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Prevention of Emergency Density With Triage: Simulation-Based Analysis and a Model Proposal*

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Abstract

The rapid increase in emergency department admissions often leads to overcrowding, leading to disruptions in treatments, an increase in workload, a decrease in service quality, and the emergence of administrative difficulties. As in all service sectors, it is extremely important to make appropriate planning to provide quality and timely service in health enterprises. This study, conducted in a public hospital emergency department, proposes a new triage practice in emergency departments. According to the proposed triage practice, the duration of the patients' stay in the emergency room and the waiting time between processes are shortened, and appropriate personnel planning that will not endanger the health and safety of the patients has been arranged. According to the simulation data created based on the recommended triage practice, it was determined that the duration of stay of yellow-tagged patients in the emergency room could decrease by 44.45% and by 83.44% in the waiting time in the first examination queue. In addition, with the new personnel plan, it is foreseen that 20.24% of the working hours of the doctor, 30% of the working hours of the nurse, 40% of the working hours of the medical secretary, and 50% of the working hours of the registry staff can be achieved.

Key words: Emergency service, Simulation, Capacity planning, System analysis

JEL Code: C22, G02

1. Introduction

The pandemic process we are going through has shown how substantial a well-organized health system is. Although health system management is seen as a serious

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and professional job, countries approach it according to different priorities in line with the structure of the society, its needs, and the combination of available resources. With the high cost of health services, efficiency also gains importance. The cost increase in health services has caused increasing importance and controversy globally. However, regardless of the causes, rising costs are putting pressure on healthcare providers to improve the quality, efficiency, and economic management of their organizations (Marmor, 2010).

One of the most substantial components of the health system is undoubtedly emergency health services. Although the importance of the emergency department (ED) has come to the fore in the process we live in, EDs are currently one of the most important elements in the ordinary system. Emergency departments provide uninterrupted service to all types of patients, from life-threatening cases to light complaints, on a 24/7 basis. In addition to reasons such as population growth, increases in chronic diseases, increased accidents, etc., the health policies implemented and several reasons arising from the attitude of the society have increased the workload of EDs all over the world and continue to increase. The increased workload causes overcrowding in EDs, disruptions in service, and a decrease in service quality. On the other hand, ED density also paves the way for the emergence of managerial problems.

Emergency departments are health units characterized by unplanned patient arrivals. The primary aim of EDs is to stabilize the patient's health status until comprehensive treatment is applied. Uncertainty and high variability in patient arrivals are other factors that complicate the management of EDs.

There are many criteria that can be used to evaluate the performance of an AS (Tan, 2013). Common criteria include waiting time, number of patients leaving without examination, patient satisfaction, and staff satisfaction. In a study conducted to optimize ED operations (Wiler et al., 2010), it was reported that the length of stay in ED was the most widely used criterion to evaluate ED performance.

One of the most important factors affecting emergency service performance is patient density. The American College of Emergency Physicians (ACEP) Emergency Medicine Practice Committee defined ED crowding as "the situation that occurs when the number of patients exceeds the treatment area capacity". Bond et al. (2007:33) define ED crowding as "the situation that occurs when the demand for emergency services exceeds the ability to provide care in a reasonable time". According to Asplin et al. (2003:174), ED density can be determined by patients followed in areas where no treatment is provided (e.g. corridors), patients in ED treatment beds, or awaiting transfer to hospital inpatient wards, and patients who cannot be properly triaged by any triage assessment method.

Emergency service crowding is a serious public health problem (Di Somma et al.,2015:171; Kelen et al.,2016:737), and it is also an international health problem regardless of the healthcare system applied (Derlet and Richards, 2000:63-68; Hoot and Aronsky,2008: 126; Pines et al.,2011:1358-1370; Di Somma et al.,2015:171). According to the data of the Ministry of Health, annual ED applications in Turkey

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are around 114.5 million as of 2015 (https://khgm.saglik.gov.tr). Again, a study conducted in the USA (Barish et al., 2012) states that half of the hospital admissions in the country are ED applications.

Excessive patient density in EDs has a significant impact on the quality of service provided to patients. The desired quality of service is measured by the length of time the patient stays in the ED, from enrollment until ready to be discharged from the ED.

It has been stated that timely patient care has a strong correlation with patient satisfaction (Bursch et al., 1993). Also, Richards et al. (2000) stated that excessive patient density in ED may cause long waiting times for patients, which in turn may increase negative outcomes and risks. On the other hand, it has been stated that the increase in patient density causes a decrease in physician productivity (Rondeau et al., 2005).

Hospitals play a central role in the delivery of health services. As in every sector, planning in hospitals is vitally important for managers. It is necessary to make the most appropriate planning within the possibilities of the health institution to provide timely and quality service to patients, especially in units such as EDs that try to cope with problems such as high patient number and variability.

