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The Hospital Radiology Service Redesign, By Using Business Process Re-engineering and Information Systems Approach

Dhia Ayu Salsabila[1], Muhammad Dachyar[2]

[1,2]*Department of Industrial Engineering, Universitas Indonesia, Depok, 16424, Indonesia*
[1]*dhiaayusalsabila1@gmail.com*, [2]*mdachyar@yahoo.com*

Abstract

Waiting time plays an important information in providing health services to patients at hospitals especially in the radiology unit. The patients requirement is to provide fast and quality health services. Infrastructure and human resource constraints are still a challenge for the hospital. The purpose of this study is to design improvements in radiology services. Thus, improve the performance and quality of radiology services in hospitals. The research using business process re-engineering (BPR) and information systems method especially the relational database. This study produced six combinations of improvement strategies for radiology service systems with different results. This study result an improvement in radiology services with the quickest waiting time by using the combination: digital radiography (DR), radiology information system (RIS), and picture archiving and communication system (PACS). The result average time of the business process was reduced from 8.79 hours to 1.59 hours, with the efficiency is 82%.

Keywords: *Radiology, Business Process Reengineering (BPR), Information Systems, Relational Database, Tele-radiology*

1. Introduction

The increasing prevalence of chronic diseases is in line with the demand for good health services [1–3], one is radiology. Long waiting time become one of the main challenges in the health care systems [4], as well as in diagnostic radiology services [5]. The increasing demand for radiology services and the limited resources of radiologists have led to a long waiting time for radiology results. Increased radiology turnaround time will cause radiology services become delay, which can affect patients complaint. Delay in health care can give a negative effect on a patient's health [6]. Some cases show losses due to delayed radiology services, both material losses and loss of life. To overcome the problem of delay problem, availability, and affordability for diagnostic radiology services, there needs to be a rapid change in the model of health care delivery in radiology services.

This study aims to design improvements in hospital radiology services using business process re-engineering and information systems approach with tele-radiology supported by the internet of things (IoT). Data is collected through interviews in hospital with radiographers and radiologists who are directly related to the process of radiology services.

Radiology refers to medical discipline that uses non-invasive imaging scans to diagnose patients. Radiology or diagnostic imaging can be used to identify various medical problems, such as heart conditions, broken bones, blood clots, and digestive conditions.

Radiology equipment often used X-ray, Computed Tomography (CT) Scan, Ultrasonography (USG), and Magnetic Resonance Imaging (MRI). Tele-radiology is a form of telehealth that can facilitate the process of radiological diagnosis remotely and is expected to reduce the costs required in patient health care. Tele-radiology will affect the need for not re-acquisition images, which will affect the reduction workload of the radiographer's [7]. Tele-radiology has been implemented in several countries.

Tele-radiology conducted in Denmark by linking imaging results in Denmark with hospitals in Estonia and Lithuania is one example of successful implementation of teleradiology [8].

Business Process Reengineering (BPR) is done to achieve significant improvements in processes dramatically in certain sizes such as cost, quality, service, and speed [9].

BPR practices have been successfully carried out in various previous studies. Starting from the manufacturing industry, food, to the service industry. In the logistics system of pharmaceutical company, the use of BPR optimization proven can helps in reducing system time for 7.55 days or 7.93% efficiency [10]. Research conducted at insurance companies shows a reduction in processing time of 76.48% with the use of sixteen BPR best practices [11].

Previous studies on pharmaceutical companies used the BPR method, while this study examined hospital radiology services with BPR methods that were combined with the information system so that this study could be considered as a new study.

Information systems involve various information technologies to perform specific tasks, interact, and inform various actors in various organizational or social contexts [12]. According to [13] information systems have the potential to improve the performance of health care providers, lead to improved quality, cost savings, and greater involvement by patients in new health care.

DDLC is one of information systems method to redesign the database management system. Database design requires several steps, starting from the design to the operation. DDLC is the process of obtaining actual system requirements, analyzing existing system requirements, designing data and system functions, and then implementing operations into the system [14]. DDLC is not strictly carried out sequentially but can involve repetition of previous steps if needed [15].

