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Patient Flow Optimization for Outpatient Department Using Discrete-Event Simulation

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ABSTRACT

The patient's waiting time and length of stay have been reported as a factor decreasing their satisfaction in the hospital, especially in developing countries. This paper focuses on modeling hospital's outpatient department workflow in a developing country and optimizing the patient waiting time as well as total length of stay. By using discrete-event simulation, many alternative scenarios have raised, such as adding more working time, altering human resources, and adjusting the staff's responsibility, those scenarios will be examined to explore better settings for the hospital. The results show that possible to achieve a 9.6% reduction in patient total length of stay and it could be accomplished without adding more resources to the hospital.

Key words: Discrete-event Simulation, Outpatient Department, Workflow Optimization

1. INTRODUCTION

Patient waiting time is an important determinant of patient satisfaction [1] and has not only been used as a performance indicator in health care for measuring the quality of services for hospitals in developed countries, e.g., Organization for Economic Co-operation and Development (OECD) countries [2], but also used for developing countries [3], [4]. Long patient waiting time has been reported in both developed and developing countries [4]. However, the duration of waiting time in developing countries is usually longer than that in developed countries. The outpatient at Bolivian hospitals also has that problem. Several repeated observation and interviewed with physicians revealed that patients usually have long waiting time while visiting for their needed services. Due to this delay, the patient satisfaction and quality of service are low. Hence, there is need to reduce patient's waiting and total time at the hospital.

Efficient patient flow is a key factor that leads to low patient waiting time and short total visit time [5]. Since the types and functions of outpatient department differ from country to country [6], this study was investigated on an outpatient department in Bolivia, a Latin America country, and aim to identify the potential enhancements to optimize patient flow. To reach that goal, the patient flow of the outpatient department was modeled and used

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to analyze patient flow using discrete-event simulation technique, a cost effective method, to optimize patient's waiting time and hospitals length of stay. Based on data extracted from the health information system and also by interviewing physicians in the hospital, patient arrival pattern and processing times were collected. From gathered data, a discrete event simulation using Arena software was constructed. Several scenarios raised for exploring better settings will be tested using that model. To measure the performance for each configuration, the patient's waiting time, the total length of stay and resource utilization will be used as metrics. These scenarios suggest that by adding more resources, and altering work-shift or changing staffs responsibility, the total entire time at the hospital can be reduced, therefore the quality of service, as well as patient satisfaction could improve for the hospital.

Our contributions are as follow.

- We modeled the patient flow of outpatient department in a developing country using discrete event simulation technique.
- From the modeled system and observations at the hospital, many appropriate scenarios were proposed, tested and examined.
- The optimal proposed scenario shows that possible to reduce the patient total time at the hospital by 9.6%. This scenario also decreases the patient waiting time and could be achieved by changing the duty of health worker at the registration center.

The remainder of this study is organized as follows. The reviews of related articles are described in the next section. The methodology is presented in Section 3. The analysis and comparison of experiments and results are detailed in Section 4. The discussion is given in Section 5. Finally, the summary of this study is given in the last section.

2. RELATED WORKS

Many researchers have focused on modeling and optimizing the hospital workflow. There are various methods have been used to analysis, e.g., linear programming, Markov chain analysis, discrete-event simulation. Specifically, discrete-event simulation is one of the most commonly used methods [7]. The advantages of discrete-event simulation over other approaches are suitable for complex process systems and able for testing various what-if scenarios by changing resources, workflows, rules or policies before actual implementation [5]. Since 2004, the analysis shows a remarkable increasing in published papers related to healthcare simulation with over 400 articles investigated in 2007 and 2008 [8].