Implementing the possible results of changes in AS processes without testing them may lead to undesirable outcomes. The simulation method is a very useful method for hospital managers in terms of seeing and evaluating the possible results of the changes to be made at this point.

The simulation is an analogy of the real system. Owing to the simulation, the possible outcomes of the changes that are planned to be made in the real system can be seen in a short time, and the costs of time and process changes can be saved.

2. Purpose

The pandemic process we are experiencing is putting increasing pressure on institutions providing healthcare services around the world. This pressure has become even more evident especially in EDs. Hospitals' emergency departments often turn into an environment of chaos due to irregular and excessive patient admissions. In addition, the complex nature of ED processes causes this chaos to turn into a bigger problem. One of the methods that can be used to end the chaos by eliminating the tightness in ED is undoubtedly resource increase. However, resource increase is not a sustainable solution method due to both cost increase and physical impossibilities. In the literature, there are many studies on the solution of tightness in EDs. However, the majority of these studies are directed towards determining appropriate resource levels. It is thought that making changes in patient flow processes without compromising patient care and safety will contribute to the solution of the problem. This study offers a model proposal for better functioning of ASs, the most dynamic unit of hospitals. The study aims to reduce the intensity by shortening the length of stay of the patients in ED. It is thought that the presented method may shorten the length of stay of patients in ED, and increase patient and staff satisfaction.

It is thought that this study, which was carried out in a public hospital ED, can also be easily adapted to other EDs. Thus, it is envisaged that better service can be provided and savings can be made in EDs across the country.

3. Methodology

This study investigated the contribution of restructuring the patient flow process to patient flow in an ED without increasing resources. In this context, a simulation model of the Sivas Numune Hospital Emergency Department affiliated to the Ministry of Health was created and the preliminary findings of the system design that could function effectively were obtained by determining the existing troublesome points. Then, personnel levels that will minimize wasted time and increase the productivity of employees have been determined. In addition, the new triage application, which is expected to improve patient flow and reduce patient accumulation in the system, was tested and capacity planning was made.

Triage is the process of classifying and sorting the injured or patients admitted to the ED according to the urgency of their condition, and determining in which area of the emergency service they will be treated. The expected benefit of triage is better patient outcomes by reaching those who need it most clinically first. There is no universal triage system throughout the world, and countries use three, four, and five-level triage systems within the scope of their health policies. While three-level triage systems classify patients into three categories as non-urgent (green), urgent (yellow), immediate (red), the four-level triage system classifies patients into four categories as urgent, serious, stable, and non-urgent. Five-level triage systems are; The Manchester Triage System (MTS), the Australian Triage System (ATS), the Canadian Triage System (CTAS), and the Emergency Severity Index (ESI) used in the USA. ESI is a triage system in which the treatment priority of the patient is determined according to the number of resources to be used. Patients who need the most resources are evaluated in the first category and have priority in treatment. The patients in the fifth category are those who do not need resources (Christopher, 2005).

Real data is needed to create a simulation model of a system. For this purpose, ED records including the period of December 2018-November 2019 were obtained from the Management Information System (MIS) of the hospital where the study was carried out. Among the gathered information, the triage code of the patients, gender, age, application date, application time, number of patients, examinations and tests requested from the patient, consultation requests, the number of patients sent to the observation room and the entrance and exit times to the observation room, and the treatment given to the patients, and other transaction numbers. This information also includes the patient's entrance and exit time to the examination. However, this information is not useful because the patient-related procedures are not recorded in the system simultaneously. It is not possible to obtain time information about procedures such as examination, treatment, imaging, laboratory tests performed on patients during the process, from MIS records.

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To determine the processing times for each patient-related process, observations were made for the relevant processes and the processing times were determined. The durations related to the transactions for which sufficient data could not be collected in this way were found by taking the opinions of the relevant personnel of the ED.

The study was carried out with the active participation of the personnel working in the ED of the relevant hospital and with the help of the hospital deputy Chief Physician and the Management Information System (MIS) officers.

4. Literature Review

Simulation has been widely used in healthcare to find potential solutions to the problem of system inefficiencies (Kim et al., 2013; Giachetti, 2008; Huschka et al., 2008; Jacobson et al., 2006; Connelly and Bair, 2004; Swisher et al., 2001). There is rich literature on the use of simulation in modeling a wide variety of healthcare settings, such as hospital subsystems, outpatient units, emergency services, national health systems, transportation of the injured to hospitals in disaster situations, and the intensive care unit (ICU) of hospitals.
Laker et al. (2017) investigated the role that computer simulation modeling can and should play in the research and development of emergency care delivery systems. In that research, the areas where computer simulation modeling was used in research related to emergency care were discussed. The four main approaches to computer simulation modeling (Monte Carlo Simulation, System Dynamics Modeling, Discrete Event Simulation, and Agent-Based Simulation), problems with their use, and examples of emergency care are described. It also covers an introduction to existing software modeling platforms and a research agenda for computer simulation modeling, as well as how to explore their use for research.

