IJABIS

by Teknik Industri

International Journal of Applied Business and Information Systems
Vol 3, No. 1, March 2019 pp. 1-8
ISSN: 2597-8993

Design Improvement of Queuing System Using Simulation and Six Sigma: A case study

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ARTICLE INFO

Article history:
Received December 18, 2018
Revised February 18, 2019
Accepted February 28, 2019

Keywords:
Simulation
Queuing system
Six Sigma
DMAIC approach
Community Health Center

ABSTRACT

The objective of this study is to minimize the patients' waiting time at the community health center so that they can be served optimally. The system comprises multi stages and multi servers namely patient admission, nurse handling, examination 1, examination 2, laboratory check, and medicine section. Based on the observation, it is found that patients must wait for 10 to 40 minutes in each stage. In order to leverage the system performance, simulation approach is performed applying Process Simulator – Promodel 2016 combined with DMAIC (Design, Measure, Analyze, Improve, Control) approach of Six Sigma. Both methods show that all stage needs to be improved but laboratory check and medicine section. The proposed scenarios have demonstrated a decreasing to 61% of the average time of queuing systems.

I. Introduction

Health care service is a form of public service that aims to meet service needs in accordance with the laws and regulations for every citizen of the goods, services and/or administrative services provided by public service providers. Public service providers are every state, corporate, independent institution established by law for public service activities, and other legal entities that are formed solely for public service activities. One of the public service providers is Puskesmas (Pusat Kesehatan Masyarakat or community health center). According to regulation of the Minister of Health of the Republic of Indonesia number 75 of 2014, the Community Health Center (Puskesmas) is a health service facility that carries out public health efforts and first-rate individual health efforts by prioritizing promotive and preventive efforts, to achieve community health levels as high as in its working area. Puskesmas is a technical health implementation unit under the supervision of the District or City Health Office.

People prefer to visit Puskesmas when she or he feels sick since Puskesmas is placed near to the housing complex, and it also serves with an affordable price compared to hospitals. Yet, the human resources and the equipments provided are limited, particularly the human resources. This condition leads to increasing number of patients stay in queuing system. Generally, Puskesmas is a multi-stage – multi-server system where patients queue for multiple stages, such as patient admission, nurse handling, examination 1, examination 2, laboratory check, and medicine section. Multi-server means that more than one server with the same capabilities are assigned based on Puskesmas management. The phenomenon of queuing can often occur in public service facilities particularly when the number of customers served exceeds the available capacity [1]. Uncomfortable situation will then appear if a number of patients' waiting on the queuing system rises [2]. Thus, adding a service facilitiy was carried out to maximize the number of customers served that it will save service costs [3]. The queuing system simulation model is used to decrease the number of patients in queuing system as well as to provide an optimal service [4, 5]. While [6] provides an overview in queuing system modeling.

Based on preliminary observations at Puskesmas Banguntapan 1 in Bantul, the average time of several processes of registration process, the examination, and taking drugs are as follows successively: 10-15 minutes, 25-40 minutes, and 10-25 minutes, with the number of queues in each process is around 3-15 people. In order to optimize Puskesmas' performance, it is highly required to design an improvement system by minimizing patients' waiting time. DMAIC (Design, Measure, Analyze, Improve, Control) approach of Six Sigma is applied to analyze variables caused waiting time and determine strategies to reduce them as well [7-9].

In this study, we utilized a simulation approach for queuing system improvement solution since it is very effectively used for relatively complex systems problem solving of the model [10]. The simulation process used Process Simulator – Promodel 2016 that allows us to simulate process flowcharts created in Microsoft Visio. This simulator shows the impact of activity interactions and variability on overall process performance.

II. Research Method

This study was conducted in Banguntapan 1 Puskesmas in Yogyakarta, Indonesia. The methodology was implemented in four stages: problem definition, data collection, simulation the existing system, and DMAIC (Design, Measure, Analyze, Improve, Control) method of Six Sigma. First, it was accomplished through an observation and overview of Puskesmas workflow to picture the layout and define the data needed within a system. The layout of Puskesmas ia given in Figure 1. According to the existing system observation, Puskesmas is a multi-stage and multi-server system shown in Figure 2 that comprises 6 stages: patients admission, nurse handling, examination 1, examination 2, laboratory check, and medicine section. There are 12 operators for overall process within the system.

