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# Optimizing The Maintenance Process In The Management Of Medical Equipment At The Hospital *By Using Quality Function Deployment*

Hong Nhung Vo Thi[1], Ngoc An Dang Nguyen[2], Nhat Nam Nguyen[2] and Trung Nghia Tran[3*]

[1]Biomedical Engineering Department, Faculty of Applied Science, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam
Vietnam National University – Ho Chi Minh City, Vietnam

[2]Faculty of Electrical and Electronics Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam
Vietnam National University – Ho Chi Minh City, Vietnam

[3]General Physics Laboratory, Faculty of Applied Science, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam
Vietnam National University – Ho Chi Minh City, Vietnam

[4]Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam

ttnghia@hcmut.edu.vn

**Abstract**

This paper aims to provide a solution to the mentioned problem, a way to optimize planning and the execution of maintenance, with the test size being 320 patient beds, by developing a 3-frame model using QFD (Quality Function Deployment) to create a priority assessment program. The priority score is based on risks, mission, and maintenance. Therefore, the traditional use of QFD can end up overridden prioritized decisions. To improve the original model, Fuzzy Logic is integrated into the model. The model helps identify essential criteria as well as optimize the budget required for maintenance. From there, it assigns priority scores and sorts the equipment based on them to create the most suitable maintenance schedule.

## 1 Introduction

In recent years, the quality management of medical devices has become increasingly difficult, due to the increasing complexity and specialization of today's machines and equipment, requiring improved requirements. safety, reliability and accuracy. Therefore, a methodical maintenance plan for

medical equipment is indispensable, which will help maintain and ensure the equipment is always in the best condition.

Performing external maintenance keeps equipment in good working order, reducing unexpected breakdowns and failures while also improving patient safety and continuum of clinical care.

The reason is that the management and control of equipment assets in the hospital has not been implemented effectively.

The state of medical equipment and machinery is often damaged, greatly affecting the medical examination and treatment process of the medical team at hospitals.

On the other hand, unscientific asset management is the cause of unexplained property loss.

For small hospitals, local health stations. These conditions can be rectified within a certain period of time. However, for large hospitals, the number of visits per year is up to several million people. With the current medical equipment repair management model, it will greatly affect hospital maintenance costs and form an unprofessional working process.

A Maintenance Management System (MMS) implementation should be used with appropriate maintenance activities for medical devices to improve the goals of the medical device system. In this document, Quality Function Deployment (QFD) is being used as an improvement method in MMS and as a guide in highlighting operational weaknesses and finding appropriate procedures to fix them to achieve customer satisfaction.

# 2 Methods

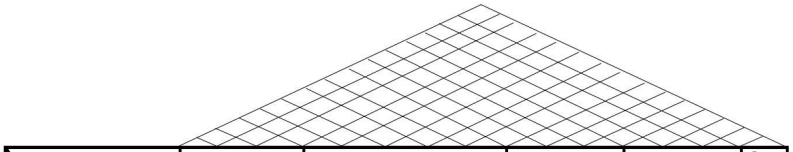
QFD is defined as a process for establishing a quality of design, which is aimed at satisfying the requirements of customers and then translating these requirements into design specifications and measurable quality targets to be used throughout the production phase. As a result, QFD is a technique for ensuring design quality while a product is still in the design stage. It is also a means of recognizing, valuing, and carrying the customer's voice throughout the design process. QFD is made up of two main components that are used in the design process: quality and function. The quality deployment component allows the customer's voice (VOC) to be included in the design process. The function deployment component brings together various organizational areas in order to translate customer inputs into detailed engineering requirements and design specifications. This component also aids in the creation of operational definitions based on the customer's requirements, which are frequently expressed in a hazy manner. Overall, QFD is intended to assist organizations in identifying the characteristics of a new or existing product (or service) that will meet the needs of various market segments, as well as the needs of the company or technology development.

QFD employs a series of linked matrices to ensure that customer feedback is translated throughout all aspects of the design, manufacturing, and delivery processes. The Customer Requirement Planning Matrix is the first of these matrices. Because of its overall appearance, it is also known as the House of Quality.

