International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:7, No:2, 2013

Study and Design of Patient Flow at the Medicine Department of a University Hospital

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***Abstract*—**Most, if not all, public hospitals in Thailand have encountered a common problem regarding the increasing demand for medical services. The increasing number of patients causes so much strain on the hospital's services, over-crowded, overloaded working hours, staff fatigue, medical error and long waiting time. This research studied the characteristics of operational processes of the medical care services at the medicine department in a large public university hospital. The research focuses on details regarding methods, procedures, processes, resources, and time management in overall processes. The simulation model is used as a tool to analyze the impact of various improvement strategies.

***Keywords*—**Patient Flow, Medicine Department, Simulation, Outpatient Department.

I. Introduction

A healthcare system is a pure service system that is characterized by a high human involvement both at service provider (doctor, nurse, pharmacist, etc.) and patients. Such system can be challenging to design, control or improve when facing the variability resulting from this human involvement. Time is always a valuable asset for patients. Waiting idly in the any part of the hospital is not a productive situation where patients can spend their waiting time to do other activities that might benefit them rather than sitting for nothing [1]. Long waiting time is therefore the major concern among healthcare practitioners and management around the world and has become the key performance indicator for the quality of patient flow. In this research, we also address this issue seriously by using the medicine department at a large public university hospital in Bangkok as the case study. The medicine department is chosen because it is the most congested medical care unit in the hospital. Currently, it accommodates about a thousand outpatients weekly. In particular, the characteristics of outpatient flow are analyzed and simulated to identify the root cause of the problem. Various candidate improvement strategies are also proposed and tested by simulation models.

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II. Literature Review

A. Patient Flow

Patient flow refers to the movement process of patients in each section within a clinical setting. The patient flow represents the ability of healthcare system to serve patients quickly and efficiency throughout the treatment period. When the flow of the system operates properly, then the flow of patients becomes smoother and all the processes involved can be resolved with minimum delay [2]. According to the review of relevant researches, most of them studied about patient flow at the outpatient department (OPD). Examples include an application of the lean technique in OPD to improve the scheduling and delivery of outpatient services in a mental health center [3] and application of the electrical medical record (EMR) in the OPD of Nagoya University, Japan. A simulation model for the entire OPD of a university hospital was constructed and used to examine the patient flow, especially the waiting time [4].

B. Key Performance Indicator (KPI)

KPI is used by comparing results of existing work and the standard or targeted outcomes. According to the reviewed researches regarding patient flow, KPIs that are popularly used for assessing efficiency and reflecting problems in the system include;

1. Waiting Time of Patients

Waiting time refers to the average time that patients are required to wait in order to do certain activities. Waiting time receive the highest priority when setting up KPI to measure the system efficiency because it reflects the non-value added activities.

2. Total time in the System / Length of Stay

Total time in the system refers to the average of the whole time that patients remain in the care treatment system. This KPI starts counting when a patient enters the department until he/she completes the final procedure and leave the hospital. The total time in the system is used to measure the efficiency of services by considering the whole system.

3. Resource Utilization

Resource utilization refers to the ability to utilize the limited resources for the maximum efficiency. Resource utilization is a KPI to assess the ability in allocating resources in the hospital in order to serve demand of patients. In addition, it can be used to assist hospital administrators regarding work scheduling and planning on increasing or decreasing number of resources in their hospitals.

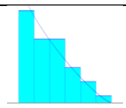
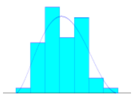
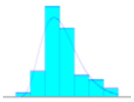
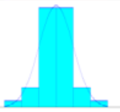
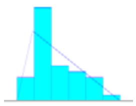
III. Research Methodology

A. Process Description and Data Collection

There are two types of data; i.e., primary and secondary data. The researcher collected secondary data mainly from the medical record section. Such data include statistics on daily outpatients in the medicine department. The secondary data was collected directly from the medicine department by interviewing the administrators, physicians and nurses. Examples of data include the number of physicians, nurses and other resources, timetable of the physicians, diagram of the examination rooms etc. For the field data collection, we had a series of meetings with the hospital's administrator, physicians and the head of nurses. Their opinions, comments and suggestion are gathered during the interview with an objective improving the system. We also coordinated directly with the nurses to set dates for surveying characteristics of services and the corresponding service time. The time that a patient spent with each service was recorded, started when the patient entering the service. The main object of interest for the data collection are the procedures in each activity of patients, service time, waiting time of patient and the number of resource that a patient used in each activity

