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Effective Dimensions of Medical Equipment Maintenance Management in Educational Hospitals: A Qualitative Study

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ABSTRACT

Background: Medical equipment maintenance plays an important role in improving the equipment's function, increasing its effectiveness and efficiency, providing continuous health services, and improving the quality of services. This study is conducted to investigate the factors affecting medical equipment maintenance management.

Methods: The present study was a qualitative investigation based on content analysis that was conducted in 2021. Data collection method was an open ended interview. The interviewees included all medical equipment operators and technicians of educational and medical centers affiliated with Qazvin University of Medical Sciences. The semi-structured interview guide was used as a data collection tool. Qualitative data obtained from interviews were analyzed by the content analysis method. The obtained coded were classified into dimensions and components using MAXQDA Software$_{12}$.

Results: According to the findings, categories of time constraints, access to information, instructions and programs, type and number of equipment, financial constraints, user, patients, training programs, and equipment repair agencies were the most important factors affecting medical equipment maintenance management.

Conclusion: Observing purchasing standards and guaranteed equipment, training all the staff involved, developing and explaining instructions and programs are essential for optimal equipment maintenance. These measurements will reduce the cost of repairing.

g medical equipment and the need to purchase equipment; improve equipment, service quality performance, patient and user safety; and increase the device life.

Key words: Medical equipment, Maintenance management, Medical center, Iran.

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Introduction

Hospitals are one of the most important health service providers. Its direct impact on people's health is of particular importance. These centers use extensive resources and facilities to promote community health and research. Developing up-to-date and high-quality medical equipment to provide diagnostic and treatment services is necessary to respond to the increasing complexity of diseases and modern technological advances. In addition, proper equipment maintenance and storage is essential due to the high cost of purchasing equipment, increasing referrals, and the dependence of clinical outcomes on them (1).

Research has shown that the use of inspection methods, periodic calibrations, and preventive maintenance can extend the life of medical equipment. Thus, it reduces the need to purchase equipment or do repairs. In addition, as the efficiency of the equipment increases, the efficiency of the diagnostic, treatment, and rehabilitation process increases as well, and higher quality services are provided (2, 3).

Authorities should plan and evaluate parameters such as the method of using the equipment's spare parts, the number of times it is used, the risk associated with using the device, and the extent of its failure. Therefore, achieving an effective and reliable maintenance strategy for medical equipment would be possible (4). Maintenance of some medical equipment including medical and diagnostic equipment is necessary. Devices that may cause patients and users' death or injury have a higher priority (5). This is of more importance in time of crisis because there isn't enough time to deal with problems and troubleshoot equipment. For example, dealing with crises such as COVID-19 pandemic requires precise planning and focus on providing adequate equipment to patients (6).

Inadequate maintenance of equipment leads to failure, reduced performance, waste of resources, an irrational increase in costs, as well as reduced indicators of efficiency, effectiveness, and patient satisfaction. Unreliable operation of equipment slows down the work of providers. Poor planning, management, and maintenance strategies or processes cause such problems (7). ISO 13485 standard and the international standard of the quality management system include medical equipment standards. These are in line with EU regulations and the regulatory policies of countries such as Japan, Canada, and the United States (8).

Proper maintenance of medical equipment can have a significant impact on service delivery process and its quality. At the same time, it reduces the costs of health system to a great extent. Therefore, factors affecting maintenance and method of responding to these factors should be considered beforehand. This study aimed to identify the factors affecting medical equipment maintenance management and has provided suggestions for improving maintenance strategies and processes.

Materials and Methods

This study was conducted based on the qualitative method and content analysis in educational and medical centers affiliated with Qazvin University of Medical Sciences in 2021.

Contributors

All medical equipment operators and medical engineering experts of the educational and medical centers affiliated with Qazvin University of Medical Sciences formed the study population. The sampling method was purposive. Furthermore, since the sample size is not an accurate criterion in qualitative studies, researchers continued sampling until data saturation was reached. The criteria for participation in the interview were having at least a bachelor's degree with at least two years of experience in the medical engineering department of hospitals during the study period, having sufficient experience and knowledge in medical equipment, availability, and willingness to participate in the study.