Connelly and Bair (2004) explored the potential of Discrete Event Simulation (DES) methods to improve the systems-level investigation of Ed operations. In the paper, the authors describe the development and operation of Emergency Department Simulation (EDSIM), a platform for computer simulation of ED activities in a level one trauma center. The simulation tool is queue-based. It provides an interactive modeling environment that facilitates the creation of reusable and hierarchically decomposable components. In the study, the effect of two different triage methods on patient service time in ED was investigated using real-life patient data to run the simulation. The authors modeled AS activities such as physical examination, nursing activity, imaging, laboratory studies, and bedside procedures such as suturing, casting, and intubation. The authors reported that their model was able to predict mean patient service time to within 10% of the true values. The simulation yielded an error of less than one hour in 28% of individual patient treatment times. The authors reported that one of the reasons their results could not accurately predict the actual timings of real events was that the simulation did not/cannot support changes in resource levels (particularly staff levels) at different times of the day. This indicates that their simulations do not allow the possibility of setting complex constraints on resource usage and task interruption.

Ruohonen et al. (2006) presented a simulation model describing the procedures performed in the private health services emergency department of a central hospital. They argue that the model created to test different process scenarios, allocate resources, and perform activity-based cost analysis, makes the ED work more efficient, and with the method, they call the "Triage Team Method" the method improves ED operations by more than 25% when applied correctly. The proposed method is based on the triage nurse requesting the diagnostic tests required for the patient during the triage phase.

Samaha et al. (2003) examined density in the emergency department of a university hospital. Researchers used simulation to evaluate the effects of the different ideas presented on ED operations. In their study, they tested all recording procedures at the bedside and directed patients with low acuity to the "Fast Way" (FW) to shorten the length of stay in the ED. The model they established revealed that the cause of the density was not dependent on the source but the process. They concluded that bedside registration provided a substantial reduction in patient waiting times.

They found that the referral of patients with low acuity to FW would free up the beds needed for more critically ill patients. For this reason, they stated that this process will speed up non-critical patients through the system and shorten the time they stay in the ED, resulting in more patients being seen.

Another study examining the results of the FW strategy was conducted by Maulla et al.(2009). In the study, evidence was presented regarding the effect of the FW strategy on the patient's waiting time in a hospital's ED. In the study, Discrete-Event Simulation (DES) model was used to predict the outputs in various triage categories and the outputs of the model were compared with the post-implementation results. The results of the study show a significant reduction in patient waiting time. However, the findings suggest that the HR strategy significantly improves service delivery to patients with low acuity, but does not proportionally improve service for patients with more acute conditions.

Rossetti et al. (1999) developed an ED simulation model for the University of Virginia Medical Center to test the impact of alternative specialist programs on patient efficiency and resource use.

Paul and Lin (2012) used DES to reflect complex ED operations. Using the DES results, they developed parametric models to control the effectiveness of various improvement alternatives and measure potential gains. The results showed that the lack of doctors during rush hours, the slow admission process of hospitalized patients to inpatient services, and the completion time of laboratory-radiology tests led to a decrease in the efficiency of EDs. It has been shown that adding a physician to the process during peak hours results in an almost 18% reduction in the length of stay of patients in the ED.

Hoot et al. (2008) used discrete event simulation to estimate ED intensity based on changes in the number of waiting rooms in ED. In this study, past patient-level data was used as input, and future patient-level data was presented as output.

In studies focused on resource allocation, the most appropriate number of personnel for each stage of the process has been found to make the ED's work more efficient. To such studies, Kirtland et al. (1995), Evans et al. (1996), McGuire (1994), Chin and Fleisher (1998), Centeno et al. (2003).

