IMPROVING PATIENT'S WAITING TIME AT A HEALTH SCREENING CENTER

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ABSTRACT
The health screening center is the first department that patients come into contact before going to other departments. Patients sometimes complain about long waiting times at this center. We develop a discrete-event simulation model of the health screening center to support the decision making process of the hospital management. It is designed such that it can readily be used for testing any scenario inside the health screening center. Input data is collected from electronic records and interviews with staff. The simulation model is validated by considering the average total times in the system of one health checkup package. In this paper, we use the simulation model to test our patient's adaptive policies to see if patient's waiting time can be reduced.

Keywords: discrete-event simulation model, health screening center, healthcare simulation

1. INTRODUCTION

Private hospital business is expected to grow because more and more patients focus on preventive healthcare. Thus, a health screening center will receive greater number of patients because its main purpose is to identify future health risks so that the action can be taken immediately or highlight any problem areas. In addition, health screening can create or improve self awareness of health and fitness and provide referrals for further care when necessary. It is the first department that many patients come into contact with before going to other departments.

We study the health screening center at one of the forefront private hospitals of Thailand. The medical personnel are renowned for their expertise and cutting-edge medical treatments. The health screening center is open from 6 AM to 5 PM. For check-ups, patients cannot eat or drink at least nine hours before; therefore, most patients arrive to the health check up center during 7 AM to 10 AM. Some medical tests take a long time, resulting in occasionally long waiting time for patients. The current target of average total waiting time is less than 1 hour, but the actual value is approximately 2 hours. The satisfaction surveys done by the hospital indicate that it is an issue that patients are not satisfied with. Some factors that affect the waiting time are the variation of medical tests in the health screening packages, the number of hospital staff, and the patient appointments. The hospital management would like to have a simulation model so that it can experiment with improvement schemes.

Discrete-event simulation (DES) models are computer programs that model the logical flow of complex processes occurring at discrete times (Kelton et al 2009). DES has become one of the most widely used Operations Research tools, including in healthcare applications. Everett (2002) describes simulation models that support the decision making process for scheduling of patients. Klein et al (1993), Jun et al (1999), and Jacobson et al (2006) provide a comprehensive literature review on simulation modeling and applications to healthcare.

2. DESCRIPTION OF THE HEALTH SCREENING CENTER

The health screening center under study consists of 6 stations. Figure 1 shows the layout of health screening center. Station 1 is the pre-assessment to inquire patients. Station 2 is the document preparation for medical exams. Station 3 is staffed by cashiers for making a payment. Station 4 is the vital sign checks and blood draw examination. Station 5 has two parts: the first part is the cardiac assessment consisting of the electrocardiogram (EKG) and the exercise stress test (EST), and the second part is radiology (Imaging services) consisting of chest x-ray, ultrasound of abdomen, a breast cancer exam and a mammogram. Station 6 is the physical examination and diagnosis, consisting of physical examination (PE), eye examination, pap smear and pelvic examination.

This health screening center offers 7 packages (see Table 1 for details of medical exams in each package). Patients make appointments before arrivals, or they are walk-in patients. When patients arrive to the health screening center, they go to Station 1 to register and do pre-assessment. If patients have made appointments, all the documents are readily available for them to sign when they arrive. Patients proceed to Station 3 to make a payment after getting the documents. Actual medical exams begin at Station 4 with the vital sign check and blood test. When patients finish with Station 4, they are split into two paths: the first one leads to Station 5 and then Station 6, whereas the second path goes to Station 6 first and Station 5 later, but patients need to return to

