Determine an Equation to Calculate the Annual Maintenance Cost for Public Hospitals

(Al Sader City Hospital as a Case Study)

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ABSTRACT

Maintenance of hospital buildings and its management are regarded as an important subject which needs attention because hospital buildings are service institutions which are very important to a society, requiring the search for the best procedure to develop maintenance in hospitals.
The research is aimed to determine an equation to estimate the annual maintenance cost for public hospital. To achieve this aim, Al-Sader City Hospital maintenance system in Al-Najaf province has been studied with its main elements through survey of data, records and reports relating to maintenance during the years of the study 2008-2014 and to identify the strengths, weaknesses, opportunities and threat points in the current system through Swat analysis, which represents " analyzing the internal factors represented by strengths and weaknesses points and the external factors represented by opportunities and threats," [41]. On the basis of that, an equation has been obtained to estimate the cost of annual maintenance. To achieve this aim, the following issues should be taken into consideration:

- Studying the actual work program of the maintenance department in Al-Sader Hospital,
- Identifying the procedures used in maintenance and ways they are implemented,
- Studying the maintenance records and reports,
- Holding interviews with the manager of maintenance and its staff to integrate the information and
- Integrating the analysis of maintenance cost by using statistical analysis system (ASA 2012).

To assess the validity of the model for the annual maintenance cost, the predicted values of the equation are plotted against the actual measured (observed) values. Based on the validation data set, the coefficient of determination (R) was found to be equal to (82.5%), therefore it can be concluded that the developed equation showed moderate agreement with the actual measurements.
Finally, it can be concluded from the study that, the developed equation should be applied in hospital to overcome the problems and weak points of the current system and to estimate the annual maintenance cost for hospitals based on the scientific method.

Key words: maintenance of hospital, maintenance management, annual maintenance cost, hospital maintenance system.

ايجاد معادلة لحساب تكلفة الصيانة السنوية للمستشفيات العامة

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الخلاصـــــة

تعد صيانة ابنية المستشفيات واساليب ادارتها من المواضيع المهمة التي يجب تركيز الجهود للاهتمام بها لكونها من المؤسسات الخدمية الاكثر اهمية في خدمة المجتمع مما يتطلب البحث الدائم عن افضل الاساليب التي تساعد في تطوير اعمال صيانة المستشفيات.

يهدف البحث الى تطوير نظام ادارة الصيانة الحالي في المستشفيات العراقية ولغرض تحقيق ذلك تم دراسة وتحليل نظام الصيانة في مستشفى الصدر التعليمي في محافظة النجف بكافة عناصره الرئيسية من خلال الاطلاع على البيانات والتقارير والسجلات للسنوات المدروسة من 2008 الى 2014 وتم تحديد نقاط الضعف والقوة والفرص والتهديدات في النظام الحالي من خلال تحليل سوات، الذي يمثل "تحليل العوامل الداخلية ممثلة نقاط القوة ونقاط الضعف نقاط والعوامل الخارجية التي يمثلها الفرص والتهديدات" [41] .وعلى اساس ذلك تم ايجاد معادلة تعمل على تخمين كلفة الصيانة السنوية ولغرض تحقيق ذلك تم:

- دراسة واقع حال عمل قسم الصيانة في مستشفى الصدر التعليمي
- التعرف على الاساليب المستخدمة في الصيانة وكيفية تنفيذها
- دراسة السجلات والتقارير والبيانات المتعلقة بالصيانة
- اجراء مقابلات شخصية مع مدير الصيانة والعاملين في القسم لغرض تكامل المعلومات
- تحليل متكامل لكلف الصيانة باستخدام برنامج التحليل الاحصائي (SAS 2012).

لغرض التأكد من صلاحية معادلة حساب الكلفة السنوية للصيانة، تم رسم القيم المتوقعة من المعادلة مع القيم الملاحظة لسنة 2014 من المستشفى المدروس لغرض التحقق من صحة البيانات وتحديد معامل التحديد (R) الذي يساوي (82.5٪) ، وبالتالي فإنه يمكن استنتاج أن المعادلة تظهر نتائج مقاربة مع القيم الفعلية.

