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Modeling and Simulation Analysis of Health Care Appointment System using ARENA

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ABSTRACT

This study evaluates appointment systems for outpatient department in a health care system and as well the patients' characteristics. The objective is to design an appointment system that will minimize the patient average waiting time in the clinic and at the same time maximize the doctor's utilization. The problem is thus considered as a multi-objective. This research proposes a model that will give a better appointment system and schedule for patients. The procedure is implemented on an outpatient clinic at Doha Hospital clinic by modeling and simulating the eight categories of an appointment system using the modeling and simulation package ARENA and the simulated result is compared with the current situation in the clinic.

Key Words :: Arena, modeling, Simulation, appointment system.

1 INTRODUCTION

Waiting time in outpatient departments have become a long time complaint of patients more especially in high population society. Patients are unsatisfied with length of waiting time in the outpatient department. Many outpatients departments throughout the world have long waiting times for treatment followed by short consultations which are the major complaint of patients. Several researches have been carried out to reduce cost and improve the efficiency in outpatient services. Most researchers have concluded that the major reason for long waiting time is poor scheduling system put in place. Outpatient departments scheduling is considered as one of the important factors that bring efficiency to the health care sector, with the aim of providing an excellent service to reach patients satisfactions and use the available resources effectively.

In this research, we studied the current appointment system. The current situation in the clinic is that the patients arrive and register at the beginning of each session and keep waiting until their turn come. In some cases patient have to wait very long time before receiving consultation from specific doctor. Eight (alternatives) are modeled and simulated using Arena software based on the two performance measures; maximizing the utilization of the doctor time and minimizing the average waiting time per patient in the clinic. The problem is modeled as a Multi-Objective optimization problem. The aim is to optimize the system by optimizing the above two objective functions generated by Arena software. In this study, we consider an outpatient clinic. The current appointment system start from single-block appointments to individual

appointments. Most of the appointment systems have shown concern in modifying and combining of single-block and individual appointment systems to create an appointment rule. Babes and Sarma [7] investigated that in most of the hospitals the single-block system scenarios is used. In this system all patients are to arrive in block at the beginning of the clinic session, allocating a date rather than an exact appointment time. This alternative creates a long waiting time for patients and increase the busy time for the doctors. Bailey [3] develops an outpatient appointment scheduling rule based on individual appointment system. In this system, patients arrive individually in each single-block at equal time length interval. Later, Sickinger and Kolisch [8] extended this work to block appointment systems in which the number of arrivals varies in each bock. Ho C and Lau H [5] have investigated the variable block/time with an interval rule that assign different number of patients in an appointment interval during the clinic session. Generally, we have two types of block appointment systems; equal-block appointment systems (number of arrival is the same in each block) and variable-block appointment systems (where number of arrivals varies in each block).

1.1 **Factors affecting appointment system**.

1. The initial block, which is the number of arrivals at the beginning of each session.
2. The number of patient(s) arrives in each block.
3. The length of interval between two consecutive arrival blocks.

1.2 Classification of Appointment Systems.

Appointment system (AS) can be classified based on the three above factors. Following are the six classes of appointment system:[6]

Class 1 The individual-block fixed interval system : In this system, patients are assigned individual appointments with a fixed interval between any

two appointments that equals the mean consultation time between any two appointments.

Class 2. The individual-block fixed interval with an initial block system: This is the same as the previous system except that an initial arrival block of more than one patient at the beginning of the session is assigned.

Class 3. The individual-block/variable-interval system: In this system, individual patients are assigned in each block but with different appointment intervals between schedule arrivals (usually, increasing appointment intervals).

Class 4. The multiple-block/ fixed -interval system: In this system, fixed number of patients (more than one) are assigned in each block but with fixed interval equals to the mean consultation time between two patients multiplied by the number of patients in the block.

Class 5. The variable-block/ fixed interval system: In this system a different number of patients in each appointment block are assigned fixed interval. Usually the number of patients assigned at the beginning is higher then it is decreased

gradually.

