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Building Medical Devices Maintenance System through Quality Function Deployment

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Abstract

Over the past years, progress in the field of medical devices and their applications in hospitals became evident. Implementation of Maintenance Management Systems (MMS) should be used with appropriate maintenance activities for medical devices in order to improve medical devices systems targets. In this paper Quality Function Deployment (QFD) is being used as an improving method in MMS and as a guideline in highlighting the weak points in the performance and finding the suitable procedures to overcome them to achieve the customers' satisfaction.Through this research, the performance of Medical Devices Maintenance Systems (MDMS) in Prince Hamzeh Hospital (PHH) was investigated and studied to find appropriate solutions aiming to make the medical device more available, more reliable and more reproducible. A sample size of 903 operators' questionnaires has been used to perform this study in PHH. QFD requirements were employed to build the new required system. A comparison was made between PHH and the Specialty Hospital (SH) to benchmark its performance and measure how much PHH is away from achieving its targets.It was found that the failure response time was the most important performance aspect in the responsiveness category, the safe medical device was the most important performance aspect in the reliability category; the calibration of maintained device was the most important performance aspect in the reproducibility category and the spare parts availability was the most important performance aspect in the availability category. A new model has been suggested to be implemented for improving the performance of MDMS. This will lead eventually to better customers' satisfaction. The model consists of correlation between the requirements of the customers and technical capabilities of the provider with their correlation.

Keywords: Quality Function Deployment; Medical Device Maintenance System; Critical Devices; Non Critical Devices

1. Introduction

Medical device is a major component of today's healthcare systems as it is utilized for patient diagnosis and treatment. Therefore a comprehensive and effective structured approach is essential to make sure that the device is fully utilized with maximum reliability and reproducibility.

During the last two decades, Medical Devices Maintenance System (MDMS) evidenced huge improvements in all its areas including process, strategy, policy, procedure and technology trying to introduce a high quality technical service for medical devices operators.

Maintenance systems have had a tremendous impact on organizations' ability to meet their objectives. The realization of this impact has directed the attention to maintenance quality and performance. It was also called the use of Total Quality Management (TQM) tools for improving maintenance quality [1].

Alot of methodologies and tools were established or improved throughout the last forty years like, TQM concept; International Standardization Organization (ISO), Just-in-Time (JIT) and Quality Function Deployment (QFD). Each one of these methodologies had its particularity properties, specifications and its influence on the service or production provided.

Any institution in the health sector depends basically on the customers to improve, support its position and to benchmark between the competitors. The scope of my research was to build MDMS through implementing QFD principles on hospitals in Jordan; this study encountered customers' (medical devices operators) satisfaction in Prince Hamzeh Hospital (PHH) and Specialty Hospital (SH) by customizing the techniques of QFD for designing effective MDMS.

Quality Function Deployment was required to provide a link between customers' requirements and the abilities of the system to fulfill the customers' requirements. Maintenance engineers were to make sure that all medical devices were accurate, reliable and reproducible.

Quality Function Deployment is a system and procedures to identify, communicate and prioritize customers' requirements so that an organization can optimize its products and services to exceed customers' expectations [2].

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It was evident that in order to improve quality of health care, medical devices must be operational all the time for optimum responsiveness, reliability, availability and reproducibility. This might be achieved by applying modern technical management concepts and administrative tools that are in line with worldwide economic development [9].

2. Related Work

2.1. Quality function deployment (QFD) in maintenance:

Kutucuoglu developed a general framework using QFD technique as a tool for Maintenance Performance Measurement System (MPMS). Using a case study example they were able to show how to develop a three stage-matrix approach: identification of key Performance Indicators (PI), selection of critical maintenance measurement units [3].

Other researches were conducted other frameworks of QFD researches such as value-based using of balance score card. Although they accounted for financial and non-financial impacts of maintenance strategies, however, they failed to provide control for improving maintenance performance on tactical and strategic level and didn't not take into account the impact of maintenance strategies on the extended value-chain i.e. suppliers etc.

Takata analyzed the technical role change of maintenance in product lifecycle and then presented a maintenance framework that showed management cycles of maintenance activities, including maintenance planning, maintenance task execution and lifecycle maintenance management. They found that Maintenance was the most efficient way to keep the function available during the product lifecycle [10].

Pramod proposed a maintenance QFD model based on QFD and Total Productive Maintenance (TPM) for enhancing maintenance quality of product, and then they checked the implementing feasibility of the proposed method through an automobile service station. They found that both QFD and TPM were popular approaches and several benefits of implementing them have been reported [12].