2. Method

The stages of the research are adjusted to the principles of Business Process Reengineering (BPR) and also the Database Development Lifecycle (DDLC). BPR is carried out in the first four stages: defining the current business process, conducting an analysis of the current business process, identification of improvement opportunities and designing the proposed improvement process.

The diagnostic radiology service process at the hospital will be modeled using iGrafx software. The stages of preparation for the implementation of the proposed model on BPR are carried out with the DDLC principle by designing the radiology service information system. The information system design is then formed from the best modeling results of diagnostic radiology improvement, which will consist of designing Entity Relationship Diagrams, Relational Schemes, Use Case Diagrams, and Data Flow Diagrams.

3. Result and Discussion

3.1. Current Radiology Service System

Before modeling the current radiology service process, the entire process of hospital diagnostic radiology services are examined. The entire process information obtained from direct observations and verified by the hospital through interviews.

The waiting time at radiology service is categorized into two parts, namely the system turnaround time and radiology turnaround time. The waiting time from the radiology “examination request” activity is made by the referral doctor until finally given to the radiology department. The administrative processes outside of radiology is defined as the system turnaround time, while the time from conducting the radiology examination until the availability of "expertise to be given to the patient" or the referral doctor is defined as the radiology turnaround time. The difference between these two categories is that the system turnaround time does not depend on radiology unit performance, while radiology turnaround time is high dependent on the availability and performance of radiologists and radiographers.

As-is process and to-be process simulations are performed using iGrafx software. A set of random numbers will be selected in each replication and used in estimating the probability distribution function in the simulation of the radiology service process. The entire process time included in the radiology service process simulation will be a time span using a uniform distribution so that every possible outcome has the same probability of occurring. Validation of the as-is model is done by using faces and event validity to ensure the as-is process model is made according to the current radiology service process. The following is an illustration of the current process model that is modeled using iGrafx software in Figure 1.

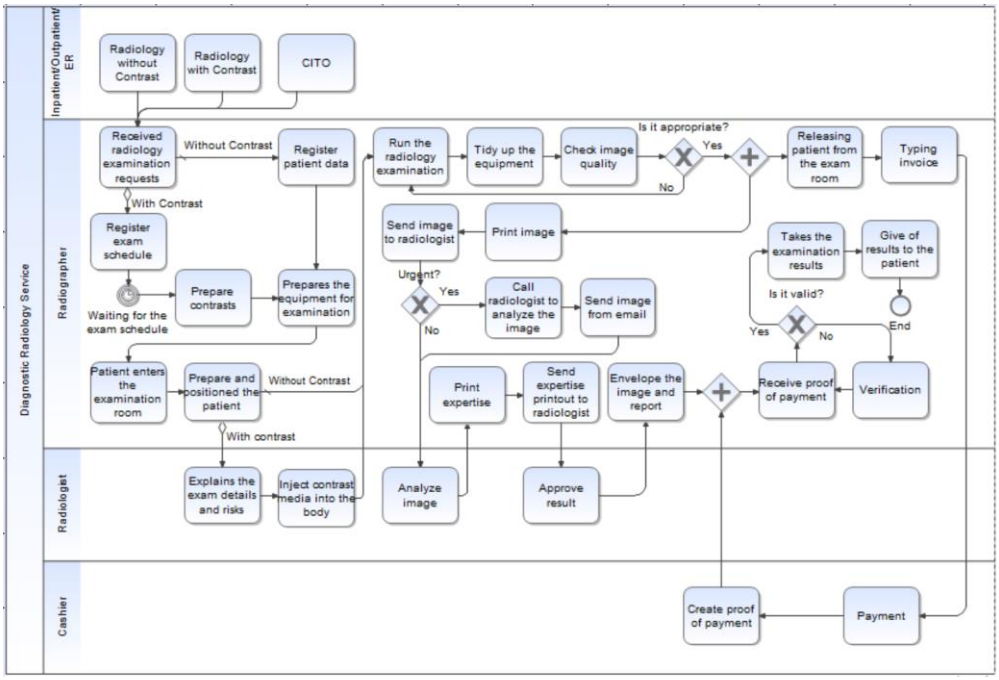

Figure 1. Radiology As-Is Process Model

Based on the simulation results of the current process model, the average cycle is 8.81 hours, with an average working time of 1.49 hours and the average waiting time for the availability of resources for 0.55 hours. The largest average waiting time in the radiographers' process group for 5.39 hours, which is caused by waiting time due to the radiologist not at the working hours for 3.95 hours. The waiting time generated by the previous process causes blocked time. The previous process is the time waiting for the results of the inspection to be processed in the radiology installation lane.

