The Critical Blood Bank's Inventory Management Improvement Using Information System Through the Implementation of Internet of Things

2 authors:

Klairine Mariana Rustan
1 PUBLICATION 0 CITATIONS

Muhammad Dachyar
University of Indonesia
102 PUBLICATIONS 185 CITATIONS

International Journal of Advanced Science and Technology
Vol. 29, No. 7s, (2020), pp. 3695-3704

The Critical Blood Bank's Inventory Management Improvement Using Information System Through the Implementation of Internet of Things

K. M. Rustan[1] and M. Dachyar[2]

Industrial Engineering Department, Universitas Indonesia, Depok 16424, Indonesia

[1]klairinemr@gmail.com, [2]mdachyar@yahoo.com

Abstract

Blood Stockout cases are a common occurrence in Indonesian Hospitals. It is crucial especially in an emergency situation, where the delay process of blood replenishment and distribution could cause death to the patient. The problem of blood replenishment and distribution is caused by the time inefficiency or manual data communication among Hospitals and Indonesian Red Cross. The purpose of this research is to design process improvement of hospital blood bank's inventory management through an information system and the utilization of Internet of Things. Business Process Reengineering approach was used to show the process improvement of management inventory in Hospital Blood Bank (HBB). The method in this study is information system development with entity relationship diagram (ERD), relational database, use case diagram, and data flow diagram (DFD). The results have five scenarios of process improvement. The best scenario could increase the efficiency of process time by 75.63%, which previously took 7.14 hours to 1.74 hours.

Keywords: *Business Process Re-Engineering (BPR), Internet of Things (IoT), Information System, Inventory Management, Relational Database.*

1. Introduction

Based on World Health Organization (WHO) standards, the minimum stock of blood needed in Indonesia amounted to 2% of the population or is estimated to reach 5.2 million blood bags per year [1]. WHO use the common term of Regional Blood Bank Center, in our case this institution is National blood transfusion unit. However, according to the annual reports of the National Blood Transfusion Unit in 2016, Indonesia's blood bank stock is only at 4.2 million bags. The blood supply at the regional level indicated that one of the regions with the greatest needs of blood is in province A, with the blood demands amounted to 947.588 bags. Only 62% or as many as 589,999 blood bags can be fulfilled by 24 existing National Blood Transfusion Unit. In province B, the population reaches around 12 million, but the National Blood Transfusion Unit is able to meet only the needs of 58%. At the same time in the regions where the demand was the least, namely province C, the fulfillment of blood needs only reached 4.46%. Meanwhile, blood stock requirements in province D is the biggest. In province D, blood stocks of 622,136 blood bags are available and their fulfillment reaches 300% of the needs of only 205,553 blood bags for 10 million population. The unequal availability of blood occurs due to a significant correlation between donor participation ratios against geographic regions and urban sizes [2]. The availability of infrastructure such as the number of National Blood Transfusion Units and facilities for blood donor, better and more accessible will effect the level of blood supply fulfilment.

The need for blood is crucial for treatment in hospitals and other medical services during emergencies. To be able to extend and improve life for millions of patients annually, a sustainable blood system for each individual patient is highly required.

There are still many cases of a lack of blood supply or lack of blood in several hospitals in Indonesia. If the proper amount and type of blood is not available when it is needed, it could lead to a danger to patients. The wait for an adequate blood supply could postpone some procedures that could lead to longer hospital stays. This may pose the potential risks for patients, such as cause death for patients [3].

Another problem encountered in the management of blood supply is blood wastage. Regarding to the conducted observations, a hospital in province A has an average of the expired blood from blood bank that are discarded and sent for disposal as waste of about 5 blood bags each month and and in May 2019 there were the largest amount of blood wastage of about 13 blood bags. According to the head of the Hospital Blood Bank (HBB), this is caused by the HBB staff who did not apply the method of first expired first out (FEFO) because HBB staffs did not see the expiration period of each blood bag before being released to be given to patients.