Lazreg proposed an integrated model linking two popular approaches (i.e. six Sigma and maintenance excellence) to improve the effectiveness of maintenance. Coupled with QFD, the model was used to deploy the design parameters in order to reduce variations and time and to eliminate the occurrence errors in the maintenance process [13].

Zhang applied QFD as a new approach for conceptual design of Product and Maintenance (P&M). In the layout process, the approach used an improved QFD tool to translate customers' requirements into concepts' specifications. An information exchange mechanism was developed to exploit the interrelation between P&M [4].

In the mechanism, a Failure Mode and Effects Analysis (FMEA) tool was used to identify and analyze failure modes and their effects on the product concept. Then maintenance concepts were generated based on the results of QFD and FMEA. The proposed approach was applied in a conceptual design case of a horizontal directional drilling machine with its maintenance.

Kianfar added the QFD methodology to Reliability-Centered Maintenance (RCM) to improve RCM capability in preserving the functions of the plants. Their objective was to preserve the plant functions with least resources. They found that more efficiency will be attained in RCM if the methodology of QFD was added to RCM [5].

In comparison with RCM, ,QFD provided additional valuable information about failure modes, in a compact form, which could be used by the maintenance design engineers when they were trying to select the best Preventive Maintenance (PM) tasks for the plants.

2.2. Quality function deployment (QFD) in medical sector:

Recent attempts to apply QFD principles to the healthcare sector concentrated upon gaining greater understanding of customers' needs and how to engineer the process to best meet these needs. In particular it has been realized that the patient was not necessarily the only customer and that it was better to consider stakeholders or strategically related interested groups. Examples of such groups were:

- Patients.
- Reference groups (consultant physicians).
- Local and national governmental authorities.
- Tax payer and/or insurance companies.
- Hospital management and staff.

Most of the early studies on QFD in medical sector were primarily conducted from the viewpoint of medical services and medical safety. In 1990, Puritan-Bennett, a medical equipment company, successfully used QFD to help redesigning its spirometry business in order to regain their market share.

Moore presented a study of the potential for applying QFD method in the analysis of the framework for safety management Regulations. He presented a first stage analysis of Ionizing Radiation Medical Exposure Regulations (IRMER) 2000 that assessed how patients' needs were expressed by the individual IRMER components of justification, optimization, clinical audit, expert advice, equipment and training. The analysis involved a QFD assessment by four radiation protection experts with over 100 man-years of experience [6].

A second stage analysis assessed how the individual IRMER components have been engineered into a safety management framework through specific requirements embodied in IRMER 2000.

Liu conducted a study in the field of shoulder surgery" A brief fatigue inventory of shoulder health developed by QFD technique". They used a QFD technique to develop an instrument to assess the severity of symptoms of neck and shoulder pain and to determine the origin of these symptoms [7]. Using QFD they were able to:

- Prioritize and assign weights to the items in the assessment scale and then make multiple comparisons to reduce error.
- Determine the risk in neck and shoulder pain.

Although this assessment tool was not able to measure outcomes, it might be able to help health care providers determining the source of patient complaints and identifying when treatment might be helpful.

3. The House Of Quality (HOQ)

The HOQ is the kernel of QFD. It is a matrix that consists of sub matrices that are related to one another. Each section in HOQ is called ‘room’. It is a structured and systematic representation of a product or process development.

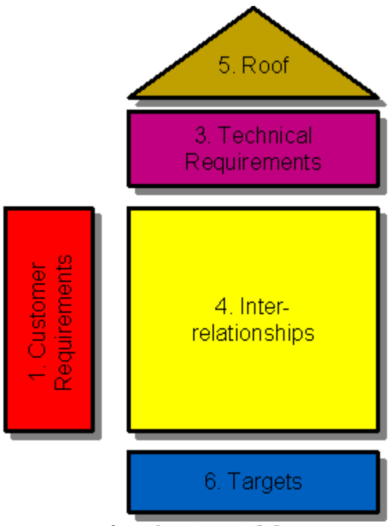

Figure 1: House Of Quality (HOQ) [8].

3.1. Customers' Requirements:

It is on the left side of the HOQ. This section documents the "VOC". It represents the "what's" of the system. Affinity diagrams and Tree diagrams are used to structure the requirements.

3.2. Planning Matrix:

It is on the right side of the HOQ matrix. It represents the customer competitive assessment. It Provides customers’ (any people who would benefit from the use of the proposed maintenance process) views on existing products. This matrix uses questionnaires to elicit information.

The requirements are usually short statements recorded and are accompanied by a detailed definition. After all the requirements were gathered, similar requirements were grouped into categories and written into a tree diagram.

