



Cairo University

**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
MASTER OF SCIENCE
In
Biomedical Engineering and Systems

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

Prof. Dr. Amr Sharawy

Prof. Dr. Manal Abdel waheed

Professor of Biomedical Engineering
Department
Faculty of Engineering, Cairo University

Professor of Biomedical Engineering
Department
Faculty of Engineering, Cairo University

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Approved by the
Examining Committee

Prof. Dr. Amr Sharawy

(Main Advisor)

Prof. Dr. Manal Abdel wahed

(Thesis Advisor)

Prof. Dr. Ahmed Hesham Kandil

(Internal Examiner)

Prof. Dr. Mohamed Ibrahim ElAdawi

(External Examiner)

Professor at Engineering and Technology, Faculty of engineering, Helwan
University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

Engineer's Name: Mona Mohamed Mahmud Ali
Date of Birth: 30/12/1984
Nationality: Egyptian
E-mail: Bioeng_mona@yahoo.com
Phone: 01067045072
Address: 3 Hassan Elsherif kobri elkoba
Registration Date: 10/10/2011
Awarding Date:/....../2017
Degree: Master of Science
Department: Biomedical engineering and Systems

Insert photo here

Supervisors:

Assoc.Prof. Amr Sharawy
Prof. Manal Abdelwahed

Examiners:

Prof. Mohamed Ibrahim ElAdwi (External examiner)
Professor at Engineering and Technology, Faculty of
Engineering, Helwan university

Prof. Ahmed Hesham Kandil (Internal examiner)
Prof. Amr Sharawy (Thesis main advisor)
Prof. Manal Abdel wahed (Thesis Advisor)

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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Table of Contents

ACKNOWLEDGMENTS.....	I
LIST OF TABLES.....	III
LIST OF FIGURES.....	VII
LIST OF ABBREVIATION	VII
ABSTRACT	IX
CHAPTER 1: INTRODUCTION	1
1.1. MEDICAL EQUIPMENT MANAGEMENT	1
1.2. MOTIVATION AND PROBLEM DEFINITION.....	1
1.3. MAINTENANCE STRATEGIES	2
1.4. THESIS OBJECTIVE.....	3
1.5. ORGANIZATION OF THE THESIS	4
CHAPTER 2: GENERAL BACKGROUND	5
2.1. GENERAL CONCEPT.....	5
2.2. MEDICAL DEVICES OF OUR STUDY.....	15
2.3. LITERATURE REVIEW.....	18
CHAPTER 3: MATERIAL AND METHODS	24
3.1. DATA SET	24
3.2. THE IMPLEMENTATION OF THE REGRESSION STATISTICAL MODEL	24
CHAPTER 4: RESULTS AND DISCUSSION	34
4.1. MULTINOMIAL LOGISTIC REGRESSION	34
4.1.1. THE ANESTHESIA MACHINE	34
4.1.2. THE VENTILATOR DEVICES.....	36
4.1.3. THE INFUSION & SYRINGE PUMPS.....	37
4.2. ORDINAL LOGISTIC REGRESSION	38
4.2.1. THE ANESTHESIA MACHINE	38
4.2.2. THE VENTILATOR DEVICES.....	40
4.2.3. THE INFUSION & SYRINGE PUMPS.....	41
4.3. FAILURE ANALYSIS	42
4.4. THE DISCUSSION	44

CHAPTER 5: CONCLUSION AND FUTURE WORK	47
5.1. CONCLUSION	47
5.2. FUTURE WORK.....	48
REFERENCES.....	49
APPENDIX A: AN EXAMPLES OF FILLED QUESTIONNAIRES	52
APPENDIX B: AN ARABIC QUESTIONNAIRES	59
APPENDIX C: AN EXAMPLES OF THE CHRONBACH’S ALPHA FOR INTERNAL HOSPITAL MAINTENANCE AND USER INTERFACE VARIABLES FOR EQUIPMENT STUDY	61
APPENDIX D: AN EXAMPLES OF THE CLASSIFICATION TABLES OF EACH INDEPENDENT VARIABLES WITH THE DEPENDENT VARIABLE.....	64

List of Tables

Table 2.1. Regression categorization.

Table 3.1. The Equipment Classification Variables Questionnaire.

Table 3.2. Hospital Maintenance Questionnaire.

Table 3.3. The User Interface Questionnaire for Medical Device.

Table 3.4. The Cronbach's alpha of hospital maintenance variable for the anesthesia machine.

Table 4.1. Example table for The classification table for the maximum value of internal hospital maintenance.

Table 4.2. The significance value for mean, minimum and maximum values and the error values of the internal hospital hospital maintenance variable.

Table 4.3. The significance value for mean, minimum and maximum values and the error values of the user interface variable.

Table 4.4 The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.5. The significance value for average, minimum and maximum values and the error values of the internal hospital hospital maintenance variable.

Table 4.6. The significance value for average, minimum and maximum values and the error values of the user interface variable.

Table 4.7. The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.8. The significance value for average, minimum and maximum values and the error values of the internal hospital hospital maintenance variable.

Table 4.9. The significance value for average, minimum and maximum values and the error values of the user interface variable.

Table 4.10. The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.11. Example table for The classification table for the maximum of hospital maintenance.

Table 4.12. The significance value for mean, minimum and maximum values and the error values of the internal hospital maintenance variable.

Table 4.13. The significance value for mean, minimum and maximum values and the error values of the user interface variable.

Table 4.14. The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.15. The significance value for mean, minimum and maximum values and the error values of the internal hospital maintenance variable.

Table 4.16. The significance value for mean, minimum and maximum values and the error values of the user interface variable.

Table 4.17. The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.18. The significance value for mean, minimum and maximum values and the error values of the internal hospital maintenance variable.

Table 4.19. The significance value for average, minimum and maximum values and the error values of the user interface variable.

Table 4.20. The significance values and error values of the technological level, intensity of uses, importance and use stress.

Table 4.21. Total number of devices, number of devices in the “critical” categories and total number of failures, according to equipment type.

Table 4.22. Total Equipment Number, Total Number of Failures, Failure Rate and Mean Time between Failures (MTBF).

List of Figures

Figure 2.1: Critical factors in planning maintenance program

Figure 2.2: The regression models

Figure 2.3: The Logistic Model Curve

Figure 2.4: The ordinal regression

Figure 2.5: The operation cycle of the anesthesia machine.

Figure 2.6: The anesthesia machine system components

Figure 2.7: The ventilator system components

Fig. 3.1: Basic implementation and analysis steps

Figure 4.1: Error rates for multinomial logistic and ordinal regression applied to Anesthesia machines

Figure 4.2: Error rates for multinomial logistic and ordinal regression applied to Ventilators

Figure 4.3: Error rates for multinomial logistic and ordinal regression applied to the syringe and infusion pumps

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.