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A Comparative Study of Medical Equipment Maintenance Cost and Performance for Selected Saudi Hospitals

Saleh S. Altayyar

Abstract*: *Healthcare technology administrators are always held responsible for the poor performance of the medical equipment maintenance team, delay in response to service requests, and long down time. Customer satisfaction are just part of the challenges they are facing. The objective of this study is to analyze and compare the cost of medical equipment maintenance, performance of medical equipment maintenance team in three major hospitals in Saudi Arabia (academic, military, and public). The annual cost of maintenance per medical equipment, work load per 1 FTE (technical employee), down time, turnaround time, cost of service ratio (COSR), hourly cost of maintenance, and acquisition cost per 1 FTE (technical employee) are used in the assessment and analytical comparison. When comparing the cost of service (COSR), turnaround time, and the down time in the three hospitals, it can be seen that the academic hospital has the lowest COSR (3.7%), the lowest down time (1.2 days) and the lowest turnaround time (1.5 days). The other two hospitals (military and public) have relatively higher COSR (6.7 and 5.8 %) respectively and high down time (29 and 10.7) days respectively. it is clear from this study that hospital that uses a combination of in house, Original Equipment Manufacturer (OEM), and independent service provider (third party) contract tend to have redundancy in technical staff which results in under worked technical staff and consequently unnecessary increased spending on maintenance, and poor maintenance performance, when measured by the annual cost of maintenance of medical equipment, down time, and turnaround time. This can be seen in the public hospital which has the highest cost of medical equipment maintenance among the three hospitals ($570).

Index Terms*: *Acquisition Cost per technician, Cost of Service (COSR), Medical equipment maintenance, Methods of Maintenance.

I. INTRODUCTION

Health care technology (medical equipment) represents the most sizable investment in Hospitals. There are wide variations in practices between different health systems and hospitals type and costs for Health care technology management. Health care technology plays as vital role in the quality of health care services provided to patients such diagnostic and treatment of disease, they are also useful for the post injury or disease rehabilitation. The terms medical device and medical equipment are used interchangeably with health care technology. In order to distinguish between medical devices and medical equipment, below is the definition of each. Medical device: An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose. Typically, the purpose of a medical device is not achieved by pharmacological, immunological or metabolic mean [1]. Medical equipment: Medical devices requiring calibration, maintenance, repair, user training, and decommissioning − activities usually managed by clinical engineers. It can be used either alone or in combination with any accessory, consumable, or other piece of medical equipment. Medical equipment excludes implantable, disposable or single-use medical devices [2].

II. METHODS OF MAINTENANCE

Service contract is an agreement to perform corrective and /or preventative maintenance to medical equipment for a specified amount of time at an agreed upon price [3]. The scope of service varies according to the type of the service contract; it may include repairs, preventive maintenance, and replacement of parts. Healthcare administrators must be aware of the service options available for them, these options range from time and materials coverage to full service, preventative maintenance only, or depot service only service contracts [3]. The service contract can either be with OEM, or with Independent Service Provider (ISO). It can also be a combination of both (OEM & ISO). In house maintenance is an option that is used by some hospitals alone or in combination with one or two these options.

In Saudi Arabia, the in house maintenance is mainly carried out by biomedical engineers who are on the healthcare facility payroll, and the OEM service contract is done through contract with the manufacturer representative in the country. However, the third party or independent service provider (ISO) maintenance contract is done by independent service provider.

Different hospitals in Saudi Arabia have different choices for medical equipment maintenance contract. Ministry of health uses a combination of in house, OEM and third party (ISO) maintenance contract for all medical equipment with capital medical equipment being maintained through OEM service contract. Academic hospitals use a combination of in house maintenance contract and (ISO) service contract. Most major hospitals use a combination of in house maintenance and OEM service contracts.