3.3. Technical Requirements:

This section lists how the company will meet the customers' requirements. This is the "HOWs" of the system. It represents the engineering characteristics or voice of the company. It no longer takes on a VOC but instead the voice of the company.

These technical requirements should be controllable and measurable characteristics of the product and there could be more than one technical requirement corresponding one customer's requirement. The generation of technical requirements is a crucial part of HOQ. During this step the VOC will be translated into the design requirements to be implemented.

3.4. Relationship Matrix:

It occupies the middle portion of the HOQ diagram which is the largest portion. It uses the prioritization matrix. It shows how well customers' requirements are addressed by product features.

The QFD team must assign a weighting based on the question: "How important is technical requirement A is satisfying customer's requirement B?" During this step consensus between customers and development should be reached on the requirements mapping.

3.5. Roof:

The purpose of this step is to consider the impacts that the technical requirements will have on each other. , this step is critical in identifying engineering trade-offs between technical requirements.

For each pair of technical requirements, the QFD team must answer the following question:” Does improving one requirement cause deterioration or improvement in another requirement? ”The "direction of improvement" is important at this point as one needs to have a measurable quantity with which to determine improvement or deterioration. The impacts are recorded as positive (+), negative (-), or no effect.

3.6. Targets:

This the final section of HOQ matrix. The purpose of this step is to integrate the results from all the previous into a set of targets to be used during design and implementation. It summarizes the conclusions of the planning matrix. It includes three parts:

- Technical priorities (relative importance of each technical requirement).
- Competitive benchmarks (relative position of the existing product).
- Targets (engineering target values to be met by the new product design).

The crucial difference between QFD and more traditional approaches was that QFD generated targets based on repeatable and statistical analysis. The prioritization of the technical requirements was performed by summing the product of the interrelation weights with the overall weighting assigned during the planning step.

4. Methodology

4.1. The proposed approach:

This study used the HOQ in QFD as the analysis model. QFD appeared to be able to provide MDMS with a better understanding of customers' translation of these expectations into appropriate service specifications and perform existing process assessment.

A generic QFD framework was applied as a reference model for MDMS. The six-phase implementation framework was presented, together with the findings of empirical research. A brief outline of the six phases and the research methodology adopted is shown below.

4.1.1. Research Model Phases:

4.1.1.1. Customers' Requirements:

The first phase of the process was to define all the external customers (medical device operators) and their requirements. There were multiple tiers of customers, such as:

- Radiology department staff.
- Laboratory staff.
- Operational theatres staff.
- Ophthalmology department staff.
- Haemodialasis department staff.

Identifying customers' expectations was the most crucial step of the QFD process and it involved the identification of what customers expect from the service. The questionnaires method was utilized to establish customers' expectations.

4.1.1.2. Planning Matrix:

The customers' requirements were ranked by applying interpolation method. The medical device operators' satisfaction was measured with available maintenance system by comparing it with a MDMS in other hospital.

A questionnaire survey comprising around 30 questions was conducted at two hospitals in Amman. This questionnaire was given to the staff of concerned departments.

Response ranking in this phase was done based on interpolation method. The performance aspect with the highest mean value was assigned 5, the one with the lowest mean value was assigned 1 and the interpolation method was applied to calculate the rank of each performance aspect based on its mean value.

The medical device operators' satisfaction with available maintenance system could be measured by calculating the following measures:

- Planned satisfaction rating
- Improvement factor

These measures were combined with the customer importance weighting to calculate the overall weighting for each customer's requirement.

4.1.1.3. Technical Requirements:

In this phase the medical device maintenance staff of the two hospitals was interviewed and all the measurable characteristics of the Medical Device Maintenance Process (MDMP); which they perceived they related to meet the operators' requirements; were identified.

4.1.1.4. Interrelations:

In this phase the requirements were translated as expressed by the customers into the technical characteristics of the MDMP. It has been identified in this phase where the interrelations between the customer and technical requirements were significant.

The level of interrelation discerned was weighted on a four point scale (high, medium, low, none). A symbol representing this level of interrelation was entered in the interrelation portion of HOQ. Each level of interrelation weighting was assigned a score. For instance; High=9, Medium=3, Low=1 and none=0.

4.1.1.5. Roof:

In this phase it has been identified where the technical requirements characterizing the MDMP supported or impeded one another. It has been worked through the cells of roof matrix considering the pairings of technical requirements these represent.