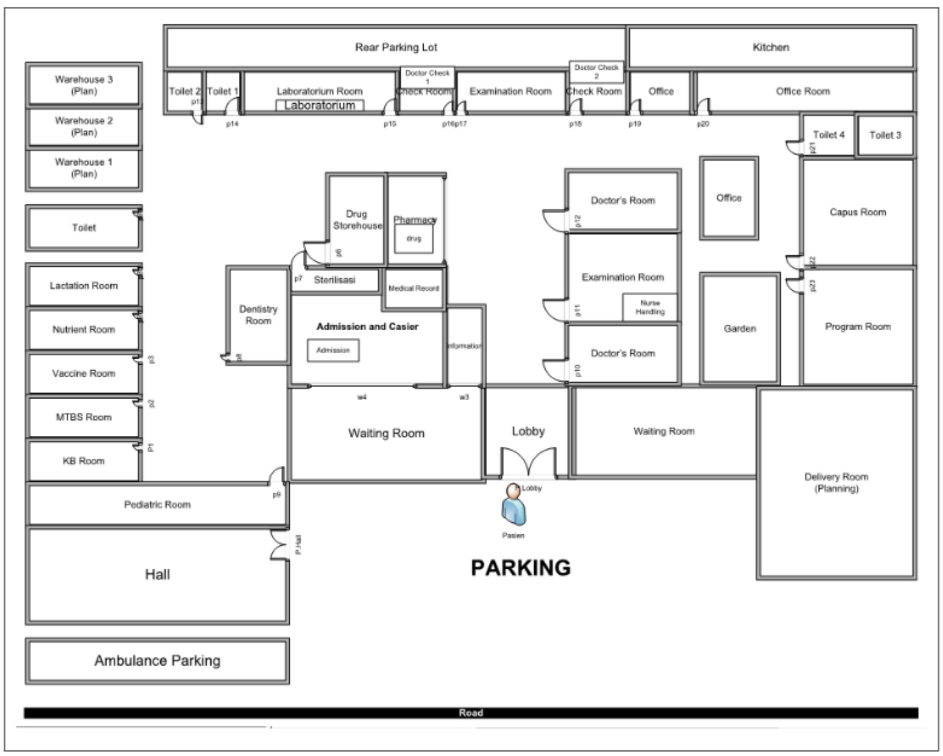

Fig. 1. Layout of Puskesmas

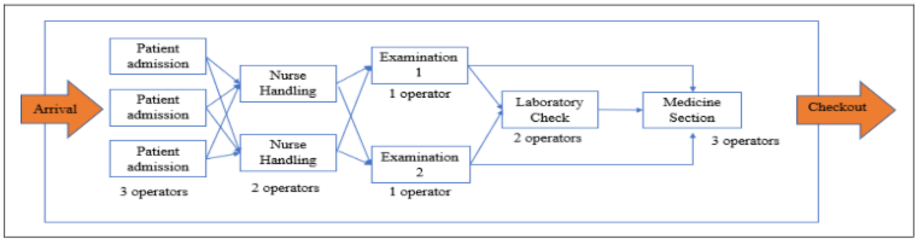

Fig. 2. The existing system of multi-stage and multi-server

Second, data was collected by the observation of daily work for 50 different patients gained in several days. The data obtained are patients' arrival time to the system, time between arrival, patients' arrival time at each task, processing time of each task, and travel time between stages. At a third stage, the existing system was simulated by Process Simulator – Promodel 2016 to identify each stage and entity flows in the overall queue model. Thus, the interaction process of the entity as well as a description of the structure of the queuing model used can be clearly pictured. The last stage, DMAIC approach of Six Sigma was applied to determine the design improvement of every previously identified problem. Fig. 3 explains the detail steps of DMAIC method.