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* Correspondence Author (s)
Saleh S. Altayyar, Department of Biomedical Technology, College of Applied Medical Sciences, King Saud University, Riyadh – Saudi Arabia,E-mail: Stayyar@Ksu.edu.sa

III. HEALTHCARE SPENDING

The total revenue of service contracts in 1996 was approximated at $10 billion [4]; the global medical device outsourcing market is projected to reach $42.6 billion by 2015 [5]. Studies suggest that maintenance service quality is not keeping pace with industry growth, rising costs and sales volumes [6]. In Saudi Arabia, there are 462 hospitals (Academic, Military, public and private) with a total of 69394 beds, 2282 healthcare centers, 2670 general and specialized medical center, and 77 specialized clinics [7]. The number of ministry of health hospitals reached 274 by 2015, and the total spending of ministry of health alone on health care in Saudi Arabia reached $16.53 billions, which amounted to 7.25% of 2015 (1436) budget [7]. The number of medical devices in the ministry of health hospitals is estimated at 600,000 piece of equipment which are maintained through 69 independent service contracts at a cost of about $140 million [8]. In a study conducted on 590 maintenance transactions at 20 hospitals in Bogotá, Colombia, involving 764 medical devices and 72 maintenance service providers, a strong statistical support for the finding that in situations with high levels of physical asset specificity, better performance is shown by internal governance structures, it was concluded that the external governance structures show lower performance levels in public healthcare institutions and suggest that healthcare managers should reconsider eliminating in-house maintenance service staff in public healthcare institutions [9]. Patricia McLoughlin highlighted three advantages to using a third party for maintenance for IT equipment, low maintenance prices, support for multiple manufacturers in a single contract, and support for older systems no longer handled by the OEM. However, she cautioned of three disadvantages that need to be taken in consideration, such as quality of service, availability of parts, and downtime [10].Although these are identified for IT equipment, but they can be true as well for medical equipment.

IV. COST OF MEDICAL EQUIPMENT MAINTENANCE

In house Maintenance is defined as the fully allocated cost and defined by Lawrence Martin along with total third party contract cost as follows [11].

$$\text{In-House Fully Allocated Cost} = \text{Direct Costs} + \text{Share of Indirect Cost} \quad (1)$$

$$\text{Total Contracting Cost} = \text{Contractor Cost} + \text{Administration Cost} + \text{Conversion Costs (Amortized)} - \text{New Revenue} \quad (2)$$

Direct costs are totally (100%) chargeable to the service such as salaries, employee benefits, materials, and supplies. Overhead costs, or indirect costs, are cost of items that benefit the service and one or more government service, such as rent, utilities, communications, and any administrative and support services provided to the service by other governmental departments. Hospitals are working on consolidating their bottom lines and cut costs, Operation cost is one of the approaches hospitals use to reduce spending. It has been speculated that in 2015, many healthcare facilities may work on improving their medical equipment maintenance strategies through reducing costs and ensuring the long-term reliability of the repaired equipment [11]. For simplicity and practicality in this study, the definitions of maintenance provided by Lawrence Martin equations (1 & 2) are rewritten as follows:

$$\text{In-House Fully Allocated Cost} = \text{Total Health care Technology Department Budget} \quad (3)$$

$$\text{Total Contracting Cost} = \text{Contract Cost} \quad (4)$$

Cost of service can be measured using cost of service ratio (COSR), which represents the annual cost of maintaining an asset, expressed as a percentage of its purchase price [12].

$$\text{COSR} = \text{Annual Cost of Maintenance} \div \text{Original Purchase Price} = \% \quad (5)$$

The COSR is very useful tool for evaluating and bench marking specific manufacturers. It is also used to measure and compare the total cost of service of healthcare technology management departments [12].Table1 shows the COSR norms for OEM contracts, Third party contract, and in house maintenance [13]. AAMI listed the overall COSR as (3-8%), [14], and USA COSR national average as reported as 5.25%, and most in house programs are aiming at 5.0% [15]. The hourly cost of medical equipment maintenance and acquisition cost per one full time technical employee (FTE) are other useful tools for measuring and comparing the cost of maintenance and operation of healthcare technology management, they are calculated as follows [14].

$$\text{Acquisition Cost Per 1 FTE} = \text{Total Inventory} \div \text{Total Number of FTE}$$

$$\text{Hourly Cost of Maintenance} = \text{Total Cost of Medical Equipment Maintenance} \div \text{Number of Working Hours of all FTE} \quad (6)(7)$$

Table1. COSR Norms

Type of Service	% of Service	Per 1M$
OEM Contract	12% - 20%	120,000
Third Party Contract	6% - 10%	80,000
In house	4% - 6%	40,000

V. OBJECTIVE

The objective of this study is to analyze and compare the cost of medical equipment maintenance in three major hospitals in Saudi Arabia, the hospitals are chosen from three different sectors (academia, military, and public). The following parameters are used in the analytical analysis and comparison.