في نهاية البحث، تم إعطاء عدد من الاستنتاجات والتوصيات؛ الرئيسي منها يجب تطبيق المعادلة في المستشفى للتغلب على المشاكل ونقاط الضعف في النظام الحالي وتحديد تكلفة الصيانة السنوية للمستشفيات وفقا للطريقة العلمية.

الكلمات الرئيسية: صيانة المستشفيات، نظام ادارة الصيانة، مستفى الصدر التعليمي، كلفة الصيانة السنوية، معادلة تخمين الكلفة.

1. INTRODUCTION

Hospital buildings are considered as an important facilities in the country because of their great responsibility to offer medical and health service for huge population, especially in the current conditions in Iraq that have led to a weak security situation, which has caused an unnatural increase in the number of patients. So it became necessary to maintain those buildings in good condition which cost the country economy huge amounts of money .

Maintenance of any building comes from the planning stage, but the organization and implementation of maintenance work are done only after the building is completed as a result of change in preoccupation conditions of the building, **Geisler, 2002**.

Every structure requires care to limit deterioration. Exposure to the elements causes all building materials to wear down eventually. Periodic inspections can help to figure out the problems early and together with regular maintenance, these practices can extend the life of building.

Set up a building maintenance schedule to remind you of any inspections or work that needs to be done. This will help prioritize required maintenance and prevent costly future repairs. Over the life of a structure, it had been shown that a small dose of planned maintenance on an annual frequency was less costly than a large one time corrective repair **Renew, 2012**.

Maintenance of hospital buildings is one of the complex subjects in the field of building maintenance, but what contributes to this nature is the accuracy of its mechanical and electrical systems. The inadequate maintenance budgets and the qualities of the physical environment in which patients receive care can be positive or negative, **Malkin and Wiley, 1992**. So maintenance work for hospitals should be planned and programmed to find adequate solutions to do better maintenance because a good building requires a good maintenance, **Hutton and Lloyd, 2006.**

The Maintenance aims to extend the life of machines and buildings in hospitals because of their high costs. Additionally, maintenance aims to reduce the lost time caused by malfunction of machines which may greatly influence the productivity of the hospital in terms of quantity and quality of medical services provided. On the other hand, hospitals administrations, for obvious reasons, prefer the maintenance work itself to be with minimal cost, effort and time but with best quality.

Therefore, the importance of maintenance arises in both health and non-health institutions alike; hence, developing countries, traditionally pay great attention to maintenance.

2. RESEARCH JUSTIFICATION

The hospitals are the most important buildings that have direct contact with patient's lives and their importance lies in the provision of humanitarian and medical services. The justifications for the preparation of this research, which was reached through the Swat analysis, are:

1- The deficiencies in the maintenance management system of government and private hospitals in Iraq.

2- Retardation the hospitals maintenance systems in Iraq.
3- No assigned maintenance tasks to specialists.
4- Lack of sufficient funds for maintenance.
5- Administrative and financial corruption.
6- The absence of real survey for information of the real situation of the reality of maintenance.
7- The lack of a clear and consistent maintenance plans by senior management.
8- Low wages and incentive rates for workers in this field.

3. DEFINITIONS OF MAINTENANCE

The following are some of the most common definitions:

- " A set of technical and administrative activities that work to keep the assets away from the occurrence of any failure that might lead to reducing the efficiency and productivity ", **Abdul, 2009**.
- " All Works carried out to maintain the building and protect it from damage in order to do its function as long as possible by repairing defects and hence reducing costs resulted from negligence ", **Chandler, 1987**.