The key question was to be answered: In the case of improving one requirement, will that deteriorate or improve in the other technical requirements? If the answer was that will deteriorate, an engineering trade-off existed and a symbol (-) was entered into the cell to represent this answer. On the other hand if the answer was that will improve; a symbol (+) was entered into the cell to represent this answer.

4.1.1.6. Targets

In this phase the following sections were established:

- Technical priorities (relative importance of each technical requirement)
- Competitive benchmarks (relative position of the existing product)
- Targets (engineering target values to be met by the new product design)

The technical priorities were calculated by summing up the multiplication of overall weighting and interrelation weighting score for each requirement.

4.2. Case study:

This study aimed to make the necessary improvement on the MDMS procedures at the PHH hospital where the following was done:

- Prince Hamzeh Hospital in Amman was selected to improve MDMS through applying QFD methodologies.
- As competitor was needed, SH was identified to apply HOQ on it.

The first step in building the HOQ was the building the customers' requirements block by identifying the VOC. This step was done through and on-site observations and interviews with customers which were 903 operators from the different departments in PHH like radiology, laboratory, operations theaters, haemodialasis and ophthalmology. The operators were encouraged to describe their needs and problems.

Affinity diagrams were used to structure the list of requirements gathered before its entry to the HOQ. To build an affinity diagram the customers' requirements were arranged in groups. A title for each group was: chose which encapsulated the meaning contained within that group. The completed affinity diagrams have been used as the basis of the tree diagrams.

When applying on-site observations and interviews with operators, it was found that their needs and problems were divided into two sections: requirements and wishes as shown in Table 1.

Table 1: Requirements and wishes of medical devices operators.

responsiveness category	Short maintenance period	Existence of more than one workshop	Organization structure (the location of the workshop)	Failure Response time	The nature of maintenance system (hospital maintenance staff or contracted local agents)
reliability category	Safe medical device	High Mean Time Between Failures (MTBF) i.e. hard duty	Training the operators on the device(during installation and periodic training)		
availability category	Existence of redundant device	Spare parts availability	Speed of obtaining the spare parts.	Performing PM	
reproducibility category	Calibration the maintained device	Doing check up process for the device after the maintenance process and before delivering it to the operator			
Wishes	contact Existence of a person in the maintenance department in the hospital to follow up the different procedures	Assigning a person representing the maintenance department in the medical devices purchasing committee	Using the original agent spare parts in non critical medical device maintenance	Existence of a senior engineer in all work shifts (specially the night shift)	Existence of an integral full computerized maintenance system with an electronic troubleshooting database showing the cause of failures & presenting the suggested action to deal with that failure

Table 2: Importance weighting of VOC.

Importance weight		
8	Short maintenance period	Responsiveness

3	Location and existence of more than workshop	
10	Failure response time	
4	Nature of maintenance system	
9	Safe medical device	Reliability
6	High MTBF	
4	Training of operators on installation	
8	Periodic training of operators	
10	calibration of maintained device	Reproducibility
5	Do check up after maintenance	
10	Spare parts availability	Availability
7	Spare parts obtaining time	
5	Doing PM	
4	Existence of redundant device	
4	Existence of administrative person	
4	Using original spare parts	

For each category, the data collected from the SH and three experienced persons representing the major sectors of MDMS in Jordan (public, private and military) were used to evaluate the value of importance weighting for each performance indicator. This value was put on the Customers' requirements on theleft side of HOQ as shown in Table 2.

From the table, it was remarked that the failure response time was the most important performance aspect in the responsiveness category, on the other hand, the location and existence of more than workshop was the least important performance aspect in the same category.

It was also noticed also that the safe medical device was the most important performance aspect in the reliability category; on the other hand, the training of operators at installation was the least important performance aspect within the same category.

It was remarked that the calibration of maintained device was the most important performance aspect in the reproducibility category; on the other hand, doing checkup after maintenance process was the least important performance aspect in the same category.

It was observed that the spare parts availability was the most important performance aspect in the availability category; on the other hand, existence of administrative person, Existence of administrative person and using original spare parts were the least important performance aspect in the same category.

The second step was identifying the technical requirements block which was referred to as the engineering characteristic or the voice of the hospital. This information was generated by identifying all the measurable characteristics of the MDMS which they were perceive they were related to meeting the specified customers' requirements.

Affinity diagrams were applied to interpret the MDMS characteristics; an additional row was put to illustrate the direction of change in each of these variables which was considered to result in an improvement in MDMS performance. The technical requirements were represented in Table 3.

Table 3: Technical requirements and its direction of changes.

⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
Administrative Procedures	Enough Staff	Infra-structure & transportation within hospital	Existence of work specialty	Enough budget	Types of spare parts contracts	Existence of suitable tools	Device Strength	Meet Standards	Continuous education and training

Table 4: Performance measures of PHH.

Performance measure		
3.65	Short maintenance period	Responsiveness
1.77	Location and	

	existence of more than workshop	
3.975	Failure response time	
0.71	Nature of maintenance system	
1.075	Safe medical device	Reliability
1.075	High MTBF	
2.325	Training of operators on installation	
2.825	Periodic training of operator	
4.4	calibration of maintained device	Reproducibility
1	Do check up after maintenance	
3.675	Spare parts availability	Availability
5	Spare parts obtaining time	
3.35	Doing PM	
3.225	Existence of redundant device	
5	Existence of administrative person	
5	Using original spare parts	

After the mean value for each performance indicator was found, the performance indicator speed of obtaining the spare parts was assigned a value of 5 because it had the highest mean value, the performance indicator check up the device after maintenance was assigned a value of 1 because it had the lowest mean value. The interpolation method was used to find the weight of each performance indicator. The other measures of operators satisfaction included in the planned matrix were:

- Planned satisfaction rating
- Improvement factor
- Overall weighting

The planned satisfaction rating quantified the level that PHH staff plan to arrive it to achieve the operators satisfaction. They were obtained from the maintenance staff of PHH. The results of planned satisfaction rating were illustrated in Table 5.

The improvement factor shown in Table 5 was calculated by subtracting the performance score of the MDMS of PHH from its planned performance score. This difference was divided by 5 to give the improvement factor. For example; the improvement factor for Short maintenance period was:

$$\frac{4-3.65}{5} = 0.07 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The overall weighting has been calculated by multiplying the importance weighting by the improvement factor as illustrated in the Table 5. For example; the overall weighting for short maintenance was calculated as follow:

$$8 \times 0.07 = 0.56 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Regarding the planned satisfaction rating, it was observed that the lowest operators' satisfaction was found in little performance aspects like periodic training of operators which was a requirement. The rest of performance aspects achieved the satisfaction.

Regarding the improvement factor, it was noted that the highest improvement needed to be done was found in doing check up after maintenance and existing of safe medical device. The lowest improvement needed to be done was found in periodic training of operators and spare parts availability which both were requirements.

It was remarked that the wishes of existence of administrative person and using original spare parts and spare parts obtaining time requirement did not need any improvement to be done.

Regarding the overall weighting, it was noted that the existing of safe medical device and do check up after maintenance requirements were the performance aspects had the highest priority to begin with because they had the highest overall weighting. The using of original spare parts wish, using original spare parts and spare parts obtaining time were the performance aspects had the lowest priority to begin with because they had the lowest overall weighting.

The interrelations matrix which formed the main body of HOQ was then constructed. The interrelations matrix combined the technical requirements and VOC. The level of interrelation discerned was weighted on a four point scale (High, Medium, and Low, None which represent with space) and a symbol representing this level of interrelation was entered in the matrix cell. To construct it, the matrices for PHH, SH and three experienced people's matrices were found as in the appendices and then brainstorming was made to construct the average matrix that represented all of them as shown in Table 6.

Each level of interrelation weighting was assigned a score, e.g. High=9, Medium=3; Low =1 and none =0. It was noticed from the table that the relationship between the short maintenance period and enough staff was high because in the case of having enough staff, a queue will not be existed and the maintenance process will take less time.

The relationship between high MTBF and enough staff was medium. The existence of enough staff affected the MTBF but its influence was not huge. When having enough staff, the device will be maintained quickly which will reduce the MTBF.

The relationship between safe medical device and enough staff was low. The safety of maintained devices did not change whether having five or ten maintenance staff.

The roof shown in Figure 2 of HOQ was constructed. The roof was used to identify where the technical requirements that characterized the MDMS supported or impeded one other. It has been worked through the cells of the roof asking the question: Does improving one requirement cause a deterioration or improvement in the other technical requirement?

The roof highlighted where a focused design improvement could lead to a range of benefits to the MDMS. It focused attention on the negative relationships in the MDMS. This represented opportunities for innovative solutions to be applied.

To construct the roof, the roofs for PHH, SH and three experienced persons' matrices was found and then brainstorming was made to construct the average roof that represents all of them as shown in Figure 2.

