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Collaborating Internet of Things (IoT) and Electronic Medical Record (EMR) to Reduce Healthcare Waiting time. Outpatient Cardiology Service Case: A BPR Approach

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ABSTRACT

Public services around the world suffer for long waiting time. Hospital as a healthcare facility ideally should not stress its patients with long waiting time, especially when it comes to elderly. In global the cardiovascular disease (CVD) represents 31% of global deaths with increasing prevalence rate at the age of 40. The outpatient cardio logical clinics are facing efficiency challenge as worldwide elderly population is estimated to double in about 30 years. This study aims to design process improvement in an outpatient cardiological clinic as to optimize their patients time spent. A case study is conducted at a well-known private hospital in Indonesia using Business Process Reengineering (BPR) approach and simulation techniques. The research outcome shows that using Internet of Things (IoT) for Electronic Medical Record (EMR) data capture results in the most streamlined and efficient outpatient workflow, and amazingly it may reducing almost 47% of time spent in one outpatient visit.
Keywords— Internet of Things (IoT), Electronic Medical Record (EMR), Business Process Reengineering (BPR), Healthcare.

1. INTRODUCTION

Cardiovascular Disease (CVD) is the main cause of death in the world [1] and its risk factor keeps escalating, reaching 32.1% in 2015 [2]. As much as 37% of death in Indonesia is caused by CVD, which commonly attacks the elderly (≥ 60 years old) [3]. More than a quarter of deaths in UK are caused by CVD, placing it as the 2nd leading cause in the country [4]. CVD accounts for 45% of all deaths in Europe [5], while it happens to be 34% in Middle East region [6]. Most populous countries in the world are reported to have the highest number of people dying from CVD [7]. As important as the clinical improvement, there is high urgency to improve service efficiency in cardiology department.

As a complex institution, hospital requires a quality information system to be able to deliver its service effectively and efficiently. Patients' Medical Record (MR) is important information in hospital. In 1972, a digital form of MR was introduced, known as Electronic Medical Record (EMR). While it is extensively used in developed countries, several studies showed its data entry issue which surprisingly results in lower time efficiency [8]–[12].

Around 60% of healthcare organizations has installed Internet of Things (IoT) to its facility and recognized its benefit [13]. Prior studies have discussed how IoT in a form of wearable device could support the treatment for patients with heart disease. In this paper, simulation technique is utilized to assess the application of EMR and IoT in a cardiology outpatient service in regards to time efficiency. We also used BPR best practices as technology adoption is one of its cores.

2. LITERATURE REVIEW

2.1. Outpatient Waiting Time

Cardiology clinic is among the busiest departments in hospital and its workload tends to increase by time. Excessive waiting time is one of the most common problems in this department. Many countries strive to overcome outpatient waiting issue by applying particular system or technology.

Prior study conducted quality improvement project to reduce waiting time in an outpatient clinic and gained 4% increase of patients seen by doctor within 60 minutes as well as 36.6% reduction in cashier waiting time as a result [14]. Other prior case studies proposed an optimized workflow at cardiology departments by automating tasks, yet did not mention how much it could affect hospital service efficiency [15], [16]. Another study reengineered outpatient workflow and the simulation result showed 20% improvement in time efficiency [17].

2.2. IoT Application in Outpatient Cardiology Services

IoT is a network of objects that are connected to internet and able to communicate with each other in order to attain a goal without human intervention [18]. IoT brings new opportunities for better healthcare delivery, especially

towards cardiovascular disease. There is a great potential to solve outpatient waiting time issue by applying IoT, yet research and simulation on how the technology impacts hospital workflow is lacking.

Previous studies have shown how IoT allows data capture of patient vital signs, including cardiac parameters, through wearable biometric sensors. The data is stored in cloud to be accessed in a real time basis using wireless connectivity [19]–[21]. The system is commonly known as Remote Patient Monitoring System and its integration with EMR has potential to support information system, therefore streamline procedures in the hospital [22]. A timely and accurate data capture improves medical recording and may as well support clinical decisions for quality care.

