
# THE EFFECT OF HUMAN FACTORS AND DEVICE CHARACTERISTICS ON THE MEDICAL EQUIPMENT FAILURES OCCURRENCE USING REGRESSION MODELING

By

**Mona Mohamed Mahmud Ali**

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
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**In**
**Biomedical Engineering and Systems**

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**Title of Thesis:**

The Effect Of Human Factors And Device Characteristics On The Medical Equipment Failures Occurrence Using Regression Modeling

**Key Words:**
Human factors; device characteristics; equipment failure occurrence; regression modeling

**Summary:**

Maintenance schedules for medical equipment are very important in order to improve its performance, reliability and probability of failure reduction. Most of the hospitals have to write maintenance contracts with the manufacturers that recommend maintenance schedules programs more frequently than the medical equipment actually needs. This action may reduce the probability of failures, but increases the cost of the maintenance contracts.

The objective of this study is to define a methodology to support the real definition of maintenance contract intervals, and introduce overall maintenance scheduling recommendations for the hospital to reduce the cost of these contracts based on the mean time between failures (MTBFs) .The study identifies the most important risk factors for medical equipment failures, in order to propose interventions that can minimize the medical equipment failure risk and maximize its operating life.

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# List of Abbreviations

**ABC:- activity based costing.**

**ABG:- arterial blood gases.**

**AR based:- augmented reality.**

**AR:- autoregressive.**

**ARMA:- auto regressive moving average.**

**CE'S:- clinical engineers.**

**CM:- corrective maintenance.**

**GIHT:- global initiative on health technologies.**

**H:- internal hospital maintenance variable.**

**HFE:- human factors engineering.**

**HTM:- health-care technology management.**

**IPM:- inspection and preventive maintenance.**

**ISO:- international standard organization.**

**JCAH:- joint commission accreditation for healthcare.**

**LPC:- linear predication coefficient.**

**MDMS:- medical device maintenance system.**

**MTBF:- mean time between failure.**

**QFD:- quality function deployment.**

**SH:- specialty hospital.**

**U:- user interface variable.**

# Abstract

Maintenance schedules for medical equipment are very important in order to improve its performance, reliability and to reduce the probability of failures. Most of the hospitals have to write maintenance contracts with the manufacturers that recommend maintenance schedules programs more frequently than the medical equipment actually needs. This action may reduce the probability of failures, but it increases the cost of the maintenance contracts.

The objective of this study is to define a methodology to support the real definition of maintenance contract intervals, and to introduce overall maintenance scheduling recommendations for the hospital to reduce the cost of these contracts based on the mean time between failures (MTBFs). The study identifies the most important risk factors for medical equipment failures, in order to propose interventions that can minimize the medical equipment failure risk and maximize its operating life.

This study includes four critical types of devices that are found in most of the hospitals like ventilators, anesthesia machines, syringe, and infusion pumps.

Six independent variables are considered in the classification of equipment use conditions. These independent variables are divided into two types, Type one includes four independent variables related to medical equipment characteristics (intensity of use, technological level, use stress, and importance). Type two includes two independent variables related to human factors (internal hospital maintenance and user interface for the clinical staff). These six independent variables are used as predictors for the occurrence of failure, which is the dependent variable.

Regression modeling is used for the prediction of which independent variable will have an impact on the dependent variable (occurrence of failure). Two types of regression models (logistic regression and ordinal regression) by using SPSS 23 package were applied. The mean time between two successive failures is estimated for the categories of indicators deemed relevant by the regression.

The ordinal regression model revealed that for the anesthesia machine and ventilator devices five independent variables (intensity of use, technological level, importance,use stress, and internal hospital maintenance) had a statistically significant impact on the equipment occurrence of failures, while for the infusion and syringe pumps five independent variables (intensity of use, technological level ,importance, use stress, and user interface) had a statistically significant impact on the equipment occurrence of failures.

The multinomial logistic regression model revealed that for the anesthesia machines three independent variables (intensity of use, technological level and use stress) had a statistically significant impact on the equipment occurrence of failures and the human factors had no statistical impact on the failure occurrence, whereas for the ventilator devices four independent variables (intensity of use, importance,use stress, and the internal hospital maintenance) had a statistically significant impact on the equipment occurrence of failures. Finally, for the infusion and syringe pumps all the six independent variables had a statistically significant impact on the equipment occurrence of failures.

The MTBF, according to the failure rate for each type of devices ranged from 2 days for the infusion pumps and syringe pumps to 27 days for anesthesia machines and ventilators. The study recommends that the maintenance intervals for the anesthesia

machines and ventilator devices should be about 30 days. It also recommends short maintenance periods for the infusion and syringe pumps.

The results further indicate large inadequacies in the maintenance contract periods used by the hospital and suggest that a better maintenance strategy would be the compatibility of the maintenance periods with the identified MTBF intervals.