Data collection

A semi-structured interview guide was used as a data-gathering tool. Supervisors and consultants' opinions, literature review, related documents including regulations and instructions for medical equipment maintenance management and other regulations or reports prepared by the Ministry of

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Health, Treatment and Education were used to compile this guide. This guide comprises general inquiries which require to be responded to openly and interpretatively (Figure 1). The prior arrangements with the participants were made before the interviews. After giving the necessary explanations for research purposes, authors obtained informed consent of the participants regarding interviews. Their words were recorded and written down with their consent. Meantime, recorded files were archived anonymously, and the research results did not contain the interviewees' names.

Data analysis

The qualitative data obtained from interviews were analyzed by content analysis method. This three-step method starts with refining data. Then, data are supplied, mapped and analyzed. In the first stage, the interviews were carefully listened to, reviewed and typed. Their words were, then, coded and classified using MAXQDA Software[12]. At the end of this process, the analysis of interviews, eventually, led to specific themes of factors affecting the maintenance management of medical equipment.

Ethical approval was obtained from the ethics committee of Qazvin University of Medical Sciences (ethics code IR.QUMS.REC.1399.494).

Results

To achieve the objectives of the study, 6 experts in the field of medical equipment were interviewed. 33.4 % (2 people) of participants were male and 66.6 % (4 people) were female (Table 1).

First, the interviews of all the experts were carefully listened to, reviewed and typed. In the next step, the words were coded by the software and conceptualized in the form of 9 themes affecting the maintenance management of medical equipment in educational and medical centers affiliated with Qazvin University of Medical Sciences (Table 2).

Time restrictions

Medical equipment wears out over time. In addition, the damage and defects become more and more costly over time. It is important to do troubleshooting and repairs, especially for critical and old equipment at short intervals. One of the interviewees declared: "…Maintenance and repairs are done in two ways: Well, we can wait for a device to break down and then repair that device. Or that we can predict; That is, measures to prevent defects. It means, checking at a fixed interval or after the equipment has worked a certain amount…."[p4].

Information accessibility

The availability of information is a basic precondition for performing managerial tasks. Medical equipment maintenance management is no exception. Establishing a comprehensive equipment identification system or database is essential for maintenance planning. Moreover, creating an up-to-date and complete database regarding maintenance documentation indicates the current situation and facilitates future planning. On the other hand, evaluation of the implemented programs can be traced by reviewing the relevant documents. In this regard, one of the interviewees said: "…If the equipment's identification card information and repairing of documents are complete, researchers can easily understand which one needs more observation, and according to what plan we should control it…."[p1].

Instructions and programs

It is necessary to pay attention to the existing scientific instructions from the purchase stage to the dismantling of the equipment. These documents include guidelines for taking the best steps for purchase and maintenance regarding the use. One of the participants declared: "… Instructions state which equipment is suitable for which departments and centers. Scheduling and the method of controlling, repairing, and cleaning are also included in the instructions…." [p6].

Type and number of equipment

Depending on the extent and vitality of its use, the equipment requires specified observation and maintenance programs. On the other hand, lack of equipment increases the workload of the existing ones. Consequently, depreciation, displacement, and washing also increase, all of which affect the life of the equipment. One of the participants

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stated: "… In the event of equipment shortage, especially during the COVID-19 pandemic, we have to constantly clean the equipment and move them between wards…. "[p3]. Another interviewee added: "…Educational hospitals with more equipment experience more personnel errors and require more training…."[p 5].

Financial limitations

In line with the difficulty of purchasing equipment, budget constraints have made maintenance an important issue as well. In support of these statements, one of the participants asserted: "…Lack of sufficient financial resources has caused problems in providing the necessary services for troubleshooting, repairing, supplying spare parts, and settling financial accounts with contracting companies…"[p2].

Users

The method of using equipment has a significant impact on the extent of repair it needs and the time it lasts. The users' level of skill and awareness is effective regarding the rate of error and troubleshooting. Therefore, users who have more experience and familiarity with the equipment can be very helpful in the maintenance process. In this regard, one of the interviewees said: "…One of the challenges our hospital faces is that nurses are constantly exchanged between wards or the new inexperienced staff is constantly being added..."[p4]. Another interviewee added: "… For example, the user has found a defect in the device. When we inform the dealer company of it, the expert says that if you had not found this defect, the device would have failed. So, the cost would be greatly reduced…. "[p1]. Another participant added: "…in the early days of COVID-19 pandemic, many devices were damaged due to incorrect sterilization. The detergent was sprayed directly on the machine. Or they disinfected the device while it was running…"[p3].

