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Business Process Re-engineering and Automation in Health Field: A Case of Medical Equipment Evaluation

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Abstract: ***With the great diversity of the existing medical equipment, the choice of the appropriate equipment became a more challenging task. Therefore, medical facilities usually evaluate any medical equipment before the purchasing process, to ensure its appropriateness. However, the medical equipment evaluation process is both time and resource consuming, therefore, different contributions had been made to improve this process. This paper aims to improve the medical equipment evaluation process using the business process re-engineering and automation techniques. First, the study presents the current "As-Is" business process using business process modeling notations, and then draw its weaknesses using simulation technique and value-added analysis. After that, it suggests the "To-Be" business process involving four re-engineering heuristics: task elimination, parallelism, communication optimization, and automation. Finally, to assess the performance of the "To-Be" business process, it was implemented using the automation feature in Bizagi Studio. After comparing the proposed "To-Be" to the "As-Is" business processes, it found that the proposed "To-Be" saved 34% of the total time consumed by the "As-Is" process. While in terms of resources, the proposed "To-Be" decreased the number of employees involved in the process, as one employee was completely dropped from the process. Moreover, it minimized the number of tasks by 16.7%. Overall, the proposed "To-Be" medical equipment evaluation business process in this study, outperformed the current "As-Is" business processes.***

Keywords: Medical equipment evaluation, re-engineering, business process, automation

1. Introduction

Ensuring patient safety and providing a high-quality service, is one of the major concerns of health service providers. One way of providing a high-quality service is by using the appropriate medical equipment. There are different types of medical equipment such as hospital beds, oxygen monitors, pressure mattresses, ultrasound scanners, to name but a few. According to [2], there are around ten thousand types of medical equipment. However, choosing the appropriate equipment depends on several factors [2], some of them could differ from one facility to another. Therefore, health facilities should evaluate the medical equipment to ensure its appropriateness before making the purchase decision.

The medical equipment evaluation process consumes time and technical resources[3]. Moreover, the evaluation process differs from one health facility to another. This difference could result from the variance in the assigned time, the evaluation purpose, or the involved stakeholders [4]. However, regardless of these differences, the strategy of managing the medical equipment in general, including its evaluation, is in continuous improvement to align with the emerging technologies in the field[5]. These improvements can be done in different ways, one of them is by using Business process management (BPM).

BPMmodel consider to be important because it play crucial role for organizations to increase their awareness, understand and improve their activities by analyze, design and execute the process including medical equipment evaluation [6].Business process can be graphicly modeledusing business process management a notation (BPMN) which had the ability to present the system process in a way that is easy to understand and simulate [7]. For the medical industry, in order to have a high level of success, they seek to alteration the equipment evaluation process by making continuous improvements. These improvements can be done by identifying the issues including speed, cost, and quality through Business process Re-engineering (BPR). BPR considers an essential part to maintain more flexibility and deal with business and technological changes in any competitive environment by redesign the workflow of the process [8].

These improvements can be implemented by using business process automation (BPA) which is used to transform the way in the process work from manual to technology with reduction in human intervention[9]. There are Different tools that can be used in order to make BPMN and automate it. One of these tools called Bizagi which is a software that enable the organization to design, implement and automate business process management BPM throw BPMN [10].

In this paper, the aim is to investigate the current medical equipment evaluation business process and modeling it as an "As-Is" process. Then, some improvements will be made to this process, and we will suggest a "To-Be" process using business process re-engineering and automation. This improvement will be done using Bizagi Studioto strengthen the medical equipment evaluation business process by speeding the process and minimize the cost.

The rest of this paper is organized as follows: Section 2 highlights the importance and the key steps of business process management and business process reengineering, in

addition to illustrate the medical equipment evaluation process, the followed assessment methods, and associated challenges. Moreover, section 2 summarizes studies that aim to improve the medical equipment evaluation process and its results. Section 3 explores the "As-is" modelfollowed to evaluate the medical equipment, simulate the current situation, and defines the associated drawbacks.Section 4 presents the proposed automated business process "To-be" modeland highlights the related improvements. After that, section 5 illustrates the testing and associated measures analysis. Finally, section 6 carries the conclusion and future recommendations.

2. Literature Review

This section presents an overview of Business process Management (BPM) and Business Process Reengineering (BPR). Moreover, it provides a brief description of medical equipment evaluation. Then, it explores related studies that aim to improve the medical equipment evaluation process using different IT solutions.

2.1 BPM

Business process management (BPM) is devoted to analyzing and modelling organization business processes [11]. A business process can be divided into two categories[12]; (1) private (internal) processes, that involved activities within the organization itself. (2) Public (external) processes, which are activities that involved an external part such deliver product to customer.

Applying BPM can help in the improvement and the growth of business applications [11]. Moreover, BPM make the activities and the processes of organization more visible, as well as, the organization will be able to determine and identify bottlenecks [12]. According to [1], there are six phases in BPM life cycle as shown in figure 1.

