Improving Outpatient Waiting Time Using Simulation Approach

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Abstract—The waiting time for patients in outpatient departments of university hospitals is a problem throughout the world. Outpatient departments face increasing pressure to improve the quality of their services through effective appointment scheduling in an effort to reduce waiting time. We analyzed the appointment scheduling system in the Obstetrics Gynecology Department at King Abdulaziz University Hospital, Jeddah, Saudi Arabia, in order to construct a simulation-based decision support (SDS) system for the evaluation and optimization of scheduling rules and waiting time. The SDS system analyzed three various appointment scenarios and examined in comparison with the current situation to determine prioritization rules so that a service guarantee to a maximum number of patients. The system was able to identify a number of critical factors that influenced patient waiting time and the formation of long lines in the clinic. Sensitivity analysis indicated that patient waiting time could be reduced by 26.3% without requiring extra resources. Modifying the scheduling scenarios by adjusting the distribution of patients based on their type (new, follow up, ...) for outpatient appointments can significantly improve patient waiting time in the clinic.

Keywords— outpatient scheduling; Average Waiting Time; Simulation Modeling and Analysis; simulation-based decision support system

I. INTRODUCTION

Saudi Arabia’s population growth, being among the fastest within the Arab countries, opens up KSA for a vast array of growth opportunities, recorded growth rate of 4.3% and 4.6% in 2013 and 2014, respectively [1]. Outpatient scheduling when left unmanaged, staff overloads, unmet patient needs, and general frustration will be produced. Therefore, there is a clear need for computer simulation tools that provide insight into the dynamics of patient flow in clinics and hospitals.

King Abdulaziz University Hospital (KAUH) is one of the largest university hospitals in the kingdom (800 beds). The hospital has two sections – public and private – that serve numerous patients. In 2012, KAUH had 250,915 outpatient appointments in 13 outpatient departments. One of the largest departments in the hospital is the Obstetric and Gynecologic (Ob-Gyn) Department, which has served a population of 160,000 in the last five years, diagnosed over 25,000 patients each year, and has a total of 29 consultants. There are 10 different clinic sessions (one consultant per session) that take place within the department each week (Sunday through Thursday mornings and afternoons). The number of patients per clinic, waiting time, and no-show rate differ dramatically among consultants.

Generally, patients have to wait a significant amount of time before being examined and treated. The main areas that have a significant impact on patient waiting time are appointment scheduling, availability of resources, patient routing, and flow schemes. A consistent and coherent approach is needed to devise new schedules for the different types of sessions as each session involves different resources.

In this study, we focused on calculating Weighted Average Patient Waiting Time (WAPWT) by implementing a simulation-based decision support (SDS) system to optimize outpatient scheduling and patient waiting time at university hospital. The major steps for developing the system are: i) study the Ob-Gyn clinic workflow, ii) collect data, iii) develop the baseline simulation model using Arena® Software (Rockwell Automation Technologies, Inc., version 13.90), iv) validate and verify the prototype system, and v) analyze different scheduling scenarios to identify appropriate improvements.

The remainder of the paper is organized as follows. Section II provides related works. Section III describes the workflow and the scheduling technique at the Ob-Gyn department. In section IV we detail our data sources. Simulation model development is provided in Section V. Section VI describes the experiments and measures used to evaluate different scheduling strategies. Finally, Section VI and VII present preliminary results, and discuss conclusions and practice implications.

II. RELATED WORKS

The increased demand for health care and outpatient clinics has inspired many researchers to investigate enhancement of health care services [1]. A number of modeling techniques are used to organize scheduling for patients, physicians, nurses, and other health care staff and
to increase the utilization of other health care resources. Most studies aim to improve the quality and delivery of health care services[2] and [3] noted that over the last few decades simulation models have focused on studying patient flow through performance analysis and optimization [4] and allocating assets to enhance health care performance [5], [6], [7], [8].

Outpatient service flow has been classified into three elements [9]: person flow, supply flow, and information flow. The first two flows from the main processes that operate a hospital’s normal outpatient services, while the third flow can significantly affect the flow of the other two elements [9]. Thus, Health Information Systems (HIS) was introduced to transfer the information via a computer network [9]. Patient waiting time has been reduced using HIS, which facilitate many hospital processes for the patient. Registered hospital patients have a flexibility to pay and to select any directly at the separate clinic or the doctors, also any supplementary tests can be finished at any checkpoint. Additionally doctors can perform some of the hospital management processes, which speed up the work.