Table 5: Planned satisfaction rating, improvement factor and the overall weighting of the performance indicators.

overall weighting	improvement factor	planned satisfaction rating		
0.56	0.07	4	Short maintenance period	Responsiveness
		They have just one workshop	Location and existence of more than workshop	
	0.205	5	Failure response time	
2.64	0.66	5	Nature of maintenance system	
7.065	0.785	5	Safe medical device	Reliability
3.51	0.585	4	High MTBF	
1.34	0.335	4	Training of operators on installation	
0.28	0.035	3	Periodic training of operators	
1.2	0.12	5	calibration of maintained device	Reproducibility
4	0.8	5	Do check up after maintenance	
1.65	0.065	4	5Spare parts availability	Availability
0	0	5	Spare parts obtaining time	
1.65	0.33	5	Doing PM	
0.62	0.0155	4	Existence of redundant device	
0	0	5	Existence of administrative person	
0	0	5	Using original spare parts	

Table 6: Interrelation matrix.

	Administrative Procedures	Enough Staff	Infra-structure & transportation within hospital	Existence of work specialty
Short maintenance period	H	H	M	H
Location and existence of more than workshop	M	M	H	L
Failure response time	L	H	M	M
Nature of maintenance system	M	H		H
Safe medical device	M	L	H	H
High MTBF	M	M	H	L
Training of operators on installation	H	H	H	L
Periodic training of operators	H	M	H	L
calibration of maintained device	H	L	M	L
Do check up after maintenance	H	L	M	L
Spare parts availability	L	H	H	L
Spare parts obtaining time	L	H	H	L
Doing PM	M	L	H	L
Existence of redundant device	L	H	M	M
Existence of administrative person	L	H	H	L
Using original spare parts	L	H	H	L

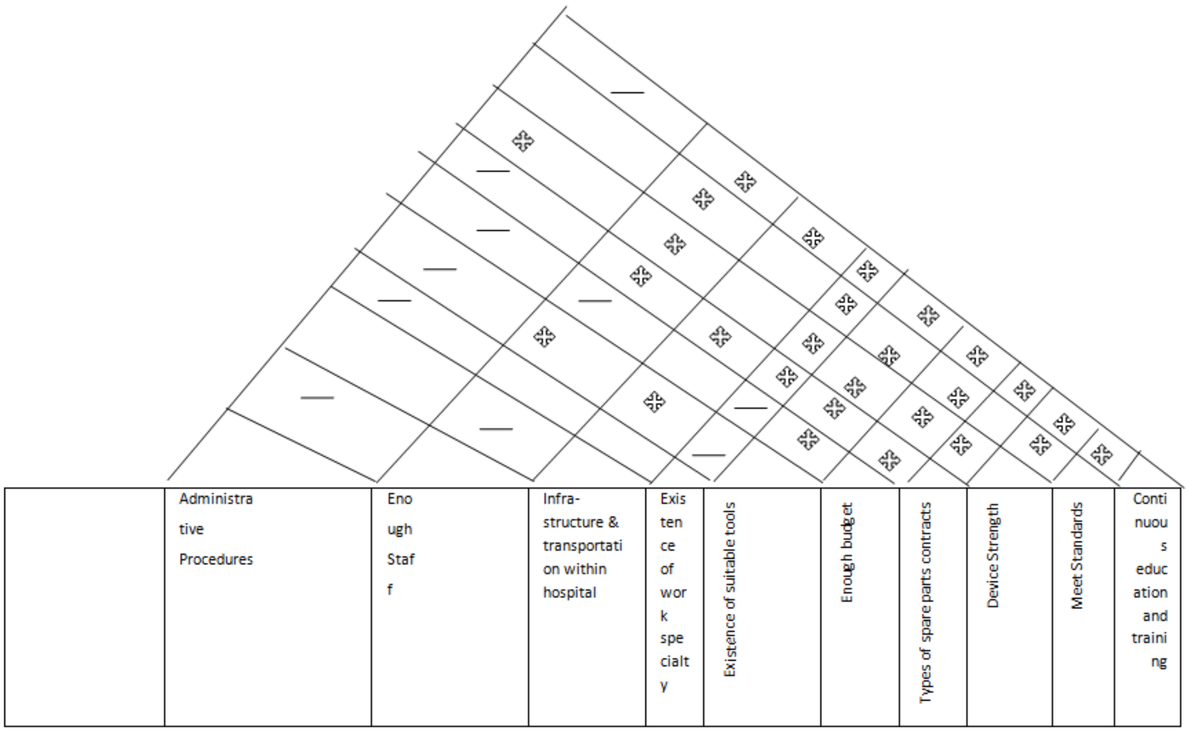

Figure 2: The roof.

In Figure 2, it was observed that the relationship between the enough staff and existence of suitable tools was direct. There was also an inverse relationship between the existence of work specialty and the enough budgets. There was no relationship between meet standards and infra structure and transportation within hospital.