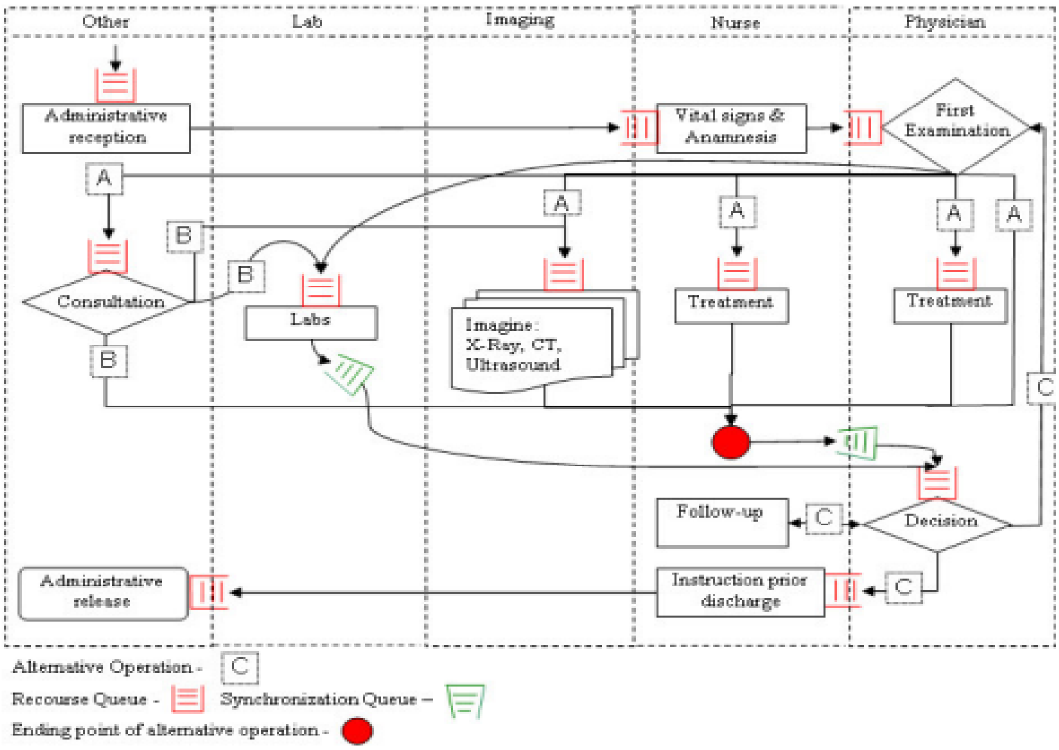
In another study on resource allocation in ED, a discrete event model was developed using the Arena Simulation Program to maximize the process flow, waiting times, and efficiency, and to use the resources correctly. A genetic algorithm is used in the system to obtain optimized resource allocation for different arrival rates within a limited budget, space, and patient waiting time (Rofaeel, 2008).

5. Data Collection and Data Analysis

In general, activities, resources, and patient flow in an ED are shown in Figure 1. Patients come to the ED by ambulance or as an outpatient. A registrar greets the patients at the entrance of the ED. After the patient is registered, the vital signs and history of the patient, called triage, are taken by a nurse. The patient then queues up for the doctor's initial evaluation. After the first evaluation, the patient may be discharged after doctor or nurse treatment, or laboratory tests or imaging may be requested (A). The patient must enter the corresponding resource queue for each of these processes. It is also possible for the doctor to refer the patient to the consultant doctor or doctors for evaluation (A). Additional examinations may be requested, depending on the laboratory test results or imaging results and, if any, the result of the consultation (B). In this case, the process is renewed. Otherwise, the patient may be asked to be followed (C). In this case, it is sent to the observation room. Otherwise, patient follow-up may be requested (C). In this case, the patient is sent to the observation room. Or, after the treatment, they are discharged from the hospital by writing a prescription and giving medical advice, if necessary.

The data required for the establishment of the simulation model were obtained from the MIS of the hospital, where the study was conducted, data dated December 2018-November 2019. Among the information obtained, patients' triage code, gender, age, application date, application time, number of patients, examinations and tests requested from the patient, consultation requests, the number of patients sent to the observation room, and the entrance and exit times to the observation room, the treatment and other procedures performed on the patients. This information includes the patient's entrance and exit time for the examination, but it is considered not useful since the recording time and the procedure time are not recorded in the system simultaneously. It is not possible to obtain time information about procedures such as examination, treatment, imaging, laboratory tests performed on patients during the process, from MIS records.

Figure 1. Activities and Resource Flow Chart in the Emergency Department



Source: Marmor, 2010:13.

The data obtained from MIS were analyzed with MS Excel (2010), and the graphs of statistical information were created with MS Excel. The simulation model was created with the Rockwell Arena v.14 simulation program, and the statistical distributions related to the processes were found with the Arena Input Analyzer Program.

As a result of the analysis, statistical information about the patients who applied to ED in the years 2017-2018 and 2019 (until 30.11.2019) are as presented in the graphics (Chart 1-2-3-4-5-6).