1) **Process identification:** That include identifying and interrelating problem-related processes. The outcome of this phase is a process architecture, from which, the targeted process is selected.
2) **Process discovery (modelling):** In this phase, "As-Is" process is documented, which describe the current situation of the process.
3) **Process analysis:** This phase includes the process of identifying and documenting all the issues in the current process (As-Ismodel).
4) **Process redesign (improvement):** This phase aim to define a set of changes that could overcome the defined issues in theprevious phase.The outcome of this phase is "To-Be" process.
5) **Process implementation:** This phase involves two main aspects which are; (1) organizational change management, that include the way participants works in the process. (2) Process automation that integrate IT systems development with "To-Be" process.
6) **Process monitoring:** After the process running, this phase focus on collecting and analyzing the process data to measure the performance of the process against some measurement.

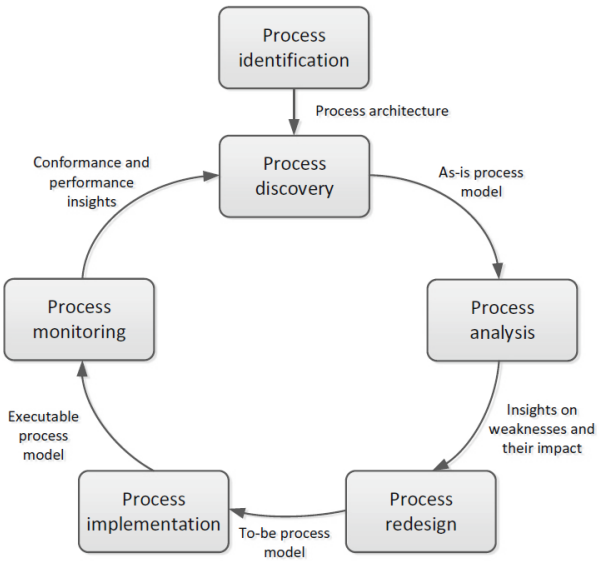

Figure 1: BPM life cycle[1]

2.2 BPR

Business Process Redesign or Reengineering (BPR) is a critical task that aims to improve organizations' performance. BPR is a popular concept since the 1990s; however, today's technological pace and associated changes made the BPR more important [13]. BRP can be defined as the radical deliberate change in the business processes to improve the current state of an organization regards the different performance measures like flexibility, cost, quality, or time [14]. Proper BPR can results in one or more advantages like driving the organization's growth, increasing profit, improve customer service, or etc. [15, 16].

BPR is a cycle that involves many steps very similar to BPM steps that stated previously, that should be done carefully and with motivation in order to achieve the desired outcomes. The steps are: identify the process, analyze the current situation and potential opportunities, Redesign the process, implementation, and finally the change management[16, 17].

There are two approaches that can be followed when redesigning business processes: explorative or exploitative redesign. While the first seeks to radically transform the current business process, the lasts aim to apply the improvements and changes on process incrementally without questioning its fundamentals[18].Exploitative redesign is the approach utilized in this paper. This approach relies on one or more redesigning heuristics striking one or more performance measures.The process redesign heuristics categorized into three categories based on the level of the redesign as illustrated below [1, 18]:

1) Task-Level

- *Task elimination*. Aims to reduce time and task associated cost by removing the non-value-added activities; for example, send, receive, or control activities like approvals.
- *Task composition or decomposition*. Composition which about combining small tasks together in one broader task in order to eliminate transportation time or reduce setup time. Decomposition which aims to utilize the use of

resources by splitting broad tasks into two tasks and assign each to a specialized resource.
- *Triage*. The goal is to utilize either processing time or used resources over splitting general tasks into two or more specialized tasks or integrate tasks into one general task.

2) Flow-level
- *Re-sequencing*.Change tasks flow relying on the cost/effect ratio with the aim of reducing over-processing which reduces the spend time subsequently.
- *Parallelism*.Aim to minimize throughput time by performing two tasks or more in parallel.

3) Process-level
- *Specialization & standardization*.Specialization which divide process into multiple based customer class, time, etc. then resources assigned accordingly. Standardization which combine resources together to handle two or more integrated tasks. Both aims to achieve better resource allocation.
- *Resource optimization*.Aim to maximize the resources utilization either by grouping, or specialization assignment with flexibility in consideration.
- *Communication optimization*.Can be achieved by automating the messages exchange, or optimizing the number or type of interactions, or optimizing the timing of interactions.
- *Automation*.Aim to improve processing time and generate more reliable results with reasonable cost. It is done through using shared data or by replacing the physical flow with networks

2.3 Medical Equipment Evaluation

Medical equipment evaluation is an essential step for each medical equipment in any hospital and it brings benefits for both patient and health services[19].This evaluation consists of providing evidence to take the decision, whether should new medical equipment be procured or not. This decision has generally been decided based on multiple essential knowledge, which are cost-effectiveness, safety, efficacy, value, performance, and availability. Also, many evaluations consider knowledge about social, legal, and ethical effects. The assessment of new medical technology is usually done by clinical engineers, medical staff, and the administration team. Where the role of clinical engineers considers being most important in the medical equipment evaluation process, as it can make a significant impact on the quality of medical equipment technology [20].