The final part of HOQ which was the targets was constructed. The targets summarized the conclusions drawn from the data contained in the entire matrix. They were made up from three parts: Technical priority, Competitive benchmarking and Targets The technical priority was calculated by summing up the product of the overall weighting shown in Table 5 and the interrelations value shown in Table 6 as shown in Table 7. For example; the technical priority for continuous education and training was calculated as follow:

$$.56 \times 9 + 9 \times 2.64 + 9 \times 7.065 + 9 \times 3.51 + 3 \times 1.34 + 1 \times 028 + 1 \times 1.2 + 4 \times 1 + 9 \times 1.65 = 148.325$$

Table 7: Technical priority, competitive benchmarking and targets.

		Administrative Procedures	Enough Staff	Infra-structure & transportation within hospital	Existence of work specialty	Existence of suitable tools	Enough budget	Types of spare parts contracts	Device Strength	Meet Standards	Continuous education and training
Technical priority		156.875	166.775	114.335	96.295	155.745	113.02	158.75	143.13	164.3	148.325
Bench-marking	PHH	One week for internal administrative procedures(from writing a spare part order to obtaining it) and three months for external	Low : 4 personnel (Need two more)	Excellent	Medium 60%	Enough budget with complexity with administrative procedures	Less than 20 % (with certain devices)	All the needed tolls existed	90%	100%	Low
	SH	One day for internal and around three days for external	It is enough	Excellent	Medium 50%	Enough budget with flexibility with administrative procedures	Less than 25 %(with certain devices	All the needed tolls existed	100%	100%	High
Targets		One hour for internal and less than one day for external	6 personnel	Excellent	High 80%	Enough budget with flexibility with administrative procedure	Less than 10 % (with certain devices)	All the needed tools existed	100% choosing the best device regardless the price	100%	High

It was noticed from the table that the enough budget performance aspect had the highest technical priority so it should be thought of it firstly and trying to solve its problems, it was also noticed that the continuous education and training had the lowest technical priority so it was not critical one.

The competitive benchmarking represented the measurement of the technical requirements identified for the MDMS for PHH and SH in Table 7. This illustrated the relative technical position of MDMS for PHH and identified the target levels of performance to be achieved.

The competitive benchmarking was obtained through direct observation of the performance aspect. For example; regarding the enough staff, it was found that there were 2 persons in SH and 4 person in PHH. Table 7 illustrated the competitive benchmarking.

It was noticed from Table 7 that, the situation of PHH in certain performance aspects like the existence of work specialty was better than that in SH. There were some cases, like the infrastructure and the transportation within the hospital, where our situation and the situation in SH were the same. The majority of the cases indicated that the situations of PHH in them were less than in SH.

The final stage of HOQ was a set of engineering target values to be met by the new MDMS .The process of building this matrix enabled these targets to be set and prioritized based on an understanding of the operators' needs, the competitor's performance and hospital current performance. It was needed to draw on all this information when deciding on these values.

The targets were obtained by observing the performance of PHH and SH in each performance aspect and comparing it to the typical situation known by the expertise opinions. For example; regarding the enough staff, it was found that it was enough in SH but it was not enough in PHH because there was a backlog and by asking the PHH staff and expertise about the optimum number needed, they suggested existing of 6 persons one of them for administrative affairs. Table 7 illustrated the targets.

It was noticed from the table that some targets were not met like the infrastructure and transportation within hospital. On the other hand a lot of targets were not met. Some targets needed a lot to do to be achieved like administrative procedures and some targets were easier to be achieved like enough staff.

The overall integration of the previous steps were gathered in Figure 3.