Based on the data, the average total number of outpatients was 964 patients per week (Monday to Friday). The collected data are entered into the Input Analyzer, a feature of the simulation package ARENA to determine the appropriate statistical distribution of the arrival process and service time. In this research, the confidence level of 95% or p-value of 0.05 is adopted for hypothesis testing. Based on the goodness-of-fit test and the corresponding mean square error (MSE) value, the resulting best fit of input data distribution are summarized in Table I.

TABLE I
The Chosen Distribution for Each Process

Process	Number of sample	Number of data	Histogram	Expression	Test Statistics		p-value	
					Chi-square	KS	Chi-square	KS
Measuring blood pressure process	60	40		0.999 + 0.631 * BETA (0.943, 2.25)	0.925	0.0896	0.365	> 0.15
Seeing physician process	60	58		2 + 18 * BETA (2.72, 3.15)	3.72	0.124	0.172	> 0.15
Payment process	56	55		0.13 + ERLA(0.167, 6)	2.86	0.0778	0.0932	> 0.15
Receiving medicine process	56	38		NORM (47.5, 1.81)	2.6	0.103	0.111	> 0.15
Making appointment	37	36		TRIA (7, 17.7, 77)	4.48	0.124	0.11	> 0.15

B. Patient Flow

The medicine department at the case study university hospital operates six days a week, starting from 7.00 am to 6.00 pm. There are three shifts, i.e., morning, afternoon and evening. The statistics indicates that the average number of daily outpatients during Monday through Friday and half day of Saturday was 964 persons. To study the flow of patients, this research uses patient tracking technique to collect data from outpatients who come for medical services at the Medicine Department. The focus is on the morning shift only because in the afternoon, the medicine department operates as specialty clinics.

Most services of the medicine department are provided within the department's area. Common processes start by measuring blood pressure in the department's area. Then the patient would wait to see the physician, and submit the medical record. If no further diagnosis is required, the patient can wait for a drug prescription or a bill. Approximately 95% of patients have been prescribed for some drugs. After paying money and receiving the drugs, the patient will return to the medicine department to set up the next appointment. Approximately 99% of patients receive appointment cards. After completing with the appointment, the patient can be discharged from the hospital. Fig. 1 shows the patient flow diagram.

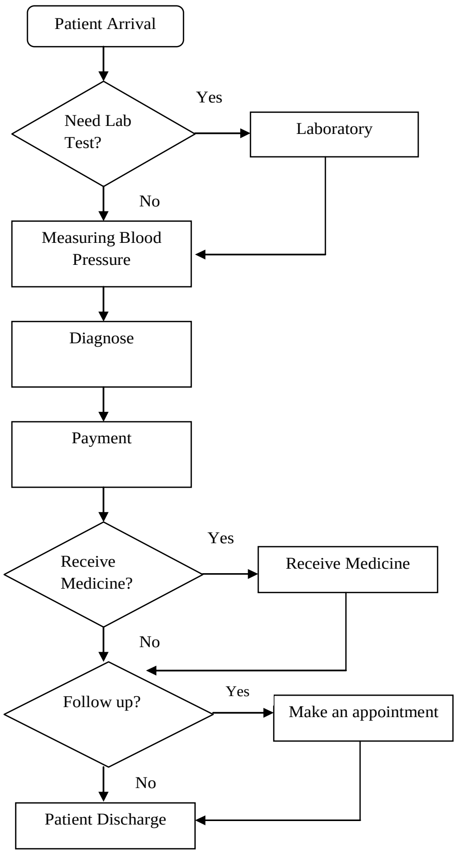


Fig. 1 Patient Flow Diagram at the Medicine Department

IV. Simulation Modeling Process

In order to investigate the service time and waiting time in the system, the simulation models are created. Based on the experiment, the number of 900 replications is run as this is likely the convert to the steady state. The analysis of the model can be done based on the reports generated. Before using the developed simulation model to analyze the efficiency of any proposed improvement strategies, we need to check to ensure that the developed model is correct. There are two steps for checking the model. The first step is the verification of the simulation model (in order to check accuracy of the model). The second step is the validation of the simulation model (in order to compare the simulation model with the actual situation). The simulation model at medicine department using Arena is shown in Fig. 2.