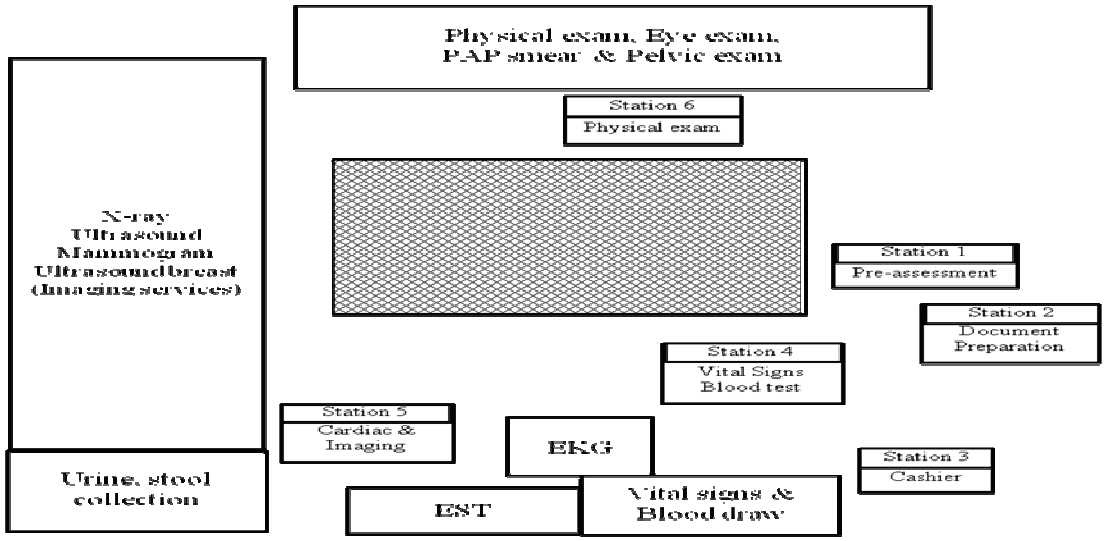

Figure 1: Layout of Health Screening Center

Station 6 again to see the same physicians for diagnosis. Patients are directed to the second path when there are more than 10 persons in the ultrasound queue. Because Station 5 consists of cardiac assessment and imaging services (the order does not matter), patients are sent to the shortest queue. The patient flow diagram is summarized in Figure 2.

3. SIMULATION MODEL DEVELOPMENT

We describe the data collection process in Section 3.1, the overview of the simulation model in Section 3.2 and the model validation in Section 3.3.

3.1. Data Collection

Empirical data was collected from computer recorded files, by interviews with doctors, nurses, and other hospital staff, and by direct observations, during July to December 2011. For the first two months, we learn about the health checkup operations, such as job details at each station, staff's work schedule, and how the staff makes decisions. Then for the subsequent month, we construct the patient's flow diagram. During the remaining 3 to 4 months, we go to the health screening center 4-5 days a week to collect time data, to interview with the staff, and to retrieve data from their patient record system (Amalga®).

Many issues arise during data collection. For example, hospital staff are sometimes reluctant to provide us data because they think we will use it to catch their mistakes. Therefore, we discuss with the department manager what we needed and what they would get from our work. We also have to create good personal relationship with the staff so that they are willing to give us interview time, and they can also help us on data collection.

For this model, we require input models for the patients' arrivals, service times at each station, resource availability, and fractions of patients undergoing each checkup package. The distribution of patients on checkup packages is as follows: the Regular package accounts for 10% of patients, Executive package: 17%, Executive Female: 7%, Comprehensive Male without EST: 10%, Comprehensive Male: 27%, Comprehensive Female younger than 40: 8%, and Comprehensive Female older than 40: 21%. For the number of patient arrivals, we consider only weekdays and no holiday. The data is examined for seasonality and trends, and we do not find significant trends. We assume that the arrivals are independent of the day of the week and time of the year. The average number of patients is 170 per day, and we simulate their arrivals with the non-stationary Poisson Process with the following distribution: 2% of patients arrive during 6-7 AM, 22% during 7-8 AM, and the remaining hourly fractions until the center stops receiving new patients at 1 PM are 25%, 22%, 15% 10% and 4%, respectively.