3.2. Analysis of Current Processes

Several processes still carried out manually and repeat in the radiology pre-examination process that causes the process of entering the same data more than once on the system.

Non-value added activities also can be reduced to improve the effectiveness and efficiency of the diagnostic radiology service process, such as the process of providing radiological imaging results that have to be printed and the process of preparing and tidying the equipment, namely cassettes and imaging modalities. Reducing the non-value added activities can reduce the radiographers' workloads.

The availability of radiologists is also an important part of the radiology service process. It is important to check that the radiologists still have the time to analyze radiology images because radiologists not only responsible for reading radiological imaging results but also carry out radiological examination practices for examinations such as ultrasound and contrast examinations that require doctor handling.

3.3. Customer Requirements of Future System

The objectives of business process reengineering and the information system design of the to-be process are determined after gathering the weaknesses of the radiology service process. To-be process are designed to provide fast service with good quality for hospital radiology services. The to-be system used by the parties involved in radiology services, such as referral doctors, radiographers, and radiologists with information systems designed to be limited to the radiology unit.

3.4. Proposed Solutions and Alternative for Improvement

There are several ways that can be done in making improvements for business processes in a company, such as benchmarking, ESIA (Eliminate, Simplify, Integrate, Automate), and BPR Best Practice. The improvement of radiology business process system are made by considering the results of simulations and discussions conducted with relevant stakeholders which can be seen in Table 1.

Table 1. Proposed Solutions.

No.	Improvement	Description
1	Design a neat storage area	Dividing the storage place of images and the results that have not finished yet in alphabetical order, month, and year.
2	Adding radiologists	Increase the number of radiologists for analyzing images to avoid delays in making reports
3	Enhanced the features of RIS	Optimizing the use of Radiology Information System (RIS) to increase the effectiveness of radiographers and radiologists
4	Changing imaging modalities from CR to DR	Simplify radiographers' work by replacing Computed Radiography (CR) into Digital Radiography (DR) to provide quality improvement and speed up the radiological examination process
5	Using PACS	Picture Archiving and Communication System (PACS) is a technology that integrated with various imaging modalities to provides storage and easy access
6	Design radiology units KPI	Key performance indicators (KPI) are made to avoid technical problems that might occur

3.5. Proposed Process

Each improvement from Table 1, that change process is modeled to provide an overview of the difference between the to-be process and the as-is process. The improvements that have been obtained also combined to produce the following six improvement scenarios as shown in Table 2.

Table 2. Improvement Scenarios.

No.	Improvement	Scenario					
		1	2	3	4	5	6
1	Adding radiologist	√					
2	Enhanced features of RIS		√		√		√
3	Changing CR to DR			√	√	√	√
4	Using PACS					√	√

The simulation results from the proposed to-be process model are then compared with the simulation results of as-is model to show the percentage of time reduction resulting from each scenario (see Table 3).

Table 3. Scenario Time Result

Scenario		Avg Cycle (Hours)	% Decrease	Avg Work (Hours)	% Decrease	Avg Wait (Hours)	% Decrease
0	As-Is Model	8,81	-	1,49	-	7,32	-
1	Adding radiologist	3,29	63%	1,69	-	1,6	78%
2	Enhanced features of RIS	8,66	2%	1,37	8%	7,29	0,4%
3	Changing CR to DR	4,73	46%	1,34	10%	3,39	54%
4	RIS and DR	4,72	46%	1,27	15%	3,44	53%
5	DR and PACS	1,63	81%	1,41	5%	0,22	97%
6	RIS, DR, and PACS	1,54	83%	1,31	12%	0,22	97%

As the result of the simulation, Scenario 6 gives the biggest time reduction. Scenario 6 combines three design improvements, namely the use of RIS, DR, and PACS. The imaging modalities integrated with RIS through PACS so that patient examination results can be stored in electronic health record (EHR) and accessed digitally quickly. This combination of improvements results in a tele-radiology system which is the transmission of radiological imaging results with radiology specialists or other doctors for the benefit of sharing studies. The results of the process change in scenario 6 can be seen in the Figure 2.