- Annual cost of maintenance per medical equipment.
- Work load per 1 FTE (technical employee)
- Down time.
- Turnaround time.
- Cost of service ratio (COSR).
- Hourly cost of maintenance.
- Acquisition cost per 1 FTE (technical employee)

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VI. METHODS

This study involves three major hospitals in Saudi hospitals (academic, military, and public). A questionnaire was developed and sent to the directors of healthcare technology management - biomedical engineering department directors (Table 2). The completed questionnaires were then collected and the data was analyzed. The maintenance cost per medical equipment is calculated by dividing the total medical equipment maintenance cost over the total number of medical equipment in the hospital, and the COSR is calculated using equation (5). The work load is calculated as the total number of medical equipment in the hospital divided by the total number of medical equipment maintenance personnel in the hospital. The hourly cost of maintenance is calculated using equation (6) based on a total of 46 working weeks per year after deduction of holidays and vacation, and 8 working hours 5 days a week, and the acquisition cost per 1 FTE is calculated using equation (7), where the acquisition cost is the total inventory.

VII. RESULTS

The analysis of the hospitals responses shows that different hospitals in Saudi Arabia use different methods of maintenance (Table 3), a large variations in the cost of medical equipment maintenance among the three hospitals in the study can be seen (Table 4). The ministry of health average annual spending on medical equipment maintenance of all its 274 hospitals is about $ 234, and the average annual spending of the three hospitals in this study is $ 411. The analysis of the data shows the military hospital to have the lowest average annual spending on medical equipment maintenance ($23), followed by the academic and teaching hospital ($433), where the public hospital in the study have the highest average annual spending among the three hospitals on medical equipment ($570) (Table 5). Hospitals that use a combination of in house and OEM maintenance contracts have the lowest average annual spending on medical equipment maintenance followed by the one that uses a combination of in house and ISO maintenance contracts. The hospital that uses all three options (in house, OEM, and ISO) tend to have the highest spending on medical equipment maintenance (Table 3 and 5). Looking at the cost of service (COSR), we can see that hospital with the lowest annual spending on medical equipment maintenance have the highest COSR (6.7) (Table 5). The academic hospital has both a reasonably low annual spending on medical equipment maintenance and the lowest COSR (3.7) compared to other hospitals in the study (Table 5). The public hospital shows the highest COSR of 5.8. (Table 5). Hospital that has the highest work load in terms of number of medical equipment per technician (1000 per 1 FTE) tends to have the highest turnaround time (10.5 days) and the highest down time (29 days) (Table 6). However, the hospital with the lowest work load (290 equipment per 1 FTE)) has relatively high turnaround time (9.8 days) and high downtime (10.7 days). Although, the academic hospital has a relatively low work load (488 equipment per 1 FTE), it has the lowest turnaround time (1.5 days) and the lowest down time (1.2 days). The public hospital has the lowest hourly cost of maintenance and acquisition cost per 1 FTE among all three hospitals ($90 and $2,867,384) respectively (Table 7). Academic hospital comes in second in the hourly cost of maintenance ($115) and third in the acquisition cost per 1 FTE ($ 5,714,286) (Table 7). However, the Military hospital has the highest hourly cost of maintenance ($125) and comes in second in terms of acquisition cost per 1 FTE (3,428,571) (Table 7).