Several hospital departments and units were studied and examined. The emergency department was considered to optimize by changing resources, such as the number of beds, nurses, and doctors [9] [10], finding the optimal schedule for physicians [11] or testing when increasing patient volume [12]. Other studies modeled the inpatient ward [13], [14]. Especially, the outpatient department was investigated in the whole department [15], [16]; in various sub-units, such as internal medicine [17], [18], surgery unit [19]; or analyzed for appointment scheduling [15]. Besides, other areas were also modeled, for example, theater operations [20] and pharmacy [21]. Modeling discrete event simulation using software is useful while these software can be customized to collect performance measures such as patient throughput, waiting times and resource utilization [22]. Many discrete-event simulation software were used and one of the most commonly used is Arena simulation, a commercial tool developed by Rockwell Automation and utilized in many companies. Other tools are Extend Sim (utilized in [10], [23]), and Witness simulation (used in [24]).

3. METHODOLOGY

3.1 System Description

An outpatient department (OPD) is a hospital unit where healthcare professionals do diagnosis and treatment for outpatients, who come to the hospital but do not occupy a bed during their stay. The outpatient department of Bolivian Municipal Holland Hospital (BMHH) serves for El Alto citizen and mainly focuses on consulting services for maternal and child patients. The operating time is from 8:00 am to 5:00 pm during weekdays. The average number of outpatients in each working day is showed in Fig. 1. The number of patients peaks at approximately 225 visits per day on Monday and gradually reduces to nearly 175 visits on Friday.

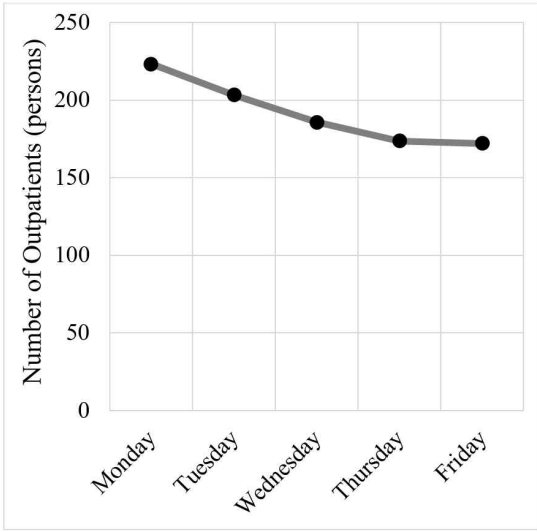

Fig. 1. The number of outpatient visits in weekdays.

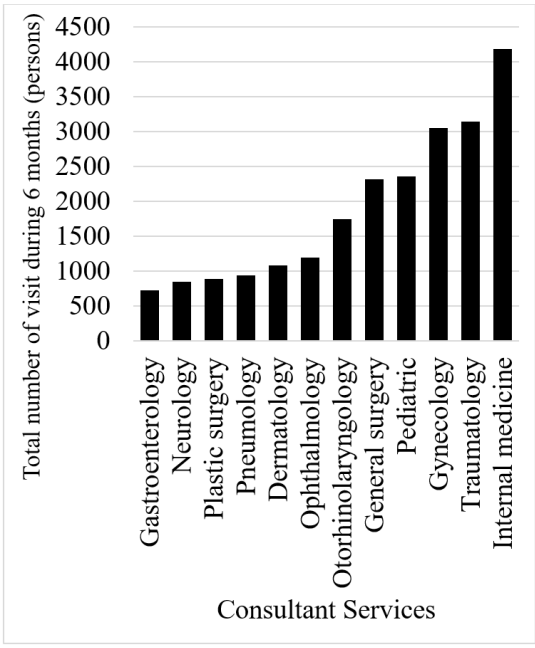

Fig. 2. Number of visited patients during 6 months.