Prior study showed IoT utilization in outpatient service using Augmented Reality that supports wearable computing, such as smart glass wearable [23]. The device allows both audio and visual recording of consultation between physicians and patients and delivers it through internet to be immediately charted by remote scribes, hence creating more time for physicians to focus on their patients without concerning excessive workload on EMR charting.

2.3. Business Process Reengineering (BPR)

BPR is radical redesign of a business process by reconsidering its basic purpose to gain significant improvement in performance regarding cost, quality, and time [24]. Technology adoption is the core of BPR as it is likely to fail and results in a longer process time when not followed by a workflow redesign.

BPR has been used broadly in studies to improve process in many sectors, including technology adoption in healthcare [25]–[27]. A number of global companies has implemented it to gain competitive edge, namely Dell, Ford, and Siemens. Nevertheless, a risk assessment is necessary to minimize the risks in BPR effort.

3. METHOD

This paper used BPR approach in four main steps, which are planning for change, designing change, assessing change risk, and evaluating change.

3.1. Existing Process (As-Is Process) Analysis

As-Is process analysis is part of planning for change. Data were collected by observing the process in order to understand the workflow and each task time. This research Long laboratory processing shows a potential of bottleneck that should be anticipated in designing the improvement. Deeper analysis on As-Is process is mapped in Fig. *1*.

was conducted in a private hospital in Indonesia. Out of 354 outpatient visits per day in average, around 25% were cardiology patients whom were handled by one full-time cardiologist.

The process is divided into 3 based on patient's payment method, which are Cash, Private Insurance (PI), and National Health Insurance (NHI). NHI patients' workflow seemed to be more streamlined, yet the patients suffered much longer waiting time since those who pay by cash or PI are prioritized. In brief, outpatient cardiology service workflow includes registration, billing, doctor treatment (Electrocardiography and Echocardiography), external treatment (Laboratory and Radiology), and medicine purchase. Registration staffs will push notification to start MR searching. Treatment will only start after the doctor checks patient's MR. We map the post-treatment Medical Record process separately as it does not interfere patient workflow but demonstrates MR workload.

The As-Is process was modeled and simulated using iGrafx software. The average time and standard deviation of each task was input along with its proper distribution obtained from 30 sample size of observation. Simulation result of As-Is process is shown in TABLE I.

Simulation result shows that average total time spent for an outpatient visit is 4.41 hours with waiting time for doctor appointment being the longest. Longest working time is on pre-treatment MR tasks. The entire MR process spends about 5.9 hours in total, whereas the whole work-hour in a shift is limited to 7 hours to work on both outpatient and inpatient MR.

TABLE I. SIMULATION RESULT OF AS-IS PROCESS

Swimlane	AvgCycle (Hours)	Avg Work (Hours)	Avg Wait (Hours)
Registration	0.19	0.07	0.12
MR (Pre-Treatment)	0.35	0.27	0.08
Pre-Treatment Room	0.14	0.09	0.05
Subprocess Treatment Room	3.07	0.15	2.92
Laboratory	1.37	0.13	1.24
Radiology	0.28	0.09	0.19
Pharmacy	0.47	0.09	0.38
Total Outpatient Process	4.41	0.48	3.93
MR (Post-Treatment)	5.55	4.55	1

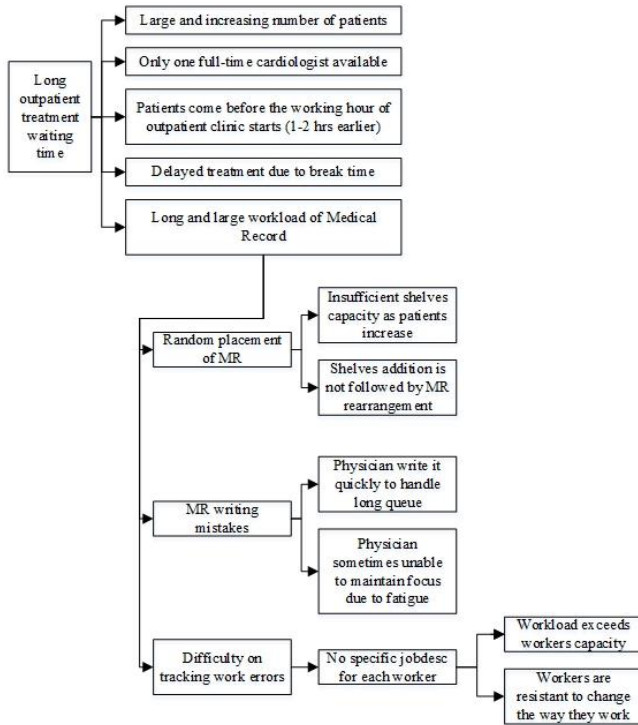## 3.2. Improved Process (To-Be Process) Design