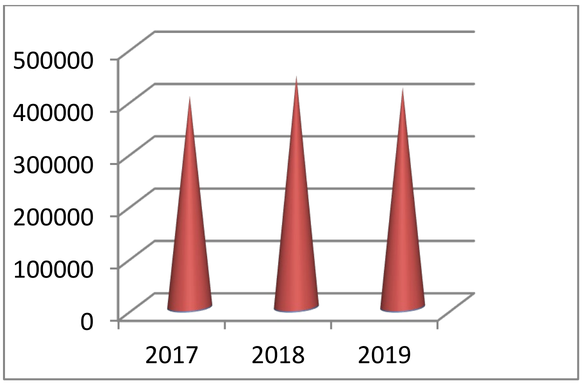


Chart 1. Distribution of Patients by Years

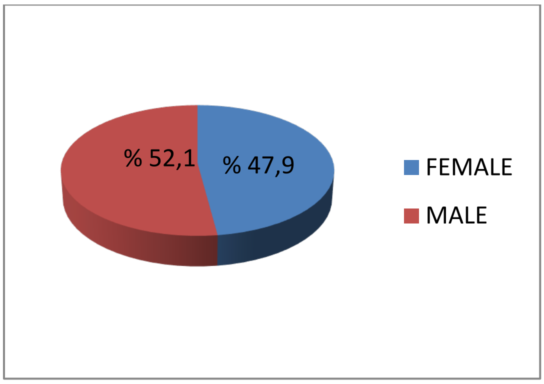


Chart 2. Distribution of Patients by Gender

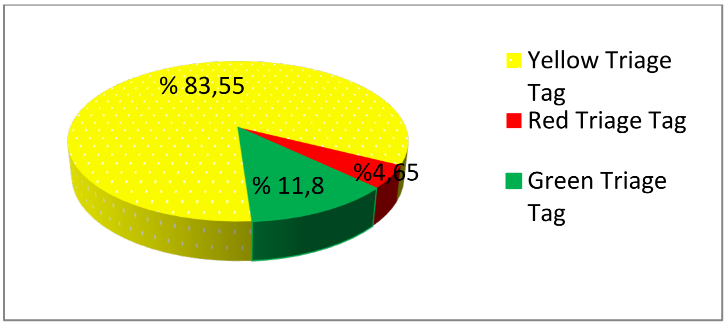


Chart 3. Distribution of Patients by Triage Tag

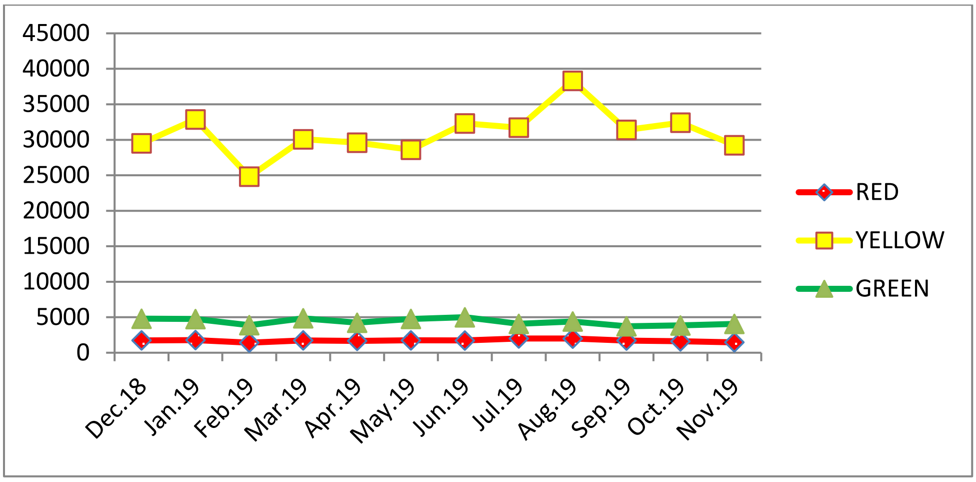


Chart 4. Distribution of Patients by Month

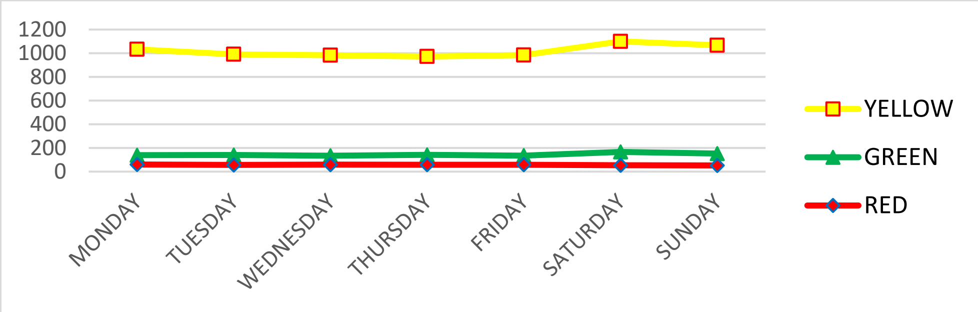


Chart 5. Distribution of Patients by Day

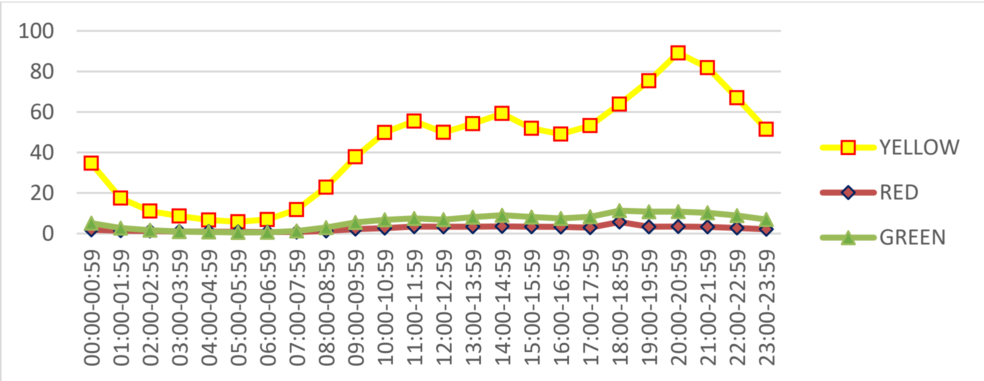


Chart 6. Distribution of Patients by Hour

To model the patient admission process, the data obtained from the MIS records were analyzed with Arena Input Analyzer and the distributions given in Table 1. The fact that the corresponding p-values of the distributions are greater than 0.05 indicates that the distribution has a high representative power (Kelton et al., 2001).

Table 1. Distribution of Patient Arrival Times

Outpatient					
Hour	Distribution	p-value	Hour	Distribution	p-value
08.00-08.59	POIS (1.97)	0,243	20.00-20.59	TRIA(-0.5,0,2.5)	0,115
09.00-09.59	POIS (1.88)	0,066	21.00-21.59	POIS (0.614)	0,069
10.00-10.59	TRIA (-0.5, 0.803, 2.5)	0,695	22.00-22.59	POIS (1.19)	0,069
11.00-11.59	-0.5 + WEIB (2.19, 1.53)	0,103	23.00-23.59	-0.5 + ERLA (0.51, 4)	0,534
12.00-12.59	POIS (1.11)	0,205	00.00-00.59	-0.5 + EXPO (1.61)	0,242
13.00-13.59	POIS (1.22)	0,099	01.00-01.59	-0.5 + ERLA (4.71, 1)	0,682
14.00-14.59	POIS (0.983)	0,089	02.00-02.59	-0.5 + LOGN (6.17, 9.96)	0,633
15.00-15.59	POIS (1.07)	0,369	03.00-03.59	-0.5 + EXPO (6.7)	0,241

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16.00-16.59	POIS (0.822)	0,174	04.00-04.59	1.5 + 50 * BETA (0.305, 0.352)	0,118
17.00-17.59	POIS (0.984)	0,097	05.00-05.59	-0.5 + EXPO (18.5)	0,627
18.00-18.59	POIS (0.875)	0,072	06.00-06.59	0.5 + 13 * BETA (0.825, 0.753)	0,326
19.00-19.59	POIS (0.62)	0,090	07.00-07.59	-0.5 +11* BETA (0.692, 0.998)	0,228
Patient Arriving by Ambulance					
	WEIB (24.4, 0.873)	0,427			

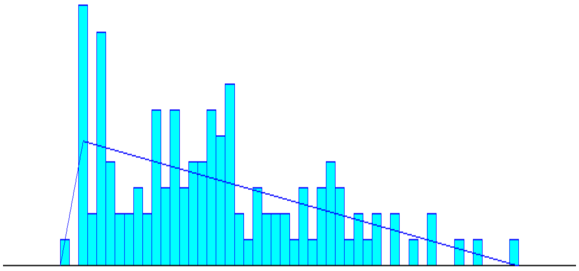