The service times at each station are collected by a stopwatch time study. Table 2 shows the input models in Arena® expressions. When patients have ultrasound tests, they need to be full bladder. The ultrasound test is done, on the lower and upper abdomen, one at a time. The physical examination consists of 2 parts: consultation and diagnosis, both of which have to be done by the same physician.

The resources at the health screening center are *registered nurses* (RN) who do pre-assessment at the registration, *nurse aids* (NA), *clinic associates* (CA) who are coordinators, *technicians* and *radiologists* work on imaging, and *physicians*. We assume that all staff of the same position are equally skilled. Resource availability during each time period is shown in Table 3.

3.2. Simulation Model Development

Waiting time in queue is the primary key performance indicator (KPI) that the hospital management is keenly concerned. Other KPIs include the total time in the health checkup center, average waiting time by package and by time period, total time by package and by time period, average total waiting time and total time of each path.

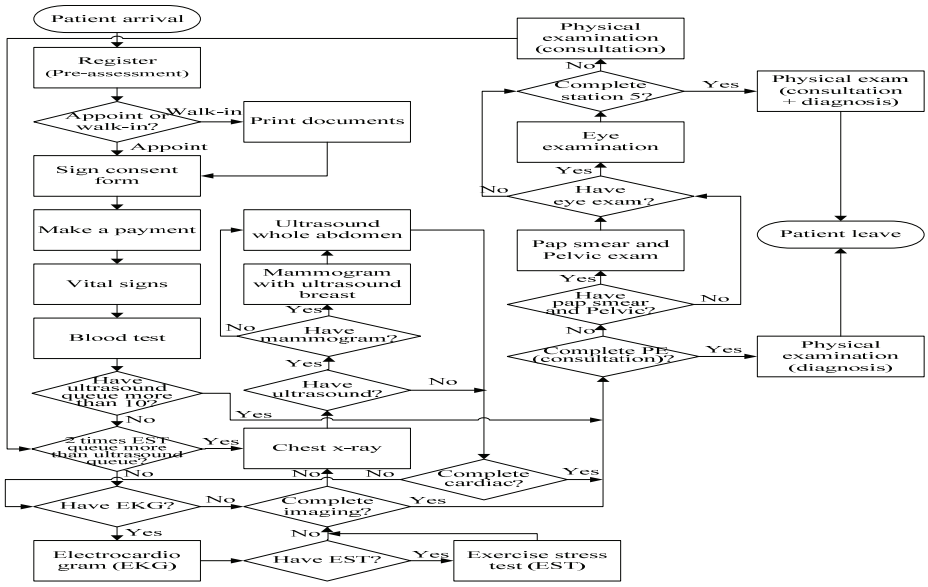

Figure 2: Patient Flow Diagram

Table 1: Examination in Each Checkup Package

	Regular	Executive	Executive female	Comprehensive male without EST	Comprehensive male	Comprehensive female younger than 40	Comprehensive female older than 40
Vital Signs	●	●	●	●	●	●	●
Blood test	●	●	●	●	●	●	●
Electrocardiogram		●	●	●	●	●	●
Exercise stress test					●		
Chest x-ray	●	●	●	●	●	●	●
Ultrasound whole abdomen		●	●	●	●	●	●
Mammogram with ultrasound							●
Pap smear & Pelvic exam			●			●	●
Eye exam				●	●	●	●
Physical examination	●	●	●	●	●	●	●

Table 2: Process Time Distribution (Unit: Min)