Successful medical equipment evaluation could be done by applying a certain system for assessing medical equipment. These systems have a clear vision of what new medical equipment can have a positive impact on patients and health services, and wither encourage their adoption into healthcare [19]. There are multiple systems for assessing medical equipment to improve the quality of users and increase the reach of appropriate medical equipment and technologies. For example,the World Health Organization (WHO) and partners in [21]established a system for needs assessment process to help decision-makers to select the right medical equipment at the national, regional, or hospital level. The needs assessment process consists of a series of documents that contain guidelines, action plans, tools, and agenda. WHO used international experts in their specialization filed to write the documents, then it has been reviewed by the Technical Advisory Group on Health Technology (TAGHT). The main objectives of developing the needs assessment process are, provide benefit for the patient, increase the effective use of appropriate medical equipment, and to put an additional burden on scientific communities to produce technologies have a positive impact on the health sector. The needs assessments are a complex and powerful process that works by collecting baselines information and comparing it to the required criteria. The process is set in seven phases, from the first phase to the fifth phase is all about collecting baselines information, which is: health service requirements, health service availability, medical devices, human resources, and finances. The six-phase is the analysis and interpretation of the collected information. And the last phase is to prioritization and appraisal of the options been found.

On the other hand, the National Institute for Health and Care Excellence (NICE) presented another Health technology assessment (HTA) system in[22],to evaluate a new medical technology. The HTA has been developed by NICE is the Medical Technologies Evaluation Program (MTEP) that was established out of a complex process. The main purpose of the NICE program is whether to recommend adopting medical technology based on evidence supports. The NICE program makes decision depend on several pieces of information such as cost-effectiveness and benefits, to improve health and social care. The MTEP process generates a recommendation based on many guidance that takes two forms. First, are the NICE guidelines, which are clinical, social care, public health, medicine practice. Second, interventional procedures, highly specialized technologies, technology appraisals, medical technologies, and diagnostics.

Regardless of the system been used to evaluate new medical equipment according to [20], the most important procedures that should be taken are evaluate environmental rules, state clinical desired characteristics, conducting a market survey, and assessing the devices were chosen.

2.4 Related Works

This section represents previous works that focus on improving the medical equipment evaluation process using IT solutions. Some of previous research focuses on developing a model or a method to improve the process of evaluating medical equipment. For example, a study [23] focus on improving the decision-making process in medical equipment evaluation. They proposed a model based on one of the artificial intelligence techniques, which is a neural network. The aim of this model is to simulate the knowledge of clinical engineers using a set of evaluation factors. The model uses three factors to select the appropriate medical equipment which are: risk, cost and importance. However, the authors valid the model by more than 30 clinical engineers via e-mail. The proposed model then can assist managers in evaluating medical equipment and to determine the appropriate equipment before the purchasing process.

Also, another study[24] deeply explored the criteria related to decision making regarding medical equipment within limited-resource conditions. The study was done based on multiple-criteria decision analysis (MCDA) methods, artificial neural networks, value analysis, besides the human factors engineering. The study analyzed a set of 21 projects and end up that the multiple-criteria decision analysis (MCDA) method with an AHP approach is the best MCDA method that can be used during the selection process of large medical equipment. That owing to the simplicity of results processing, the less amount of time needed comparing to other MCDA methods and its closeness to human intuition.

On the other hand, there are research concentrate on building systems or tools to improve the evaluation process. A study[25]contributes to the importance of evaluating equipment's in the field of health industry because it takes a lot of time, effort and budget. So, they proposed a system dedicated to evaluating the equipment in terms of several aspects include technical or financial aspects. Their proposed system is a web application called vendor evaluation program for medical equipment. It was designed with considerate to be easy, flexible in addition it is saving time and effort. The system works as follow, first, the category needs to be chosen such as X-ray then choose one of the equipment type whither for example it is a mobile x-ray or digital x-ray equipment. Afterward, they need technical and financial details to be entered if it does not match to the specification of the emergency care research institute then it will be rejected. However, if it matches to the specification then it will be evaluated based on the TOPSIS method which refers to a technique for order preference by similarity to an ideal solution then show the result of the equipment evaluation.

Another study[26] presented and demonstrate a pilot of a new Windows-oriented integrated system that able to evaluate the medical equipment cost-effectiveness and quality, to use medical equipment in safety, effectiveness, and efficiency manners. The system assists clinical engineers in the evaluation and monitoring process by using cost and quality indicators. Besides the evaluation process, the system offers many functions such as replacement management, data analysis, and scheduled maintenance. However, the main job of the system is to handle all clinical engineering departments (CED) assignments and provide a general method to their management tasks. To achieve the main objective of the system, it is been founded on a star model, constructed of a major module and peripheral parts. Where the system is a combination of three software modules, each one handles certain jobs. First PRAXIS, which considers the main part, an application for the administration of biomedical technology. Second Vigilance Information Exchange Module (VIEM), a platform for exchanging data about medical equipment. Third Quality Control Protocols Module (QCPM), software that assists in quality control and quality assurance.

Moreover, an author of another study [27] emphasize the importance of applying healthcare technology assessment (HTA). It indicates that medical technologies selection may cost the hospitals as well as it has some consequences. Thus, applying such assessment has an activeand storing role not just in wealthy countries, but even in small countries. However, the author proposes the use of one of decision support systems tools as a solution to HTA issue, which isthe analytic hierarchy process (AHP). The tool applied pairwise comparison to accurately identify and select the most suitable technology. To ensure the effectiveness of this tool, they conduct a case study for the selecting process of neonatal ventilator by clinical engineers who using AHP. The author concludes by that highlighting the importance of applying business tools in healthcare field. As these tools have proven its relevant to this field.

