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A Simulation Modelling Study: The Case of Department of Gynaecology and Obstetrics of A University Hospital, Turkey

Bir Üniversite Hastanesinin Kadın Hastalıkları ve Doğum Bölümü'nde Simülasyon Modelleme Çalışması

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ABSTRACT

Patient waiting time is a significant topic in all services of medical institutions. It has considerable effects on patients' satisfaction. Particularly long waiting times and long queues of patients are one of the prominent problems that are to be dealt with by hospital administrators. The aim of this study is to offer structural suggestions to reduce waiting times and increase efficiency of staff at one of the busiest departments, Department of Gynaecology and Obstetrics of a university hospital in Ankara. Simulation technique is used in order to achieve this goal. ARENA software is employed, possible scenarios are developed and several recommendations are made. Due to these scenarios, minimum patient waiting times were achieved. It can be said that all these scenarios can be useful in planning workforce, increasing satisfaction of patients and reducing queues at the department.

Keywords: Simulation, waiting time, hospital

ÖZET

Hastaların memnuniyet düzeyleri üzerinde önemli bir etki yaratan hasta bekleme süreleri, sağlık kurumlarında sunulan her hizmet alanında dikkat çeken bir durumdur. Özellikle uzun bekleme süreleri ve uzayan hasta kuyrukları, hastane yöneticilerinin çözmesi gereken problemlerin başında gelmektedir. Bu çalışmanın amacı da Ankara'da bulunan bir üniversite hastanesinin en yoğun bölümlerinden birisi olan Kadın Hastalıkları ve Doğum Bölümü'nde hastaların kuyrukta bekleme sürelerini azaltıcı ve personelin de çalışma oranını artırıcı yapısal öneriler sunabilmektir. Bunu gerçekleştirmek için simülasyon tekniğinden yararlanılmıştır. ARENA yazılımı kullanılarak gerçekleştirilen simülasyon çalışması sonucunda elde edilen sonuçlar doğrultusunda ise olası senaryolar geliştirilmiş ve birtakım öneriler sunulmuştur.

Anahtar Kelimeler: Simülasyon, bekleme süresi, hastane

1. INTRODUCTION

Simulation is a modeling approach applied to several problems that can occur in administration and processes of health institutions (Özcan, 2005). Although simulation technique is a helpful tool in system analysis of health institutions, it has not become a common method as it is in other systems. The use of simulation technique is increasingly becoming popular in analysis of health systems in recent years (Sönmez, 2009).

Simulation technique is a method of analysis that models work flows of a task in the computer environment; by applying the developed model, the technique helps to gather valid data about the system's behaviors (Taha, 2007). Simulation is used in predicting directions and outcomes particular decisions, determining causes of observed results, revealing the effects of changes, finding all system variables, assessing ideas and identifying their ineffectiveness, developing and encouraging generation of a new idea and in testing integrity of the whole plan (Özdağoğlu, 2009). Simulation technique enables to simulate real events, whose applications would have considerable costs, in the computer environment; it

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also provides hundreds of alternative models for the implementers to choose (Aksaraylı et al, 2009).

The main aim of the simulation study is to present information about change inclined system through proofs produced from simulation technique (Brosh, 1985). Simulation technique has several advantages. It is easily understood, methodology can be used as a model and it provides information about the behaviors of complicated systems. Besides, simulation models are flexible. They offer a research laboratory for the real system. In terms of health institutions, the main advantages of simulation technique are reducing patient waiting times, optimization of resource use in health institutions, decreasing transaction costs, enhancement of service-performance level, enhancement of facility locations, examination of capacity requirement and examination of change reforms (http://www.efficiencyengineers.com) One disadvantage is that complicated systems made simulation technique time consuming and costly (Anderson et al, 2011).