Some studies have focused on simulating appointment scheduling for patients [10] without increasing resources such as: senior house officer, consultants, registrars or specialists, audiologists and receptionists. The study was concluded by proving that a dramatic reduction in patient waiting time without adding any type of the resources.

One study simulated the impact of merging several factors, such as operations, scheduling, and resource allocation, on patient waiting time [11]. The best outcomes were obtained when multiple changes were implemented simultaneously; these reduced patients waiting time by up to 70% and physical space requirements by 25% with the same appointment volume [11].

III. DESCRIPTION OF THE OB-GYN DEPARTMENT (PROCESS MAPPING)

A. Patient Types

In the Ob-Gyn department, there are number of different patient types, which vary based on their booking method. Table 1 illustrates a summary of patients served by the Ob-Gyn clinic in KAUH.

<table>
<thead>
<tr>
<th>Patient type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>A patient who is visiting the outpatient clinic for the first time</td>
</tr>
<tr>
<td>Follow-up</td>
<td>A patient who has visited the outpatient clinic before with the same medical complaint</td>
</tr>
<tr>
<td>Walk-in</td>
<td>A patient who arrives at the outpatient clinic without having an appointment</td>
</tr>
<tr>
<td>Extra</td>
<td>A patient who arrives at the outpatient clinic without having an appointment and no need to collect his patient file</td>
</tr>
</tbody>
</table>

B. Scheduling Rules

KAUH has no call center; patients must make an appointment at the front desk. All Ob-Gyn appointments are made through the central appointment desk in the hospital or at the clinic. There are two different types of appointments: regular booking (new and follow-up) and walk-in, or extra.

The appointment rule at the hospital that is currently practiced requires fixed intervals between two successive appointments and assigns two slots for new patients and one slot for follow-up patients. The hospital does not accept more than five new patients, 35 follow-ups, and five walk-ins per clinic session, but these figures vary among clinics. For example, in 2012, an experienced consultant had over 2000 outpatient visits, whereas a new consultant had 200 outpatient visits.

C. Patients Flow Logic

As shown in Table 1, there are many different types of patients visiting the clinics. They have varying healthcare needs and different care pathways through the clinic and the hospital.

The workflow of the Ob-Gyn Department is illustrated in Fig. 1. The steps are described as follows:

1. The patient arrives at the department’s reception area for registration. If the patient is a walk-in (has no booking), she will be scheduled in the system right away and wait until her file is received by the department. If the patient’s file is not needed, the patient will be considered an extra.

2. The patient (all types) then waits in the waiting room until she is called for screening. There is one screening nurse and one screening room for the entire department. The screening nurse records the patient’s vital signs.

3. The patient returns to the waiting room and waits for the doctor to see her.
   a. If the patient is new, she has to visit the intern prior to the consultation with the doctor.
   b. If the patient is not new, she will see the resident, the registrar, or the consultant.

4. When the consultation is over, she proceeds to the reception area to book her next appointment if needed.

5. If the doctor requests blood tests or x-rays, both are performed outside the clinic; at laboratory and x-ray department, such services are shared among all hospital departments, booking and scheduling are handled at their sites.

Although the clinic’s structure may seem simple, it is complex in its procedures, which makes it difficult to identify appropriate interventions, modeling will support
in identifying the performance problems and options for improvement.

IV. SIMULATION MODEL DEVELOPMENT

Our goal is to create a simulation model that reasonably reflects real-life situations. There are two groups of data: treatment-related and appointment-related. For one session, the treatment-related data include patient type, start and end time of the treatment service, and patient log-on and log-off times for the consultation service. The appointment-related data consist of physician schedules, patient appointment time, appointment type, and no-show data. Other modeling components, such as patient flow paths, routing probabilities, and scheduling

Figure 1. Patient Flow Diagram.
rules, are represented accurately in the model. Most of the required data are not available in the electronic medical records; they are collected manually by observing patients and by interviewing administrators, doctors, nurses, and clerical personnel.