Table 1: Summarization of Related Works

Reference	*Objective*	*IT solution*
[23]	Improve decision-making	Artificial Intelligence Model
[25]	Improve Time and make it more reliable	Automated System
[27]	Improve decision-making	Decision Support Tool
[26]	Improve cost and quality	Windows-oriented integrated system
[24]	Improve decision-making	Multi-criteria decision analysis method (AHP)

3. As-Is Medical Equipment Evaluation Process

This section presents the current state of medical equipment evaluation process. The BPM model in this paper does not represent any specific organization, as the authors deeply investigate the literature as well as an online available document from some hospitals about their equipment evaluation process. The driven model is developed by using Bizagi Studio. However, five roles are engaged in this medical equipment evaluation process which are;

1) **Requester**: who has a need for a specific medical equipment and ask for an evaluation.
2) **Procurement Department**: who are responsible about assessing and reviewing the evaluation form in terms of cost, manufacturer and supplier.
3) **Request Coordinator**: who is responsible to organize the flow of information between requester and other parties, as well as ensure effective communication between them.
4) **Medical Equipment Administration**: who approve a new evaluation request or evaluation results.

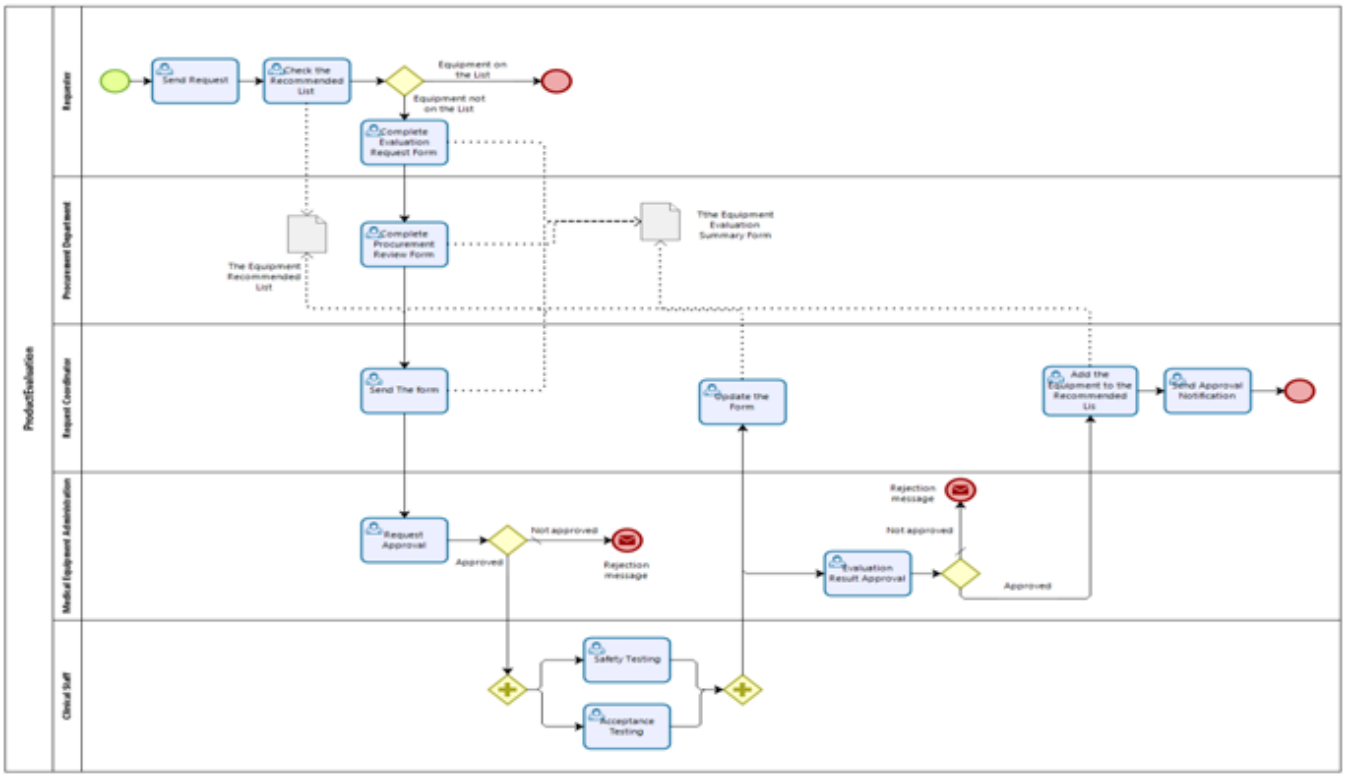

Figure 2: Medical Equipment Product Evaluation Process (As-Is) Model

5) **Clinical Staff:** The clinical team who conduct the required testing to the equipment such as safety and acceptancetesting.

As shown in figure 2, the process starts by the requester who send a request for evaluating a specific medical equipment. The requester then will be asked to check whether this equipment exist in the recommended list or not. If it is already existing, then the equipment does not require an evaluation, and the process will be terminated. If it does not exist in the recommended list, the requester will fill evaluation request form that include personal information as well as information about the equipment itself. This form will be sent toprocurement department, who will review the information and fill procurement review form which include information about the equipment such as cost, manufacturer and supplier. The form will be sent to the request coordinator who will forward it to medical equipment administration. After that, medical equipment administration will review the final form and they will decide whether to approve the request or not. If the evaluation request is rejected, the process will be terminated, and a notification message will be sent to requester. Otherwise, the request will be sent to the clinical staff in order to be tested. The clinical staff will conduct two types of testing in parallel; safety test and acceptance test. The tests result will be recoded and sent to the request coordinator who will forward it to medical equipment administration to be approved. If the evaluation result is rejected, the process will be terminated, and a notification message will be sent to requester. Else, in the evaluation acceptance case, the request coordinator will update the recommended list and add this new equipment to it. As a final step, the request coordinator will send a notification message to inform the requester about the acceptance result.