The waiting duration of the patients in the observation rooms was obtained from the MIS records. Operation process times were determined by making observations in the ED. The obtained data were analyzed with Arena Input Analyzer (Figure 2), the distributions given in Table 2 were found. No observations were made for the Consultation and Resuscitation procedures. Processing times were determined by interviews with doctors working in the ED. In such cases where there is a lack of information, triangular and uniform distributions are often used. The triangular distribution is used when the smallest, largest, and most probable values are available for predictions. For the resuscitation process, the triangular distribution was used in line with the information obtained from the doctors and the literature (Söyler, Koç;2014). Uniform distribution is used when there is a lack of information and all values in a certain range are equal (Kelton et al., 2001). Since it has a larger variance than other distributions used in cases of lack of information, it was preferred for the consultation process in the study.

Table 2. Procedure Process Time Distributions

Procedure	Distribution	p-value
Patient Registration	10.5 + LOGN (15.9, 14.9) (Sec.)	0,076
Triage	TRIA (15.5, 23, 72.5) (Sec.)	0,466
Examination (Red Zone)	171 + ERLA (28.6, 2) (Sec.)	0,340
Examination (Yellow Zone)	132 + WEIB (45.3, 1.27) (Sec.)	0,147
Examination (Green Zone)	TRIA (73.5, 76, 124) (Sec.)	0,175
Treatment (Nurse- Red Zone)	82 + WEIB (49.3, 1.27) (Sec.)	0,481
Treatment (Nurse- Yellow Zone)	82 + WEIB (49.3, 1.27) (Sec.)	0,481
Treatment (Nurse- Green Zone)	65.5 + 94 * BETA (1.19, 1.51)(Sec.)	0,086
Medical Record	NORM (33.8, 9.31) (Sec.)	0,646
Consultation	UNIF(3,8) (Min.)	
Staying in the Observation Room (Red- Female Patient)	10 + WEIB (102, 1.07) (Min.)	0,369
Staying in the Observation Room (Red-Male Patient)	15 + EXPO (96.7) (Min.)	0,110
Staying in the Observation Room (Yellow-Female Patient)	10 + EXPO (25.8) (Min.)	0,099