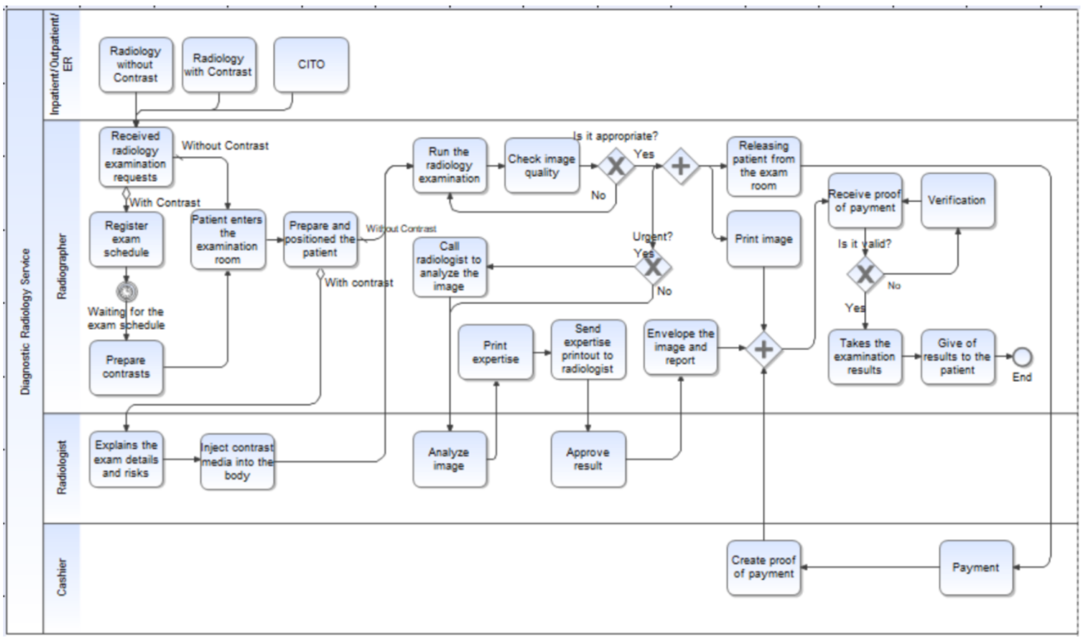

Figure 2. Scenario 6

In the future, tele-radiology can be used to cross hospitals. Tele-radiology can be carried out between primary health facilities and secondary health facilities or affiliated hospitals so radiologists can coordinate with each other and build cooperation.

3.6. Database Design

Database system architecture design is described using Entity-Relationship Diagram (ERD). ERD describes a conceptual database design that will be built on a diagnostic radiology service to-be system. The ERD diagnostic radiology service consists of nine regular entities and two weak entities. Patients, Billing, Radiology_Order, Radiology_Study_detail, Radiology_Study, Employee, Modalitiy, Report, and Doctor are included as regular entities, while Order_Type, and Inventory, are included as weak entities. ERD is then converted into a relational scheme, Figure 3, to provide a simpler and easier picture to understand.