We presented a three-domain structure for preventive maintenance priority utilizing QFD, as shown in Fig. 3, which includes the requirement domain, function domain, and concept domain.

## 2.1 Requirement domain

The requirement domain is illustrated under the HOQ model. In which, customers (WHATs) of this model are patients and users of medical equipment (clinical staff); The department responsible for fulfilling the requirements (HOWs) is the BME (engineering department). Patient requirements include the level of safety and availability of the medical device. And clinical staff requirements are selected based on experience and density of medical device usage.



| | Risk | | | Performance Assurance | | | | | User Competence | | | The cost | | | Standard compliance | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Physical risk | Funtion | Maintenance requirements | Mission Criticality | Age | Electrical Safety | Replacement of the parts | Regular inspection | Qualification of technicians | Complexity of device | Device Availability | Spare parts availability | Repair | Update | Meet standards | Importance factor | CHI satisfactian | Goal | Improvement Ratio | Absolte weight | Relative weight |
| Safe of the medical device | 9 | 9 | 9 | 3 | 3 | 9 | 3 | 3 | 3 | 3 | | | | | 9 | 5 | 4 | 5 | 1.25 | 6.25 | 12.78 |
| Efficiency | | 9 | 9 | 1 | 9 | 9 | 3 | 3 | 3 | | | 3 | 9 | | 9 | 5 | 3 | 5 | 1.67 | 8.33 | 17.03 |
| Durability | | 1 | 3 | 1 | 9 | 3 | 3 | 3 | 3 | 9 | | 3 | 9 | | 3 | 4 | 3 | 5 | 1.67 | 6.67 | 13.63 |
| Maintenance service | 9 | 3 | 9 | 3 | 9 | | 3 | | | | | | 3 | | 9 | 5 | 3 | 4 | 1.33 | 6.67 | 13.63 |
| Periodic inspection | 3 | 9 | 9 | 9 | 3 | | 3 | 9 | 9 | 3 | 9 | | 3 | | 9 | 3 | 2 | 4 | 2.00 | 6.00 | 12.26 |
| Mission Criticality | | 3 | 3 | 9 | 1 | | | 1 | | | | 9 | 1 | 3 | | 4 | 3 | 4 | 1.33 | 5.33 | 10.90 |
| Avoiding suspension of service | 9 | | | 3 | | | | 3 | 3 | 9 | 9 | 3 | 9 | | 3 | 4 | 3 | 5 | 1.67 | 6.67 | 13.63 |
| Downtime | | | | | 9 | | | | | | | | 1 | | | 2 | 2 | 3 | 1.50 | 3.00 | 6.13 |
| **Absolte weight** | 397 | 466 | 575 | 359 | 540 | 309 | 208 | 292 | 282 | 320 | 233 | 231 | 493 | 33 | 583 | 5322 | | | | 48.92 | |
| **Relative weight %** | 7.46 | 8.75 | 10.80 | 6.75 | 10.14 | 5.81 | 3.91 | 5.50 | 5.29 | 6.02 | 4.38 | 4.34 | 9.27 | 0.61 | 10.96 | | | | | | |
| **Rank** | **6** | **5** | **2** | **7** | **3** | **9** | **14** | **10** | **11** | **8** | **12** | **13** | **4** | **15** | **1** | | | | | | |

**Figure 1:** The house of quality matrix (HOQ) of QFD model for preventive maintenance prioritization of medical equipment (requirement domain)