In order to ensure faster availability of blood in hospitals for patients, process improvements in inventory management are needed. By using BPR, the improvement process utilizing information systems and using the internet of things can accelerate the processing time of Hospital Blood Banks from National Blood Transfusion Unit form a system that can control the inflow and outflow of blood, especially in the process of blood demand and distribution towards hospital.

The aim of this study is to decrease process time in inventory management, especially in the process of replenishment distribution of blood in the Hospital Blood Bank (HBB) from Indonesian Red Cross (IRC) by implementing an Information System that utilizes the Internet of Things (IoT) and the Business Process Reengineering (BPR) method to show the results of improvements.

This study is conducted by in-depth interview with 10 experts who are a head of HBB, head of IRC, HBB staff, IRC staff, HBB IT staff, and IRC IT staff.

2. Literature Review

2.1. Information system in blood bank

The role of computerized information systems in decision making has been significant in regional blood bank management. The operation is very complex at the level of regional blood banks. Therefore, blood bank managers would not be able to make optimal decisions in blood collection and distribution without the help of a computerized system.

In the existing literature, there had been already three basic computer models which are a short-range forecasting model for controlling inventory levels, a short-term and improving blood distribution program system for hospital delivery schedules and a computer aid in the medium-term planning model for scheduling mobiles blood. Demonstrated application of a blood bank information system called Sistema Integrado de Bancos de Sangue (SIBAS) which is used at the blood transfusion service center in Macau that incorporates a policy-based expert system and strategic analysis to support decision making. The SIBAS system has been implemented and provides interfaces for barcode reading and printing, electronic donor card reading and writing, monitoring blood donations and automation of blood testing devices [4].

2.2. Business process reengineering (BPR)

In recent decades, the companies continuously make improvements to be able to compete in the market. Companies are forced to make improvements to their business processes continuously for customers who are constantly demanding better goods and services. This improvement is conducted with an improved model called the continuous improvement models. This model tries to make the measurement and understanding of the current process and make improvements based on the results of the understanding and measurement. Over time flies, rapid and fundamental differences often required. Companies constantly seek new breakthroughs fundamental, not just a small change but a big change. Therefore, there is the new approach, known as Business Process Reengineering (BPR), in which BPR is an approach to make changes of recreating a core business processes quickly and dramatically. BPR principles rely on the idea that is quite different with models that have been proposed that continuous process improvement [5]. It is suggested that in a system that has a long process must be eliminated and replaced by a new system, which is more innovative and effective [6].

The objective of BPR is to ensure the process modernization. In addressing the gap between the evolution of the required functions, rules, and existing business processes [7].

2.3. Internet of Things (IoT) in blood supply chain

Internet of things in the blood supply chain provides benefits from various aspects, as follows [8]:

1. Tracking

a) Inventory calculation

The application of real-time inventory count is to automate the count of the overall blood stock levels in the HBB. By the usage of real-time inventory count, it is easier for the regional blood center in planning future blood collection and replenishment from HBB since all of the counted blood stocks data have been gathered.

b) Security and traceability

An online platform provides a system which could trace blood unit which is connected into the RFID and barcode that are attached in each blood bag. It would lead to the integration of sharing information and coordination among blood service organizations within the supply chain in order to mitigate blood transfusion risks to the patient, as if human error, incorrect blood products, and errors in medication administration.

2. Identification and authentication

a) Automatic ID/barcode that can enable transfusion administration

It is crucial to avoid mistake in checking identity between each patient and particular blood product. The usage of RFID-blood bags and the traceability system could help to ensure the right blood type and its quantity is delivered to the right patient.

3. Automatic data collection

a) Management of blood supply

The main objective of blood inventory is to maximize blood utilization in such a way that blood shortage and outdated rates are at minimum levels. Using RFID and barcode to connect each blood bag to the blood inventory system can increase the ability to manage blood information more efficiently.

b) Blood tracking

Replenishment and allocation of blood products from regional blood center to the hospital blood banks based on the particular demand from each hospital could be more efficient through the utilization of Real-time blood tracking and tracing system.

4. Detection

a) Transportation monitoring

In order to maintain the quality of blood, it is vital to control temperature during transportation. Through the usage of real-time temperature detection and tracking technology blood transportation could ensure the quality of blood products.