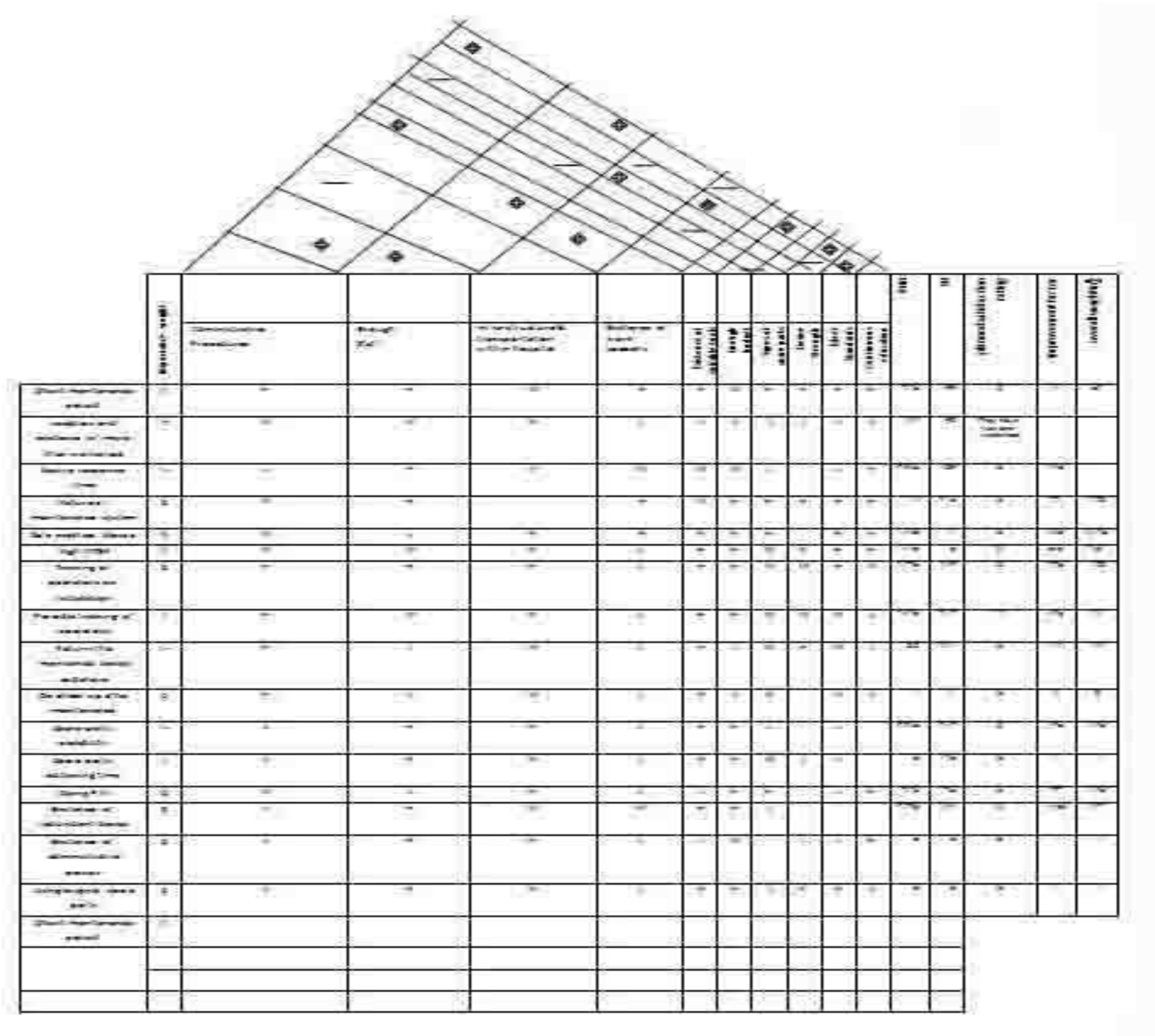

Figure 3: Overall integration of House Of Quality (HOQ).

5. Conclusion

This paper used QFD to build MDMS in PHH. It investigated the responsiveness, reliability, availability and reproducibility of medical devices in PHH. It included a questionnaire's analysis regarding the VOC.

Through this research, it could be seen that applying QFD in building MDMS clarified the targets and how to achieve them. Among ten targets three of them were achieve and the others could not be achieved by implementing the suggested procedures.

This model could be used to show the decision makers which variables were mostly affecting the performance of MDMS and then reasonable decision should be taken on such variables to improve the performance.

For optimizing the planned satisfaction rating, the periodic training of operators should be only concentrated on. It was concluded that the highest improvement needed to be done was found in doing check up after maintenance process and the existing of safe medical device.

It was deduced that the existing of safe medical device and do check up after maintenance process requirements were the performance aspects that had the highest priority to begin with. It was concluded also that the enough budget performance aspect had the highest technical priority so it should be thought of it firstly and trying to solve its problems.

In general, it was drawn that the situation of PHH in some performance aspects such as; availability of work specialty was better than that in SH. There were some cases such as; the infrastructure and the transportation within the hospital, where the situation of PHH and SH were the same. The majority of the cases indicated that the situation of PHH was not better than in SH.

Administrative procedures in PHH should be studied and improved in order to reduce the routine time required for requesting spare parts. Some requirements of the QFD in PHH have not been met, such as; enough staff performance, types of spare parts contracts, availability of work specialty, devices strength and continuous education and training.

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