Performance Measures for Improvement of Maintenance Effectiveness

A Case Study in King Abdullah University Hospital (KAUH)

Khalid R. Al-Momani[1], Mohammad D. Al-Tahat[2], Enas T. Jaradat[3]

[1]Operations and Maintenance Department, King Abdullah University Hospital, P.O. Box 630001, Irbid 22110 – Jordan. Tel: + 962 2 7200600. E-mail: (momanki@just.edu.jo)
[2]Industrial Engineering Department, University of Jordan, Amman. [3]King Abdullah University Hospital.

ABSTRACT

This study was conducted in order to assess the needs of performance measures improvement of the health care services; it involved the radiology department at King Abdullah University Hospital (KAUH) in Jordan. Usefulness of the mean time between failures (*MTBF*), the mean time to repair (*MTTR*) and availability (*A*) of the equipments and the underlying types of information required for the improvement of the maintenance system provide guidance to biomedical engineers or maintenance managers endeavoring to develop strategy for maintaining subunits**.** The results show that despite the general increase in availability (*A*) of equipments, still there is a considerable mean time to repair (*MTTR*) of the equipments from the registered failure day, this (MTTR) varies according to the type of equipment and its complexity. There are many advantages of such analysis.

Keywords: Performance measures, Maintenance, Mean time between failure, Mean time to repair, availability, system effectiveness

1. INTRODUCTION

ONE of the most important constituents of the maintenance system in any organization is the performance measures and evaluation processes of maintenance system, maintenance which is the group of activities that aims to protect equipments, machines, programs or reordering it in the acceptable situation that helps to achieve targets [1], this process will improve the maintenance system from the aspects of control, management, availability (*A*) which could be defined as the probability that a system will operate at any specified instant of time[3], efficiency, quality, productivity. In this paper we concentrate on the definitions and basic concepts of the maintenance performance measures process. As well as explain the need for such a process and the advantages achieved when having a reliable performance measures system. We also search in the characteristics of the system and the different divisions and classifications and the level of compatibility and achievement of the required issued. The radiology department had been taken as a case study when evaluating the availability (*A*) of the equipments, the need of comparing our results with the measure that supposed to be the best is arises, and this is as a trial from us to improve the performance measures system.

What can be measured can be achieved, this is the main idea the performance measure and evaluation system is build on. Performance measures process is an important management quantitative tool that reflects the level of good performance in an organization as a digital form [1]; this helps to specify the effectiveness and efficiency of the work done. The performance measures process aims to improve the performance measure and understanding management in more deep and wide range.

1.1 Importance of performing the performance measuring process:

If some activity can not measure, then we can not take control over it, which leads to loss of management, so it is important that we should have some measures that we depend on. The performance measures process is not used only to collect the information concerning some measures but think about it as a whole management system which

1-4244-0451-7/06/$20.00©2006 IEEE

includes discovering of failure location and avoid aggregation of them.

The following list of performance measures metrics will be employed to assess progress in reaching the strategic objectives listed above.

1- To what level the performance is improved?
2- Did the goals had been achieved.
3- Does the operation is controlled from the industrial quality side.
4- The locations that need improvement.
5- To what limit the customer needs are satisfied?
6- Provide standards that help to hold comparisons.
7- Finding the location that need specific concerning.
8- Make sure that the decisions taken were built on truths not feelings.
9- Find out the problems covered by feelings.

From the previous it could be said that the performance measures process is used in maintenance to provide the necessary information that helps in taking decisions about what must be do.

This process was used to improve out ability to learn from mistakes skilful investigation of accidents and the responsible sharing of data that will help to identify the root cause of errors.

Points that should be found in performance measures process:

1- Usage of two measures at least, one may be misleading.
2- The whole system should participate in all its levels and people responsible of choosing between and building measures must agree on validity of these measures before starting using them.

TABLE I: TIME MEASURES AND THEIR SIGNIFICANCE [1]

	Measure	Significance
MDT	Mean down time	-Total measure of effective of maintenance -Availability of maintenance -The quality of preventive maintenance
MTBF	Mean time between failure	-Reliability of equipment -Compatibility of planned maintenance -Quality of maintenance works
MTTR	Mean time to repair	-Efficiency of maintenance team -Quality of equipment design
MPT	Mean preventive	-Compatibility and quality of preventive maintenance

1.2 Classification of performance measures in maintenance

Performance measures can be classified:

According to the levels and concepts as follows:

1- Individual performance measures.
2- Performance measures systems.
3- Relationship between performance measures systems and their surrounding environment, performance measures can be classified in different ways according to the interested field .It could be internal or external, financial or non financial, diagnostic or strategic, the type of decisions and procedures inside the organization define the used strategy, so performance measures can not be considered as a tool to provide us with information for control part but as an incite tool to decision leading.