4. To-Be Medical Equipment Evaluation Process

As the process of "As-Is" in the previous section is facing challenges due to the tasks that need to be done manually by the performers which will decrease the quality of the evaluation process, take more time, effort and higher cost. In order to make it more efficient and eliminate this kind of challenges a new automation business process for equipment evaluation using re-design heuristics is proposed. The objectives of the redesign stage are simply to reduce the transaction, hangover tasks, the long period is taken during the request and most importantly enhancing the quality. There are ten heuristics for the redesign process, however, only four had been used in this study.

Task Elimination The first step before starting to redesign any business process is to make a value-added analysis that considers being critical to identify the non-added value processes to the requestor. As the increases in the transaction through the processes will slow it down. So, the proposed solution is to remove unnecessary tasks that done by request coordinatorwhich are "send the form " and "Update the form" since these two does not add any value to the requestor based on the value-added analysis table (See table2).

Parallelism is the second heuristic, the two processes of "add equipment to the recommended list" and "send approval the notification" is one of the processes that do not rely on each other, keeping them, in the same way, will cause unnecessary delays for the requestor. So, in order to enhance the performance and reduce the waiting time, task parallelism had been used for these two.

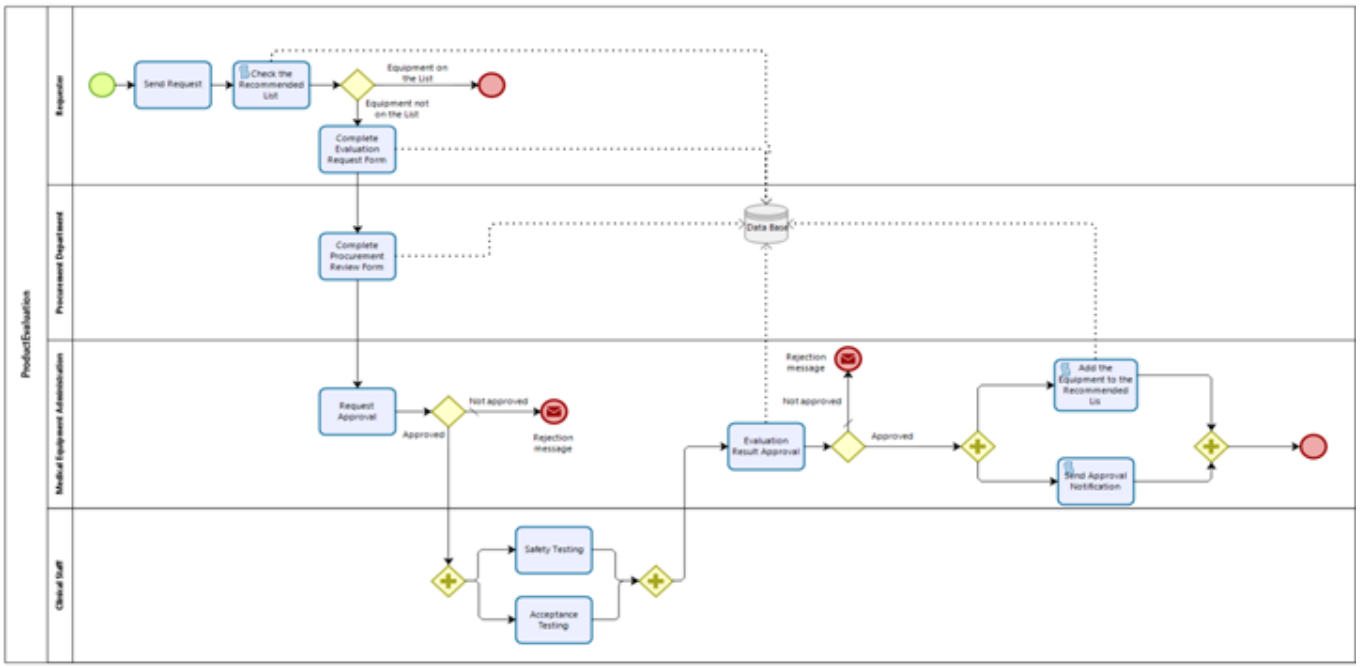

Figure 3: Medical Equipment Product Evaluation Process (To-Be) Model.

Table 2: Value-Added Analysis

Value – Added Analysis		
Step	*Performer*	*Classification*
Send Request	Requestor	VA
Check recommended list		VA
Complete form part one		VA
Complete form two	Procurement department	BVA
Send the Form	Request coordinator	NVA
Request Approval	Medical equipment administration	BVA
Safety testing	Clinical staff	VA
Acceptance Testing		VA
Update the form	Request coordinator	NVA
Evaluation result approval	Medical equipment administration	VA
Add equipment	Request coordinator	BVA
Send Approval		VA

Communication Optimization several forms had been exchanged by email in "As-is" process include the "evaluation request form" and the "procurement review form".This manual exchangecauses inefficiency in the process and due to human intervention, delays or errors that may occur to the content of these forms. Therefore, these two forms had been replaced by a single database in order to save any updates of the forms automatically and make it more centralized. This heuristic will lead to better communication optimization.