Figure 1. Issue Tree Analysis of As-Is Process

Based on the analysis, we use BPR best practices to design several alternatives on solution for process improvement. In this hospital, each patient has his/her own doctor, the one who handled the very first time. Solution of having extra cardiologist is brought with assumption of allowing all patients to be flexibly handled by whichever cardiologist.

EMR is offered as one of the solutions by eliminating MR (Pre-Treatment) tasks and supporting online check of external treatment results. Using EMR does not fully eliminate MR tasks due to regulation that requires hospital to keep external referral document in a paper record. Nonetheless, the entire To-Be MR process will not affect patient workflow and its workload will reduce, depending on the number of patients got referred in the particular day.

IoT can be utilized in outpatient cardiology services to capture patient's vital cardiac parameters and transmit them automatically to EMR. IoT also enables automatic EMR charting through remote scribes in a real-time basis. TABLE II shows patient health data captured by biometric sensors along with their response time.

TABLE II. VITAL CARDIAC PARAMETERS CAPTURED BY IOT BIOMETRIC SENSORS

Captured Data	Sensor Response Time (second)	Reference
ECG	10	[19]
Heart rate	5 - 60	Expert Interview
Pulse rate	2	[20]
Blood pressure	2	[20]

Changes in process due to the proposed solutions are explained briefly in TABLE III.

TABLE III. DESCRIPTION OF TO-BE MODEL MODIFICATIONS

No	Solution	BPR Best Practice	Model Modification
1.	Adding 1 extra cardiologist	Extra resources	Resource setting One similar treatment task addition with equal patient distribution
2.	Using EMR	Task elimination Contact reduction	Elimination of all pre-treatment MR tasks Reduction of contact to check external treatment result as it is done through an online system Different time allocation in writing and typing MR, as well as checking EMR
3.	Using IoT	Task automation Task elimination Flexible assignment Contact reduction	Task addition of wearing and working sensor, also its data transmission to EMR Elimination of MR checking task as it is parallelized with consultation Elimination of MR writing/typing and special treatment scheduling as it is automated Assumption of adopting new lab instruments with higher specification (50% time reduction in lab processing)

Those three solutions are combined, resulting in four models to be simulated and assessed in regards to its process time. Below is the combination of process improvement solution (See TABLE IV). To-Be Model 4 along with its Treatment Room subprocess is demonstrated to illustrate all the solutions (See Appendix A, Appendix B, and Appendix C).

TABLE IV. COMBINATION OF PROCESS IMPROVEMENT SOLUTION

Model	Solutions		
	Adding 1 cardiologist	*Using EMR*	*Using IoT*
1	√		
2		√	
3		√	√
4	√	√	√

4. RESULT AND DISCUSSION

4.1. Simulation Result of To-Be Model

Based on the simulation result, there are two solutions with optimal average cycle time of outpatient cardiology visit. Model 3 and 4 is only slightly different, with model 3 being 0.07 hours longer in its waiting time (See TABLE V). Assuming there are 20% of patients being referred in a day, Medical Record model simulation results in an extreme time reduction, where 5.55 hours become 1.81 hours in total as the workload becomes less (See TABLE VI).