According to a specific standard or criterion:

1- Performance measures that related to equipment performance such as : total effectivity, availability and reliability.
2- Performance measures related to cost such as the cost of operation and maintenance cost of work and cost of used materials,
3- Performance measures concerning the process it self such as the percentage between the planned work to the unplanned work.

According to measured factors:

1- Time:

Table I illustrates some of the time measures and their significance that had been used in the performance measures process.

2- Materials: such as the mean stock out time.

3- Costs: such as the percentage between total maintenance costs to the equipment cost which depends on the equipment state and the need to change by new equipment and another measure is the total materials cost to the total cost.

Performance measures as an important rule in the feedback chain that is used to achieve goals and criteria that are responsible for activity management, by answering the following questions

1- What should be done?
2- What is done?
3- When to take on corrective maintenance.
4- When to change the used goals and.

Our objective is to know at any given instant of time the availability (A) of each sub-system in the overall system under study and the effect of availability and other system parameters on the overall effectiveness of the system.

2. PROCEDURE

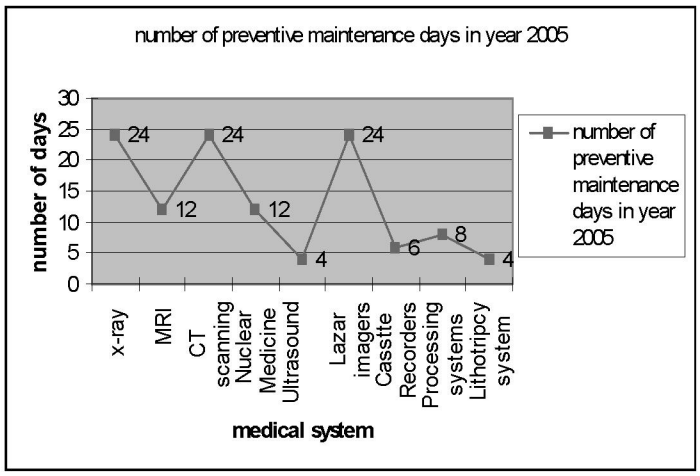

Fig. 1. Preventive maintenance schedule in year 2005.

The radiology department system contains (10) medical sub-systems. The System is divided into the following sub-systems:

- X-ray system: this system contains (4) general x-ray equipments and (3) fluoroscopy equipments and mammography equipment.
- Magnetic Resonance Imaging (MRI) system.
- Computerized Tomography (CT) scanning system, this system contains (2) different models of CT scanning equipments.
- Nuclear medicine system: this system contains equipment with a single head gamma camera and equipment with a double head gamma camera.
- Ultrasound system: this system contains ultrasound equipment.
- Lazar imager system: this system contains one wet lazar imager and two dry lazar imagers.
- Two Cassette recorders.
- Processing system: this system contains (2) types of processors one of them is mammography processor.
- Lithotripter system contains lithotripter equipment.

The basic assumption is that all the sub-systems are independent and the failure of one does not affect the failure of the other sub-systems.

2.2 Maintenance Information Stream:

- Collection of information about failures and costs for which data have been obtained from acquired divisions as well as the corporate officers, services repots, and return back to the history card of each equipment.
- Analysis of this information about Mean Time Between Failure (*MTBF*) which is defined as ,for a particular interval ,the total functioning life of a population of an item, divided by the total number of failure within the population during the measurement interval ,this definition holds for time ,cycles ,kilometers or other measures of life units [3] ,Mean Time To Repair *(MTTR),* Availability (*A*), and the costs maintenance.
- Putting the best maintenance program
- Recording and registration of the standard changes that would happen during the life time of the equipment.

The above procedure helps us to:

1- Evaluate and analyze the needed data for maintenance management and reordering of the spare parts.
2- Following history cards of the equipment
3- Renewing of maintenance procedures and preparing for overhaul repair.
4- Renewing of equipments.

The Performance measures that were used to compare the performance of the medical systems in the radiology department and the availability (*A*) of these equipments gave quantitative measures relative to the evaluation period with precedence and maintenance constraints. As a result a project was developed for the evaluation techniques presenting in deciding which of the many available scheduling for maintenance type is appropriate in lowering the costs of maintenance. There are two types of maintenance works in (KAUH):

1- Critical maintenance; those works are rare and must be done immediately and there is no time to plan for them, so it is under maintenance time plan.
2- Routine maintenance, corrective maintenance, preventive maintenance and predictive maintenance is under the organization plan. Those works are under the uncompleted work register, and are programmed when workers are available with the needed materials.