Automation is another proposed improvement that will lead to an enhancement by reducing error rate and the delays that caused by manual processes. There is a need for an automation process that checks automatically in the recommended list in order to increase the information availability and enhance the speed of the process. So after the redesign, these value-added tasks "check for recommended list", "Add equipment to recommended list" and "Send approvalnotification" will be a script where the task is automatically done which will lead to time improvement.

Moreover, the Request coordinatorwas responsible for the non-added values tasks that had been eliminated and cause the evaluation organizer employee to basically, acts as an intermediary between the procurement department and medical equipment administration by transfer, sending, or update forms. However, these tasks had been converted to be done automatically, which lead to the elimination of the evaluation organizer, since he does not add any additional value to the process after the implementation of four heuristics as shown in figure 2. This led to reduce hangover tasks and to decrease the cost which also will lead to enhance the speed of the process.

4.1 To-Be Medical Equipment Evaluation Process Automation

The Bizagi studio allows automate processes in organizations, to satisfy more complex business requirements. Therefore, to define and control the performance of the proposed (To-Be) medical equipment evaluation process and offer more transparency for hospitals.

The To-Be process was automated by the Bizagi studio. The Bizagi studio automated task is done in four steps: data model, forms, business rules, performers. The first step, the data model constructed by Bizagi studio for the (To-Be) process contain thirteen tables, that categorized into three types: seven master tables (Request, Equipment Evaluation, Equipment, Recommended list, Criteria, Request Validation, Clinical Tests), four parameters (Equipment Type, Requester Type, Job Type, Test Types), and two stakeholders (Requester, Employee). The data model is represented in figure 4.

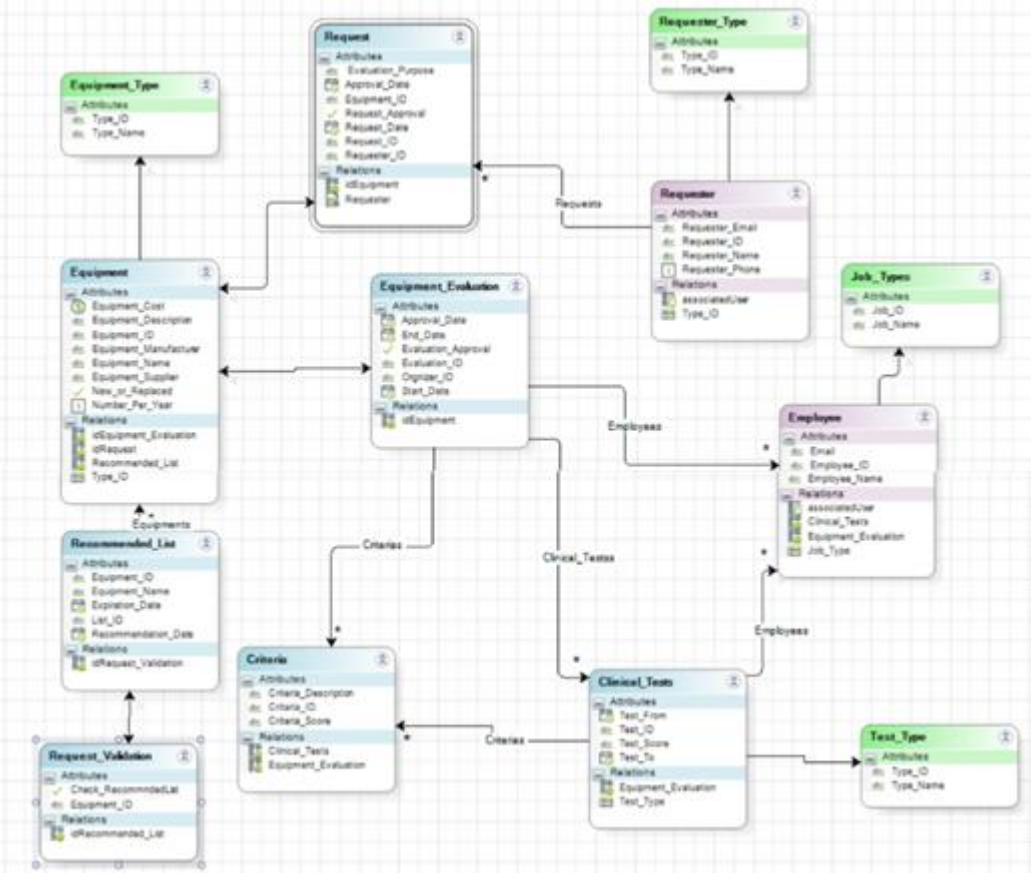

Figure 4: The Data Model of the Proposed Medical Evaluation Process

Second, the Bizagi studio allows build forms and connects them to the data model. Five forms were built for employees to fill in the To-Be process, figure 5 show an example of one of the forms. The forms as follows:

1) **Evaluation Request Form**, for the requester to enter his/her information, request information, and equipment information.
2) **Procurement Review Form**, for the procurement department to enter more information about the equipment such as cost and supplier.
3) **Request Approval Form**, for medical equipment administration, to approve the request and enter the date of the approval.
4) **Testing Form**, for clinical staff to enter the test information, test results, and clinical staff information who perform the test.
5) **Evaluation Result Approval Form**, for medical equipment administration, to approve the evaluation result and enter the date of the approval.