Staying in the Observation Room (Yellow-Male Patient)	10 + WEIB (22.7, 0.647) (Min.)	0,122
Injection	NORM (143, 18.1) (Sec.)	0,068
Resuscitation	TRIA (30,45,60) (Min.)	
Radiological Imaging	UNIF(1.5,4) (Min.)	

Figure 2. Green Zone Doctor Examination Period



TRIA (73.5, 76, 124) (Second)
Corresponding p-value_0,175

6.Limitations And Assumptions In The Study

While modeling a system, trying to model the real system down to the smallest details is both very time-consuming and costly. Therefore, the simulation model should be created under assumptions that can represent the system, cost as little as possible, and provide beneficial findings to the decision-makers of the system. In this study, some assumptions were made for the simulation models creations. Otherwise, trying to include a system with a very complex structure such as EDs in the model down to the smallest detail would not be possible and would make the modeling process very difficult.

In this context, the basic assumptions applied during the study are listed below:

• For each resuscitation patient arriving by ambulance, 112 Command and Control Center informs ED and ED personnel takes the necessary measures to meet the patient.

• For patients arriving by ambulance, the registration process does not prevent the initiation of intervention, and the registration period does not affect the duration of the patient's stay in the ED.

• Since the ambulance gets directions by the 112 Command and Control Center with the approval of the hospital, every patient arriving by ambulance receives medical intervention, and no patient is turned away in any way.

• It was assumed that patients who get sent to the observation room left the ED when they left the observation room. Among these patients, the procedure times of those who get sent to the inpatient service and those who get transferred to other institutions were evaluated during the observation period.

• All outpatients are admitted to ED.

• Patients move between the relevant departments without losing time. (For example, the patient does not waste time for reasons such as the need for the restroom).

• The processing time of the officers serving in each field is the same for the personnel working in that field.

• The transfer process between departments that are very close to each other is ignored. (For example, the triage point and the registration desk are in the same place, and the patient's time loss between two is about 1-2 seconds).

• Personnel assigned in each area provide uninterrupted service. (The staff meet their mandatory needs when the patient is not present. If this is not possible, additional personnel are involved).

• The required analyzes and examinations are requested at once.

• All consultation procedures are carried out over the phone.

• No patient leaves the ED without seeing a doctor after registering.

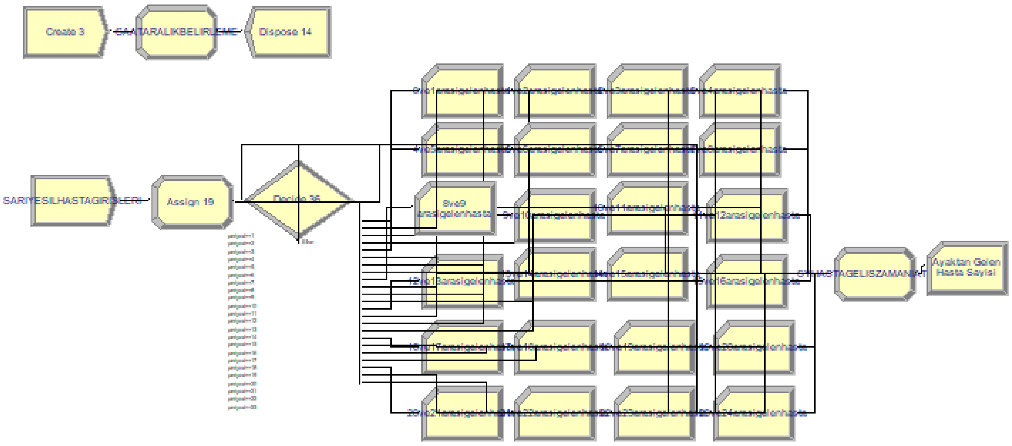
• Waiting areas are large enough to accommodate a sufficient number of patients, and the number of beds in the ED observation rooms is sufficient.

7. Creating The Simulation Model

A simulation model was created based on the flowchart given in Figure 1. After creating the simulation model, the errors of the model were corrected by using the "Check Model" tab. Figure 3 shows the Arena model of the patient arrival process.

To check whether the created simulation program represents the ED processes, the operation of the program was tested with a doctor working in the Ed, and it was verified that the model represents the ED processes. The number of patients entering the system was checked by running the program. When the program outputs were compared with the actual data, it was observed that the number of patients entering the system was parallel to the real data. The following results were obtained by running the model with ten repetitions after a 24-hour warm-up period.