Class 6. The multiple-block/variable-interval system: In this system a fixed number of patients (more than one) with different appointment intervals (increasing appointment intervals) are assigned.

In this research we have investigated 8 alternative systems based on class 1, class 2 and class 4. The modeled alternative systems were compared and then select a set that contains the systems with the best performance.

2 DESCRIPTION OF THE CLINIC SITUATION

In this section, we discuss the flow of the patients in the clinic, how the required data is collected and how we build the Arena simulation model.

Patient flow in the Clinic: Patients start arriving at the clinic at 7:00AM and go directly to the registration unit to take number. Patients have to wait until their turns come to receive consultation from the doctor. After receiving consultation a patient may either leave or need to take some laboratory tests, in this case patient goes to lab process and then returns back and waits in the doctor queue to receive consultation again.

Data Collection: The data collected was for a period of one and a half month [2]. The data collected includes arrival time for each patient, type of patient : new patient or follow up, patients waiting time in the doctor queue, service time in the doctor room, number of patients sent to the lab and the time it takes until the patient come back from the lab to the doctor queue. These data were analyzed using Arena input analyzer. We obtained the following results based on patient type: Table 1 shows the statistics results obtained from the input analyzer.

Table 1: **Current situation in the clinic**

clinic hours	**7 hours**
Doctor's working hour	**5 hours**
Number of resources(doctors)	**1**
Average patients served	**33**
average waiting time	**2.16 hours**
doctor utilization	**almost 100 percent**

Table 2: **Summary of Statistics obtained from the Arena Input analyzer**

index	statistics	parameter
1	Service time for New patients	4+Expo(1/4.86)
2	Service time for follow-up patients	Expo(1/6.32)
3	Service time for return patients	Expo(1/2.9)
4	Lab time for return patients	7.17+Expo(1/3.65)
5	Percentage of patients that needs lab test	9.5
6	Percentage of patients that show up in the clinic	90
7	Percentage of no show patients	10

3 MODELING OF THE APPOINTMENT SYSTEM

In this section, the clinic appointment system for the outpatient department is modeled. The current situation at the clinic is discussed, the alternatives for the systems are constructed and finally the structure of Arena model is discussed. The current appointment system is segmented into three parts.

1. **Waiting in the Doctor Queue**: The service in this clinic is offered to three type of patients; New patients, follow up patients and return patients. The first two types need to takes number from the reception to see the doctor. The third type is either new or follow up patient, however doctor sent some patients to take lab tests, these patients come back to the doctor queue as a return patients. When the arrival patients take numbers from the reception, they should wait in the waiting room until their turns come. The receptionist start giving numbers at 7:00am while the doctor start attending the patients at 9:00am (i.e doctor starts serving the patients at 9:00am), therefore there must be a queue generated by patients before the doctor start giving the service.

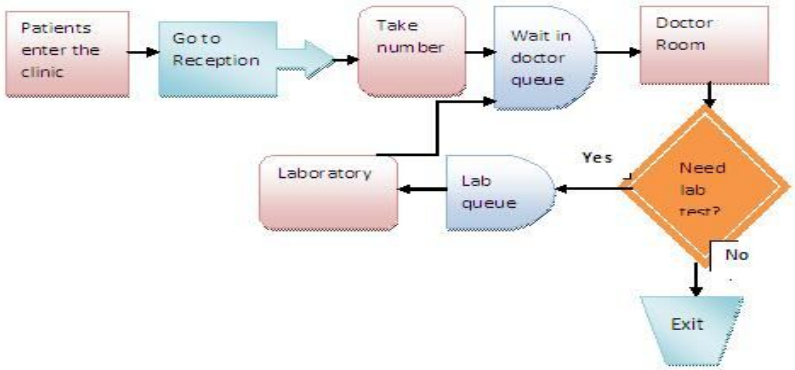

Figure 1: **The clinic daily routine**.