Table II shows the corrective maintenance plan in year 2005 and it illustrates the breakdown percentages of the equipments under corrective maintenance and the type of repair of the medical system, these percentages differ due to the different types of equipments and its complexity. It was obvious that the nuclear medicine system had the highest percentage of (43 %) of critical repairs. Fig.1 shows the preventive maintenance schedule in full year 2005, the ultrasound and lithotripters systems had the lowest percentage of preventive maintenance works with (4) day per year. The CT scanning system, lazar imagers, and the x-ray

systems had the highest percentage of preventive maintenance days with (24) day in year 2005.Fig.3 shows the mean preventive maintenance time (*MPT*) in year 2005.

The availability (*A*) is a measure of the system condition at the startup of a mission and is a function of the relationship between hardware, personnel and procedures [3].The (*A*) of each sub-system was calculated as seen in Fig.2. It is obvious that the overall system will perform, even if one of the sub-systems fails, although the failure of one of them will have some effects on the overall effectiveness of the system success.

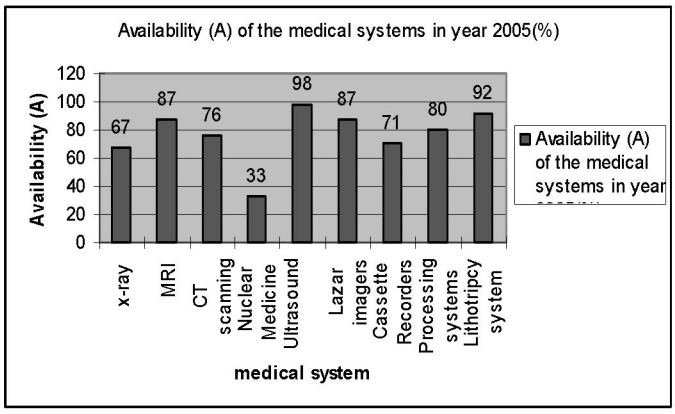

Fig. 2. Availability (A) of medical systems in year 2005.

Fig.2 above shows the availability (*A*) percentages of each of the medical sub-systems in year 2005; it was obvious that the complexity of the medical system play an important in the variations in the repair period which consequently affect the availability (*A*) of the equipments. The ultrasound and lithotripters systems had the highest percentage of availability with (98%) while the nuclear medicine system is the less available system with availability percentage of (33%).

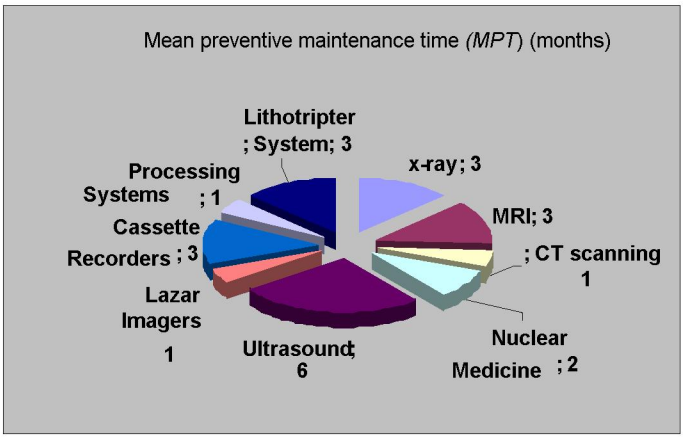

TABLE II: CORRECTIVE MAINTENANCE PLANNING

Medical system	Type of Repair	Percentage of equipments under corrective maintenance (%)
x-ray	Critical	23
	medium	12
	small	65
MRI	Critical	3
	medium	10
	small	87
CT scanning	Critical	0
	medium	3
	small	97
Nuclear medicine	Critical	43
	medium	12
	small	45
Ultrasound	Critical	1
	medium	6
	small	93
Lazar Imagers	Critical	1
	medium	3
	small	96
Cassette Recorders	Critical	4
	medium	2
	small	94
Processing systems	Critical	1
	medium	4
	small	95
Lithotripter system	Critical	2
	medium	16
	small	82

Fig. 3. Mean preventive maintenance time (*MPT*) in year 2005.

The need for spare parts and maintenance materials during the studying period:

To determine the needs of spare parts or other tools in general, the responsible person must be precise as possible, and as the accuracy increase the cost decrease, the machine and equipments in the radiology department are all controlled by a maintenance provider company, the maintenance contract value is (155.578.028) US$, this maintenance contract involves the maintenance works costs, the costs of the needed spare parts and the cost of delivery. We can not play a rule in this part of maintenance during the studying period because of this contract.

But the type of costs that we are interested in is the costs that increase without decrease in storage of spare parts, the most important points of theses costs are:

Cost of failure when the production stopped due to

the following reasons:

1- When there is a failure in one of the important production machines.
2- The lost cost due to the un-utilization of the other equipments that depend in their work on the production machine.
3- The issues and prepaid constant costs without utilization of them such as the workers salaries who work on the equipments in parts 1 and 2.
4- Cost of loss or unsatisfying customer.