Simulation model has two different types. The first type, continuous models, deals with constantly changing systems. The second type, discrete simulations, only follows behaviors of systems in a particular given time. A typical example for that is the prediction of an average waiting time in a line and the length of waiting line (Taha, 2007). Simulation is also used for designing queue systems, communication networks and stock control. The technique of modelling with simulation, particularly waiting line models are very complicated, therefore fruitful outcomes are acquired (Taha, 2007; Krajewski et al, 2013)

Simulation models, just like other tools of decision, should be made in a systematic way. First the current problem should be defined and goals should be set. The second step of simulation model is testing it. Here, it is important that the model developed reflect the reality or not. If the results are unexpected, the conceptual model and its parameters should be examined until the model produces satisfactory results (Özcan, 2005) Simulation process consists of four different stages. These stages are data collection, random number assignment, model formulation and its analysis (Krajewski et al, 2013).

Literature review on simulation model use in health institutions, particularly in hospitals, showed that the model is mostly used by emergency services and clinics. For instance, Levy et al. (1989), Guo et al. (2004) and Hashimoto and Bell (1996) studied on capacity planning in clinics. One common feature of these studies is that they all considered patient waiting times in "micro" level (Günal and Pidd, 2010; Sezen, 2012). In their research, Levy et al. (1989) developed a simulation model of a new outpatient services centre in South Carolina. They combined existing outpatient sevices within the hospital with offsite services at the outpatient diagnostic centre. The analysis of facility utilization rate, patient waiting and flow times and the number queues in the clinic was simulated using the model. Therefore a minimum facility design requirements was determined based on the expected demands. In their research, Guo et al. (2004) constitute a simulation model for the evaluation and optimization of scheduling rules in the Division of Pediatric Ophthalmology. Hashimoto and Bell (1996) used a computer simulation to assess patient flow in an outpatient internal medicine clinic. They subsequently identified inefficiencies, implemented interventions, and successfully reduced patient wait total times in clinic from 75.4 minutes to 57.1 minutes.

Duguay and Chetouane (2007) aimed to reduce patient waiting times, ameliorate service and increase the efficiency of system by employing simulation at an emergency service of a hospital, in Canada. In this research they considered physicians, nurses, and examination rooms as control variables. Five alternatives were designed for different variable settings. Then they used discrete even simulation model to evaluate key performance improvements. In this study each alternative was simulated for each day using ten replications of 12-h lengths. Three of these alternatives yielded a significant improvement of sojourn time and waiting duration. According to these scenarios decrease of up to 2 h was achieved compared to the actual situation in the emergency department.

Komashie and Mousavi (2005) used simulation technique at an emergency unit of hospital in London, in order to help administrators to understand the behaviors of the system. This study allowed administrators to understand the system and how patient flow is affected by changes in processes and status of sources. Ahmad and Alkhamis (2009) benefited from simulation technique as a decision support system in running an emergency service department in a public hospital in Kuwait. They used simulation in order to reduce patient waiting times and calculate optimum numbers of doctors, laboratory technicians and nurses for maximizing efficiency. In this study a comprehensive survey prepared and used in the interview with doctors, nurses and hospital personel in charge. They presented a optimization simlation model and this model provides optimal staffing allocation that would allow 28% increase in

patient throughput and an average of 40% reduction in patients' waiting time with the same resources. In their research, Paul and Lin (2012) applied simulation technique at an emergency department of a hospital and found out that the slowness of transactions for patient admission and the problems encountered about feedback times of laboratory and radiology test units resulted in congestion. It was found that if these issues are resolved, waiting time at the emergency service will reduce by 18%. Gül et al. (2012) created 10 different scenarios based on patient length of stay, resource utilization rate and performance criteria for patient efficiency in emergency department of a hospital using simulation model. Gül and Güneri (2012) studied a discrete-event system simulation model of the ED of a university hospital which serves about 40.000 patients annually in Elazığ. In this study they changed shift hours and increased the quantity of doctors and nurses worked in evening shift. This simple change provided a significant improvement of 30% in average patient length of stay.