VIII. DISCUSSION

The average spending on medical equipment (annual cost of maintenance of medical equipment) in the major hospitals ($411) is 50% more than the average spending of the ministry of health on medical equipment maintenance ($274) which can be due to low cost ministry of health maintenance contracts since the majority of the its hospitals are serviced through independent service providers (third party), where the contracts are mainly offered based on value of the bid. This is also supported by the low hourly cost of maintenance that can be seen in the public hospital ($90) (Table 7) which is lower than the average hourly cost of service ($105) reported by AAMI benchmark study [14]. Tables 3 and 5 show that hospital that uses a combination of in house and OEM maintenance contracts have the lowest average annual spending on medical equipment maintenance followed by the one that uses a combination of in house and ISO maintenance contracts. The hospital that uses all three options (in house, OEM, and ISO) tends to have the highest spending on medical equipment maintenance. This can be attributed to duplication of technical staff which can be explained by the work load defined as the number of equipment per one FTE (488 equipment for the academic hospital, 1000 equipment for the military hospital, and 290 equipment for the public hospital) (Table 6). A strong correlation can be seen between the work load and annual cost of maintenance of one medical equipment, the higher the work load the lower the annual cost of maintenance of medical equipment. Comparing the work load of the hospitals in the study (number of medical equipment per one 1 FTE) to that of the benchmarking study of AAMI, the academic and military hospitals fall in the lower 25% percentile and the public hospital falls in the median [14], which also supports the argument that public hospitals are over staffed due to duplication of independent organization providers staff and in house staff for the same function.

When examining the cost of service (COSR), turnaround time, and the down time, it can be seen that the academic hospital has the lowest COSR (3.7%), the lowest down time (1.2 days) and the lowest turnaround time (1.5 days). The other two hospitals (military and public) have relatively higher COSR (6.7 and 5.8 %) respectively and high down time (29 and 10.7) days respectively. They also have high turnaround time (10.5 and 9.80) days respectively (Tables 5 and 6). High down time represents loss to the hospital in terms of reduction in the patient capacity. The longer the downtime the more loss in hospital revenue, although the hospitals in the study are not private hospitals that generate revenue, the long down time results in.

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patients scheduling disturbances and jeopardizes hospital image and credibility, By comparing the acquisition cost per 1FTE (Table 7) with that of AAMI study, the academic hospital fell in about 26th percentile, where the other two hospitals fell in the lower 25th percentile. All hospitals are below the median which is $7,622,581 [14], the hourly cost of maintenance of the academic and military hospitals ($115 and $125) respectively exceeds the average hourly cost of the AAMI study ($105 per hour) [14] (Table 7). However, the hourly cost of maintenance of the public hospital ($90) (Table 7) is lower than the average hourly cost of the AAMI study ($105 per hour) [14]. By comparing the acquisition cost per 1FTE (Table 7) with that of AAMI study, the academic hospital fell in about 26th percentile, where the other two hospitals fell in the lower 25th percentile [14].

IX. CONCLUSION

In conclusion, it is clear that hospital that uses a combination of in house, OEM, and independent service provider (third party) contract tend to have redundancy in technical staff which results in under worked technical staff and consequently increase in maintenance cost and poor maintenance performance, when measured by the annual cost of maintenance of medical equipment, down time, and turnaround time. This can be seen in the public hospital which has the highest cost of medical equipment maintenance among the three hospitals ($570), Although the public hospital shows a very low work load which is indicative of under worked staff, it did not reflect on the performance which can be seen in the high down time and high turnaround time (10.7 and 9.8) days respectively. The military hospital uses a combination of in house and OEM, it has the lowest annual cost of maintenance of medical equipment ($231). However, it has high down time and turnaround time which can be explained to be due to the technical staff high work load (1000 equipment per 1 FTE). The down time and turnaround time are the highest among the three hospitals (29 and 10.5) days respectively. The academic hospital has both in house and independent service provider (third party) contract, it has a reasonable annual cost of medical equipment ($433) and very low down time and turnaround time (1.2, and 1.5) days respectively. In this study, all three hospitals have much lower acquisition cost of maintenance per 1 FTE than that reported by AAMI study ($7,622,581) [14].

X. RECOMMENDATIONS

Based on the finding of this study, and since most hospitals in Saudi Arabia tend to have a combination of in house and independent service provider (ISO) maintenance contracts, it is recommended that a clear definition of the tasks and areas of responsibility of each be developed and made clear in the service contract. A clear distinction should be made between the areas of responsibility of in house staff and the independent service provider (ISO) staff to avoid unnecessary spending on maintenance, redundancy, and poor performance.