4. TYPES OF MAINTENANCE

Maintenance includes the following types, **Higgins and Morrow, 1977**

1- Unplanned maintenance: Maintenance activities occur without any prior planning.
2- Preventive maintenance: Maintenance activities are performed according to a plan and within the time periods for the purpose of reducing the probability of failure and improving the performance.
3- Corrective Maintenance: The maintenance activities take place after the occurring of a failure. The purpose is to restore the situation back to the normal conditions.
4- Scheduled maintenance: A preventive maintenance in which maintaining activities are carried out according to specific quantitative criteria such as periods of time, number of operating times or Mileage.
5- Condition-based Maintenance: A preventive maintenance in which maintaining activities are promoted based on the outcomes of the inspection and routine testing**.**

5. DEFINITIONS OF HOSPITAL

A hospital can be defined as a health care institution in which patients are treated by specialized staff and equipment. The most popular type of hospitals is the general hospital, which normally has an emergency department.

A district hospital is typically the major health care in its region, with large numbers of beds for long-term care; specialized hospitals are included, **Martin et al., 2009.**

1- Rehabilitation hospitals: Which include children's hospitals, seniors' hospitals, and hospitals for dealing with specific medical needs such as (psychiatric problems).

2- Teaching hospitals: In addition to provide treatment for patients, they provide education for doctors, pharmacists and nurses.
3- The medical facility: Smaller than a hospital; it is generally called a clinic.
4- Hospitals are unproductive service institutions usually funded by the public sector such as Ministry of Health and health insurance companies.

5.1 Objectives of Maintenance in Hospitals

The most important objectives of maintenance in hospitals include **Geert, and Pintelon, 2002**:

1- Prolonging the productive life for the machinery and equipment and all facilities of the hospital.
2- Maximizing the use of the existing equipment and services.
3- Making sure of the permanent readiness for all machines and equipment, especially for emergencies.
4- Ensuring the safety of patients and staff when they use the devices and extensions that available in the hospital.
5- Reducing costs through sustainable running of all the machines and equipment and increasing their productivity. This does not mean final objective is to reduce maintenance costs, but to get the best level of cost within the level of maintenance.

5.2 Execution of Maintenance Work in Hospitals

Maintenance work in the hospitals is done in general by dividing the hospital into parts so that maintenance can be done easily. For instance, the hospital is divided into parts for maintenance purposes, **Shah, 2009**:

1- Buildings: A timetable is set to carry out building maintenance which covers the following:
   - Painting and washing kitchen every three months; while wards and restaurants as well as other hospital facilities once a year.
   - Painting and washing doctors' clinics every two or three years.
   - Furniture maintenance every two years.
   - Street re-pavement and corridors every four years.
   - Water pipe and sewer networks every eight years.
2- For the maintenance of electrical, mechanical and medical instruments, a list is made to carry out maintenance work on them:
   - Daily inspection of electrical connection.
   - Testing electrical points and calibration, wires and electrical connections every month
   - Generators and machines yearly.
   - Checking all instruments according to a timetable and in agreement with instrument nature and expected breakdown

3- A variety of works; Because in a hospital, there are many units such as washing machine unit, the elevators which need regular inspection and which need maintenance to be used regularly,

therefore, their electrical, electronic and mechanical systems should be always inspected together with the communications system. Warehouses should also be maintained.

6. STUDY THE REALITY OF THE IRAQI HOSPITALS MAINTENANCE MANAGEMENT SYSTEM

6.1 Introduction to the Case Study

Al-Sader City hospital is one of the most important medical health institutions among the hospitals of Al- Najaf province; it is located on the main road linking Najaf city to Kufa city. Al-Sader City was implemented by a German company at a cost of 22 Billion ID and on a total area of (67,500) square meters. It was opened in 1983 with a capacity of 200 beds; this capacity was continually increasing to reach at the end of 2013.

6.2 Human Resources and Training and Development in Al-Sader City Hospital

Human resources are important factors for the success of the maintenance process at any institution. The details of human resources in Al-Sader hospital are shown in **Tables 1 and 2**.

There are two types of courses in training and developing department at Al-Sader medical city:

1- Basic: Courses are needed by the employees for promotion from one level to above.
2- Developing: Courses are needed to develop the efficiency and ability of workers.