It is necessary to define the term system effectiveness; the term "fitness for use" applies to all products and services, for complex products, fitness for use is often called "system effectiveness "and it is a measure of the extent to which a system maybe expected to achieve a set of specific mission requirements, it is a function of availability, reliability and capability of the system [3].

3. CONCLUSION

Findings of the scoping study provide a clear blueprint of the way forward for implementing performance measures process and its benefits.

The benefits of our performance measure process fall under three main headings:

- Planning with confidence to provide what the patient or customer wants, when they need it, just in time, right first time.
- Flexibility which is being able to react quickly to market changes without high levels of stock.
- Improvement in overall equipment effectiveness as a measurable rout to increased availability.
- The main advantages of carrying out such an analysis are as follows: the overall effectiveness of the system is stated numerically as a function of the few vital system parameters which will help to take control on any of the system parameters at any stage performance evaluation process. and the importance of various parameters of the system had been evaluated by varying these parameters within broad limit and calculating the influence on the overall effectiveness , finally the quantification provides a means of predicting the actual performance of the system ,which can be compared with the actual goals.

The challenges in our performance measures process was in measuring patients outcomes such as measuring quality and the interpersonal comprises of satisfaction.

4. RECOMMENDATIONS

- All engineers need an understanding of the economic and regulatory environments of health care as well as the unique industry specific requirements and issues.

- Engineers interested in advancing into technology management positions need additional educational the fundamental of bossiness and management as well as an opportunity to develop their manage-mental skills. This will provide engineers with an increased awareness of the cost-containment issues prevalent in the healthcare industry that can play a role in lowering of costs associated with the development of healthcare technology and the delivery of health care services. The future research will concentrate on the reliability and compatibility influence on the system effectiveness.

REFERENCES

[1] World Health Organization, "World health report 2000", October 4, 2001 [On line]. Available: http://www.who.int/whr/2000len/report.htm.

[2] Y. A, Hayajneh and others, "Effects of use, perceptions & knowledge of a hospital information system by staff physicians", *proceeding of the international informatics and biomedical engineering symposium*, Amman, March, 2006 p.71.

[3] A K Govil: Reliability Engineering, TATA McGraw-Hill publishing company limited, New Delhi, 1983

[4] Amstadler, Bertran, L.: Reliability Mathematics, McGraw-Hill, Book company, N.Y., 1971

Brief biographical about the authors:

Khalid R. Al-momani was born in Amman, Jordan in 1969. He received the Mechanical Engineering degree from The University of Jordan, Amman , Jordan in 1992 and the PhD degree from the Institute for Problems of Natural Resources Use and Ecology, National Academy of Sciences of Belarus in 2003.Dr. Momani was an Associate Editor for Mechanical Review at Jordan Engineers Association and an organizing member for The Scientific Committee at Mechanical Division in the Jordan Engineers Association for the years 1995 and 1996.He was the Director of the Mechanical Department at Operation and maintenance Unit, Jordan University of Science and Technology (1997-2002) He was scientific researcher at Republican Scientific and Technical Center RSTC (ECOMIR), Belarus (2002-2003). And Post-Doctorate position at Gifu University, Intelligence Control Systems Engineering Department, Japan, He is member of Jordan Engineers Association, Eco-Ethics International Union. (Germany), Republican Scientific and Technical Center (ECOMIR) / Belarus, International Academy of Information Technology/ Belarus, Institute of Problems of Use of Natural Resources and Ecology/ Belarus, Central Scientific and Research Institute of water resources complex use /Belarus. He is currently Manager of Operation & Maintenance Department, King Abdullah University Hospital and a part-time lecturer at Industrial Engineering Department in Jordan University of Science and Technology.

Mohammad D. Al-Tahat is a University assistant Professor of Industrial Engineering with the University of Jordan, where he teaches and conducts research in design and methods of Industrial Engineering. He received the bachelor's degree (B.Sc.) at 1990 in production and Metallurgy engineering from the University of Technology in Iraq, the Master degree (M.Sc.) at 1992 in industrial Engineering from the University of Jordan, and the PhD. degree at 2003 from the University of Bologna in Italy. He works with the Jordanian Industry for more than 6 years as an Industrial and manufacturing engineer.

Enas T. Jaradat received her B.Sc. Degree in biomedical engineering from Jordan University of Science and Technology, Irbid, Jordan, in 2004. She is currently with the biomedical engineering section in king Abdullah University Hospital, Jordan. She is a member of Biomedical Engineers Society in Jordan Engineers Association.