2. **Doctor Diagnosing Process**: After the patients enter the diagnoses room, the service time is different according to the patient's type; new, follow up or return. New patient service time is usually the longest service time, since the doctor needs to diagnose the patient's and identify the patient's problems and conditions. Follow-up patients' service time is less than that of the new patients because the doctor already has a record about these patient's conditions and problems and they usually come for check-up with doctor. The Return patients' service time is usually the lowest service time, because the doctor only looks at the lab results and gives prescription to the patients based on the results.

3. **Lab Process**: Some number of patients needs to take lab test and then return back to the doctor room with tests results usually in the same day. The lab process normally takes about 10 minutes to finish. A highest priority is given to these patients who took lab tests (return patients), therefore, they see the doctor the next available time immediately and without having a number.

3.1 Generating the proposed Alternative Systems

We constructed eight alternative system and model them using the Arena soft-ware, in each alternative we get the estimate of; average waiting time per patient and average doctor time utilization and each of these two results were calculated based on 100 numbers of replications. When constructing the alternative systems, we consider the following; initial number (I) of patient(s) to be schedule at the beginning of each clinic session, time period (T) between each two consecutive scheduled, number of patients (N) scheduled in each time period T. The eight alternatives were constructed based on the class two and four discussed .The figure below describes the alternatives in details;

Table 3: **The description of scenarios considered in the project**

system	class	scenario	Description
1	2	(1 7 1)	1 patient each 7 minutes with initial arrival of 1 patient
2	2	(1 7 2)	1 patient each 7 minutes with initial arrival of 2 patients
3	4	(2 7 1)	2 patient each 7 minutes with initial arrival of 1
4	2	(2 7 2)	2 patient each 7 minutes with initial arrival of 2
5	2	(1 8 1)	1 patient each 8 minutes with initial arrival of 1
6	2	(1 8 2)	1 patient each 8 minutes with initial arrival of 2
7	4	(2 8 1)	2 patient each 8 minutes with initial arrival of 1
8	4	(2 8 2)	2 patient each 8 minutes with initial arrival of 2

4 RESULTS AND DISCUSSIONS

Arena is a simulation software that can be use to model any given system by mimicking the behavior of the real system, usually on computer [9]. In this section, we discuss how we used the Arena software in simulating the seventy two constructed alternative systems.

We used the flowchart modules in Arena to describe the arrival process of patients, how they are being processed and disposed after finishing the process. In this model we used one create module to generate initial arrivals, one create module for walk-in arrivals and for each block and each time slot a create module is used. For demonstration, to model 2 patients each 10 minutes with initial arrivals of 3 patients, we use 2 create modules, one is used to create the arrivals which creates maximum arrivals of 1 arrival of 3 entities and the first creation starts at 00:00 minutes. In the second create module the number of arrivals is 2 each 10 minutes, maximum arrivals is 1 and first creation time starts at 10:00 minutes. The decide module is used to decide whether the patient shows up or not, this is set to 90% to show and 10% for the no-show patients who are disposed immediately. Another decide module is used to determine the arrival type; 12:5% for new patients and 87:5% for follow up patients. Then the assign module is used to assign attributes to the patient type to individualize them; for new patients we assign doctor service time obtained from the data collected 4+Expo (1/4.86), where Expo(r) means the exponential distribution with rate r. For the follow up patients, we assignExpo (1/6.32) and for return patients we assign Expo (1/2.9). The priority for new, follow up and return patients is assigned higher than the priority for the no show patients. The process module is used to assign the process in which it determines the process time in that depends on patient type. The decide module is used to model whether the

patient is sent to lab test or disposed, from the collected data there are 9:5% of the patients that need lab test and then come back to see doctor again. The time for the lab process has the distribution 7.17+Expo (1/3.65). The last module is the disposed module that is used to model system leaving process. We run the model for 100 numbers of replications and time duration of seven hours. The statistical data collected were average waiting time per each patient on the doctor queue, average number of patient on the doctor queue and average utilization for the doctor.