The previous study used IoT in order to support the blood supply chain in the hospital in the technical area of application that reading the blood bags barcode through RFID. This paper provide the knowledge to fill the research gap in the area of business process improvement by utilizing the IoT in the inventory management amongs hospitals and National blood.

3. Methodology

This paper specifically addresses the issues in management inventory in HBB that focused on the flow of process and information in replenishment and distribution of blood. Data were collected and processed through several steps in this study. Preliminary data was collected from in-depth interviews regarding the details of the time spent in the existing process HBB's inventory management from ten experts.

Data processing started by mapping the existing process of management inventory in HBB. An analysis of the existing management inventory system and system requirements is conducted. Existing system has several shortcomings that need to be improved based on customer requirements. The collected solutions were integrated into an alternative management inventory in HBB which leads to designing 5 scenarios that requires an information system (IS), the utilization of RFID technology, additional external couriers and the usage of temperature monitoring device. The IS for management inventory in HBB is designed using a information system development approach with Entity-Relationship Diagram (ERD), Data Flow Diagram (DFD), and Use Case Diagram. Simulation with iGrafx software was conducted to compare the time-based operational performance of the existing process and proposed to-be processes.

4. Result and discussion

4.1. Existing process (As-Is process) Analysis

The process that took place between HBB and IRC in the existing process was modeled into an as-is model with Business Process Model Notation (BPMN) by using iGrafx software. In BPMN, business processes are divided into pool and lane. For this study, pool is defined as a system that is carried out and lane is defined as process category. There is one pool, the Hospital Blood Bank's Inventory Management which is divided into 2 lanes, namely shipment, request and received blood (dropping system) as illustrated in Figure 1.

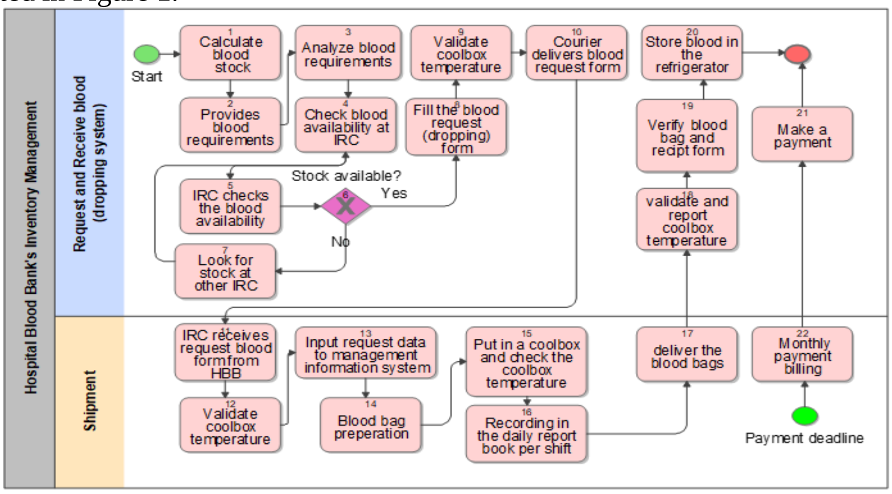

Figure 1. As-is model

International Journal of Advanced Science and Technology
Vol. 29, No. 7s, (2020), pp. 3695-3704

According to the simulation result that is shown in Table 1, the average cycle time is 7.14 hours, the average working time is 3.78 hours, and the average waiting time is 3.36 hours. There is an average waiting time in this business process, especially in the process of requesting and receiving dropping because HBB couriers have shifts from 16.00 to 21.00. Therefore, the request process must wait for the availability of IRC couriers and cannot be done at any time.