The data were collected over a period of one month. Data collectors were assigned to track physicians and patients; no personal patient information was included in the data collection. A post analysis was conducted to test the inter-rater reliability between data collectors to ensure that all observers had consistent views of the individual tasks being performed.

Several challenges were identified in the process of observing the patient flow and collecting data for use in the simulation model. Most notably, the medical staff tended to move between several tasks for short durations, we decided to merge some short tasks to keep the model reasonably simple. Another challenge was that there are several ways to exit the clinic, which made it difficult to track patients.

The next step was to analyze the accumulated information. Three primary performance measures were chosen to quantify the impact that changes to the clinic’s process might have: a) waiting time, b) the number of patients who had seen during the observation period, c) patient throughput, and d) service time.

A. Waiting Time

The distributions of the waiting time for the patient at the Ob-Gyn Department are: i) patient waiting time for registration, ii) patient waiting time for the screening nurse, and iii) patient waiting time for the consultation. Walk-in and extra patients must wait for their files to be collected as well.

Table 2 shows statistics for waiting time for one session and is classified by patient type. For each patient type, the table shows the total time a patient spent in the clinic, the average waiting time for screening, the average waiting time for consultation, and the percentage of patients who wait longer than the average waiting time (64.85 min) for their 1st service.

Our data analysis results reveal that:

- Patients had long waiting time for the doctor consultation even when their consultation only took a few minutes. For example, if the total time from arrival to departure had a value of 100, then 70% was recorded as consultation waiting time. This percentage was higher for the other two types of patients (new and walk-in).
- The average waiting time is 64.85 minutes (standard deviation [SD] 42.72).

<table>
<thead>
<tr>
<th>Patient type</th>
<th>Average waiting time for consultation (min)</th>
<th>% of patients wait 64.85 min for 1st service</th>
<th>% no Show</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>70.33</td>
<td>66.66%</td>
<td>5%</td>
</tr>
<tr>
<td>Follow-up</td>
<td>64.56</td>
<td>42.59%</td>
<td>19%</td>
</tr>
<tr>
<td>Walk-in</td>
<td>18</td>
<td>100%</td>
<td>NA*</td>
</tr>
<tr>
<td>Extra</td>
<td>11.38</td>
<td>0%</td>
<td>NA*</td>
</tr>
</tbody>
</table>

*: Not Applicable

B. Arrival Pattern

An important factor that affects patients’ waiting time is the length of the waiting queue compared with the number of patient arrivals in the clinic as well as the number of patients examined and released (patient throughput). Patients have fixed appointments; however, there are always patients who do not arrive on time, who arrive as extras or walk-ins, who are delayed, or who arrive early. Figure 2 shows the length of the queue in 20-minute segments from 1:00 p.m. – 4:00 p.m. in an average day. Based on the figure we conclude that the distribution of patient arrival pattern is Lognormal with the expression -0.5 + LOGN (4.97, 8.26) and square error of .0096.

The inter-arrival pattern distribution reflects the throughput of the system. Figure 3 shows the histogram of the inter-arrival pattern in which we can observe that increasing patients’ arrival rate will result in increasing the waiting time, the total number of served patients, and the utilization of staff, changes must be made in order to develop an effective arrival policy.
C. Service Time

In the Ob-gyn clinic, there are four processes: registering, screening, primary checking for new patients, and consulting. Collected data show that registration time is very small (has no significant to the model) and the screening time ranges from one to two minutes.

Table 3 shows statistics for the consultation time of one experienced consultant session. Figure 4 shows the service time distribution for the consultant in which we find that the distribution represents Lognormal with the expression of $0.5 + \text{LOGN}(12, 10.5)$ and square error of $0.005432$.

**TABLE 3. CONSULTATION TIME STATISTICS BY PATIENT TYPE**

<table>
<thead>
<tr>
<th>Patient type</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Variance</th>
<th>95% confidence</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>2</td>
<td>113</td>
<td>70.33</td>
<td>59.79</td>
<td>10.55</td>
<td>130.12</td>
</tr>
<tr>
<td>Follow-up</td>
<td>2</td>
<td>153</td>
<td>64.56</td>
<td>42.32</td>
<td>22.23</td>
<td>106.88</td>
</tr>
</tbody>
</table>

![Figure 4. Service Time Distribution.](image)

The data collected from the clinic used to develop the one-session overbooking simulation model. The model assess to estimate patient waiting time, the number of patients served in one session, the total time spent in the clinic, and the number of hours the clinic stay open.