TABLE V. SIMULATION RESULT OF OUTPATIENT TO-BE MODELS

Model	Avg Cycle (Hours)	Avg Work (Hours)	Avg Wait (Hours)
1	3.12	0.48	2.64
2	4.14	0.41	3.72
3	2.34	0.28	2.05
4	2.27	0.28	1.99

TABLE VI. SIMULATION RESULT OF MEDICAL RECORD (POST-TREATMENT) TO-BE MODEL

Swimlane	Avg Cycle (Hours)	Avg Work (Hours)	Avg Wait (Hours)
MR (Post-Treatment)	1.81	1.81	0

Adding extra cardiologist shows a significant time reduction, around 1.29 hours (29.25%) in average waiting time while the average working hour remains the same.

Applying EMR is the solution showing the least impact with only 0.27 hours reduction (6.12%) in waiting time. There is also reduction in working time as patients will no longer have to go back to the Treatment Room only to get their external treatment result checked. Doctor can obtain the result through an integrated online system and immediately send a prescription accordingly to the pharmacy.

Applying EMR and IoT is results in 46.94% overall time reduction. Assessment of patient health data can be conducted using biometric sensors while the patients are in queue. Supported by remote medical scribing system, appointment is also expected to last shorter yet higher in quality. Adopting IoT in outpatient care will allow not only more accurate patient data but also complete and interactive EMR. IoT will facilitate easier discussion between doctors through comprehensive wireless data sharing, which results in quality diagnosis and care. The simulation result of model 3 is shown in TABLE VII.

TABLE VII. DETAIL SIMULATION RESULT OF TO-BE MODEL 3

Swimlane	Avg Cycle (Hours)	Avg Work (Hours)	Avg Wait (Hours)
Registration	0.2	0.07	0.13
Pre-Treatment Room	0.02	0.01	<0.01
Treatment Room	1.28	0.05	1.23
Laboratory	0.76	0.14	0.61
Radiology	0.32	0.13	0.19
Pharmacy	0.47	0.08	0.39
Total Outpatient Process	2.34	0.28	2.06

All the proposed solutions are combined. The simulation result of the combined model demonstrates the shortest average waiting time with only 0.07 hours difference with model 3, reaching 48.53% overall time reduction. It can be inferred that the combination of all solutions utilizes more effort for a similar impact. Simulation result of To-Be model 4 is detailed in TABLE VIII.

TABLE VIII. DETAIL SIMULATION RESULT OF TO-BE MODEL 4

Swimlane	Avg Cycle (Hours)	Avg Work (Hours)	Avg Wait (Hours)
Registration	0.19	0.07	0.12
Pre-Treatment Room	0.02	<0.01	<0.01
Treatment Room	1.24	0.05	1.19
Laboratory	0.72	0.14	0.58
Radiology	0.31	0.13	0.18
Pharmacy	0.46	0.08	0.38
Total Outpatient Process	2.27	0.28	1.99

Based on overall simulation result of the To-Be models, solution model 3 is selected as the most optimal process.

4.2. Risk Assessment of Selected Solution Implementation

BPR risk is assessed based on importance score of BPR Critical Success Factors (CSF) and Critical Failure Factors (CFF) and organization performance score of each factor. The CSF used in this paper are collected from several prior studies about BPR in healthcare [28]–[32]. The CFF used in this paper is based on one applied in public sector [33].

Factors are weighed by 5 experts, including 1 BPR consultant, 1 EMR experienced user, and 3 experts from the hospital being studied, which has experienced technology

adoption in its facility. The next step is organization performance rating towards each factor, which is done by 10 representatives of the organization, including director, all managers, and the cardiologist as one of the most affected users. TABLE IX shows the average weight of the factors and score of organization performance regarding each factor.