Studies dealing with paint flows generally examine patient admission policies. For example, in Brahimi and Worthington (1991)'s research, different appointment systems were analysed. The research focused on reducing usage rate of doctors and patient waiting times (Sönmez, 2009). In a similar study, Najmuddin et al. (2010) developed a simulation model at the department of Gynaecology and Obstetrics in order to analyse multi-stage patient flow system. Their simulation model was used to reduce patient waiting time and increase service quality at the department of Gynaecology and Obstetrics. Rohleder et al. (2011) applied a simulation model at an orthopaedic clinic in Alberta to rehabilitate support processes. The analysis of data acquired prior and in conjunction with application showed that average waiting times at the clinic have been considerably reduced. Suo and Yau (2006) examined admission process in a public hospital in Shanghai, calculated patients' time of arrival and duration of each transaction and analysed work flow and transaction times by using simulation technique. VanBerkel and Blake (2007) analysed patient waiting lists in at a surgeon clinic in Canada. They used simulation technique to analyse section performance and to assist capacity planning. They constituted standard patient lengths of stay and combined options for stabilizing and decreasing waits for selective procedures were proposed. Wijewickrama and Takakuwa (2006) studied on an internal clinic of a university hospital and made a simulation study in order to examine doctor programs and different appointment programs for several types of patients. The research showed that patient waiting times can be reduced without extra sources and through integration of doctors' programs with some different appointment programs by using optimisation program. Elkhuizen et al. (2007) did a simulation research at the departments of Neurology, Gynaecology and Obstetrics to analyse capacity that is needed in appointments, depending on hospital sources. In this study was proposed the extra capacity needed for neurology department and taking into account variations in demand for different weekdays and a realistic schedule for doctors' consultations. Bai-lian et al. (2010) also used a simulation model at a public hospital in China in order to determine distribution of waiting times and to search the effects of potential precautions in reducing waiting times. According to this model, a flexible management of doctor scheduling and introduction of an appointment system may reduce waiting time for outpatient. Ajami et al. (2011) collected data from 663 patients in their research on reducing waiting times at the emergency services; they also used simulation technique. The results indicated that there is a need of an extra intern at the department of Otolaryngology for reducing waiting time from 112.19 minutes to 99.24 minutes.

2. MATERIAL AND METHOD

The aim of this study is to offer structural suggestions to reduce waiting times and increase efficiency of staff at one of the busiest departments, Department of Gynaecology and Obstetrics of a university hospital in Ankara. In this study, Monday, Wednesday and Friday were chosen as representative days of the week with regard to past patient records and opinions of the staff. In our study, a time study was conducted during three weeks in the department for input modeling. During the weeks it is figured out that Mondays, Wednesdays and Fridays were the most crowded days, so the time study was piloted for that days during three weeks. Totally 194 patients' data were recorded for this study.

The patients are first arriving to the secretariat Office to register and if they are new arrival to the hospital they have to fill a form, but if the patient is a control patient (who came before and will show the results) he/she just register him/herself. After registering process the patients are going to examination room regarding to their purpose of coming. If they are control patient, they will be in thee examination room during the evaluation and explanation duration of test results of patients, if they are not control patient (new arrival), they will be in the examination room throughout their examination. For all type of

the processes in the examination room the doctors served he patients. All of the queue disciplines of the department is FIFO and we have enough space for all the waiting patients.

The durations that patience spent at the secretariat, start and end times of physical examination were followed by employing the observation method. The major problem occurred during data collection were that there is congestion of patients in front of doctors' rooms at particular hours (morning 8.30-10.30 and afternoon 13:00-15:00) and disorganization of patient traffic in the rooms, which caused difficulties in keeping records of examination durations. There are 14 rooms at the Department of Gynaecology and Obstetrics including 1 nursing room, 1 ultrasound room, 1, antenatal care room, 2 intern room and 8 physical examination rooms. The average number of patients in a day at the department is between 200 and 250. Appointments for physical examination for Gynaecology can be made by phone or through internet. Appointments for antenatal care can be made from the Obstetrics Policlinic. With the exception of Tuesday's training hours (until 12.00), physical examinations are done on weekdays between 8:30 and 17:00.