Table 1. Simulation result of as-is model

HBB's Inventory Management process	Transaction Statistics (Hours)		
	Avg Cycle	Avg Work	Avg Wait
Total	7.14	3.78	3.36
Shipment	2.15	2.15	0.00
Request and Receive Blood	4.99	1.63	3.36

4.2. Current requirements of future system

In order to understand the needs and preferences of customers for system improvement, an analysis using Voice of the Customer (VoC) was conducted. This VOC was generated from gathering the results of interviews with customers. From the results of the interview, it obtained that the need for improvement in the HBB inventory management process consists of:

- Warnings or notifications on the alert to provide warnings when blood stocks in the HBB have reached re-order point and notifications
- Notification when the blood bag has expired and must be discarded
- Notification for IRC when there is a dropping request from HBB
- Complete requests and receipts data
- Easier procedure for request dropping
- Couriers provided by IRC or third parties
- Coolbox temperatures in the transportation process that can be monitored to keep the cold chain of blood bags
- Data collection reports that are made without repetition of input data
- Blood stock in IRC and HBB can be accessed in real-time
- Choose the most suitable blood bag to be released first

4.3. Problem, proposed solution, and alternative improvements

Based on the system improvement requirements obtained from VoC, an PIECES analysis is made showing the problems of a process and the solutions to those problems which are described in Table 2.

Table 2. Design of improvement

Process	Problem	Solution
Checking blood stock at HBB and stock reporting	The process is done manually and the head of HBB could not know the blood stock if it is not reported by the HBB staff and if the HBB staff does not carry out their duties properly, then when the stock reaches the re-order point there will be no replenishment.	Real-time blood stock data updating (eliminate, automate)
		Notifications are sent when stock has reached the minimum stock limit (automate)

Process	Problem	Solution
Fill in the blood request form manually from HBB to IRC	The blood request form must be written and requires a signature from the head of the HBB which is often absent that could make the blood request delayed.	Blood request process is filled and sent online which can be directly carried out by the head of HBB (simplify, automate)
Receive blood requests from HBB	The process is done manually	The system should be transformed into an online process *(*automate, eliminate*)*
Check blood stock availability at IRC	The process is done manually	Transforming into an online process and utilizing RFID technology (automate, eliminate)
		There is a blood request notification for IRC (Automate*)*
HBB courier delivers a request form and picks up blood bags	HBB must provide facilities to pick up blood bags and deliver request form	IRC provides couriers to deliver blood to BDRS as well as pre-facilities such as vehicles (motorcycles for not too much blood quantity and cars for large quantities of blood). (automate, eliminate)
	The process takes a longer time because the courier had to depart from HBB	
Verification of blood bags and receipt form	Verification of blood bags is done manually which causes the process takes longer time and there could be human errors in the process.	Verification using RFID technology (automate, eliminate)
Coolbox temperature validation	Coolbox temperature must be stable at 2-6^{O}C. This process is very important because in the shipment process the temperature of the coolbox deviates from 2-6^{O}C, then the blood bag is not suitable for use.	Coolbox is equipped with a temperature monitoring device (automate, eliminate)

4.4. System Design

The use case diagram of the proposed information system design for the HBB inventory management process is shown in Figure 2 which shows the actors who are involved and their respective roles in the HBB inventory management process.

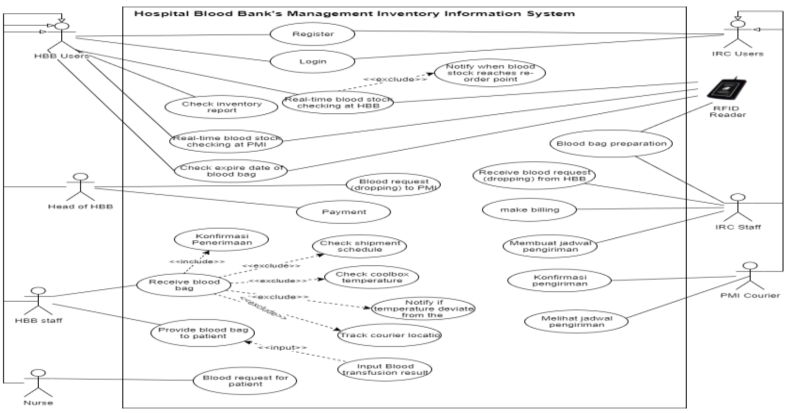

Figure 2. Use Case Diagram

In the use case diagram that has been made, there are several types of actors, each of these actors has their respective roles in the HBB inventory management system. A description of the role of each activity can be seen in Table 3.