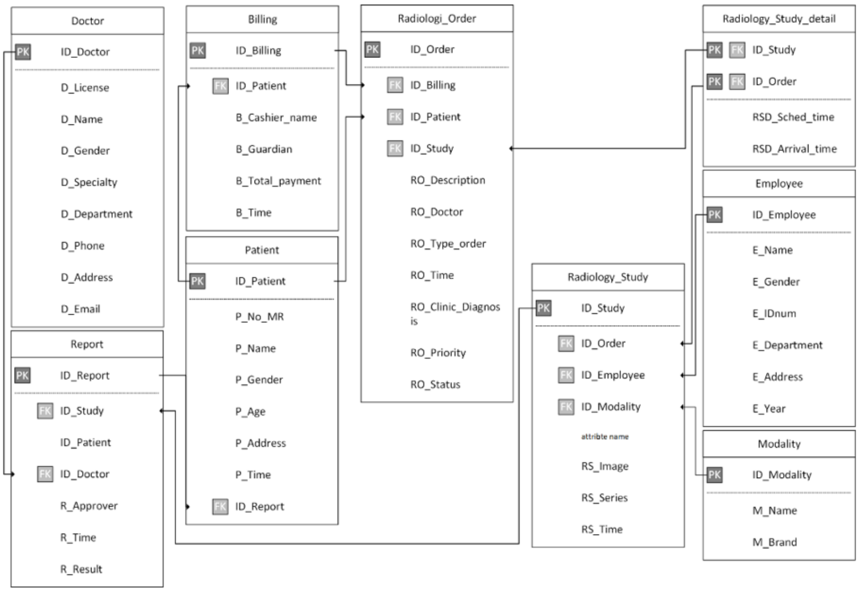

Figure 3. Relational Scheme Radiology Services

3.7. Use Case Diagram

Use case diagrams show the relationship between actors and systems (see Figure 4). The diagnostic radiology service process starts from the request for diagnostic radiology sent by the referral doctor through the information system. Examination requests sent will be accompanied by patient data. The referral doctor will also be able to change patient data and fill patient's clinical diagnosis through the system.

The requests will be received by radiographer through the system. The radiographer will update the inspection request by adding the date and time the appointment if the inspection requires scheduling. The system will group the inspection request data and can later be seen by the user through the system. Request data that has been received by the radiographer through the system will immediately send a list of patient payment bills to cashier. The payment status will change when the bill already paid along with the proof of payment. The radiographer will also carry out inventory management through the system in accordance with radiology request orders. If the referral doctor requests the results to be printed, the use of the film will be recorded in the system. The radiographer will update the examination status to record the examination time when the patient arrives at the radiology unit and the examination is ready to start.

The radiographer will take imaging images through the imaging modalities, the imaging results are then sent to the system. The system will send the results of the examination to the imaging list which will be opened by the radiologist. In addition to sending the results to the system, the radiographer can also print images directly if indeed as the patient requests. Both the radiographer and the radiologist can see the results of the imaging through the system and can manipulate the image to help better diagnosis. Imaging results can be seen more clearly, and if there is a critical sign, namely the condition of the patient that must be treated immediately, the radiographer and radiologist can mark the results of the imaging and provide information on the results to the referral doctor as soon as possible so the critical condition can be treated immediately. The radiologist analyzes and writes the results of the expertise through the system. The results of the expertise that has been made are then given approval by the radiologist to be able to be given to the patient. If the results of the expertise have not been approved by the radiologist, then the results of the expertise cannot be given to the patient. All activities carried out in the system will be recorded.

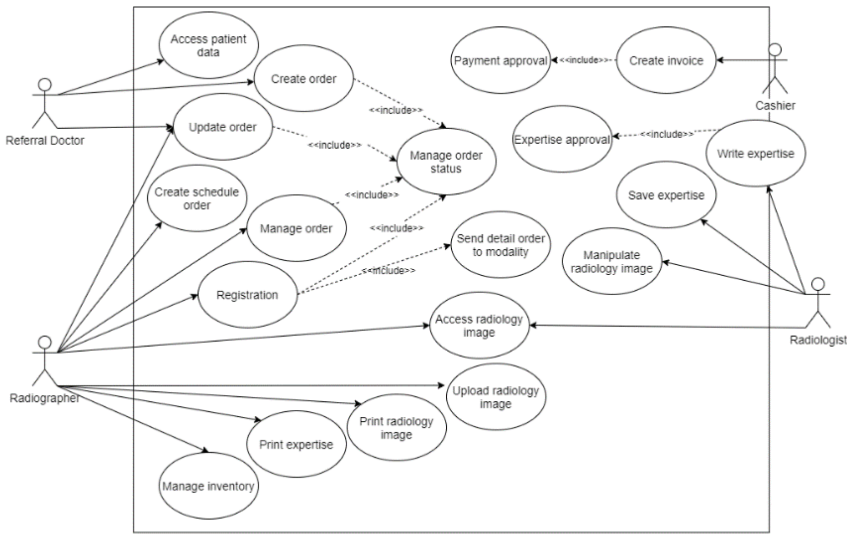

Figure 4. Use Case Diagram Radiology Services

3.8. Data Flow Diagram

Data Flow Diagrams are built to see the data flow of the proposed system. DFD also illustrates the input and output of each entity and process that exists in the system so that the DFD describes a logical model of data in the system. DFD of to-be diagnostic radiology service system is illustrated through the context diagram in Figure 5.