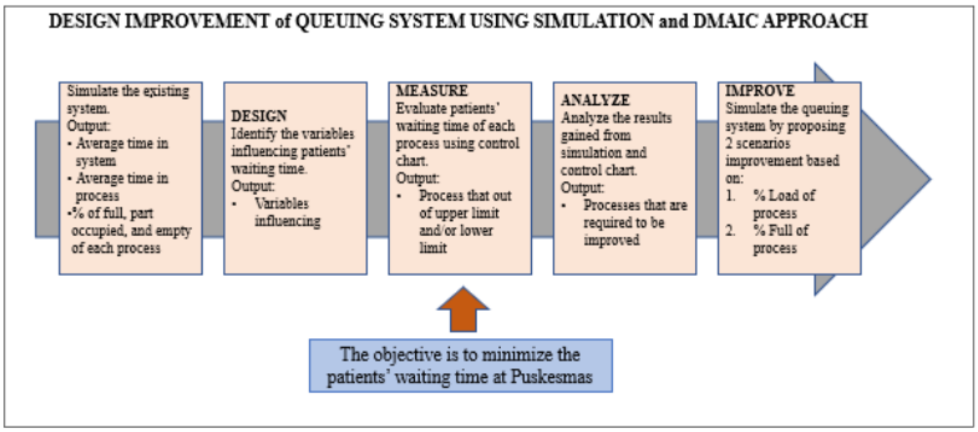

Fig. 3. The research framework

- Design is to identify the variables affecting the patients' waiting time within queuing system;
- Measure is to evaluate patients' waiting time of each process utilizing control chart;
- Analyze is to analyze the resutls obtained from simulation and control chart, and specify the process to be improved;
- Improve is to simulate the proposed improvement as well as evaluate the results.

Simulating the existing system using Process simulator - Promodel 2016 has delivered the average percentage of activity stage. The control charts determine whether any process is out of upper and lower limit. These results lead to 2 scenarios proposed for improving the queuing system performance. The first scenario is adding server for tasks with high load consisted of % full and % part occupied. The second is related to the task with % full

III. Results and Discussion

A. *Existing System*

Data gained from 50 patients of each stage are arrival time of patient into the system, arrival time at each stage, and processing time at each stage. Based on the observation, in every 3 minutes a new patient enter the system at Puskesmas as it was conducted during the daily work started from 8 a.m to 12 p.m. Table 1 shows the average time of time between arrivals and processing time at each stage. Patients spent more time at Laboratory check process while remain processes are 1 to 5 minutes in average. of 50 patients observed, there are a few who skip Laboraty check depended on the doctor's advice at Examination 1 or Examination 2. These patients are directly transported to medicine section. Meanwhile, several patients must complete the Laboratory check before moving to medicine section. However, this sample was examined randomly so that the 50 patients observed may be different at each stage. The travel time of each stage and server is explained in the following Table 2.

Table 1. The average time of existing system

Stage	Time (minute)
Time between arrivals	1.56
Patient admission	1.73
Nurse handling	1.29
Examination 1	3.75
Examination 2	5.32
Laboratory check	7.69
Medicine section	2.52

Table 2. The average travel time between stages and servers

Travel Process	Average (Min)
Patient admission to nurse handling	0.17
Nurse handling to examination 1	0.117
Nurse handling to examination 2	0.117
Examination 1 to medicine section	0.15
Examination 2 to medicine section	0.2
Examination 1 to Laboratory check	0.117
Examination 2 to Laboratory check	0.083

According to Fig. 2 linked with Table 2 above, patient admission consisted of 3 operators who serve a patient of each. After discharge, they are directed to one of 2 nurse handling rooms where the general check is conducted such as weight and blood tension check. Puskesmas provides 2 doctors assigned at examination 1 and 2. More than one patient may be called at the same time. Only one patient enters to the each examination room while others are at the waiting room. The doctor at examination 2 serves patients longer than at examination 1 with the average time of 5.32 minutes compared to 3.75 minutes. Patients take the longest time at Laboratory check reaching almost 8 minutes. Yet, the time spent depends on patients' conditions to be checked at Laboratory.

The existing system then was run into the simulation with 6 times replication and 8 hours replication length. Based on Fig. 4., there are 4 states of entity or patient within system, namely move logic, waiting, in operation, and blocked. The average time an entity or patient spent in system was 167.17 minutes reaching 3 hours seen in Fig. 6. Blocked state of 81.68% showed that the patients were unable to move to a server because the next path was occupied. It means that of 3 hours patients were in system seen in Fig. 6, the percentage entity or patients spent waiting for a discharged destination was the highest among other states. The percentage of time the entity spent traveling to the next server, either in or out of a queue or with resource called Move Logic was 0.33% or about a half minutes of 3 hours. This information is equal to Table 2 that the average time of patients travel among all processes within the system was almost 1 minute. Waiting for resources refers to the percentage of time entity spent waiting for a resource or another entity to join or combine which was the second state after blocked state of 16.06%. An entity or patient being served was up to 2% or it was around 3.08 minutes in each process. This was verified by the observation results that 3.7 minutes a patient was served in every process seen in Table 1. Both simulation and observation gave the same information of existing system evaluated.