Patients

The number of patients who use the equipment affects the rate of depreciation and failure, and its lifespan. In addition, the way patients use the equipment may damage the equipment suddenly or in the long run. One of the participants confirmed this statement saying: "… For instance, the patient jumps over a bed instead of turning the bedside upside down. Well, we have problems like this. An agitated patient hits and damages the equipment…."[p5].

Training programs

In-service training is especially important for new employees. It should be presented in different ways according to the variety and frequency of equipment usage. In this regard, training by the supervisor and succession is also necessary. Consistent with these statements, one of the participants affirmed: "…The method of using the new equipment is taught by the associated companies. In addition, we attach the quick user guide to the devices. This is because training needs to be reminded…"[p4]. Another interviewee added: "…If medical equipment experts are newcomers, they will learn the work alongside the previous employee…"[p1].

Equipment repair agencies and companies

Receiving services from repair agencies requires a clear process in announcing the demand and calling an expert to the hospital. Moreover, the guarantee period is effective in this process. Currently, due to the above-mentioned financial limitations and overdue debts, these companies refuse to provide pre-settlement services. The statements of one of the interviewees testify to this: "… We need to notify the company and arrange with them to come for repairs or we send the device to them. Next, we must keep follow up to receive the repaired equipment.…" [p6]. Another participant stated: "… After the end of the guarantee period, if we owe money to companies, they will cooperate less with us. We even had to work and repair the equipment ourselves several times. Some companies work only with cash…"[p2]

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Table 1. Demographic variables of the interviewees

Variable		N
Gender	Female	4
	Male	2
Age	30 <	3
	30 >	3
Level of education	Master's degree	3
	Bachelor's degree	3
Work experience	5 years <	3
	10 years >	3
Recruitment status	official	1
	Temporary to permanent	1
	Temporary	2
	Non official	2

Table 2. Factors affecting the maintenance management of medical equipment in Educational and Medical Centers affiliated with Qazvin University of Medical Sciences

Categories	Sub-categories
Time restrictions	Duration of equipment use Equipment life Schedule assessment and control Schedule minor repairs The rate of wear and tear
Information accessibility	Accessibility of systems Completion of equipment identification card Existence of detailed documentation
Instructions and schedules	Existence and access to scientific instructions for purchase, maintenance, and repair Existence and implementation of quality control schedules Specialist's inspection schedule Periodic control schedule Minor repair schedule Lubrication schedule
Type and number of equipment	Wash schedule Frequency and method of moving the equipment Equipment workload
Financial restrictions	Economic sanctions Inflation Lack of funds Overdue debts to representative companies
User	User exchanges between wards Expertise Operating skills Troubleshooting skills Experience and background Errors Forgetting the method of operation Disinfecting and washing mistakes Cleaner's inattention to the disinfecting and washing instructions and materials
Patients	Visit times Mistakes and accidents Operating method

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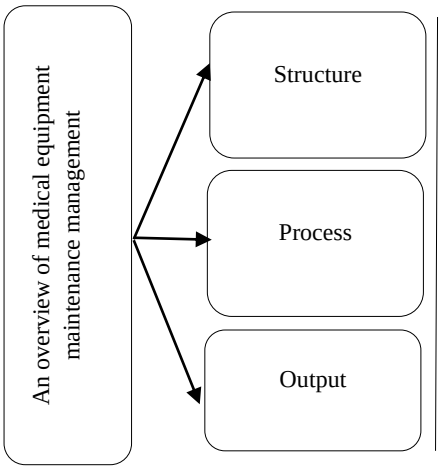
Categories	Sub-categories
Training programs	Users' training Cleaners' training Expert training regarding hospital's medical equipment Frequency and intervals of training Training method
Equipment repair agencies and companies	The degree of cooperation The manner and extent of coordination The amount of after-sales service Distance from service providers



- What is the role of medical equipment maintenance management in hospitals?
- What is the process of medical equipment maintenance in hospitals?
- How is the medical equipment maintenance management in hospitals evaluated?
- What are the deficiencies of medical equipment maintenance management?
- What are the guidelines for evaluating medical equipment maintenance?
- What are the influencing factors regarding medical equipment maintenance management evaluation?
- What are the most important activities and responsibilities related to the maintenance and repair of medical equipment?
- Have experts and users of medical equipment received the necessary training in the field of equipment maintenance and repair?
- What are the challenges and barriers to performing medical equipment maintenance?