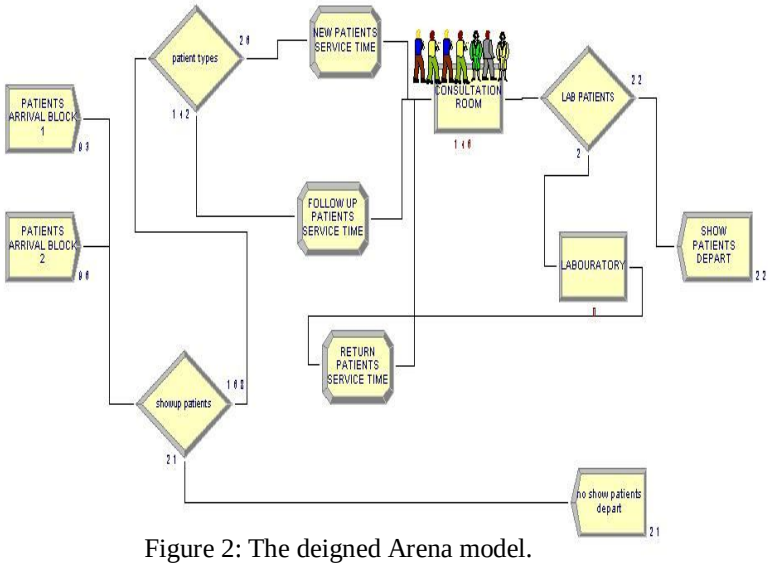

Figure 2: The deigned Arena model.

Table 4: The simulation result from Arena using the proposed schedules

index	scenario	average waiting time	average utilization of physician
1	(1,7,1)	4.605	68.04
2	(1,7,2)	1.8004	86.56
3	(2,7,1)	1.0742	79.93
4	(2,7,2)	4.94	87.6
5	(1,8,1)	6.384	71.93
6	(1,8,2)	5.45	70.99
7	(2,8,1)	8.1828	78.07
8	(2,8,2)	15.0163	87.44

5 CONCLUSION

In this research, we have considered the problem of designing an appointment system in health care system. Eight alternative systems have been modeled based on class 1, class 2 and class 4 appointment systems discussed earlier, and also according to the number of initial arrivals, time between appointments and number in each appointment. This is done in order to select the system that will minimize the patients waiting time in doctor queue, minimize the number of patients waiting in queue and maximize the

doctor's utilization. These systems are simulated using ARENA. From the result obtained in table 4 above, it is clear that the proposed and designed model gives a result which is better than the current clinic situation. The clinic can therefore choose from the best among the simulated scenarios.

REFERENCES

[1] Alrefaei M H, Nahila A B, Abulebda and Kayal K. Simulating and optimizing scheduling system of outpatient department. Proceedings of international conference on operational research and statistics (ORS 2011) April 7 - 8, 2011.

[2] Aliyu I Aliyu. Genetic algorithm for designing health care appointment system. Msc mathematics thesis at Jordan University of Science and Technology 2014.

[3] Bailey NT. A study of queues and appointment systems in in hospital outpatient departments with special reference to waiting times. Journal of the operational research society .vol 2 (1991) pp 845-855.

[4] Cayrli, T. E. Veral and H Rosen. Assessment of patient classification in appointment system design. Production and operations management. Vol 12 (2008) pp 338-353.

[5] Ho C and Lau H (1992). Minimizing total cost in scheduling outpatient appointments. Journal of management and science Vol 38 (1992) pp 1750-1764.

[6] Klassen, K and Rohleder, T (1996). Scheduling outpatient appointments in a dynamic environment. And assessment of patient classification in appointment system design. Journal of Production and operations management. Vol 14 (1996), pp 83-101.

[7] Babes M and Sarma G V. Outpatient Queues at the Ibn-Rochd health center. Journal of Operation Research Society 1991; 42(10), pp 845-855.

[8] Sickinger, Rainer Kolisch. The performance of a generalized Balley-welch rule for outpatient appointment scheduling under inpatient and emergency demand. Journal of Health care management science 2009; 12(4), pp 408-419.

[9] A. M. Law, W. D. Kelton, Simulation Modeling and Analysis. McGraw-Hill, New York, (1991).

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