Figure 5 illustrates the simulation model based on the workflow described in the previous section. Several assumptions were made based on the data collected:

- Registration time is insignificant compared with the waiting time and consultation time. Therefore, registration time was not considered in this study.
- The screening time tends to be constant value of around one minute with function $0.5 + \text{EXPO}(0.894)$, which can be dismissed.
- Each patient visits once during the day.
- A patient’s early arrival is not considered.
- The nurses who assist the doctors do not impose or become a constraint in the model.
- The system is not based purely on appointments; walk-in and extra patients are accepted and appointments are scheduled for after the final appointment. If the walk-in patient arrives 30 minutes before the clinic closes, she will not be accepted.

Parameters in the simulation model are as follows:

- walk-in patients did not exceed 5% of the total patients
- a period of 25-30 minutes was required to get a walk-in patient’s file
- patients are assigned to a consultant; however, if the consultant is busy, the resident doctor or the registrar doctor can consult with the patient
- the patient consultant is determined as follows:
  - 7% of patients assigned to consultant 1 were seen by that consultant, and 3% of patients assigned to consultant 1 were seen by the team
  - 6% of patients assigned to consultant 2 were seen by that consultant, and 4% of patients assigned to consultant 2 were seen by the team
- we focused on an afternoon sessions (1:00 p.m. – 4:00 p.m.) because that is when most appointments are scheduled
- The simulation ends by serving all patients who enter the clinic.

D. Model Validation

To validate our model, the modeling approach was compared with the original data. The results in Table 4 show the average total waiting time (in minutes) for patients that is classified by patient type. The tolerance of our simulation model is between 0.23% and 5.1%, with the exception of extra patients in which the tolerance value is 30.3%, the tolerance value may be different because extra patients are greatly varies in their arrival pattern.

**TABLE 4. ORIGINAL VS. SIMULATED APWTA IN MINUTES**

<table>
<thead>
<tr>
<th>Patient type</th>
<th>Follow up</th>
<th>New</th>
<th>Walk-in</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>21.00</td>
<td>30.5</td>
<td>45.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Observed</td>
<td>20.95</td>
<td>29</td>
<td>51</td>
<td>16.5</td>
</tr>
</tbody>
</table>

V. SCHEDULING EXPERIMENTATION

To represent a single performance measurement for all types of patients together, we developed our own formula similar to the weighted average patient waiting time (WAPWT) [12], the main difference the new WAPWT will be calculated using the following formula at equation 1:

$$WAPWT = \frac{(APWTA_{walk-in} \cdot x) + (APWTA_{new} \cdot y) + (APWTA_{walk-in} \cdot z) + (APWTA_{extra} \cdot t)}{x + y + z + t}$$

Where:

- APWTA is the average patient waiting time for booked patients
• APWTW is the average patient waiting time for walk-in patients
• APWTN is the average patient waiting time for new patients
• APWTE is the average patient waiting time for extra patients
• NA is the number of patients with appointments
• NS is the number of walk-in patients
• NN is the number of new patients
• NE is the number of extra patients

We used the current scheduling as a reference in comparison with the suggested alternative scheduling in order to find the optimal outpatient scheduling with minimum index-weighted average patient waiting time (WAPWT). The schedules examined revealed that new patients significantly affect waiting time for all patients because they require many of clinic's resources for long period. Therefore, changing the service order of the new patients and/or its percentage are key factors in decreasing waiting time. We tested three scheduling types and two different percentages 30%, and 40% to be allocated for new patients, 30% reflects the current situation and 40% test what-if number of new patients increased by 10%.

Figure 5. Arena® Flow Chart
The following section discusses three alternatives scenarios:

Scenario 1: New patients served first
First schedule tested served the new patients at the beginning of the day. New patients were not accepted as walk-ins.