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Saleh S. Altayyar, Biomedical Technology Department, College of Applied Medical Scienses, King Saud University, Riyadh – Saudi Arabia, 00966505456035 , Stayyar @ Ksu.edu.sa.
Ph.D Biomedical Engineering - Mississippi State University - Mississippi state MS. USA.

Publications:

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- Saleh S. Al Tayyar "Raising your BPM Maturity Level; Saudi Arabian Case Study" Building Business Capability Conference. (11 – 15 November 2013. Las Vegas, N. , USA).

Achievements:

- Vice Executive President for Medical Devices Sector at the Saudi Food & Drug Authority (Sep 2008 – Sep 2014).
- Established a state of the art medical devices regulatory system in Saudi Arabia that achieved the respect and recognition of the international regulatory arena.
- Chair, Asian Harmonization Working Party (AHWP), an organization of more than 23 member economies working toward harmonization of medical devices in Asia, Africa, Middle East, and Latin America for three years,
- Chair, Riyadh Biomedical Engineering Club.
- Chair, Medical & Clinical Engineering Chapter at the Saudi Council of Engineers.

Board Memberships:

- Board of Saudi Standard, Metrology and Quality Organization (SASO).
- The Scientific Board for Applied Medical Sciences (SBAMS), Saudi Commission for Health Specialties.
- The Board of International Medical Devices Regulators Forum (IMDRF).
- Member of the advisory board of many colleges and universities in Saudi Arabia.

Refereed and co-authored innovation in healthcare, Diabetic foot, and clinical engineering management.

Table 2. The Questionnaire

Type of hospital (please check one)	Government	Military	Academic	Semi Government	Private
Number of Beds					
Number of Medical Equipment					
Department Annual Budget (SAR)					
Number of clinical / biomedical Engineers					
Equipment Inventory (SAR).					
Turnaround time					
Down time					
Please complete the following by choosing the method (s) used in your hospital and the cost of maintenance for each					
	In house	**Third party**	**OEM (Vendor)**		
Methods of maintenance					
Annual Cost of maintenance for each method					
Annual Cost of spare parts for each method.					

Table 3. Hospitals Information

Hospital Name	Hospital Type	Number of Beds	Number of Medical Equipment	Equipment Inventory (dollars)	Method of Maintenance
A	Academic	1200	20,519	240,000,000	In house + ISO
B	Military	1200	35,000	120,000,000	In house + OEM
C	Public	1500	26,972	266,666,668	In house +ISO+OEM

Table 4. Medical Equipment Maintenance Cost

Hospital	Cost of In house Operation (dollars)	OEM Contract Cost (dollars)	ISO (Third Party) Contract (dollars)	ISO +OEM Combined (dollars)	Spare Parts Cost (dollars)	Total Cost of Medical Equipment Maintenance (dollars)
Academic	4,853,333	----------	3,066,667	----------	960,000	8,880,000
Military	3,146,667	3,333,333	----------	----------	1,600,000	8,080,000
Public	441,600	----------	----------	12,770,800	2,177,778	15,390,178

Table 5. Medical Equipment Maintenance Analysis

Hospital	Total Maintenance Cost (dollars)	Equipment Inventory (dollars)	Cost of Service Ratio COSR %	Annual Cost of Maintenance per Medical Equipment (dollars)
Academic	8,880,000	240,000,000	3.7	433
Military	8,080,000	120,000,000	6.7	231
Public	15,390,178	266,666,668	5.8	570

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Table 6. Medical Equipment Maintenance Cost Analysis

Hospital	Number of FTE's	Work load (Equipment / FTE)	Down Time (days)	Turnaround time (days)
Academic	42	488	1.2	1.5
Military	35	1000	29	10.5
Public	93	290	10.7	9.8

Table 7. Hourly Cost of Maintenance and Acquisition cost per FTE

Hospital	Number of Working Hours	Hourly Cost of Maintenance (dollars)	Acquisition Cost per 1 FTE (dollars)
Academic	77,280	115	5,714,286
Military	64,400	125	3,428,571
Public	171,120	90	2,867,384

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