Process	Arena Expression
Signing consent forms	NORM(5,2)
Printing consent forms	0.5 + EXPO(1.04)
Printing order documents	0.5 + EXPO(0.857)
Charging program	DISC(0.95, 1, 0.99, 2, 1.0, 3)
Assessment for appointment patients	0.5 + LOGN(2.35, 2.36)
Assessment for walk-in patients	0.5 + GAMM(1.71, 1.53)
Cashier	8 * BETA(3.54, 8.24)
Vital signs	2 + GAMM(0.745, 2.43)
Drawing blood	1.1 + LOGN(1.48, s0.743)
Electrocardiogram (EKG)	2 + WEIB(1.82, 1.5)
Exercise stress test (EST)	NORM(24.9, 3.59)
X-ray	0.08 + LOGN(1.75, 0.696)
Mammogram	NORM(8.78, 2.14)
Ultrasound whole abdomen	5 + 26 * BETA(1.47, 1.77)
Ultrasound upper abdomen	9 + WEIB(9.44, 1.45)
Ultrasound lower abdomen	3 + 11 * BETA(1.32, 2.34)
Ultrasound breast	TRIA(6, 8.25, 18)
Eye exam	NORM(4.57, 2.14)
PAP smear and Pelvic exam	NORM(5.95, 2.46)
Physical examination (consultation)	NORM(5.71, 1.69)
Physical examination (diagnosis)	NORM(8.00, 2.74)
Physical examination (consultation and diagnosis)	NORM(10.30, 6.36)

Table 3: Resource Availability by Time Period

	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
RN at Station 1	3	5	5	3	3	2	1	1	1	1	1	0
CA at Station 1	1	5	4	3	1	0	0	0	0	0	0	0
CA at Station 2	3	4	4	4	4	4	4	4	4	4	4	0
CA at Station 3	1	3	3	3	3	3	3	3	3	2	1	0
Vital signs NA	1	3	3	3	3	1	1	1	1	1	1	0
Blood draw NA	1	3	3	3	3	1	1	1	1	1	1	0
EKG NA	1	3	3	3	3	2	2	2	2	1	1	0
EST NA	1	2	2	4	3	3	3	3	3	1	1	0
EST RN	1	1	1	4	3	3	3	3	3	1	1	0
X-ray technician	1	1	1	1	1	1	1	1	1	1	1	0
Ultrasound technician	0	4	7	8	8	8	8	6	6	3	3	0
Ultrasound radiologist	0	2	3	4	4	4	4	2	2	1	1	0
Mammogram technician	1	1	1	1	1	1	1	1	1	1	1	0
Mammogram radiologist	1	1	1	1	1	1	1	1	1	1	1	0
Eye physician	0	1	1	1	1	1	1	1	1	1	1	1
PAP physician	0	1	1	1	1	1	1	1	1	1	1	1
Station 6 physician	0	1	1	1	1	1	1	1	1	1	1	1

The simulation model is developed on Arena version 12 (Rockwell Software) with the run length of 720 minutes (from 6 AM to 6 PM) and no warm up period. One-hour additional time is to allow the department to clear patients out of the system; it does not close until the last patient leaves. We ignore some details of the real setting, e.g., patients can request physicians whom they would like to see. Sometimes they arrive to a health checkup center in a group. If they cannot wait for the diagnostic results, the hospital can send them by e-mails or by post. We make the following simplifications in our simulation model: we assume that patients do not make physician requests; patients arrive one at a time, and patients wait for their diagnosis results, except when they arrive at Station 6 after 4 PM

3.3. Model Validation

Validation is the process of checking if the simulation model can adequately represent the real system. In this paper, we use the average total time of comprehensive male package going the first path (Station 5 first and Station 6 later) for validation. Rossetti (2010) describes the two sample t-test for comparing two means to validate the data from the simulation model with that from the actual system. Based on the sample size of 30 replications, the p-value of the test is 0.1; therefore, the simulation model can be used to model the actual system.