Table 3. Actors in use case diagram description

Actors	Description
IRC Users	Every IRC staff who has an account can access the web-site from the IRC side.
HBB Users	Every HBB staff who has an account can access the web-site from the BDRS side
HBB Staff	Operationally responsible for giving blood to patients, monitoring blood stock and receiving blood bags from IRC and reporting to the Head of HBB
Head of HBB	Responsible for analyzing blood needs to conduct blood requests to IRC as well as evaluating blood supply in HBB.
IRC Staff	Responsible for receiving blood requests from HBB and preparing blood bags that are requested by HBB.
Nurse	Request blood bags for patients
IRC Courier	Conduct blood delivery to BDRS as well as supervise and keep coolbox temperatures not exceeding the eligibility limits for the storage of blood bags.
RFID reader	Read and send information into the information system from the RFID tag in the blood bag

Other than use case diagram, data flow diagram (DFD) is required to map the flow of data in the system design. Figure 3 illustrates the design of the context diagram for HBB's inventory management information system. In the context of the diagram could not show the data store in the system. This context diagram has six external entities that will relate to this information system. The intended external entities are HBB Officers, IRC Officers, HBB Heads, IRC Couriers, HBB Storage, and Patients. Each external entity is a source of data for the process and/or purpose for data out of the process.

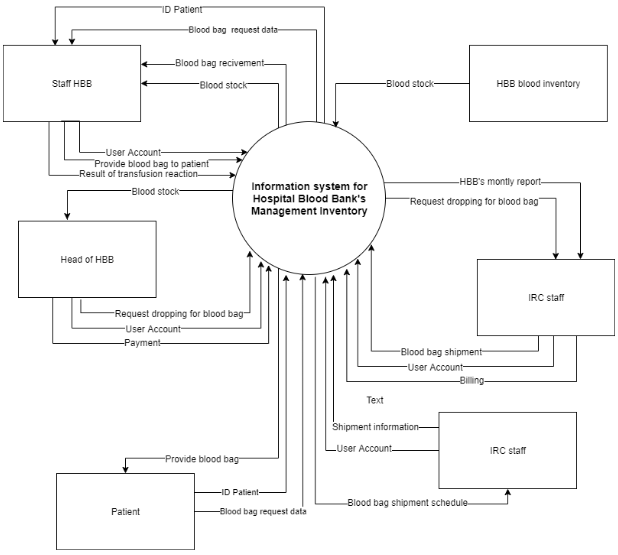

Figure 3. Context diagram

DFD Level 0 of information system for the inventory management in HBB is shown in Figure 4. This DFD level 0 contains 7 main processes, namely logging in, storing blood stock, dropping requests, sending blood bags, receiving blood bags, releasing blood bags to patients, and making reports. In this system, the final output to be obtained by this

International Journal of Advanced Science and Technology
Vol. 29, No. 7s, (2020), pp. 3695-3704

system is that the report will be received by the head of HBB and IRC staffs.

