DESIGNING A COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM FOR MEDICAL DEVICES IN ROYAL MEDICAL SERVICES

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ABSTRACT
The effective maintenance management of medical technology influences the quality of care delivered and the profitability of healthcare facilities. Medical device maintenance in Jordan lacks an objective prioritization system; consequently, the system is not sensitive to the impact of device's downtime on patient morbidity and mortality. Through this paper, the existing computerized maintenance management system in royal medical services was investigated, a list of its requirements was created, such a system was conceptually designed, and finally an object oriented model was built based on the conceptual design. A conceptual design was created showing how the system will function when implemented. This design employed logical view and deployment view depicting the specific entities of the system and how these entities interact with one another. The operator can always add these views and they will be fully instructed on the proper methods for achieving this. With the completed model the developer will be able to generate skeletal code, in a variety of programming languages, which will further assist in the implementation process.

Keywords: *Computerized Maintenance Management System (CMMS); Royal Medical Services (RMS); Medical Device Management System (MDMS)*

1. INTRODUCTION
As medical device becomes more sophisticated and plays a more crucial role in modern healthcare, maintenance issues demand ever-increasing attention. The most critical problem facing the medical device is the downtime. One of the most common causes of medical devices' downtime is poor maintenance. For that problem Daily check up for medical devices must be done as well as the Regular training on medical devices maintenance (Tawarah, 2009).
Maintenance has a very important part to play during the life cycle of an item of device. It tries to maximize the performance of the device by ensuring that it operates regularly and efficiently, by attempting to prevent breakdowns or failures, and by minimizing the losses incurred by breakdowns or failures.
This can be achieved by employing Computerized Maintenance Management System (CMMS) as a fundamental information resource providing the technology management staff with a wealth of support-related information as well as assisting management in decision making.
Development of CMMS is essential for managers and engineers, not only to provide quick management solutions, but also to predict future outcomes based on historical device's performance data.
The most commonly employed method of work order prioritization for repair requests in Jordan is the First-Come, First-Served (FCFS) method. While the FCFS approach might be acceptable for many applications, it is not always appropriate when applied to the healthcare sector, as is the case when a vital, life-support machine undergoes failure and consequently, is out of service until the service work order reaches the head of the queue.
One approach to address these shortcomings requires focusing on the effect posed by device failure on patients, rather than focusing on the device with the highest maintenance demand.

2. LITERATURE REVIEW

2.1 Computerized Maintenance Management System (CMMS)
Maintenance optimization is greatly facilitated when companies adopt a World Class Manufacturing/Maintenance (WCM) philosophy or management strategy in conjunction with CMMS implementation. It was stated that CMMS software was seen first around 1976. Today it is widely used in manufacturing plants all over the world.
Wireman (1994) was of the opinion that if CMMS are to be properly examined it is important to have an understanding of the primary maintenance functions incorporating: maintenance inspections and service, device installation, maintenance storekeeping, craft administration.

He went on to outline the objectives of CMMS covering: improved maintenance costs, reduced device's downtime as a result of scheduled preventative maintenance, increased device's life, ability to store historical records to assist in the planning and budgeting of maintenance and ability to generate maintenance reports.
(Travis *et al.*, 1997) outlined other difficulties associated with modern maintenance management. In their paper the top five problems encountered by maintenance managers were prioritized and suggested that CMMS is the solution to these problems. The problems are outlined as follows:

- Little or no support from management to implement world class maintenance practices, CMMS reports can highlight the levels of downtime and reduce costs.
- Inventory problems, the need to reduce spares and still have parts on hand. Control of spares modules is part of most of the modern CMMS packages

Lamendola (1998) emphasized the need to eliminate non-value added activities especially with respect to documentation of work within maintenance. He stated that "This philosophy has long been the essence of Computerized Maintenance Management Systems."
Industries such as oil and gas or nuclear power plants are in need of an efficient CMMS to manage their maintenance activities throughout the plant lifecycle (Supramani, 2005).
Ruud (2009) investigated the implementation of CMMS at Sapa Thermal Heat Transfer (Shanghai) on the maintenance department to save on doing unnecessary maintenance and make it easier to order spare part, scheduled maintenance and to see the problems and the solution the problems in the CMMS database. The investigation showed that CMMS contributed to manage the maintenance so much that the machine should have availability above 90 percent.

3. METHODOLOGY

3-1 CMMS Requirements and Specifications

In order to conceptually design the CMMS of RMS, a list of system requirements was created which based on the recommendations of (BME) experts, and the requirements of the medical devices operators.