After three weeks the average number of patients was calculated considering the busiest days, and these averaged values were used for all days in the simulation model. For validating the information gathered from time study, the data from database of the hospital information system was used (Table 1).

Table 1: Number of Patients for Validation Process of The Similation Model

	Data gathered from Time Study	Data gathered from Information System
Working Hours	Number of Patients	Number of Patients
08:00 – 09:00	40	43
09:00 – 10:00	61	65
10:00 – 11:00	43	40
11:00 – 12:00	14	15
12:00 – 13:00	0	2
13:00 – 14:00	40	40
14:00 – 15:00	43	45
15:00 – 16:00	23	20
16:00 – 17:00	0	2
Mean	29	30
Variance	447,20	463,94
Standard Deviation	21,15	21,54

T-test was applied (and α = 0,1) to compare the results from two different sources and there is no evidence to conclude that the two systems is different. Same approach was applied to the other input models. The results obtained from the simulation model like patient waiting times, average utilization of resources, were verified by the personnel of the department.

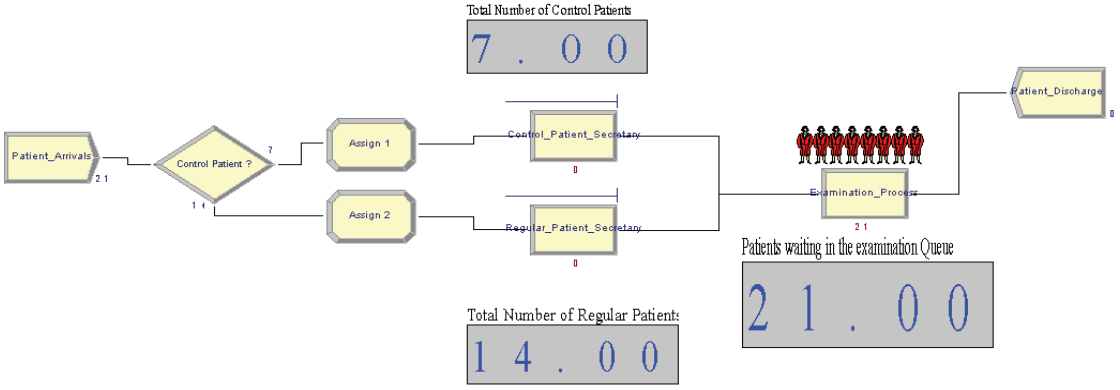

Figure 1: Simulation Model Used and Work Flow

After observation of times, collected data was used to form work flow (Figure 1) and in determination of probability distributions of processing times. The reasons for using simulation technique in this study are complicated structure and randomness of the health systems as people are the most important figures in these systems. Therefore, in comparison to analytical models, simulation models are closer to real systems. ARENA software (v.14) was preferred to apply simulation study. A computer with 4 GB RAM and 2.9 GHz processor was used to do simulation study. In the study, the following simulation model, created by ARENA software, is used.

3. RESULTS

Table 2 shows statistical data about the time spent at secretariat and the stage of physical examination of the patients, who visited Department of Gynaecology and Obstetrics. According to the table, average waiting time at secretariat for patients who came for control is 37 seconds (0.616') with a standard deviation of 0.191, average time spent for admission transactions for patients with reservation is 1 minute 52 seconds (1.87') with a standard deviation of 0.877, average time spent for patients with reservations at physical examination is 6 minutes 8 seconds (6.14') with a standard deviation of 3.2 and average time spent at physical examination for patients who came for control is 1 minute 50 seconds (1.84') with a standard deviation of 0.665. According to the results of chi-square test, there is a statistically significant difference between patients who came for control and who came with appointments in terms of. Average time spent at physical examination ($p<0.01$). The p-value is the largest value of the type-I error probability that allows the distribution to fit the data and the higher the p-value means, the better the fit.