TABLE IX. BPR RISK ASSESSMENT

Category	Factors	Weight	Organization score
CSF	Competent IT	4.78	3.67
	Project planning	4.37	3.05
	Effective training	4.18	3.65
	BPR best practice utilization	4.37	3.37
	Critical business process prioritization	4.18	3.37
	Comprehensive process analysis	3.78	3.46
	Senior manager's BPR knowledge	3.95	3.27
	Real expectation of BPR result	3.78	3.57
	Skill and knowledge regarding process	4.13	3.67
	BPR project is initiated due to need for performance improvement or competitive pressure	3.78	3.84
	Organization accountability	4.00	3.86
	Team communication and collaboration	4.51	3.78
	Clear role and tasks for project team members	3.78	3.54
	User involvement in BPR project	4.57	3.42
	BPR team consists of experienced user	4.37	3.44
CFF	Managers' interest in their authority	3.78	2.32
	Employees' interest in their job	4.00	2.35
	Employees' uncertainty about project results	2.93	2.63
	Employee's being tense	3.29	2.70
	Lack of readiness	3.18	2.26

Based on factors weight and score, BPR risk can be assessed using the following formula [33].

$$S = \sum_{i=1}^{n} W_i P_i - \sum_{j=1}^{m} W_j P_j \qquad (1)$$

Where S represents organization readiness, n is the number of BPR CSF examined, Wi is importance weight of each CSF, Pi is organization score towards each CSF, Wj is importance weight of each CFF, and Pj is organization score towards each CFF.

The calculation of (1) indicates organization readiness score to adopt EMR and IoT, which is 178.64. Based on specified range, the risk of implementing BPR in this hospital is categorized as having very low risk (See TABLE X).

TABLE X. POINT RANGE FOR BPR RISK ASSESSMENT

Risk Level	Total Score
Very high risk	< 0
High risk	0-50
Moderate risk	51-100
Low risk	101-150
Very low risk	>150

Organization score on factor with the greatest weight, which is Competent IT, reaches 3.67. The organization also holds the highest score for organizational accountability, which is weighed 4.00. Overall, this organization shows high score in CSF, reaching 3.53 in average, and lower score in the CFF. Based on the risk assessment, this hospital shows great readiness to implement the proposed solution to support quality care, both medical and operational.

5. CONCLUSION

This research proposed process improvement in outpatient cardiology services to reduce waiting time. Four scenarios of solution were designed based on BPR approach and opportunity given by latest technology. Simulation result shows that EMR and IoT application provides the most significant time reduction, reaching 46.94%, with sensible effort. A risk assessment on implementing the proposed solution shows there is very low risk for the hospital to implement the selected solution but there are several areas where the hospital should focus its effort more.
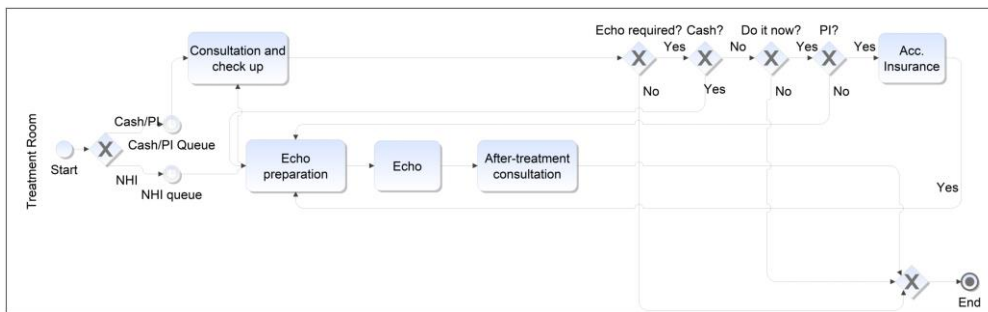
This paper is limited to time efficiency in cardiology services. Future research can focus on financial aspect of implementing IoT to enhance healthcare delivery and quality in the same or other particular units.
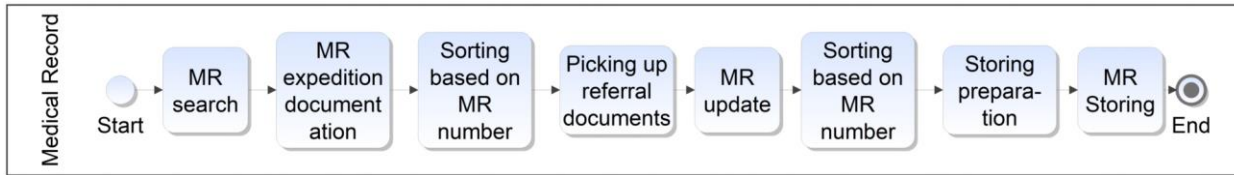
APPENDIX

