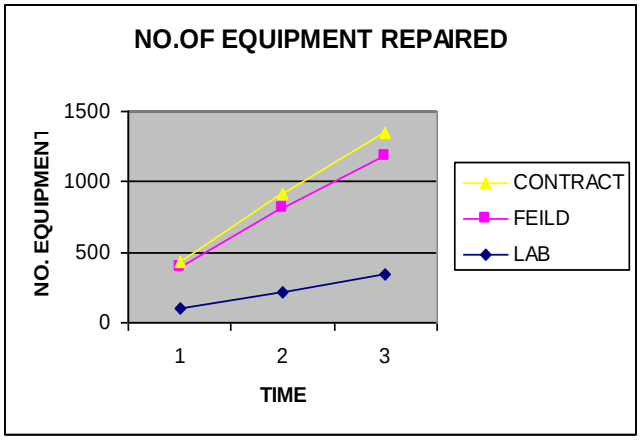

Figure 3: versus number of devices.

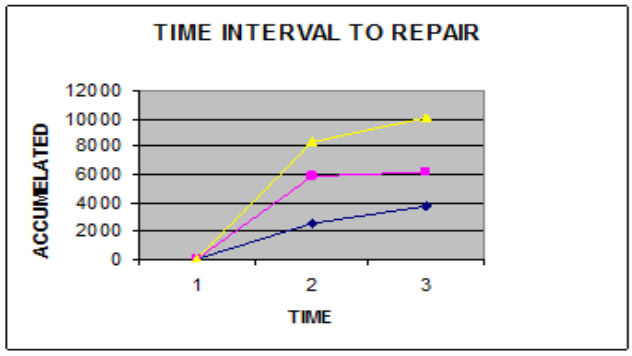

Figure 4: The time needed to repair versus accumulated time

Summary and Conclusion

The simulation models provide some opportunities to analyze the current situation of systems for improving system parameters with the performance measures. Some scenarios are analyzed before purchases of expensive devices. Therefore, the better organizational structures are designed for the systems with many organizational goals as higher level of customer satisfaction.

A maintenance unit of QAMH in Jordan is investigated with initial model and alternative models for evaluating the medical Devices need service, number of medical devices need to be repaired and The time needed to repair.

The results are discussed with the management of QAMH. This study has noticed them to start works on a new organizational development process.

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