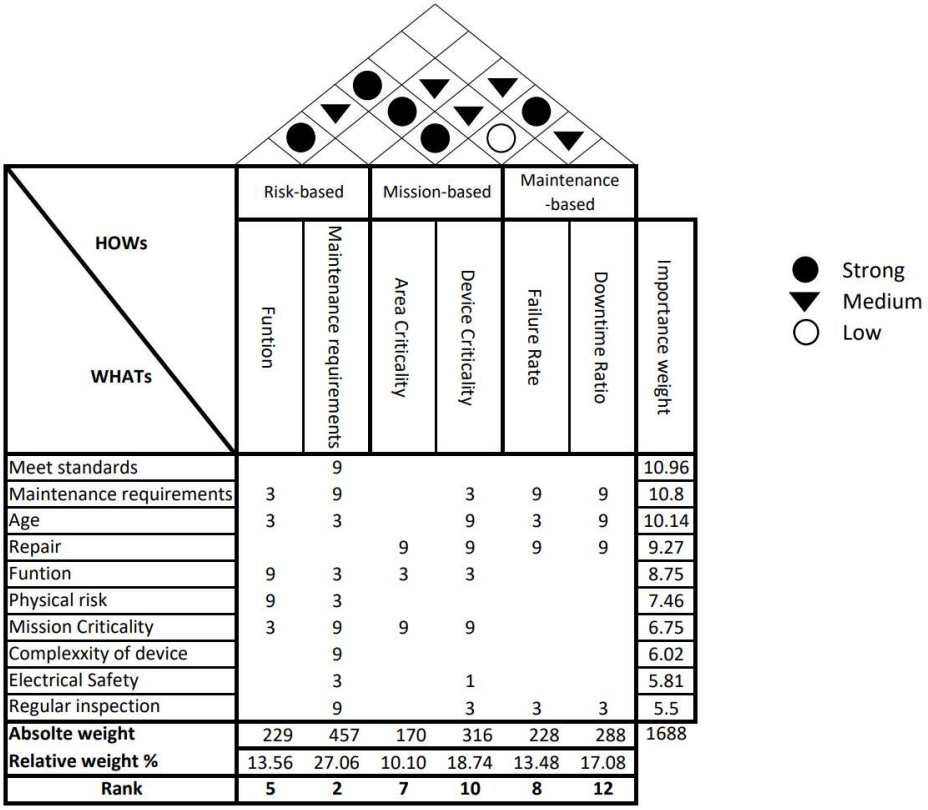
Figure 1 depicts the HOQ of the requirements domain of the QFD model to prioritize the maintenance and repair of medical equipment. The requirements of the client client and clinical staff were met by addressing five specifications including risk, performance, training, cost, and criteria with accompanying sub-criteria. The left column contains requests from patients and clinical staff; the central main part contains the specifications and relationship matrix; the right column is the significance level and planning matrix of the HOQ and finally the design goal matrix.

The relationship between WHATs and HOWs was rated with a score of 9 for strong, 3 for moderate, 1 for low, and blank for unrelated requirements. In order to demonstrate the prioritization of customer needs, rating scales are established and goals are prioritized to be improved based on the absolute weights of "HOWs" (requirements). Skill). Based on the evaluation of the weights, it can be seen that the requirements have high priority such as: Customers tend to give high priority to equipment performance (17.04%); durability, maintenance and downtime (13.63%); and safety level (12.78%). As for the requirements from the technical team, high priority is given to standard requirements (meeting standards, 10.96%), risk requirements (maintenance requirements, 10.8%) and requirements. performance requirements (time of use, 10.14%)

## 2.2 Function domain

The next phase of the model is to identify the key criteria among the technical standards for prioritizing performance in preventive and corrective maintenance. There are 10 technical criteria selected based on importance to input (WHATs) illustrated by the design matrix with HOQ similar to Figure 3.17 except for the planning matrix. The standards are classified into 3 groups of HOWs including risk criteria (function, maintenance requirements), mission criteria (area criticality, device criticality), maintenance criteria (failure rate, downtime ratio).

The criteria are selected based on the actual situation at CIH:




| WHATs \ HOWs | Funtion | Maintenance requirements | Area Criticality | Device Criticality | Failure Rate | Downtime Ratio | Importance weight |
|---|---|---|---|---|---|---|---|
| Meet standards | | 9 | | | | | 10.96 |
| Maintenance requirements | 3 | 9 | | 3 | 9 | 9 | 10.8 |
| Age | 3 | 3 | | 9 | 3 | 9 | 10.14 |
| Repair | | | 9 | 9 | 9 | 9 | 9.27 |
| Funtion | 9 | 3 | 3 | 3 | | | 8.75 |
| Physical risk | 9 | 3 | | | | | 7.46 |
| Mission Criticality | 3 | 9 | 9 | 9 | | | 6.75 |
| Complexxity of device | | 9 | | | | | 6.02 |
| Electrical Safety | | 3 | | 1 | | | 5.81 |
| Regular inspection | | 9 | | 3 | 3 | 3 | 5.5 |
| **Absolte weight** | 229 | 457 | 170 | 316 | 228 | 288 | 1688 |
| **Relative weight %** | 13.56 | 27.06 | 10.10 | 18.74 | 13.48 | 17.08 | |
| **Rank** | **5** | **2** | **7** | **10** | **8** | **12** | |