Table 2: Statistics of Time Spent at Secretarial and the Stage of Physical Examination by Patients

	Times Spent at The Secretarial of Control Patients	Times Spent at Physical Examination of Control Patients	Times Spent at The Secretarial by Patients With Reservation	The Time Spent at Physical Examination by Patients With Reservation
Mean	1.84	0.616	1.87	6.14
Minimum	0.5	0.23	1.00	3
Maximum	2.93	0.95	4.17	18
Std. Deviation	0.665	0.191	0.877	3.2
Count	118	59	131	214
Prob. Distribution	Beta	Triangular	Beta	Gamma
Chi-Square p-Value*	0.005	0.249	0.005	0.0268
Kolmogorov-Smirnov p-Value*	0.15	0.15	0.046	0.010

(**Note:** *p 0.01 was taken as level of significance)

Figure 2. shows distribution of times that were spent by patients with reservations. According to these result, distribution of times fits with gamma distribution.

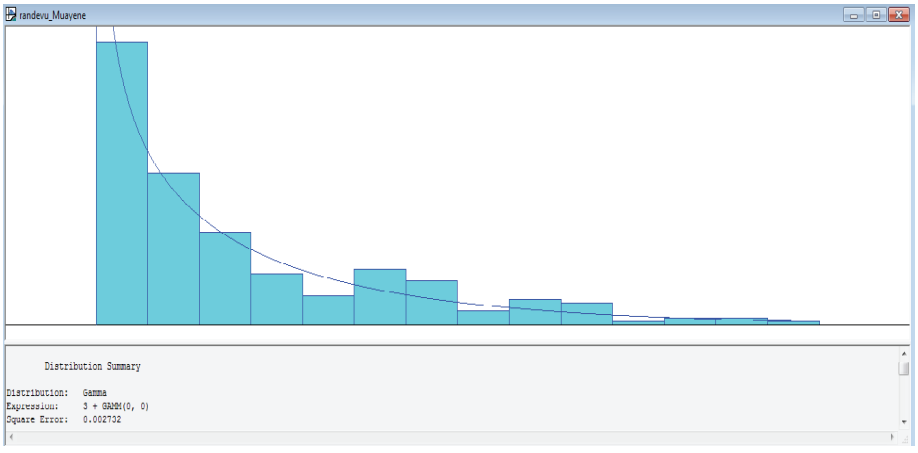

Figure 2: Statistics of The Time Spent at Physical Examination by Patients with Reservation

Figure 3. shows distribution of times spent at the secretarial by patients with reservation. As it is seen on the graph, distribution of times fits with beta distribution.

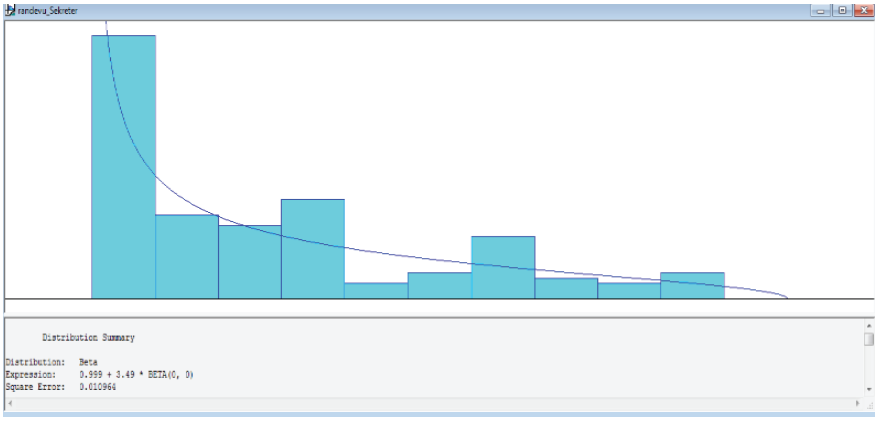

Figure 3: Distribution of Times Spent at The secretariat by Patients with Reservation

Figure 4. shows distribution of times spent at the secretarial of control patients. As it is seen on the graph, distribution of times fits with triangular distribution.