Figure 1. Semi-structured interview questions guide

Discussion

This study was conducted to find factors affecting medical equipment maintenance management in Qazvin's hospitals. After conducting interviews and receiving expert's opinions; dimensions of time restrictions; information accessibility; instructions and programs; number and type of equipment; financial limitations; user, patients, and training programs, equipment repair agencies and companies were identified as the most important factors affecting medical equipment maintenance management.

The factor of time was emphasized by all the interviewees. Over time, the need for control and repair of medical equipment increases. Adherence to the correct schedule of each maintenance program and the intervals of their implementation directly affect the equipment's life and its frequency and severity of failure. Accordingly, Chaudhary et al.(9) 's study demonstrated that delays in the implementation of the maintenance program and lack of access to spare parts needed for timely repair of damaged equipment are the most important causes of failure of diagnostic medical equipment.

The availability of information plays a significant role in the development of equipment maintenance plans. All the documents related to the actions taken in this field such as periodic visits, device repairs, inspections, troubleshooting, and even personnel training should be comprehensively collected and maintained. This information can be used to develop and modify the maintenance program. Therefore, the more detailed and reliable documentation in this field is, the more successful the developed program will be. In this regard, KHodadadi et al. (10) have introduced an accurate and structured information system for online registration of all information and details related to medical equipment. This is a requirement for management of medical equipment, especially in times of crisis. Fuaddi et al. (11) have also developed a web-based information system with a robust and integrative infrastructure as a tool for

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medical equipment maintenance management to facilitate the implementation of the maintenance program.

Instructions and programs were the basic factors emphasized by the interviewees. Experts, in the present study, stressed the need to develop a comprehensive and accurate plan for periodic inspections, minor repairs, annual inspections, lubrication, and troubleshooting following standards, instructions, and devices' brands. They also pointed out that the correct and timely implementation of this program is of particular importance for highly sensitive and critical devices. An intelligent maintenance program can help extend the life of medical equipment and reduce its operating costs (12). Additionally, Ladanza et al. (4) stated that in the event of disruption due to compliance with some existing guidelines, authorities should apply specific codes to classify guidelines and schedules. Finally, a new set of key indicators should be provided to evaluate the performance of medical equipment maintenance.

The type and number of medical equipment is another effective dimension. Shortage of medical equipment increases workload, relocation, washing and disinfection, depreciation, and the need for repairs. In this regard, Salah et al. (13-15) found that the cost of maintaining medical equipment was directly related to their availability. Many studies found that poor low-income countries generally face a shortage of medical equipment. This shortage and lack of adequate access to equipment have led to a reduction in the quality of provided services. On the other hand, the complexity of medical equipment in terms of number and variety in large and educational hospitals should be reflected in the form of an efficient program for safe and appropriate use of equipment in maintenance management programs (4).

Financial resources and constraints are decisive factors for medical equipment experts. Many studies have shown that medical equipment accounts for a significant share of the hospital's annual costs. Therefore, proper maintenance management can have a significant impact on improving the hospital's economic status (12, 16). Arab Zozani et al. (17) emphasized that the allocation of budget and financial resources according to the plans, priorities, and instructions is the most optimal. Furthermore, the study by Aunión-Villa et al. (18) showed that the visit burden, the length of stay, the number of beds and operating rooms, the number of staff, and the purchase value of devices have a significant effect on the maintenance costs of electrical medical equipment. On the other hand, maintenance of the equipment requires financial resources, which are limited in the current economic status and the COVID-19 pandemic, especially in public hospitals. As Altayyar et al. (19) suggested, the cost of maintaining and repairing medical equipment in public hospitals with lower tariffs is higher. Such conditions have caused problems regarding cooperation with repair companies, which in turn prolongs the repair process and the unavailability of equipment.