Appendix A. Outpatient To-Be Process Model
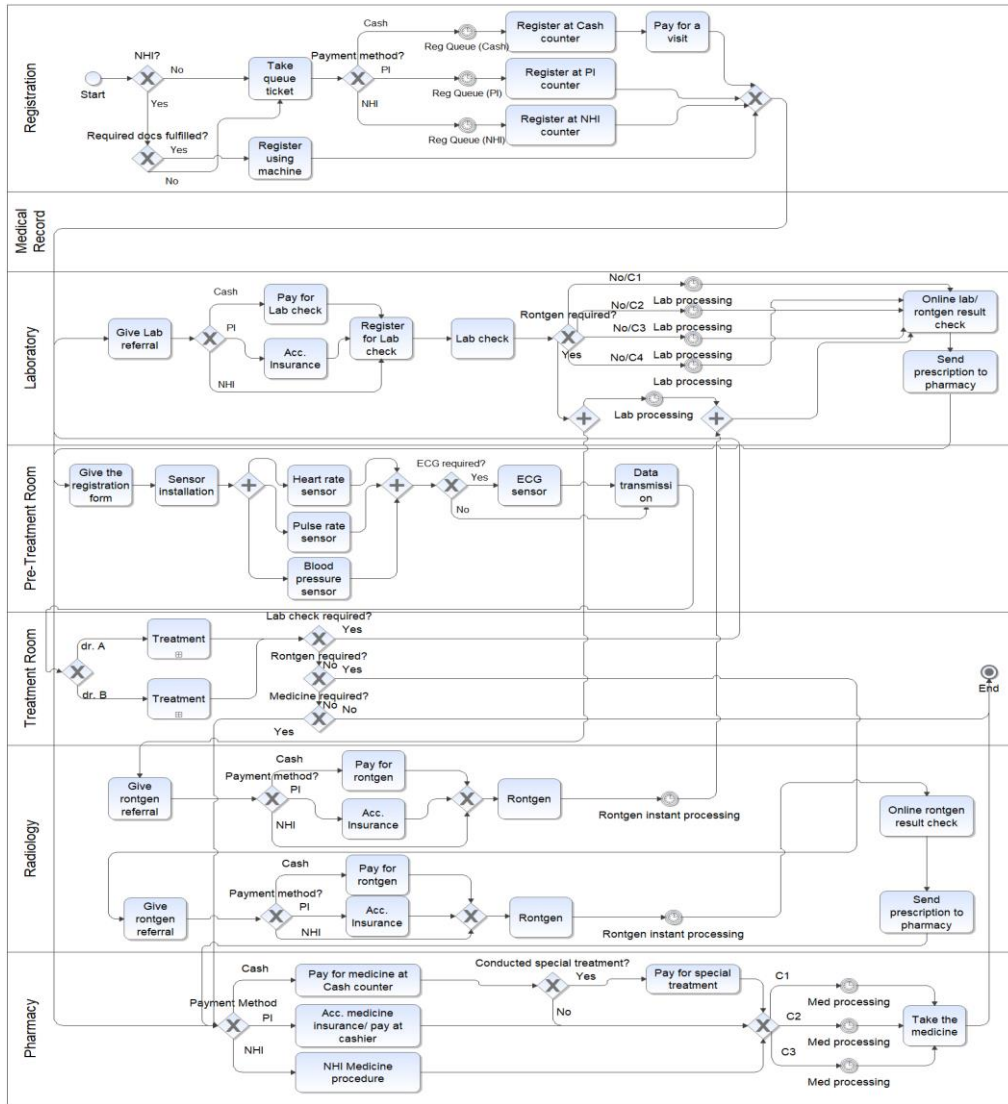
Appendix B. Treatment Subprocess To-Be Model

Appendix C. Medical Record (Post-Treatment) To-Be Model

ACKNOWLEDGMENT

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