3.4. Scenario Comparison

We are interested in reducing total waiting time in the system. We compare the following five scenarios:

- *Policy 1*: As-is condition.
- *Policy 2*: To have the ultrasound test only once for the whole abdomen. Currently, if patients do not have full bladder, they will have ultrasound tests on the upper abdomen first. Then they keep drinking water until feeling full bladder and return to have ultrasound tests on the lower abdomen. Thus, the ultrasound radiologists work on them twice. But if they wait until being full bladder, the ultrasound radiologists will meet them only once.
- *Policy 3*: To assign diagnosis physicians at Station 6 on the first-come, first-serve basis. At present, physicians are assigned to patients when they check in at the registration, in order to balance the physicians' work load. When patients are finally due for diagnosis, they may experience long waiting time, even though some physicians at Station 6 may be available at that moment.
- *Policy 4*: To evenly schedule patients' arrivals throughout the day. Due to food and drink fasting, most patients arrive to the health screening center in the early morning, resulting in heavy traffic that propagates down the system. But if we can set patients' appointments such that patients evenly arrive, the health screening center will face less traffic variation and thus less system congestion.
- Policy 5: To simultanously implement all policies.

With the run length of 720 minutes and 30 replications, the patient's total waiting times are shown in Table 4. As expected, Scenario 5 is most effective in reducing the total waiting time because all policies are included. However, if these policies are examined individually, Policy 4 of having equal arrival rate per

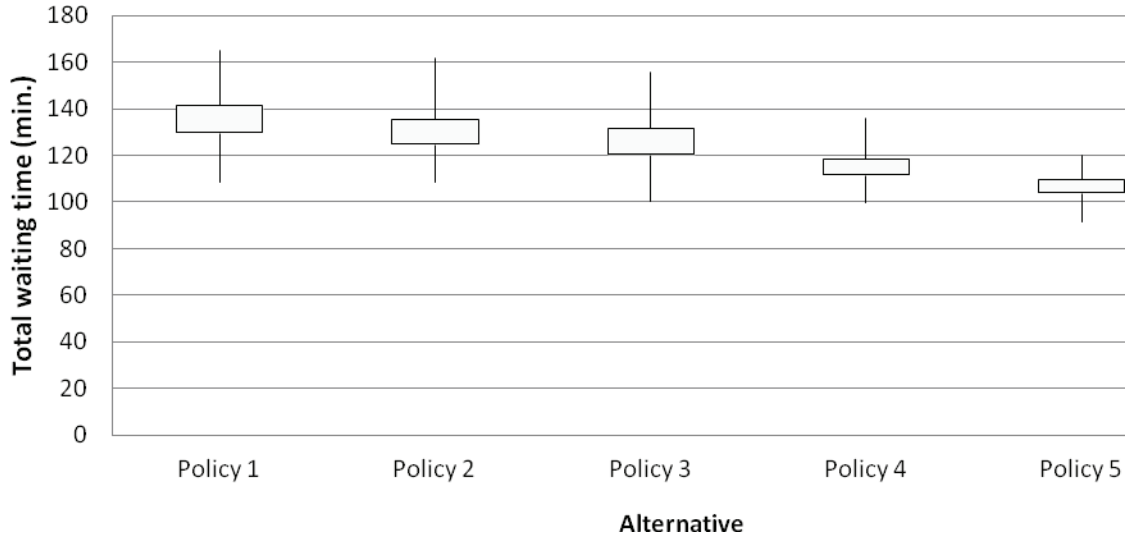

Figure 3: Alternative Comparison in Terms of Total Waiting Time

Table 4: Comparison of Total Waiting Time

	Total waiting time (min)	95% confidence interval (min)
Scenario 1	135.64	(129.81,141.47)
Scenario 2	130.08	(125.05,135.11)
Scenario 3	126.16	(120.59,131.73)
Scenario 4	114.9	(111.51,118.29)
Scenario 5	106.64	(103.87,109.41)

hour can reduce total waiting time more than other policies (Figure 3).

Policy 2 of having ultrasound tests once for each patient cannot reduce the waiting time by much because the process time of two ultrasound tests and one test do not differ by much. Policy 3 is more effective than Policy 2 because physician resources are pooled; patients are assigned diagnosis doctors on the first-come first-serve basis.

4. CONCLUSION

Simulation models are very useful for what-if analysis. In this paper, we develop our simulation model for experimenting with improvement plans at the health screening center. We validate it with a statistical test and show that it can adequately represent the actual system.

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