Fig. 4. The entity states of existing system

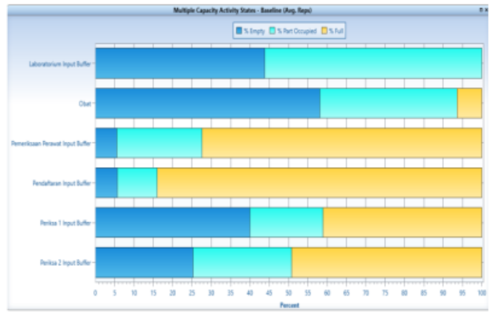

Fig. 5. The task load of existing system

Scoreboard (Avg. Reps)					
Replication	Name	Total Exits	Average Time In System (Min)	Average Time In Operation (Min)	Average Cost
Avg	Pasien	44.83	162.17	3.08	0.00

Fig. 6. The average time of existing system

Related to utilization of multiple capacity activity shown in Fig. 5, the patients' admission was the highest task load of 83.93% in which it was utilized in full condition followed by nurse handling, examination 2, examination 1, and medicine section. Yet, laboratory check was not utilized fully but 60% partially occupied. It was the highest percentage of partially occupied among other processes. Vice versa, only 10.38% of patients' admission was in part-occupied conditions. The number of process partially utilized varied from 20% to 25% for examination 1, 2 and nurse handling. According to the simulation, 95% of activity utilization belongs to patients' admission and nurse handling for both full and part-occupied. The observation results also showed that resources' waiting time to serve patients in both of these processes were mostly 0 minute. The very small number of idle time for them representing that these processes was always busy. The time between patients arrival ranged from 0 to 6 minutes. the other high load activities were found in examination 2 and 1, and the least load activity was medicine section. There were full and part-occupied activity in medicine section but they were about 13% less than part-occupied in laboratory check. Even though, laboratory check was only consited of empty and part-occupied activity. Compared to high load activity of patients' admission and nurse handling, medicine section was the least load that most of its time was in empty activity.

Fig. 6 explained that the average of patient spent in the system was 162.17 minutes or about 2.7 hours. If we calculated the patient spent for all process, it will be the average of 3.08 minutes time 6 processes equals to 18 minutes. Of 2.7 hours, it is around 11% of patients' time spent following all process required while the remain is for waiting either being server or travel to each process. It can be concluded that patients' waiting time was very high percentage. Therefore, it is necessary to improve Puskesmas performance identifying the causes and design an improvement employing DMAIC Six Sigma method.

B. Improving System

- **Define (D)**
  It is the stage of defining quality problems in service [13] at Puskesmas. Based on the problem evaluated using simulation and observation supported by interview with several operators, the high number of queues was occured due to lack of capacity.
- **Measure (M)**
  Utilizing P-control chart, service time of each process was evaluated to analyze whether any process was in or out of both lower control limit (LCL) and upper control limit (UCL). It can control service quality and determine when to improve the quality. All chart tends to picture the similar graph that most time observed spread between average line and the upper control limit (UCL) line. It indicated that patients served more than the average time of 3 minutes.

Moreover in examination 1 and 2, being served by a doctor at each facility, patients were in queue attaining 30 minutes. However, they were under control limit but examination 1. There was a time placed out of the upper control limit.

- **Analyze (A)**
  Since there was a P-control chart out of upper control limit, examination 1, the system was required to be repaired. All chart also indicated that the patients in operation were close to the UCL. Thus, the system must be improved in terms of the service time, travel time, and queue time as well. Supported by the existing system simulation results of load capacity and entity state, there were several processes to be improved started from the highest full capacity to the lowest one: patients admission, nurse handling, examination 2, examination 1, and medicine section. Simulation suggested to add the number of operators in patients admission, nurse handling, examination 1, and examination 2.
- **Improve**
  In order to improve the performance, 2 scenarios were proposed for the system. The propose scenarios were then simulated and analyzed to choose the best scenario between them.

C. Simulation of Scenario 1 and 2

We aregued that the activities improved were patients admission, nurse handling, and examination 1 based on full activities of multiple capacity activity states in simulation and control chart. The main problem identified was lacking of operators. Thus, by assigning more operators to those activities, we assumed that the average time patient in system decrease. Scenario 2 was based on the task load gained from the simulation at which these process was added by an operator of each. All process was improved but laboratory check because it did not perform full activity. In accordance with the existing system, the number of replications is 6 times and the length of replication 8 hours. The number of operators for both the existing system and improving system scenarios were shown in Table 3.