**Figure 2:** The design matrix of QFD model for preventive maintenance prioritization of medical equipment (function domain)

## 2.3 Concept domain

The concept domain is the output of the design matrix. The output is an expression representing the influence of the six specification weights on the resulting weights.

Equation (2) represents the Priority Score in preventive maintenance and repair, along with a table describing the evaluation level of each specific criterion.

$$\boldsymbol{PS} = (FN) \times 13{,}56 + (MR) \times 27{,}06 + (AC) \times 10{,}10 + (DC) \times 18{,}74 + (FR) \times 13{,}48 + (DR) \times 17{,}08 \quad (2)$$

The criteria will be rated from 1 to 5 points or from 1 to 3 points depending on the level of survey and the annotations explained in Table 3-2 below help aid in scoring each specific criterion.

| Criterion | Description | Threshold | Score |
|---|---|---|---|
| **Funtion (FN)** | Device function | Life support | 5 |
| | | Therapeutic | 4 |
| | | Diagnostic | 3 |
| | | Analytical | 2 |
| | | Miscellaneous | 1 |
| **Maintenance Requirements (MR)** | Maintenance activities depending on the device type | Extensive | 5 |
| | | Above average | 4 |
| | | Average | 3 |
| | | Below average | 2 |
| | | Minimal | 1 |
| **Device Criticality (DC)** | The importance level of the device | Critical | 3 |
| | | Important | 2 |
| | | Necessary | 1 |
| **Failure Rate (FR)** | Number of failures a year based on device criticality | ≥ 5 for critical<br>≥ 10 for important<br>≥ 20 for necessary | 3 |
| | | 2 ≤ for critical < 5<br>5 ≤ for important < 10<br>10 ≤ for necessary < 20 | 2 |
| | | < 2 for critical<br>< 5 for important<br>< 10 for necessary | 1 |
| **Area Criticality (AR)** | Assessment of area criticality for patients | Urgent | 5 |
| | | ICU/Theatre/NICU | 4 |
| | | Diagnostic/Laboratory area | 3 |
| | | Inpatient-Outpatient department | 2 |
| | | Non clinical area | 1 |
| **Downtime Ratio (DR)** | Ratio between the duration of downtime in days to days a year | Ratio ≥ 20% | 3 |
| | | 10% ≤ Ratio < 20% | 2 |
| | | Ratio < 10% | 1 |

**Table 1:** Describe the standard parameters and proposed points of the criteria

# 3 Resuts

To evaluate the model, a few devices in the table below are selected as examples.

For example, ventilators that are life-supportive, requiring maintenance are of particular priority to the ICU use area, are very important equipment with high failure rates and time rates stop working depending on the actual condition.

Based on the use of equation (2), the priority score results are shown in table 3-3 below:

| Device | | FN | MR | AC | DC | FR | DR | Priority | %PS |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Ventilators, Intensive Care | 5 | 5 | 4 | 3 | 3 | 2 | 375 | 93 |
| **2** | Infusion Pumps, General Purpose | 4 | 3 | 2 | 1 | 1 | 3 | 239 | 59 |
| **3** | Scanning Systems, Magnetic Resonance Imaging, Full-Body | 3 | 5 | 3 | 3 | 2 | 1 | 307 | 76 |
| **4** | Blood Gas Analyzer | 3 | 4 | 3 | 2 | 3 | 1 | 275 | 68 |
| **5** | Anesthesia Units | 5 | 5 | 4 | 3 | 3 | 3 | 392 | 97 |