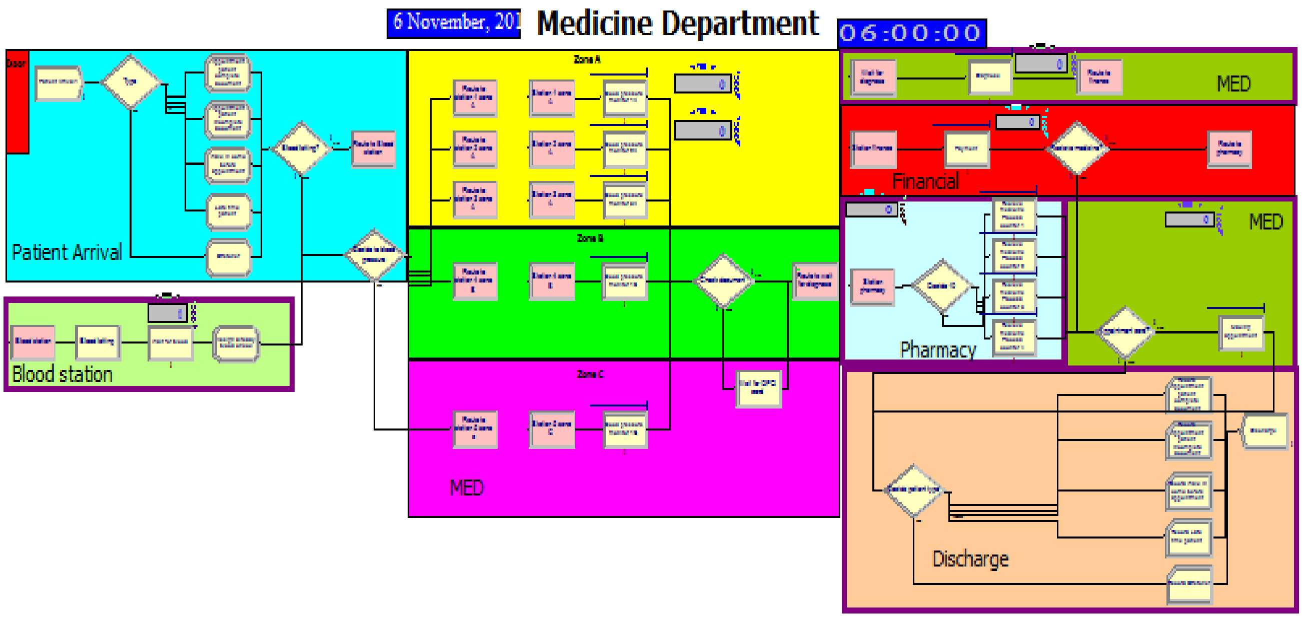


Fig. 2 Simulation Model at the Medicine Department using Arena

A. Verification

Having built the model, it needs to be checked for the correctness. This step is called model verification. The model was verified by checking the flow of patient. First, the researcher ran the model and gradually checked it throughout the system. Then, the verification was completed when the researcher found that the entity (patient) in the model flowed correctly according to the real system. Therefore, the researcher checked it with the patient flow diagram. This ensures that the model is able to operate without any errors.

B. Validation

The process of validating the simulation model can be conducted by using the values that are simulated from the model compared with the observed data [5]. The comparison will be made based on differences of the mean of time usage between results from the simulation model and the observed data. If the two set data compared closely, the simulation model is considered as valid. In general, the discrepancy between model and observe results should be less than 15%. These discrepancies were partially attributed to natural human delay in real life, and the inclusion of exceptional (outlier) cases. Table II shows the comparisons between simulated output and observed data for average process and waiting time. It can be seen that the two values are quite close. Hence, the discrepancy is rather small. The next step involved statistical t-test for significance of the difference between the means of two independent samples to test whether the simulation model is valid or not. Subsequently, we propose the candidate improvement strategies and use the simulation model to analyze the effectiveness and quantify the impact of the strategies.