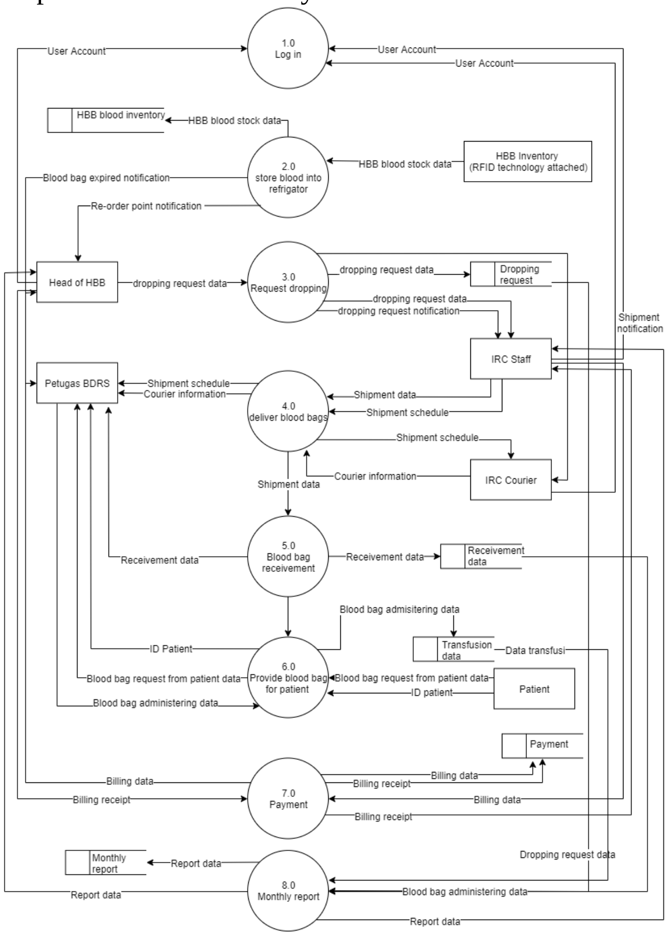

Figure 4. Data flow diagram level 0

4.5. Design to-be process

Several solutions are proposed in the 5 to-be process scenarios, where the proposed improvements cover the creation of IRC and HBB coordinating process information systems, the use of RFID tags on blood bags, couriers provided by IRC and the usage of temperature monitoring device. Scenario models are shown in Table 4.

Table 4. Scenario models

Scenario	RFID technology	Information system	IRC courier and temperature monitoring device
Scenario 1		√	
Scenario 2	√	√	
Scenario 3			√
Scenario 4		√	√
Scenario 5	√	√	√

Scenario 5 is the best time decrease in the process improvement. This scenario shown in Figure 5 is a combination of scenario 2 and scenario 3. This scenario is made using information system, RFID technology, proposing couriers from IRC or third parties, and utilizing temperature monitoring devices for coolboxes.

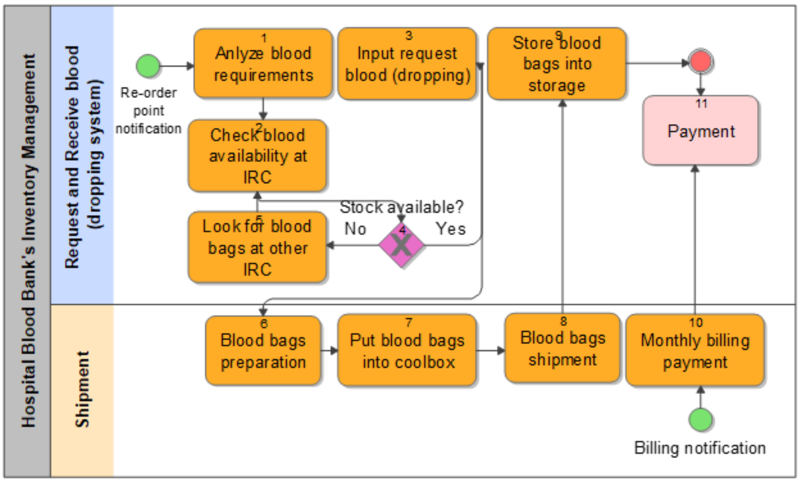

Figure 5. To-be process scenario 5 model

The complete result of this simulation is shown in Table 5. Based on the simulation results, for the entire business process for this scenario, the average cycle time is 1.74 hours, the average working time is 1.74 hours, and there is no waiting time in this scenario.

Table 5. Simulation result of scenario 5

HBB's Inventory Management process	Transaction Statistics (Hours)		
	Avg Cycle	Avg Work	Avg Wait
Total	1.74	1.74	0.00
Shipment	1.14	1.14	0.00
Replenishment and receivement	0.59	0.59	0.00

4.6. Simulation result to-be model

According to the simulation results from each scenario, a decrease in processing time is obtained based on the average cycle time and the average work time. The percentage of time reduction from the simulation results for scenario 1 is 0.42%, scenario 2 is 13.74%, scenario 3 is 60.22%, scenario 4 is 64.99%, and scenario 5 is 75.63%. While the reduction in processing time based on working time for scenario 1 was 11.64%, scenario 2 was 49.21%, scenario 3 was 24.87%, scenario 4 was 33.86%, and scenario 5 was 53.97%. The reduction in process time derived from the simulation results of the to-be process model is compared with the time of the as-is process model which can be seen in detail in Table 6.