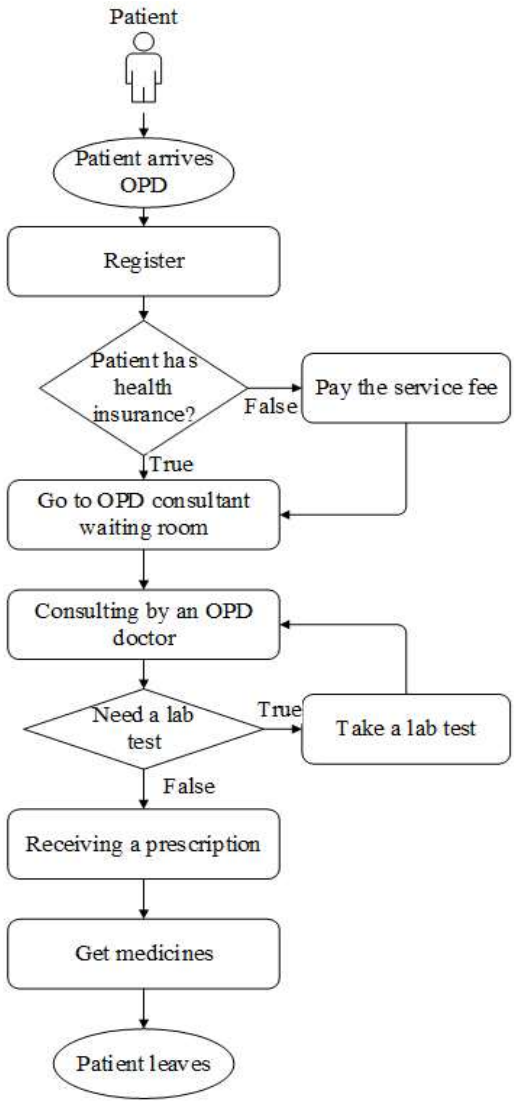

Fig. 3. Outpatient flows and processes.

Fig. 2 illustrates the breakdown of all visit during the first six months in 2016. The internal medicine, traumatology, gynecology, pediatric and general surgery are the most consultant visited services. It is observed that the proportion of patients are adult female (the woman over than 16 years old) is 45.8%, and that of children below 17 years old is 26%.

The patient flows and processes are demonstrated in Fig. 3. There are 2 types of patients, with and without health insurances. As the policy - the children, under 6 years old, and the pregnant woman have health insurance by default, therefore over 60% of OPD patients are free to take treatment. When a patient arrives at the OPD, firstly, he (or she) needs to visit the registration center which is the working area of two staffs having the different responsibility: one for patient registration i.e., issuing a visiting ticket, and one for billing if patients must pay service fees. After getting a ticket that assigned to a consultant doctor room, patients go to the waiting room, which is located in front of the consulting rooms. Until their own turn comes, the nurse who belong to a doctor room calls his or her name and the doctor will start to consult for them. If the physicians require, patients need to take some laboratory tests or other investigations and visit the consultant room again when finished. After consulted, the patients might go to the pharmacy to get medicines. Finally, the patients leave the hospital.

3.2 Model Construction

The model, reflecting patient flows, was designed using the Rockwell Arena Simulation software [25]. Arena, a simulation tool, is used broadly for workflow analysis. With the graphical user interface, Arena supports both technical and non-technical users in order to easily build, validate, and test constructed models for several scenarios. With collected information, the input analyzer could illustrate and analyze to discover appropriate distributions of these data with several random distributions, e.g., Poisson, Normal, Exponential, and Triangular. After examining, the output analyzer also assists users in comparing the various results generated from different schemes.

In this particular hospital simulation, Arena can demonstrate many time-persistent plots in real running time. Thus, at each moment, the current queue lengths could be recorded and visualized in order to verify the accuracy of the model.

3.3 Data Collection

Health Information System is an state-of-the-art information system that be able to connect to technological devices such as smart phone, wearable devices [26] in order to assists physicians, nurses and other medical staffs to work more effectively in the attempt to improve the quality of healthcare services. Input data for the model is collected by retrieved and extracted from the health information system in the hospital. Over 24,000 visits with timestamps were recorded to the database during 6 months. Fig. 4 shows the patient visit pattern in working hours from Monday to Friday. The frequent observation at the hospital also points out that patients usually arrives before the working hour. It indicates that the busiest periods are from 7 to 9 a.m. Other sources were gathered by interviewing and discussing with managers, physicians, nurses, registrar or cashier, and reviewing the actual system in the working time. The processing times for each step is collected and shown in Table 1. In this table, TRIA stands for triangular distribution with three arguments (min, mode, max) and UNIF stands for uniform distribution with two arguments (min, max).