Table 3 shows a model for proposed courses by the Ministry of Health in hospital for year 2013.

6.3 Survey of Approaches Maintenance Management in Al-Sader City Hospital

Based on the field visits and following-up on one side and the understanding of the tasks, duties and objectives on the other side, the organizational framework of maintenance department can be structured as shown in **Fig. 1**. This figure represents the structure for the programming of maintenance work in the hospital and also reflects a simple embodiment for the tasks and the works carried out by the department.

6.4 Statistical Analysis of the Data

The researcher adopted the data on maintenance cost during the last seven years (2008-2014) through interviews with Department head in the hospital as well as with Department Head in the Najaf health directorate and official documents, records and statistics related to the hospital. On the other hand, the researcher adopted interviewing with the maintenance department staff in order to integrate information. The data were represented by curves for easy discussion as shown in **Figs. 2** and **3**.
The statistical analysis system (SAS 2012) was used to estimate regression coefficient (multiple regressions) of y variable on difference dependent variables represented by (maintenance of water

installation, electrical installation, transportation, furniture, building, machinery and equipment and gardens) in seven years (2008-2014) to develop an equation as shown below.

$$Y= 7405316890 -86.05 X_1-18.72 X_2+624.21 X_3-58.34 X_4+5.48 X_5-7.86 X_6-14.56 X_7 \quad (1)$$

Where:

X_1: Maintenance of water installation
X_2: Maintenance of electrical installation
X_3: Maintenance of transportation
X_4: Maintenance of furniture
X_5: Maintenance of building
X_6: Maintenance of devices and equipment
X_7: Maintenance of gardens, and
Y: Annual maintenance cost

6.5 Validity of the Annual Maintenance Cost Equation

To assess the validity of the model for the annual maintenance cost, the predicted values of the equation are plotted against the real measured (observed) values of hospital for validation data set for years under study (Log were taken because the small number of data) as shown in **Fig .4**.

The coefficient of determination, (R), from **Fig. 4** is (0.825%), which means that the seven studied factors (X_1, X_2, …, X_7) explain (82.5%) from annual maintenance cost (Y) and (17.5%) from other factors.

It is clear from **Table 4** that the error lays within the good categorization. Therefore, it can be concluded that AMCA equation shows moderate agreement with the actual measurements.

7. CONCLUSIONS

1- There is no scientific system which the maintenance management can resort to determine allocated maintenance cost and priorities of maintenance activates. The difference between the actual and allocated reached to (21%).

2- Weakness of balance between the number of technical and engineering staff in the maintenance unit is compared with that of administrative and technicians. There is a lack of some necessary specializations where the number of engineers is (33%), technicians (54%), craftsmen (11%) and administrates (2%) of the total number of maintenance staff.

3- The maintenance staffs are not enrolled in training courses for maintenance of modern medical instruments and training courses to improve their capability in maintenance management.

4- Validity of alternative hypothesis is stated that there is an equation able to calculate the allocated cost of maintenance where its coefficient of determination (R) is (82.5%) between predicted values of the equation and the real observed values of hospital.