**Table 2:** Sample data is based on a proposed point assessment to give a percentage of the priority index of the devices

By using the PS(%), priority in the maintenance and repair of medical equipment is classified into 4 groups:

- Group I: Very high priority with PS ≥ 80%
- Group II: High priority with 70% ≤ PS < 80%
- Group III: Medium priority group when 55% ≤ PS < 70%
- Group IV: Low priority group with PS < 55%

The first type is a very high priority class and the device is expected to be maintained every 3 months with the priority ratio of or greater than 80. In the second type, the high priority level, Preventive maintenance should be carried out within 4 months if the priority percentage is within 70 to 80. The third type is the average priority, containing all the equipment that needs to be considered for protection. Preventive maintenance within 6 months in case the percentage is priority within 55 to 70. The fourth type has a low priority level, including all devices with the priority rate below 55 Consider maintenance once a year or may be visually inspected and considered for the next prevention and maintenance such as minimum prevention maintenance.

For example, for ventilators (93%), Anesthesia Units (97%) and external defibrillators (92%) are classified as Group I: the priority of these types of devices is very high because they belong to the life support group and are required for maintenance every 3 months to ensure a safe level of use; for magnetic resonance imaging systems (76%) classified as Group II: the priority level of this type of equipment is high and is maintained at a frequency of every 4 months; for infusion pump (59%), blood gas analyzer are classified as Group IIII, these types of equipment will be performed maintenance every 6 months; for film-reading scanners (37%) are classified as Group IV and will be maintained once a year.

# 4 Conclusion

Through the model, we see that the important criteria to assess the priority in the maintenance and repair of medical equipment are leading the risk criteria accounting for 40.61%, followed by

maintenance accounting for 30.56% and finally, use accounting for 28.83%. The risk criterion accounts for 40.61% of the weighting of the priority index, so in essence the correlation between the risk assessment and the priority level in maintenance and repair is reflected relatively highly and closely. Based on that result, it is possible to consider improving equipment performance and minimizing risk by properly considering criteria that have a major impact on performance such as maintenance requirements (27.05%), equipment importance (18.74%) and equipment downtime (17.08%).

This study also emphasized the importance of the existence of detailed history for all devices to guide the decision makers in the Hospital to manage medical equipment appropriately. Maintenance should be based on the history of incidents and spare parts that have replaced the stored details of each medical equipment.

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The authors declare that they have no conflict of interest.

# References

[1] W. Orozco, G. Narváez, L. F. Galvis, and D. M. Cano, “Gestión de mantenimiento de equipos biomédicos en el contexto del proyecto de investigación de producción más limpia en el cluster de salud de medellín, colombia,” Rev. Ing. Biomed., vol. 9, no. 18, pp. 15–19, 2015.

[2] S. Taghipour, Reliability and maintenance of medical devices. LAP Lambert Academic Publishing, 2012.

[3] N. Saleh, A. Sharawi, M. Abd Elwahed, A. Petti, D. Puppato, and G. Balestra , “A new approach for preventive maintenance prioritization of medical equipment,” in Proc. XIII Mediterranean Conf. on Medical and Biological Engineering and Computing, Seville, 2013, pp. 1059–1062.

[4] N. Saleh, A. Sharawi, M. Abd Elwahed, A. Petti, D. Puppato, and G. Balestra , “Preventive maintenance prioritization index of medical equipment using quality function deployment,” IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 3 ,pp. 1029-1035 May 2015.

[5] S. Taghipour, D. Banjevic, and A. K. S. Jardine, “Prioritization of medical equipment for maintenance decisions,” Journal of the Operational Research Society, vol. 62, pp. 1666-1687, 2010.

[6] “Home,” Schulich School of Engineering. [Online]. Available: http://www.enel.ucalgary.ca. [Accessed: 01-Jan-2022].

[7] N. Saleh, A. A. Sharawi, M. A. Elwahed, A. Petti, D. Puppato, and G. Balestra, “Preventive maintenance prioritization index of medical equipment using quality function deployment,” IEEE J. Biomed. Health Inform., vol. 19, no. 3, pp. 1029–1035, 2015.