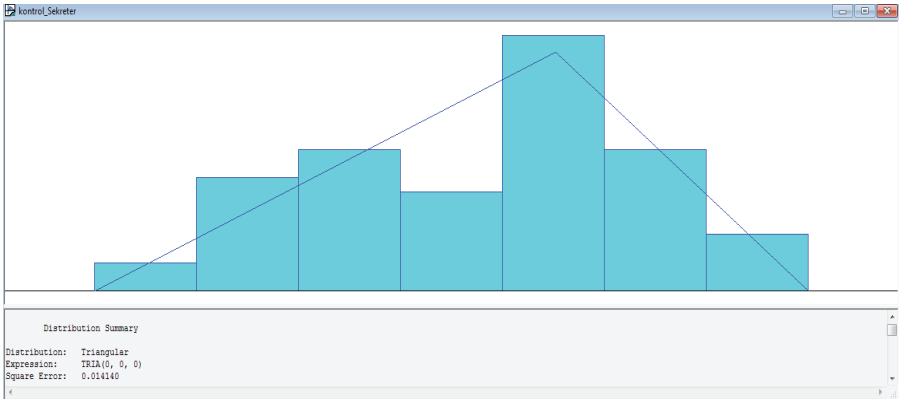

Figure 4: Distribution of Times Spent at The secretariat of Control Patients

Figure 5. gives information about distribution of times spent at physical information of control patients. As it is seen on the graph, distribution of times fits with beta distribution.

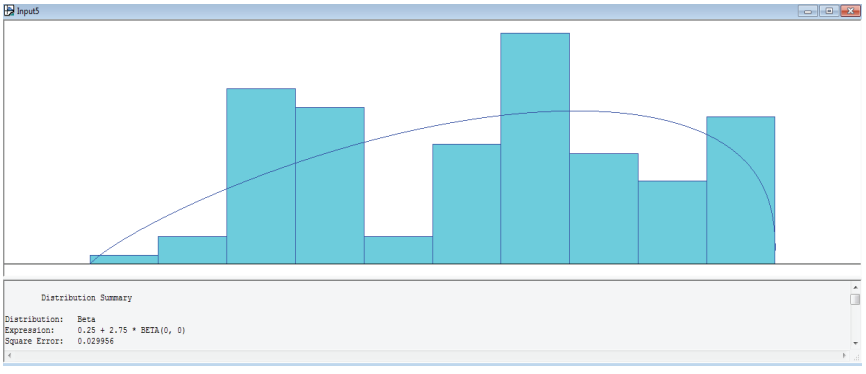

Figure 5: Distribution of Times Spent at Physical Examination of Control Patients

Table 3 indicates number of patients and doctors that were used in simulation program. Number of secretaries for each day is 4. Data on table shows a duration of one week. Arena software allowed repeating it 1000 times (with a total number of 1000-week simulation). This study took 3.34 minutes.

Table 3: Number of Patients and Staff According to Working Days

Hours of Labor Patient Arrivals		Monday		Tuesday		Wednesday		Thursday		Friday	
		Number of Doctors	Patient Arrivals	Number of Doctors	Patient Arrivals	Number of Doctors	Patient Arrivals	Number of Doctors	Patient Arrivals	Number of Doctors	
08:00	09:00	40	0	0	0	40	0	40	0	40	0
09:00	10:00	61	4	0	0	61	4	61	5	61	4
10:00	11:00	43	5	0	0	43	5	43	6	43	4
11:00	12:00	14	5	0	0	14	5	14	6	14	4
12:00	13:00	0	0	0	0	0	0	0	0	0	0
13:00	14:00	40	7	40	8	40	7	40	6	40	6
14:00	15:00	43	7	43	8	43	7	43	7	43	6
15:00	16:00	23	7	23	8	23	7	23	7	23	6
16:00	17:00	0	7	0	8	0	7	0	7	0	6

The results acquired in simulation study are shown on table 4. According to the result, total number of patients in a week was found 1157. Average time spent by patients from their admission at secretariat to physical examination was calculated 21 minutes 39 seconds (21.66'). Average total time spent by a patient including times spent at secretariat and physical examination was found 28 minutes 15 seconds (28.025'). The work load rate for doctors was calculated 0.47 and 0.18 for secretaries. The findings coincide with the data obtained through observations.