Table 6. Comparison between As-is model and To-be model

Scenario	Transaction details (Hours)				
	Avg Cycle	%Time reduction	Avg Work	%Time reduction	Avg wait
As-Is Model	7.14		3.78		3.36
Scenario 1	7.11	0.42%	3.34	11.64%	3.77
Scenario 2	6.16	13.74%	1.92	49.21%	4.24
Scenario 3	2.84	60.22%	2.84	24.87%	0.00
Scenario 4	2.50	64.99%	2.50	33.86%	0.00
Scenario 5	1.74	75.63%	1.74	53.97%	0.00

5. Conclusion

This paper succeeded in achieving its objective which was to accelerate the process of inventory management in Hospital Blood Bank by making improvement in its replenishment and shipment from Indonesian Red Cross process. Improvements in the coordination process between IRC and HBB resulted in 5 proposed scenarios based on literature studies and information obtained from in-depth interviews. 5 based scenarios consist of scenario 1 using information systems, scenario 2 using information system and information technology utilization, scenario 3 using IRC couriers and utilization of temperature monitoring technology, scenario 4 the utilization of information system, couriers provided by IRC, and temperature monitoring equipment (a combination of scenarios 1 and 3), and scenario 5 the utilization of information system, RFID technology, couriers provided by IRC, and temperature monitoring devices (a combination of scenarios 2 and 3).

The scenario with the least decrease in time is scenario 1, which is 0.42%. The scenario with the greatest decrease in time is scenario 5, which is 75.63%. The proposed scenarios can be used by the hospital partially or as a whole depending on the needs and capabilities of the organization. If the hospital wants to obtain the best reduction in processing time in blood supply management it is recommended to use scenario 5.

Acknowledgments

I would like to grant my special thanks to Mr. M. Dahcyar as my lecture who helped throughout my research work. Also, my completion of this research could have not been done without the support of my family and friends.

References

[1] WHO, *Blood Transfusion Safety (BTS) World Health Organization*., 2016.
[2] P.J. Saberton, A. Paez, K.B. Newbold, and N.M. Heddle, "Geographical Variations in the Correlates of Blood Donor Turnout Rates: An Investigation of Canadian Metropolitan Areas", Journal of International Journal of Health Geographics, vol. 8, no. 1, (**2009**), p. 56.
[3] M.N. Sahid Ramadhan, A. Amyus, A.N. Fajar, S. Sfenrianto, A.F. Kanz, and M.S. Mufaqih, "Blood Bank Information System Based on Cloud Computing in Indonesia", Journal of Journal of Physics: Conference Series, vol. 1179, no. 1, (**2019**), p.
[4] H. Lowalekar and N. Ravichandran, "Blood Bank Inventory Management in India", Journal of Opsearch, vol. 51, no. 3, (**2014**), pp. 376–399.
[5] R.E. Indrjait and Djokopranoto, *Business Process Reengineering*. *The Preinexus Indonesia*, 2016.
[6] M. Dachyar and E. Christy, "Designing Process Improvement of Finished Good on Time Release and Performance Indicator Tool in Milk Industry Using Business Process Reengineering Method",. In: *Journal of Physics: Conference Series* (2014).
[7] M. Hammer and J. Champy, "Reengineering the Corporation: A Manifesto for Business Revolution", (1993).
[8] W. Boonyanusith and P. Jittamai, "Transforming Blood Supply Chain Management with Internet of Things Paradigm Transforming Blood Supply Chain Management with Internet of Things Paradigm", Journal of Proceedings of the Hamburg International Conference of Logistics (HICL), vol. 23, (**2017**), p. 23.