TABLE II
COMPARISON BETWEEN SIMULATED OUTPUT AND OBSERVED DATA FOR AVERAGE PROCESS AND WAITING TIME

Activity	Process Time (minutes)			Waiting Time (minutes)		
	Observed data	Simulation	% different	Observed data	Simulation	% different
Measuring blood pressure	1.09	1.22	11.93	10.00	11.00	17
Diagnose	10.77	10.34	3.99	41.61	40.10	3.63
Payment	1.15	1.13	1.74	37.00	34.39	7.05
Receiving medicine	31.22	27.50	11.92	41.00	48.60	18.53
Making appointment	26	24.24	6.77	13.00	15.32	17.85
Total	70.23	64.43	8.26	142.61	149.41	4.77

C. Development of Improvement Strategies

According to the observation, most patients arrive very early at the hospital and wait for physicians, resulting in crowdedness in the waiting areas. Furthermore, after running the simulation model we found the bottleneck in diagnose and receiving medicine process. Therefore, we plan to simulate changes in working schedule of physicians and also add one more pharmacist to the receive medicine process. At present, there are, on average, 35 physicians working daily from 9:00 to 12:00 (morning shift). By adjusting the working schedule of some physicians to be one hour earlier, those physicians will have to start working at 8:00AM. For the pharmacy section, there are four pharmacists working from 9.00AM to 1.00PM (morning shift). By adjusting, the number of pharmacists will be change from 4 to 5 persons. Table III shows the summary of results from this improvement strategy.

Table III summarized the results from the strategy. Based on the results obtained from Table III and Fig. 3, the average waiting time for a patient in the examination room (diagnose) is 40.10 minutes compared to the simulation result with the reduction down to 34.37 minutes. This is the 14.28% reduction. The average waiting time for receiving medicine is reducing from 48.60 to 29.27. The strategy also results in the reduction of the total waiting time for 19.19%. Fig. 3 compares the waiting time across the stations in the flow of patient.

TABLE III
SUMMARY OF RESULTS FROM THE SCENARIO

Activity	Process Time (minutes)			Waiting Time (minutes)		
	Current situation	Scenario	% change	Current situation	Scenario	% change
Measuring blood pressure	1.22	1.22	-	11.00	10.23	-7.00
Diagnose	10.34	10.32	-0.19	40.10	34.37	-14.28
Payment	1.13	1.13	-	34.39	33.57	-2.38
Receiving medicine	27.50	27.49	-0.03	48.60	29.27	-39.77
Making appointment	24.24	24.31	+0.288	15.32	13.30	-13.19
Total	64.43	64.47	+0.06	149.41	120.74	-19.19

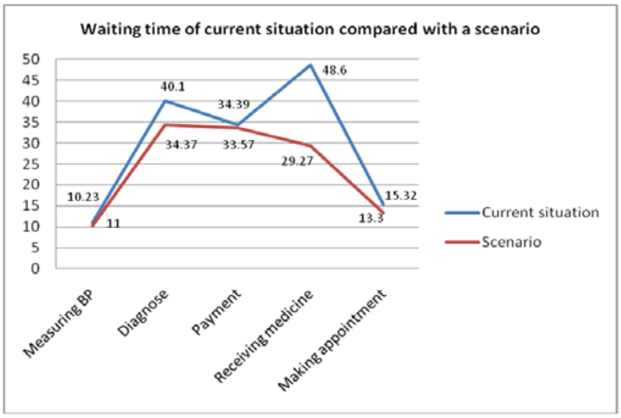


Fig. 3 The comparison of waiting time between the current situation and simulation results

V. Conclusion

In this study, a patient flow was modeled by using the discrete-event simulation model. It was developed for the medicine department of a large public university hospital in Bangkok with the focus on reducing the waiting time of outpatient and to identify the bottleneck that leads to a long queue of patients during the medical processes of outpatient services. The alternative strategies are proposed for improving overall processes. Based on the results from analyzing the patient flow by using the simulation model, it is proved that there is a long waiting time for a patient in some process especially in diagnose and receive medicine process. Therefore, the suggested improvement made by the changes in working schedule of physicians and also add one more pharmacist to the receive medicine process. The result shows that the scenario can help to reduce the waiting time for outpatients in the diagnose and receiving medicine process and also automatically reduce the whole average waiting time and the total time of overall system.

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