3.4 Performance Measures

Since the patients usually have long waiting lines at the registration center in the peak time, the simulation model has an objective for exploring alternative configurations to improve the quality of

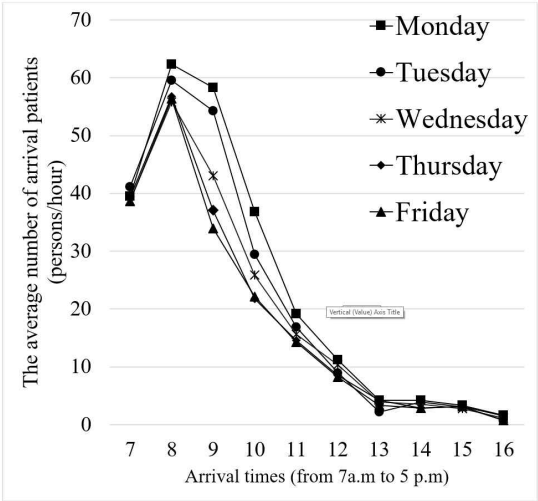

Fig. 4. The patient visit pattern in working hours from Monday to Friday.

Table 1. Summary of processing time

Process	Time (minutes)
Register	TRIA(0.75,1.5,2)
Billing	TRIA(2,2.5,2.75)
Go to consultant waiting room	UNIF(0.5,1)
Internal Medicine Consulting	TRIA(7,10,13)
Traumatology Consulting	TRIA(7,10,15)
Gynecology Consulting	TRIA(7,10,15)
Pediatric Consulting	TRIA(7,10,17)
General Surgery Consulting	TRIA(7,10,20)
Other Consulting Services	TRIA(7,15,20)
Pharmacy	TRIA(3,5,6)

service and patient satisfaction. Thus, the average patient waiting time and length of stay are used as performance measurements when testing several scenarios. Besides, the utilization for the health worker is also considered as a performance metric.

4. EXPERIMENT AND RESULT

4.1. Scenarios

As various repeated observations and discussions with the receptionist, the queue congestion usually appears in early morning working hours at the registration center. Moreover, the simulation

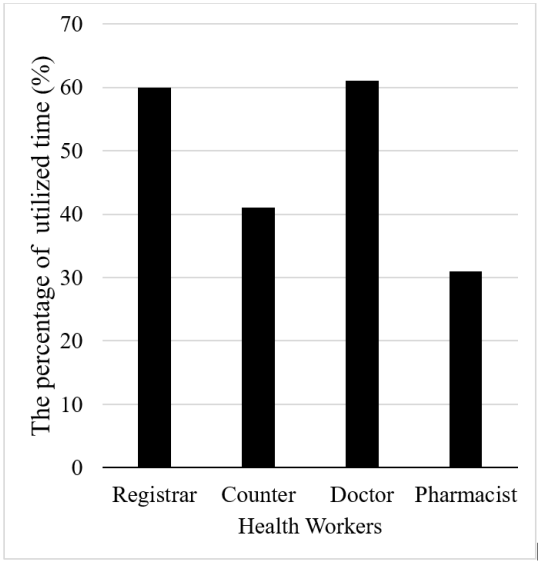

Fig. 5. The average percentage of utilization time.

suggests that the length of registration queue might exceed over 60 people at 10 am. The current setting also indicates that the average utilization time of receptionist, who records the patient visit, is significantly higher than counter, who is responsible for payment. The average percentage of utilization time is shown in Fig. 5.

From current configuration insight, the following scenarios were designed:

- Scenario 0 – Using current (default) setting at the hospital.
- Scenario 1 – Changing the working time for the registration center sooner than present 1 hour.
- Scenario 2 – Adding a staff for registration queue from 8 am to 12 pm.
- Scenario 3 – Changing the duty of 2 staffs at the registration center to both supporting visit ticket generating and billing.

In order to analyze the waiting time, the length of stay and other evaluation metrics, 30 replications of each scenario were executed and observed.

The implementation and processing steps of scenario 0 and 1 are shown in Fig. 6, scenario 2 is shown in Fig. 7, and scenario 3 is shown in Fig. 8.