Table 4: Waiting Times and Possible Scenarios of Staff Usage Rates

	Base	Scenario 1	Scenario 2	Scenario 3
Total Patient Number (Per Week)	1157	1156	1156	1117
Average Waiting Time	21666	21707	13650	10275
Total Time in System	28025	28065	20009	16636
Waiting time in Examination Queue	21591	21622	13535	10246
Waiting time in Secretarial Queue	0.075	0.085	0.115	0.029
Doctor Utilization	0.4771	0.5025	0.4612	0.465
SecretaryUtilization	0.1838	0.1960	0.245	0.177

In this study, three different scenarios were realised in order to achieve the aims. In the first scenario, the number of doctors was diminished to 5 and the number of secretaries was diminished to 2 for each working day at the least busy hours (16:00-17:00). According to this scenario, usage rate for doctors increased 3% and usage rate of secretaries increased 1% although there was no significant difference observed in patient waiting times. In the second scenario, the number of doctors was increased by 2 and the number of secretaries was diminished by 2 for each working day at the busiest hours (9:00-10:00). Accordingly, patient waiting time was not reduced although the number of doctors was increased. Usage rate of secretaries rose from 18% to 24%. In the third scenario, it was thought that patients were regularly visiting the department. The number of patients was assumed stable and equal for each hour. With regard to the weekly number of patients (1.157), it was considered that 33 patients visit the department in a working hour. In the third scenario found that 1117 patient can come to department weekly. According to this scenario, 52.6% decrease was observed in patient average waiting times. In addition, patient waiting times were reduced by only making visits of patients regular without employing extra workforce or bearing extra costs.

4. DISCUSSION

In this study, the processes of admission and physical examination were modelled Department of Gynaecology and Obstetrics of a university hospital. The study aimed to patience waiting times and increase efficiency of staff. In line with this aim, the system was observed, work flow was formed and simulation model was developed. After observations, the

average patient waiting times (28.025 minutes) were tried to be reduced by using recommendations. In the study, factors affecting patient waiting times are listed below after observations. These are:

- Provision of same reservation times for patients who can show results of inspections and physical examinations
- Patients that are examined by interns should collect their vouchers from the secretariat.
- Because there no electronic numbering system at the department, patients were not exactly sure about their physical examination time.
- Patients visit hospital considerably earlier than their reservation times and line up.
- Automation system at the secretariat sometimes slows down and sometimes does not work at all.
- Patients who come for policlinic appointments form unnecessary queues at the secretariat

According to the findings obtained from simulation modelling, it was observed that proper functioning of the reservation system and adaptation of employees to the system will reduce patient waiting times to a minimum level. In this context, some recommendations are made in resolving the identified problems. Accordingly, scenarios were developed. In the first scenario, when the number of doctors was diminished to 5 and the number of secretaries was diminished to 2 for each working day at the least busy hours (16:00-17:00), it was found that waiting times mostly remained same; however a smaller workforce can provide the same service. Following these results, working load of secretaries were increased in the second scenario and patient waiting times were reduced. In the third scenario, number of doctors and secretaries were remained same but visits of patients were equally distributed for each working hour. In doing so, minimum patient waiting times were achieved. It can be said that all these three scenarios can be useful in planning workforce, increasing satisfaction of patients and reducing queues at the department.

In the study, recommendations are made to reduce patient waiting times in queues and to improve hospital administrative policies. These recommendations are listed below:

- Electronic numbering system should be adapted at the department so that patients can be provided information about approximate times about their transfers to the physical examination room. This information may prevent congestion that occurs in front of the physical examination rooms.
- The variety of work done at the secretariat can be decreased (giving an appointment, giving a voucher etc.)
- New arrangements can be made for the reservation system (e.g. taking approximate duration of physical examination for a patient into consideration)

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