The manner of using medical equipment is another effective factor which is also confirmed by Al-Bashir et al. (20). A professional user can prevent equipment from becoming inaccessible by continuously monitoring if the equipment is working properly and detecting defects early. On the other hand, cleaning the equipment has not always been given special attention. It has, however, a significant impact on the quality of patient care and the costs associated with maintaining the equipment (21). A professional user can be recruited by attracting capable personnel or training the present personnel.

Training was one of the aspects emphasized by the interviewees. In this regard, the study of Bahraini et al. (7) also showed that both medical equipment engineers and equipment users need to receive up-to-date scientific and practical training to repair, troubleshoot and maintain devices properly. They should also be trained to provide accurate reports about the device performance. All the people who work with medical equipment in any way should be trained appropriately. Training can be in the form of conferences, group or case

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training, training by the direct supervisor, and even virtual training through multimedia files. It is best to evaluate and recall these exercises over time.

Interviewees identified equipment repair agencies and companies as a factor that could facilitate or hinder the process of control, service, maintenance, and repair. khelood.A et al. (22) stated that providing appropriate after-sales service, providing suitable spare parts for equipment by repair companies , transparency and contract terms between the company and the hospital, and the delay in repair and delivery of equipment are determining factors in choosing an agency and cooperation with it. As mentioned, the main reason for companies for not cooperating in the right time is due to the hospitals' financial issues. Therefore, choosing companies that have longer and better after-sales service is a smarter choice. At the same time, concluding contracts where the terms of payment and fulfillment of obligations are based on the hospitals' real financial status will significantly prevent further problems.

Conclusion

This was a qualitative content analysis. It introduced a set of factors that overshadow medical equipment maintenance management. According to the extracted statements, observing purchasing standards and guaranteed equipment, training all the staff involved, developing and explaining instructions and programs are essential for optimal equipment maintenance. The effects of time factors, including depreciation and the need to replace parts, must be adhered to inspections and repairs schedules. The study also found that lack of equipment increases the workload of available one and increases depreciation. This lack increases the risk of damage to the device due to the increased frequency of moving and washing. Personnel errors and the incorrect use of equipment were also identified as the most common causes of sudden breakdowns. In response to many of these factors, training programs in all areas related to the purchase, use, disinfection, and maintenance of medical equipment were emphasized by experts. It is worth mentioning that movement restriction due to COVID-19 pandemic, poor cooperation of medical equipment officials in some hospitals and the length of data collection process of all hospitals were the most important limitations of this study.

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Conflict of interests

The authors declared no conflict of interests.

Authors' contributions

Khosravizadeh O designed research; Maleki A, Ghanbari E, and Shafiei pour M conducted research; Safdari M and Ahadinezhad B analyzed data; and all authors wrote the manuscript. All authors read and approved the final manuscript.

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References

1. Amerieon A, Alijanzadeh M, Teymourzadeh E. Effective factors on the management of medical equipment maintenance in a military hospital: A qualitative study in Iran. EBNESINA Journal. 2015; 17(3): 11-8. [In Persian]
2. Moradhasel B, Ghaderi F. The status of medical equipment maintenance management in the hospitals of Hamedan University of Medical Sciences in 2015. Health and Development Journal. 2018; 7(3): 274-85. doi: 10.22062/JHAD.2018.91294. [In Persian]
3. Masmoudi M, Ben Houria Z, Al Hanbali A, Masmoudi F. Decision support procedure for medical equipment maintenance management. Journal of Clinical Engineering. 2016; 41(1): 19-29. doi: 10.1097/JCE.0000000000000135.
4. Iadanza E, Gonnelli V, Satta F, Gherardelli M. Evidence-based medical equipment management: A convenient implementation. Medical & Biological Engineering & Computing. 2019; 57(10): 2215-30. doi: 10.1007/s11517-019-02021-x.