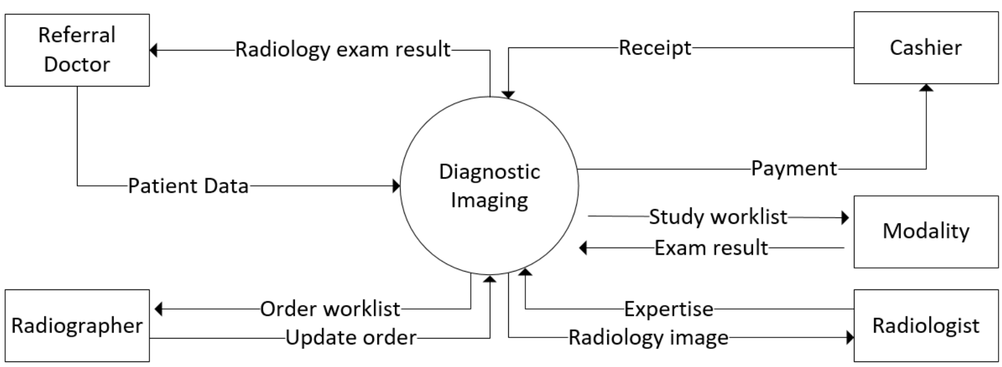

Figure 5 Context Diagram

DFD level 0 which gives clearer details about the context diagram is illustrated in Figure 6.

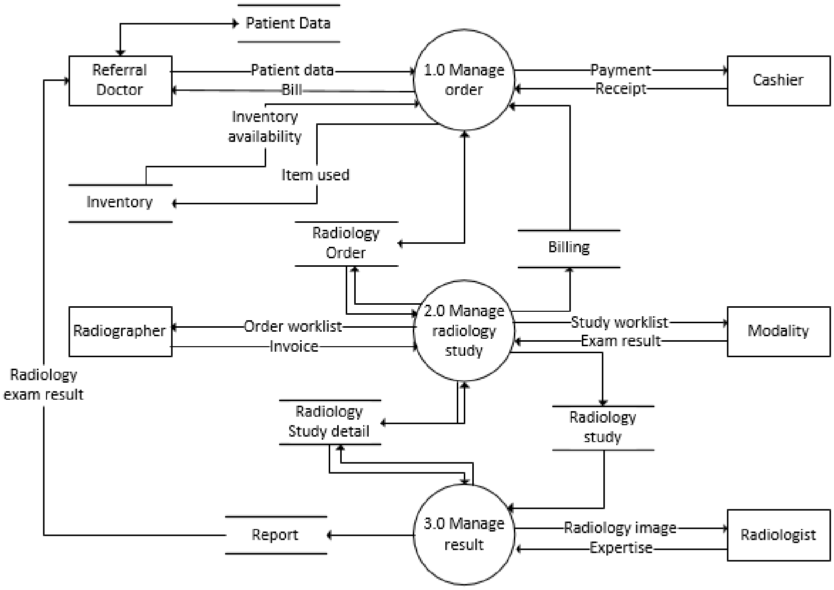

Figure 6. DFD Level 0

4. Conclusion

Improved radiology services resulted in six types of process improvement scenarios, namely the increase in the number of radiology specialists, increased use of RIS, the implementation of the DR, to the implementation of teleradiology.

BPR with information system aids is proven to produce improvements in hospital radiology unit services. Of the six simulated scenarios, the fastest results are in teleradiology, with the average overall process time being reduced from 8.81 hours to 1.54 hours. The reduction in average overall time for this combination of improvements is 83%, with a reduction in average working time of 12% and a reduction in average waiting time by 97%.

Entity-relationship diagrams (ERD) and relational schemes are built as database design materials in radiology information systems. Use case diagrams show the relationship of actors with the system and the data flow diagram (DFD) is designed to show the data flow in the proposed system model.

Suggested improvement for hospitals is scenario three by replacing CR tools into DR with the fastest reduction time 4,73 hours.

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