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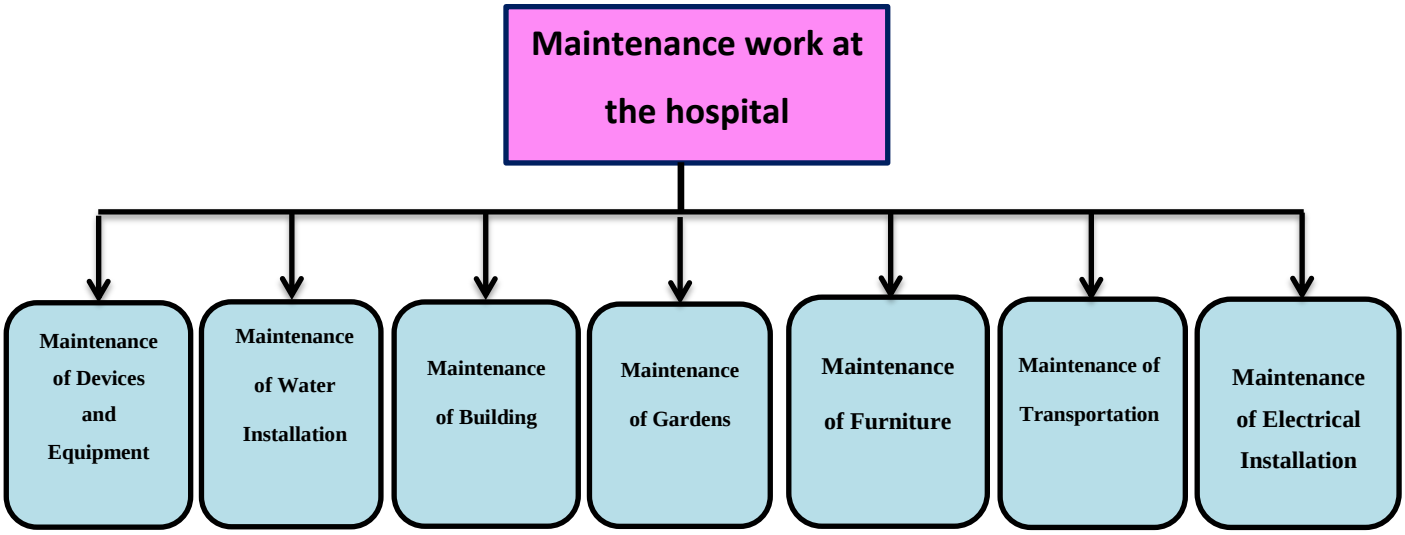

Figure 1. The approach of maintenance execution.