After contacting the vendors of CMMS and asking them to send information about their products, a final list of criteria necessary in the CMMS was determined as follow:

Table 1: The final list of criteria necessary in the CMMS

Inventory number	Department	Warranty period	Fault description
Serial number	Local agent	Job number	Cause of fault
Model number	Manufacture	Technician name	Action taken
Device's name	Installation date	Start date of job order	Price
Predictive maintenance	Scheduling	History/Reports	System requirements

When performing maintenance, the maintenance technicians had to travel many hours because many of the stations are located in areas so remote. For coordinating the maintenance approach, regional central offices coordinated the actions of all medical devices maintenance technicians. These technicians based in regional depots located in centralized areas around the country, thus decreasing travel time to remote stations.
The application itself resided in the central office on multiple servers, thus minimizing system failures in case a server crashes. The CMMS was accessible almost from all over the country via the Internet. All users of the system with a correct user name and password were able to login to it.
The maintenance organization used the CMMS to coordinate the maintenance of the medical devices failures. The five maintenance steps of Notification, Assignment, Job-In-Progress, Closure, and Reporting were integrated into it.
Firstly, the system handled notifications for both types of maintenance: preventative, and reactive. The CMMS accounted for preventative maintenance by keeping a master schedule.
When a new device is installed, the CMMS scheduled routine maintenance for that device at regular time intervals and automatically generated work orders when those intervals expire. The scheduler added the schedules of all maintenance jobs to a calendar so that users may always obtain a snapshot of current maintenance personnel resources.
For notifying the CMMS of reactive maintenance, system users were able to complete and submit online work order request forms. Submission of a work order request notified the system that a device had failed and that it requires (should it be in present or in past) maintenance attention.

Next, work order requests reached the system in electronic form, so the central operator could quickly and easily convert them into work orders and assigned (should it be in present or in past) them to maintenance technicians.
The system notified technicians about work orders immediately, thus removing physical bottlenecks found in traditional paper assignment processes. Instead of retrieving physical work orders, maintenance technicians were able to receive all information about a particular job at any time, from anywhere in the country.
The CMMS added value to the third step, jobs in progress, by allowing maintenance technicians to access past work orders, technical diagrams, maintenance best-practices, and station device's histories.
Work orders required maintenance technicians to document their maintenance work so that future technicians could benefit from it. The work orders notified the system of errors, difficulties and major milestones during maintenance works so that the central office could always be informed of the entire MDMS.
The CMMS eliminated most work traditionally required for the fourth step, closure of a maintenance call. In the past, administrators have spent a great deal of time and energy converting completed paper work orders into electronic formats. But because work orders in the CMMS were already electronic, the only job remaining for the central operators was be to follow up on completed maintenance to make sure all repairs were completed to satisfaction.
The CMMS enhanced the traditional reporting step by allowing all users in the system to generate and view reports. Traditional maintenance processes allowed only managers to request reports. In addition, all CMMS users had the ability to save reports and run them again at later times. Not only this empowered all users of the system, but it also provided them with knowledge that helped them do their jobs well.

3.2 Conceptually Designing a CMMS

The conceptual design of a CMMS for the MDMS in RMS included all information requirements, work order flow and functional capabilities of the system. The conceptual design was (should it be in present or in past) divided into the following sections:

1. System Access
2. Creation of a Work Order
3. Work Orders in Progress
4. Look-Ups
    - ❖ Work Orders
    - ❖ Station Information
    - ❖ Specific Device
    - ❖ Problems Information
    - ❖ Device Manufacturers
    - ❖ User Information
5. Scheduler
6. Reporting

The first section described how users connect and login to the system. The creation of work orders section explained how the system was notified of maintenance and how work orders were created. The section of work orders in progress explained how maintenance technicians used work orders during maintenance calls to document work and reference information within the system.
The look-ups section described the information available through the system and how a user might access it. The scheduler section described scheduling capabilities of the system. Finally, the reporting section described the reporting features of the CMMS.
Ultimately, the conceptual design organized the system requirements in a format more tangible than a simple list. An object-oriented model of the CMMS was built using the conceptual design.

3-3 Building the Object Oriented Model

The design of the CMMS of RMS was presented in logical view. It focused more on how the design of the system was implemented. It depicted the specific entities of the system and how these entities interacted with one another.
In the logical view, objects were grouped into classes and are organized in packages; the logical view consisted of classes, class diagrams, interaction diagrams and packages.
There were three different categorizations, or stereotypes, for classes: boundary, entity, and control. A boundary class is a class that allows the system to communicate with the rest of the country. Forms and hardware were all examples of boundary classes (O'Dnoghue *et al.*, 2004).

Entity classes contained information for storage. An example of this would be a Station class which contains the identifying information of a station. A control class was responsible for managing the events of the system. The relationships between the classes of the system were presented in a class diagram.

The logical view was not the only view of the CMMS of RMS. It also allowed the user to produce a deployment view of the system. The deployment view of the system provided the user with a lot of information about the medical device like: the inventory, the serial number, the model number, the name of the device, the manufacture, the local agent and the tender number.

4. RESULTS

The needs for the system were researched and combined to form a requirements document that outlined all needed functions of the system.

A conceptual design was created showing how the system functioned when implemented. This design employed logical view and deployment view to depict the specific entities of the system and to show how these entities interacted with one another.

5. DISCUSSION

The operator could always add these views and they were fully instructed on the proper methods for achieving this. With the completed model; the developer was able to generate skeletal code, in a variety of programming languages, which assisted in the implementation process.

6. REFERENCES

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