Scenario 2: New patients in blocks
Block bookings are used in this scheduling technique the size of each block varying between 3 - 4 patients. After one block of various patient types are served, one new patient is served.

Scenario 3: New patients served last
This is the same as Scenario 1 except that new patients are served at the end of the day rather than at the beginning of the day.

VI. ANALYSIS RESULTS

The results for the models based on each of the three schedules tested are listed in Table 5.

<table>
<thead>
<tr>
<th>Schedule Number</th>
<th>Average waiting time for follow-up patients</th>
<th>Average waiting time for new patients</th>
<th>Average waiting time for walk-in patients</th>
<th>Average waiting time for extra patients</th>
<th>WAPWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>64.56</td>
<td>70.3</td>
<td>30.1</td>
<td>4.7</td>
<td>24.80</td>
</tr>
<tr>
<td>New at first</td>
<td>33.3</td>
<td>25.5</td>
<td>57.8</td>
<td>18.5</td>
<td>30.85</td>
</tr>
<tr>
<td>Blocks</td>
<td>5</td>
<td>2.8</td>
<td>31.8</td>
<td>5.1</td>
<td>6.52</td>
</tr>
<tr>
<td>New at last</td>
<td>28.9</td>
<td>35.7</td>
<td>57.8</td>
<td>18.5</td>
<td>30.85</td>
</tr>
</tbody>
</table>

A. Results for New Patients (30%)

The collected data analysis shows that the new patients represent 30% of the total patients served. Figure 6 illustrates the results of APWTN with increased patient number in which serving new patients last leads to the same current scheduling, while serving them first leads to better results. This figure also illustrates that the second schedule, which serves the new patients between blocks, is the most efficient schedule with results showing an average reduction of 16.6 % at the highest patient rate in comparison with the current schedule.

Figure 7 shows the same results for follow-up patients in which serving new patients first and last has longer waiting time than the current schedule, while the block schedule is the most efficient with an average reduction of 8.3% in comparison with the current schedule.

Considering the effect of walk-in and extra patients, we calculated the weighted average patient waiting time (WAPWT) given by equation 1. Figure 8 shows the results of this parameter in which schedules serving new patients first and last have nearly identical waiting times as the current schedule, while the block schedule is still the best schedule with an average reduction of waiting time by 12.5%.

B. Results for New Patients (40%)

In this scenario, we increased the number of new patient over the normal percentage. Figures 9, 10 and 11 show the results of increasing new patients from 30% to 40%. The results show improved waiting time for the new and follow-up patients by 18% and 10%, respectively. The WAPWT indicator is nearly identical with no improvements.
VII. CONCLUSIONS AND FUTURE WORK

The current situation with most Saudi university hospitals outpatient department is one in which patients are often waiting for an unacceptable length of time for service, which may be up to one hour (64.85 min) on average. For some patient types, the waiting time is about 70 minutes. In this study, we have researched the complex flow of outpatients through the Ob-Gyn department that treats over 25,000 patients each year where several different appointment schedules have been examined.

Three key performance indicators of improved patient waiting times measured the effectiveness of the proposed schedules. The results show that patient wait time can be significantly reduced with more efficient schedule planning and improved management.

A simulation analysis was performed on an outpatient department of a university hospital in Saudi Arabia. Results show that under the existing system, patients have to wait long periods of time for consultations that only last a few minutes. The experimentation process focused on this issue in an effort to decrease the waiting time by identifying an optimal schedule for both patients and doctors.

The impact on WAPWT was analyzed to identify an optimal DSM using an optimization program. The program identified an optimal scenario that could reduce the average waiting time by 26%. Another scenario was identified that could save 61 hours of patient waiting time per day by employing 29 doctors instead of the 31 doctors employed in the existing system.

Immediate future work associated with our model is to consider implement the changes suggested by the model at the clinic and then evaluated the system performance to determine if the implemented changes resulted in real improvement. In addition, with the acceptance of the simulation approach SDS system can be developed integrated with the daily outpatient scheduling process for real-time online simulation.

C. Effect of New Patient Percentage

Increasing the number of new patient had negative effect on average patient waiting time. Figure 15 shows the comparison between the current schedule and the block schedule when new patients are at 20%, 30%, and 40%.
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