Third, to ensure the proper execution of the To-Be process, business rules were defined, which is used to control the path of the condition. There are three exclusive getaways in the process. The first one is to check the recommended list if the check-recommended list variable is equal to true then exit else complete form one. The second expression is from request approval if the value of approval is equal to true then enter the testing part. Else, it will be rejected. The final expression is for the evaluation result approval if the evaluation approval equal to true then it approves else it will be rejected.

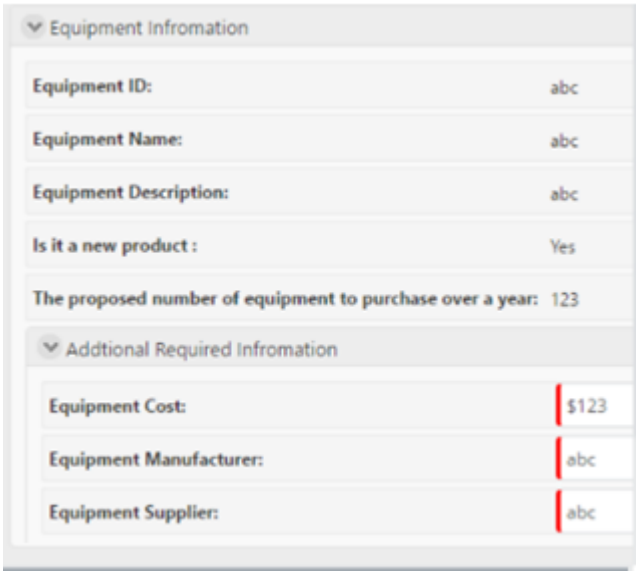

Figure 5: Procurement Review Form

Fourth, each activity created in the business process for end-user interaction requires a definition that will allow Bizagi studio to evaluates the allocation roles definition and allow only these users to access and work on the activity allocated to them. Therefore, performers for each activity been assigned in the To-Be process. Where the performers are the user that have the qualities to be assigned to activities. There are four performers as following, requester, procurement department, medical equipment administration, and clinical staff.

5. Testing and Measures

In order to evaluate the proposed To-Be process model, the reengineered model is simulated using Bizagi. Then, the simulation results of both As-Is and To-Be models are compared regard the different performance measures.

1) Time

Through the analysis, it has been clearly found that time is the most affected measure from the re-engineering. The time consumed by each task is mostly decreased. It also found that some of the tasks are no longer require any time to be done because it assigned to be performed by the system (automated) for example: Check the Recommended List, Add the Equipment to the Recommended List, Send Approval Notification. Furthermore, the NVA tasks like Send The form to Medical equipment administration, Update the Form are eliminated
(See Figure 6 and Figure 7).All that contributes to shortening the total time of the whole evaluation process and affected the average time subsequently.

To clearly indicate the change of any quantity that can be measured over time different mathematical formulas can be used. The Percentage Change is the one that used here. Percentage change is a simple mathematical formula that calculates the rate of change over time, where the positive result determines the increase, and the negative value represents the decline [28, 29].

	Name	Type	Instances completed	Instances started	Min. time (m)	Max. time (m)	Avg. time (m)	Total time (m)
2	ProductEvaluation	Process	15	15	240	21120	5696	128640
3	NoneEnd	End event	6					
4	Rejection message	End event	6					
5	NoneEnd	End event	2					
6	Rejection message	End event	1					
7	ParallelGateway	Gateway	3	3				
8	ParallelGateway	Gateway	3	3				
9	ExclusiveGateway	Gateway	15	15				
10	ExclusiveGateway	Gateway	9	9				
11	ExclusiveGateway	Gateway	3	3				
12	NoneStart	Start event	15					
13	Check the Recommended List	Task	15	15	120	120	120	1800
14	Request Approval	Task	9	9	2880	2880	2880	25920
15	Safety Testing	Task	3	3	14400	14400	14400	43200
16	Send The form to MEPG	Task	9	9	120	120	120	1080
17	Acceptance Testing	Task	3	3	14400	14400	14400	43200
18	Update the Form	Task	3	3	120	120	120	360
19	Add the Equipment to the Recommended Lis	Task	2	2	120	120	120	240
20	Evaluation Result Approval	Task	3	3	2880	2880	2880	8640
21	Send Approval Notification	Task	2	2	120	120	120	240
22	Send Request	Task	15	15	120	120	120	1800
23	Complete Evaluation Request Form	Task	9	9	120	120	120	1080
24	Complete Procurement Review Form	Task	9	9	120	120	120	1080

Figure 6: Simulation Results Medical Equipment Product Evaluation with Regard to Time Analysis (As-Is Model)