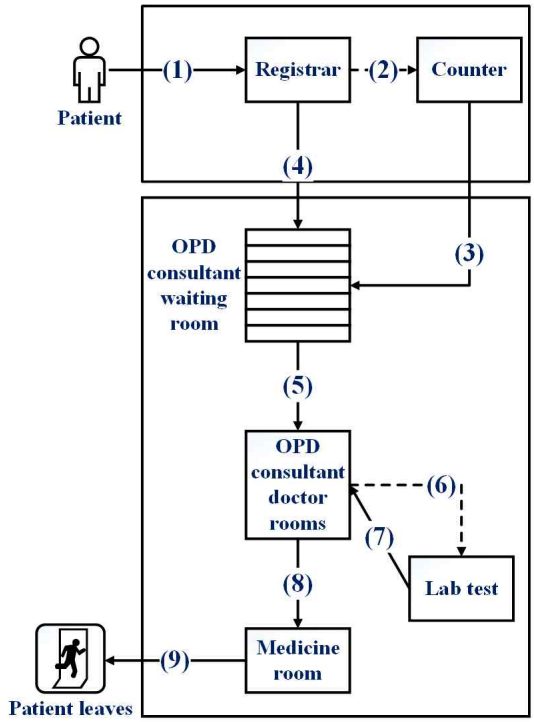

Fig. 6. The implementation and processing steps of scenario 0 and 1 by Arena simulation.

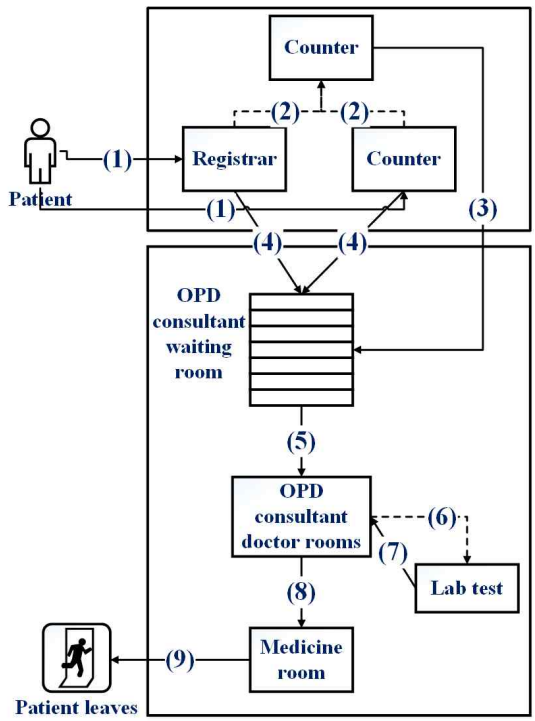

Fig. 7. The implementation and processing steps of scenario 2 by Arena simulation.

Scenario 0 and scenario 1 have the same processing steps but (1) the registrar work at 8 am in scenario 1 and 7 am in scenario 2. The system use the same data in two these scenarios but the Arena software processes the patient queue from 7 am with scenario 1, so that (2) (3) (4) the system makes the patient queue at counter and OPD consultant waiting room before 8 am. Steps (5) (6) (7) (8) (9) are similar to from step "Go to OPD consultant waiting room" to step "Patient leaves" in Fig. 3.

In scenario 2, (1) Arena software arranges randomly and equally the number of patients who came to hospital before 8 am at registrar 1 and registrar 2. After that, the patients are arranged so that the number of 2 queues is equal from 8 am to 12 pm. After 12 pm, the system use only one registrar and it processes as scenario 0. Steps (2) (3) (4) (5) (6) (7) (8) (9) are similar to from step "Patient has health insurance?" to step "Patient