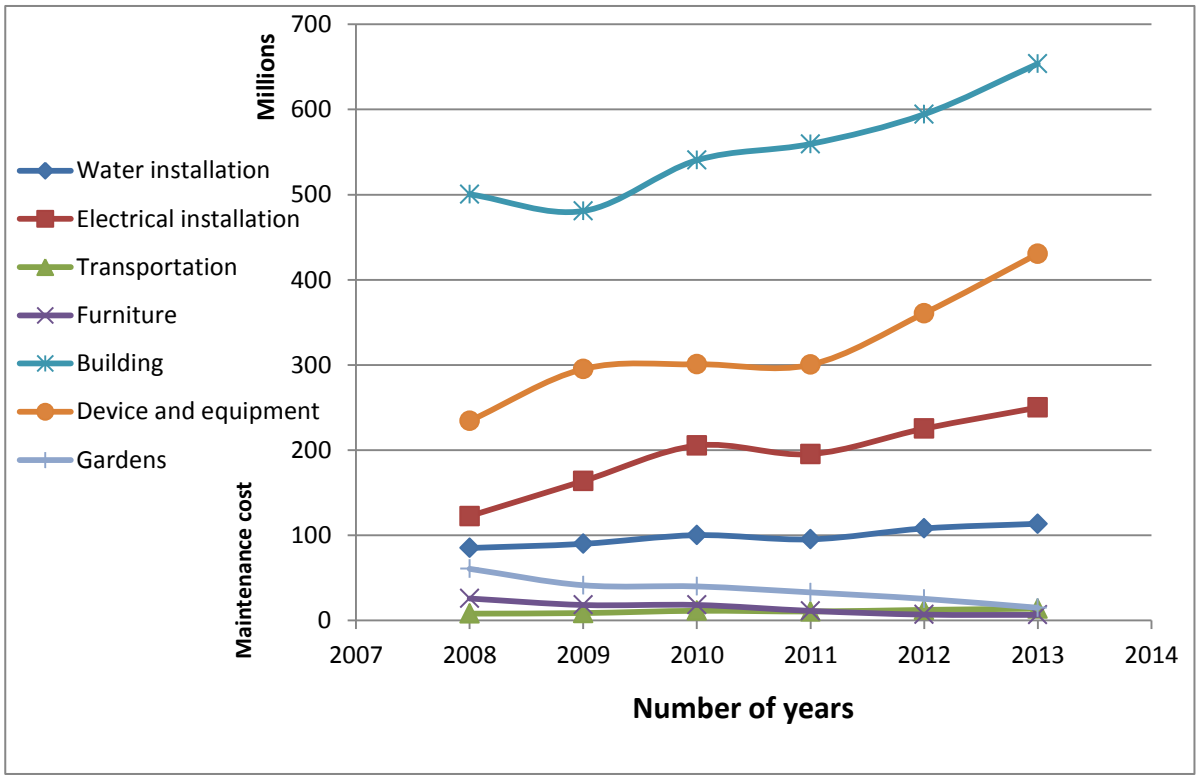

Figure 2. The actual maintenance cost of maintenance types during the years under study.

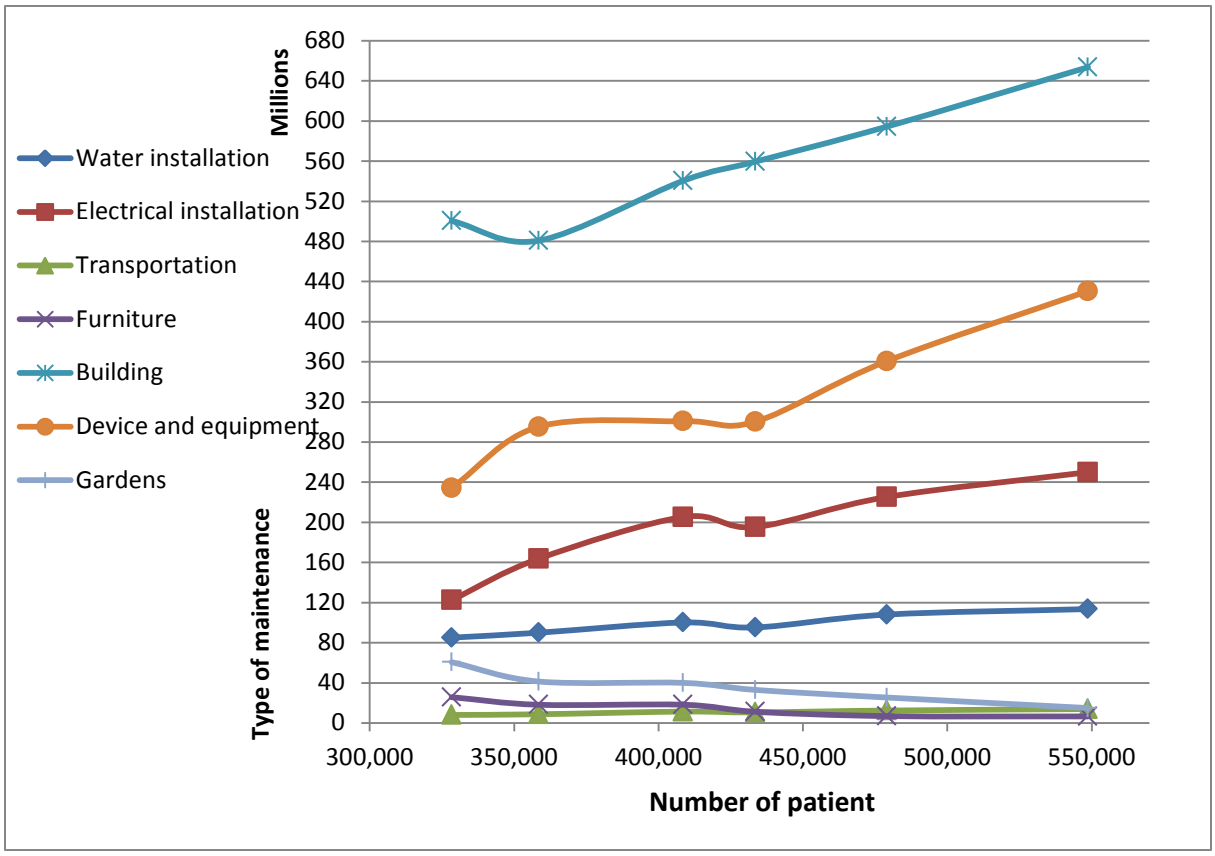

Figure 3. Distribution of maintenance types with the number of patient.