[DOI: 10.18502/jebhpme.v6i3.10854]

5. Organization WH. Medical equipment maintenance programme overview: WHO Medical device technical series: World Health Organization; 2011. Available from URL: https://apps.who.int/iris/bitstream/handle/10665/44587/9789241501538-eng.pdf?sequence=1&isAllowed=y. Last access: Nov 10, 2021.
6. Organization WH. Oxygen sources and distribution for COVID-19 treatment centres: Interim guidance, 4 April 2020. World Health Organization; 2020. Available from URL: https://apps.who.int/ iris/bitstream/ handle/ 10665/331746/WHO-2019-nCoV-Oxygen_ sources-2020.1-eng.pdf. Last access: Nov 10, 2021
7. Bahreini R, Doshmangir L, Imani A. Influential factors on medical equipment maintenance management: In search of a framework. Journal of Quality in Maintenance Engineering. 2019; 25(3). doi: 10.1108/JQME-11-2017-0082.
8. Abuhav I. A complete guide to quality management in the medical device industry: ISO 13485. CRC Press. 2018.
9. Chaudhary P, Kaul P. Factors affecting utilization of medical diagnostic equipment: A study at a tertiary healthcare setup of Chandigarh. CHRISMED Journal of Health and Research. 2015; 2(4): 316-23. doi: 10.4103/2348-3334.165741.
10. Khodadadi V, Bakrani A, Vafaie MH. Factors affecting medical equipment management in the COVID-19 pandemic crisis: A mixed qualitative and quantitative study. Hospital Practices and Research. 2021; 6(1): 23-8. doi: 10.34172/ HPR.2021.05.
11. Fuaddi M, Sabarguna BS. Web-based maintenance information system in medical equipment management. AIP Conference Proceedings 2019; 2092(1): 040003. doi: 10.1063/1.5096736.
12. Hernández-López LA, Pimentel-Aguilar AB, Ortiz-Posadas MR. An index to prioritize the preventive maintenance of medical equipment. Health and Technology. 2020; 10(2): 399-403. doi: 10.1007/s12553-019-00371-y.
13. Organization WH. Decontamination and reprocessing of medical devices for health-care facilities. 2016. Available from URL: https://apps.who.int/iris/bitstream/handle/10665/250232/9789241549851-eng.pdf?sequence=1&isAllowed=y Last access: Nov 10, 2021
14. Oosting RM, Wauben LSGL, Madete JK, Groen RS, Dankelman J. Availability, procurement, training, usage, maintenance and complications of electrosurgical units and laparoscopic equipment in 12 African countries. BJS Open. 2020; 4(2): 326-31. doi: 10.1002/bjs5.50255.
15. Moyimane MB, Matlala SF, Kekana MP. Experiences of nurses on the critical shortage of medical equipment at a rural district hospital in South Africa: A qualitative study. Pan African Medical Journal. 2017; 28: 100. doi: 10.11604/pamj.2017.28.100.11641.
16. Mahfoud H, El Barkany A, El Biyaali A. Preventive maintenance optimization in healthcare domain: Status of research and perspective. Journal of Quality and Reliability Engineering. 2016; 1-11. doi: 10.1155/2016/5314312.
17. Arab-Zozani M, Imani A, Doshmangir L, Dalal K, Bahreini R. Assessment of medical equipment maintenance management: Proposed checklist using Iranian experience. Biomedical Engineering Online. 2021; 20(1): 49. doi: 10.1186/s12938-021-00885-5.
18. Aunión-Villa J, Gómez-Chaparro M, García Sanz-Calcedo J. Assessment of the maintenance costs of electro-medical equipment in Spanish hospitals. Expert Review of Medical Devices. 2020; 17(8): 855-65. doi: 10.1080/17434440.2020.1796635.
19. Altayyar SS. A comparative study of medical equipment maintenance cost and performance for selected Saudi hospitals. International Journal of Engineering and Advanced Technology. 2017; 6(4): 226-31.
20. Al-Bashir A, Al-Tawarah A, Jawwad AKA. Downtime reduction on medical equipment maintenance at the directorate of biomedical engineering in the Jordanian MOH. International

[DOI: 10.18502/jebhpme.v6i3.10854]

Journal of Online Engineering. 2017; 13(2): 1-14. doi: 10.3991/IJOE.V13I02.6422.
21. Elkomy Sh, Cookson G, Jones S. Cheap and dirty: The effect of contracting out cleaning on efficiency and effectiveness. Public Administration Review. 2019; 79(2): 193-202. doi: 10.1111/puar.13031.
22. Mkalaf KA, Gibson PR, Flanagan JT. A study of current maintenance strategies and the reliability of critical medical equipment in hospitals in relation to patient outcomes. world academy of science, engineering and technology. International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering. 2013; 7: 2655-62. doi: 10.5281/zenodo.1088118.

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