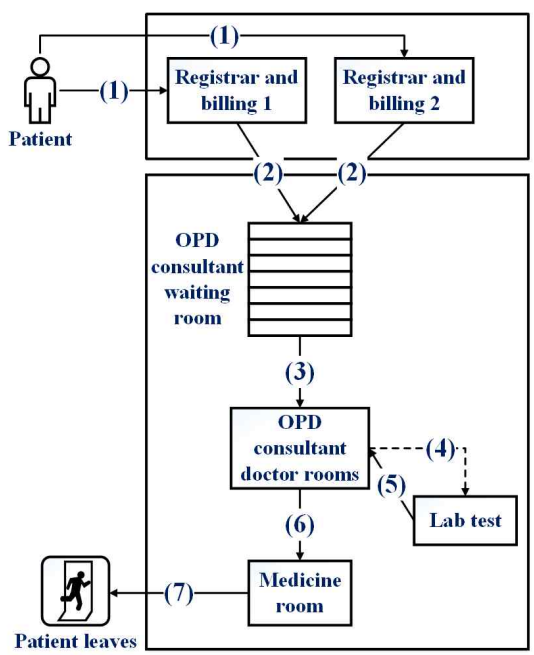

Fig. 8. The implementation and processing steps of scenario 3 by Arena simulation.

Table 2. Summary of processing time

Queue	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Registration	64.404	18.408	14.646	40.530
Counter	1.764	1.068	14.160	
General Surgery	19.986	31.824	41.556	29.148
Gynecology	33.684	64.530	48.318	49.566
Internal Medicine	69.654	106.758	109.524	78.198
Pediatric	23.592	36.744	39.900	24.798
Traumatology	38.064	50.952	57.396	38.856
Other Consultant	20.736	50.748	52.680	39.570
Average Consultant	31.578	55.138	57.427	42.520
Pharmacy	24.774	34.746	31.860	27.738
Average Total	117.198	103.716	104.478	105.474

leaves" in Fig. 3.

In scenario 3, (1) there are two staffs at the registration center to support visit ticket generating and service fee billing. Therefore, the system arranges patients into 2 queues like scenario 2 from 8 am to the last patient come. However, there is no counter anymore, hence if the patient must to pay service fees, the total time at registration center of one patient W_P is

$$H_P = W + P_t + P_b$$

where W is the waiting time at registration center, P_t is the processing time to issue ticket, and P_b is the processing time for billing. Steps (2) (3) (4) (5) (6) (7) are similar to from step "Go to OPD consultant waiting room" to step "Patient leaves" in Fig. 3.

4.2 Waiting Time

We analyzed the changes in the patient's waiting time between several scenarios using Arena simulation. The original scenario (scenario 0), which is the current configuration at the hospital, was executed at first. The detailed patient's waiting time for particular queues and the total waiting time illustrated in Table 2. The average total waiting time of patients W_t in table 2 can be given as

$$W_t = \frac{1}{N}\sum_{i=0}^{N} W_i,$$

where N is the total number of patients and W_i is the total waiting time of patient i at the hospital. In the scenario 0, the average of total patient's waiting time in all queues was 117.198 minutes. The total patient's waiting time was decreased to 103.716, 104.478 and 105.474 minutes for scenario 1, scenario 2, and scenario 3, respectively. The corresponding decrease rates are 11.5%, 10.85%, and 10.00%.

4.3 Length of Stay

The patient's average total length of stay time at registration, consultant room and/or pharmacy, and the total length of stay at the hospital are illustrated in Fig. 9. For the original setting, the average time were approximately 67 minutes and 135 minutes for registration center and whole hospital respectively. And the rest of time at the consultant room and/or pharmacy was 67 minutes.

All of the proposed scenarios could reduce the patient's length of stay at registration and the whole hospital. The highest reduction in total length of stay is achieved by scenario 1 with the average total is 121.44 minutes. Next places are scenario number 2 and 3 with the entire time are 122.27 minutes and 123.27 minutes, respectively. However, each scenario has a different way in the changed time at registration center and rest of

process. For example, scenario 1 reduces from 67 minutes to nearly 21 minutes (about 68 percentage) at registration, but the time for consulting and others are increased from 67 minutes to 100 minutes. Scenario 2 has a similar change pattern as scenario 1, where the average patient's registration time was decreased to roughly 23 minutes. The smaller time reduction happens at scenario 3, where 35 percentage of patient registration time was reduced.