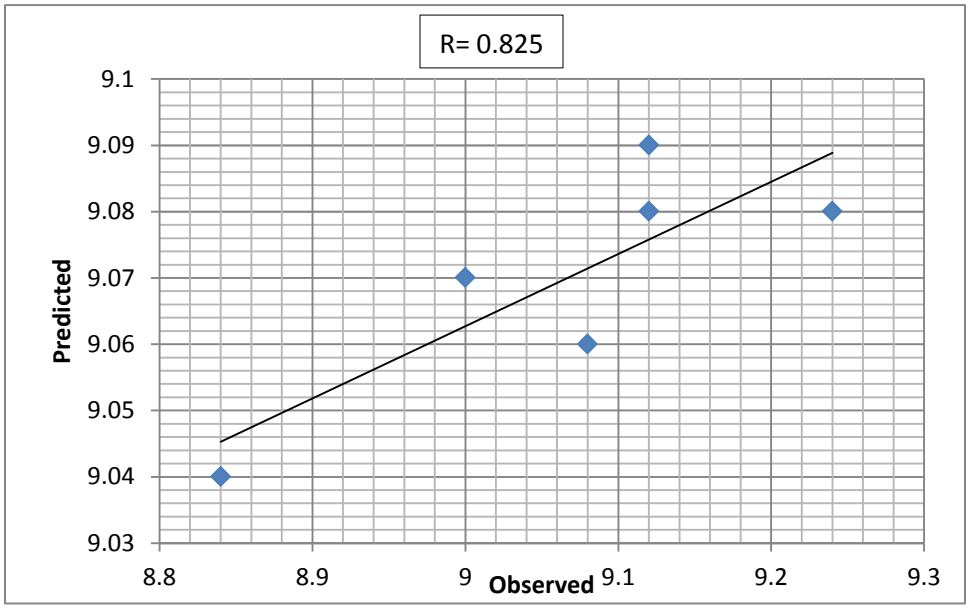

Figure 4. Comparison of predicated and observed data set.

Table 1. The cross-classification of the total staffs by profession and type until 2013.

Profession	Permanent staffing		Temporary		Total
	Mail	Female	Mail	Female	
Engineer	9	5	—	2	16
Technician	18	2	6	—	26
Craftsman	5	—	—	—	5
Administrative	1	—	—	—	1

Table 2. The cross-classification of the permanent staff by the level of the profession and academic qualification.

Profession	Master	Bachelor	Institute	Industrial School	Intermediate	Primary	Total
Engineer	1	15	—	—	—	—	16
Technician	—	—	16	6	3	1	26
Craftsman	—	—	—	—	2	3	5
Administrative	—	—	—	—	1	—	1

Table 3. Model for proposed courses in Al-Sader medical city.

No.	Name of course	Duration	The participants	Place of course
1	Operation and maintenance of electric jolt devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
2	Operation and maintenance of Lithotripsy devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
3	Construction Project management	Weekly	All specialties	Department of medical device manager/Division of

				training and development
4	Operation and maintenance of MRI devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
5	Operation and maintenance of X- ray devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
6	Operation and maintenance of ECG devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
7	Operation and maintenance of anesthesia devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
8	Operation and maintenance of occupational safety	Weekly	All specialties	Department of medical device manager/Division of training and development
9	Operation and maintenance of scanner- CT devices	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development
10	Electronics	Weekly	Engineers and technicians (medical devices)	Department of medical device manager/Division of training and development

Table 4. Error categorization, (%), **Schexnayder, 2003.**

MAPE		
Good	**Fair**	**Poor**
Less than 25	25-50	More than 50