Table 3. The number of operators

Process	Existing system	Scenario 1	Scenario 2
Patients admission	3	4	4
Nurse handling	2	3	3
Examination 1	1	2	2
Examination 2	1	1	2
Medicine section	3	3	4

Blocked states where the patients were unable to move to a server due to the next path occupied showed a better condition in scenario 2. Compared to the existing system of 81.68%, the second scenario has decreased around 8% blocked state, while scenario 1 improved only 1.5%. The percentage of time when the patients wait for resources or another entity to join or combine were greater than the existing system respectively 17% and 22.63%. However, when the percentage multiplied with the average time in system of scenario 1 and 2, both 2 scenarios were around 6 minutes faster than the existing system. In scenario 1, 17% multiplied with 120.17 minutes equals to 20 minutes. Either 3 or 5 operators assigned in each scenario, the performance of patients' waiting at a server has slightly been improved to 20 minutes. The similar results were also occured in move logic states that the existing system was lower than the 2 scenarios. After multiplying the percentage of move logic with the average time in system, there was no any different compared to the existing system of a half minute. Adding 3 or 5 operators into the system did not affect the travel time since the system layout did not change. The entity being served were more than 2% of the existing system. According to Fig. 9 and 10, the number of average time in system sharply decreased from 160 minutes to 99 minutes. Related to the average time in operation, it was 0.8 seconds faster. The average time a patient spent in system was preferable employing the proposed scenarios.

Between both scenarios, it can be seen that the second scenario performance represented much better corrective when an operator was assigned into each process except laboratory check. The entity state and the processing time in system changed, although the average time in operation obtained similar amount of 3.08 minutes. This scenario was based on full activity analysis of the existing system.

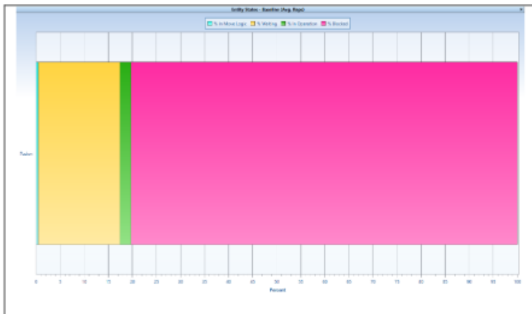

Fig. 7. The entity states of scenario 1

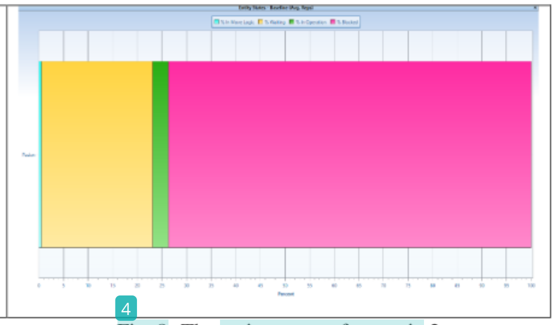

Fig. 8. The entity states of scenario 2

Scoreboard (Avg. Reps)					
Replication	Name	Total Exits	Average Time In System (Min)	Average Time In Operation (Min)	Average Cost
Avg	Pasien	54.83	120.17	2.75	0.00

Fig. 9. The average time of scenario 1

Scoreboard (Avg. Reps)					
Replication	Name	Total Exits	Average Time In System (Min)	Average Time In Operation (Min)	Average Cost
Avg	Pasien	84.50	99.27	3.07	0.00

Fig. 10. The average time of scenario 2

IV. Conclusion

This study has gainned the results of simulation of the existing system as well as the proposed scenarios. The improvement was conducted by simulating 2 proposed scenarios based on simulation results of existing system collaborated with DMAIC Six Sigma method to identify the task load conditions in each work station. This produced an efficiency of the average time patients spent in system by 61% or 1.04 hours. The second scenario was chosen as it has leveraged the system performance better by specifying an operator in each process with high task load identified in the existing system evaluation. In sequence from the highest to the lowest percentage, they are patients admission of 4 operators, nurse handling of 3 operators, examination 1 and 2 of 2 operators each, and medicine section of 4 operators. For further, designing a new layout of servers may give a different result in order to leverage Puskesmas performance as well as reducing patients' waiting time in system.

Acknowledgment

This article is the result of research grants financed by the Directorate of Research and Community Service, Directorate General of Research and Development Strengthening, Ministry of Research, Technology and Higher Education, in accordance with the Beginner Lecturer Research Contract, Number: 109 / SP2H / LT / DRPM / 2018, January 30, 2018.

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