	Name	Type	Instances completed	Instances started	Min. time (m)	Max. time (m)	Avg. time (m)	Total time (m)
2	ProductEvaluation	Process	15	15	120	20520	3672	83880
3	NoneEnd	End event	9					
4	Rejection message	End event	4					
5	NoneEnd	End event	2					
6	Rejection message	End event	0					
7	ParallelGateway	Gateway	2	2				
8	ParallelGateway	Gateway	2	2				
9	ExclusiveGateway	Gateway	15	15				
10	ExclusiveGateway	Gateway	6	6				
11	ExclusiveGateway	Gateway	2	2				
12	NoneStart	Start event	15					
13	ParallelGateway	Gateway	2	2				
14	ParallelGateway	Gateway	2	2				
15	Check the Recommended List	Task	15	15	0	0	0	0
16	Add the Equipment to the Recommended Lis	Task	2	2	0	0	0	0
17	Send Approval Notification	Task	2	2	0	0	0	0
18	Send Request	Task	15	15	120	120	120	1800
19	Complete Evaluation Request Form	Task	6	6	120	120	120	720
20	Complete Procurement Review Form	Task	6	6	120	120	120	720
21	Request Approval	Task	6	6	2880	2880	2880	17280
22	Safety Testing	Task	2	2	14400	14400	14400	28800
23	Acceptance Testing	Task	2	2	14400	14400	14400	28800
24	Evaluation Result Approval	Task	2	2	2880	2880	2880	5760

Figure 7: Simulation Results Medical Equipment Product Evaluation with regard to Time Analysis (To-Be Model).

$$Percentage\ Change = (A - B) \setminus B \qquad \textbf{(1)}$$

where B is the original number to be compared with.
In this case:
A represents total time consumed in To-Be model
B is the total time consumed in As-Is model
Time Percentage Change = -0.34794
Whereas the change value is negative that means the time consumed is decreased.Briefly, the time consumed during the reengineered Product Evaluation business process is 34.79% lower than the As-Is model.

2) Resources

Resources planning is a crucial and critical task done to sufficiently allocating the organization's resources and ensure that no resource is being exhausted or underwork. It also helps to ensure that all resources are meeting the desired cost-benefit measurements and used time effectively [30].By comparing As-Is and To-Be models it can be seen that the number of tasks decreased by 16.7%, which is one of the factors thataffected the resource allocation. Table3 and Figure2 shows the inefficient resource allocation clearly.

The re-engineered model assumes to improve resources' allocation. Some resources are imperceptibly affected where their load is decreased slightly in order to free them to do other tasks like Medical Equipment Administration, Clinical Staff and Procurement Department. Even more, the Request Coordinator is completely eliminated because he is only responsible for managing the form exchange and equipment recommended list and all these tasks can be automated as what done in reengineering. That helps to increase the quality of those tasks, decrease the processing time and cut-off associated costs.

Table 3: Simulation Results Medical Equipment Product Evaluation with Regard to Resource Utilization

Resource	*As-Is Process*	*To-Be Process*
Procurement Department	1.11%	1.03%
Request Coordinator	3.89%	0.00%
Medical Equipment Administration	66.67%	16.49%
Clinical Staff	91.94%	82.47%

Finally, the aim of applying heuristics redesign in any process is to enhance four factors, time, cost, quality, and flexibility. The heuristics have been applied to the "As-Is" process leads to improving time, cost, quality factors. To demonstrate this improvement, table 4 present heuristics with factors change. To demonstrate more, the following is the reasons for the change in each factor.

Table 4:Heuristics and Factors

Heuristic	*Time*	*Cost*	*Quality*
Task Elimination	+	+	-
Parallelism	+	.	+
Communication optimization	+	+/-	+
Automation	+	+/-	+

Task Elimination

- Time is improved because eliminating non-value-added activities leads to an increase in the speed of the process.
- Cost is decreased as eliminating non-value activities reduced the handling cost of these activities. Also, task elimination results in removing the request coordinator employee, which reduced the cost of this employee.
- Quality is reduced as the request coordinator is removed there will be no employee to checks the forms and the recommended list.

Parallelism

- Time is improved since processing two activities synchronously reduces the waiting time.
- Quality is enhanced because parallelism leads to speed the process which makes the requester more satisfied.

Communication optimization

- Time is decreased as utilizing a database to exchange forms instead of emails eliminate delays and reduces forms exchange time.
- Cost is increased because the purchase database and maintenance will cost the hospital more. But at the long term, the database will help reduce the overall cost since database result in centralized all forms and messages, which lead to reducing the cost of multiple versions of the same form and number of messages exchanged between employees.
- Quality is improved as using a database to exchange forms instead of emails leads to less human intervention and fewer human errors. Also, using dataset result in centralized, which increase information availability.

Automation

- Time is improved because multiple activities are done automatically enhanced the speed of the process and reduce delays between activities.
- Cost is increased as automation required the hospital to purchase new software or system and maintain it. On the other hand, the cost will also be decreased because there will be no need to pay a salary to an employee.
- Quality is improved since multiple activities are done automatically leads to less human intervention and errors.

6. Conclusion and Future Work

Using the appropriate medical equipment is one of the factors that ensure patient safety and provide high- quality services. Therefore, this paper aim to improve the medical equipment evaluation process using re-engineering and automation technique. Four re-engineering heuristics were applied which are, task elimination, parallelism, communication optimization, and automation. The proposed"To-Be" shows an improvement in terms of time, cost, and quality. Especially The time that became more faster by 34.79% than "As-Is" process. As a future work, it is having been noticed that there is a need to take the advantages of emerging technologies to improve the automation of medical equipment evaluation process.

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