4.4 Utilization Time

The percentage of utilized time for all types of analyzed employees is shown in Fig. 10. The utilized time is expressed as

$$Utilized time = \frac{Time\ spent\ working}{Total\ amount\ of\ time\ available}.$$

Doctors and pharmacists almost have no change in time utilization among several tested cases, which are about 0.63 and 0.59, respectively. The changes only happen at the registration center, where scenarios were adjusted to optimize the patient registration time. In the scenario 1, while the working time of register and counter are shifted earlier 1 hour, the utilization both are decreased. The highest reduction of utilization time occurred at scenario 2, which adding 1 more person to issue tickets for patients. By the other way, register and counter were unified to handle the same responsibility in scenario 3, thus there is an equal utilization as 0.50 for both staffs at the registration center.

5. DISCUSSION

We analyzed the patient time at the registration center and entire hospital by testing many what-if scenarios, which are raised while observing the system and examining collected data. The results have shown that all proposed configurations could reduce the patient's waiting time and the total length of stay by using different arrangements. However, each scenario has its own advantage and disadvantage. Indeed, since adding 1 working hour is required for counter and register in the first scenario, this arrangement might cause protests from staffs or need to add extra salary for them. The second scenario has the same outcome as the first one, but an additional staff is needed while human resources for health care is still facing problem in developing countries like Bolivia. The last scenario only adjust the responsibility of register and counter by unifying their work to have same mission for issuing ticket and billing if needed. Since this scenario does not need an additional resource or changing work shifts, it could be implemented at

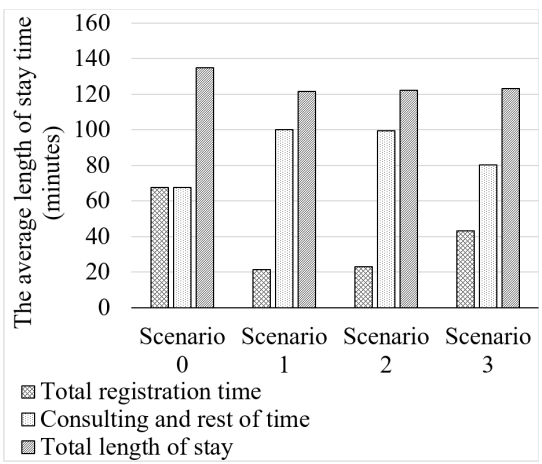

Fig. 9. The patient length of stay at the hospital (minutes).

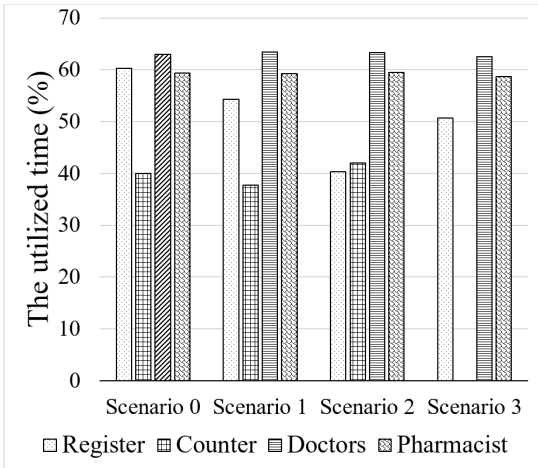

Fig. 10. The health worker's utilization time in outpatient department.

the hospital without extra cost. Additionally, the last scenario also brings the balance in utilization time at registration room.

The modeled simulation also allows for testing variety scenarios of the workflows. Based on the experiment from various examination results, the manager could generate ideas and observe the impact if the proposed framework is implemented.

6. CONCLUSION

In summary, this study examined the workflow of outpatient department, especially in the registration center, to optimize the patient time at the hospital. A discrete event simulation, reflected the hospital workflow, was modeled and analyzed. The results have shown that a 9.6% reduction of total patient time at the hospital as well as the balance of utilization time could be achieved by adjusting the duty of health workers at the registration center. These results are advice for hospital's decision-maker to increase the patient satisfaction and quality of services.

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