Figure 3. Arena Model of Outpatient Arrival



8. Results

In the current situation, the total working time of the personnel working in the ED has been found with the formula below and is given in Table 3.

Total Working Time = Number of staff on duty x 24

Table 3. Total Staff Working Time

Simulation 1 (Current Status): Total Staff Working Time (Hours)						
	Doctor	Nurse	Medical Secretary	Triage Nurse	Injection Nurse	Registrar
Red Zone	48	72	24			
Yellow Zone	72	48	48	48	24	48
Green Zone	48	48	48			

The number of patients entering and exiting the system according to the current situation simulation and the patients' duration of stay in the ED is given in Table 4. A total of 1190 patients entered the system and 954 patients left the system. Fifty-four patients with the red triage code entered the system, and all of these patients left the system after their treatment. The duration of stay in the system for patients with red triage code was 8.53 minutes and a maximum of 467.69 minutes, and the duration of stay in the system for a red-tagged patient was found to be 98.08 minutes on average. For yellow-tagged patients, 987 patients entered the system, and 751 patients left the system.

Table 4. Simulation-1 Duration of Patients' Staying in ED

	Number of Patients Entering the System	Number of Patients Leaving the System	Patient Staying Time in the System (Minutes)		
			Min.	Max.	Mean
Red Zone	54	54	8,53	467,69	98,08
Yellow Zone	987	751	6,25	373,94	66,34
Green Zone	149	149	3,21	7,67	4,47
Total	1190	954			

The mean duration of stay in the system for yellow-tagged patients is 66.34 minutes. One hundred forty-nine green-tagged patients entered the system and all of the patients left the system. The average duration of stay in the system for green-tagged patients is 4.47 minutes. Since the majority of red-tagged patients received diagnostic tests, it was considered normal for these patients to stay in the system for an average of 98 minutes. 69.23% of yellow-tagged patients do not require diagnostic tests, so a yellow-tagged patient stays in the system longer. The reason for this situation can be explained by the high number of patients and, accordingly, the loss of time between ED processes. The average duration of stay in the system for green-tagged patients was 4.47 minutes and considering the number of patients, no tests were requested from these patients, and patient complaints were simple cases, it was considered normal.

When examined in terms of capacity utilization rates, according to the current situation simulation results (Table.5), the utilization rate of a doctor in the red zone was found to be 13.75%. There are two doctors on duty in the red zone. The average number of patients varies between 48-63 per day. Under these conditions, it is natural that the utilization rate of doctors is low. To increase this rate, the number of doctors on duty can be reduced from two to one. However, since red-tagged patients are considered to be patients with life-threatening conditions, the absence of a doctor to intervene in case of possible short-term patient visits may endanger the patient's life. Therefore, it will be understood that the number of doctors in this field should be two.

Three doctors work in the yellow zone, and the utilization rate of the doctors working in this area was 68.98%. This usage rate can be considered favorable for a sector that requires extreme attention as the health sector.

The number of doctors working in the green zone was two, and the utilization rate of a doctor was found to be very low at 7.5%. The number of doctors in this field can be reduced, especially at night when the number of patients is low, or a different patient can be referred.

The rate of nurses working in the treatment areas was 7.49% for the red zone, 48.39% for the yellow zone, and 0.69% for the green zone. The low utilization rate of a nurse indicates that the number of assigned nurses can be changed. Especially for nurses working in the green zone, the utilization rate is very low. In the green zone, where approximately 149 patients receive service daily, most of them do not need nurse treatment. Therefore, assuming that the number of nurses working in this area is high, it was thought that the number of nurses should be rearranged.

In the red treatment zone, there is a medical secretary who is assigned to carry out the analysis, examination requests, discharge, and referral of the patients. The utilization rate of medical secretaries in the red zone was 3.2%. Considering the number of daily patients and the duration of the medical secretary procedure, the usage rate is normal. The number of medical secretaries in the yellow and green zone is two for each. The utilization rates were 15.59% and 2.58%, respectively. The low rates indicate that the number of medical secretaries working in these zones can be reduced.

The utilization rates of triage nurses, registrar, and injection nurses are given in Table 6. The number of triage nurses and registrars is two, and their utilization rates are 24.07% and 19.04%, respectively. According to the capacity utilization rates, the personnel assigned in these areas can be reduced. The injection nurse capacity utilization rate was found to be 1.2%, which is considerably low. Patients can be directed to the nurse on duty in the green zone for injection, without a nurse being assigned for the procedure.

Table 5. Simulation -1 Capacity Utilization Rates

	Doctor		Nurse		Medical Secretary	
	Current Capacity	Utilization Rate (%)	Current Capacity	Utilization Rate (%)	Current Capacity	Utilization Rate (%)
Red Zone	2	13,75	3	7,49	1	3,2
Yellow Zone	3	68,98	2	48,39	2	15,59
Green Zone	2	7,5	2	0,69	2	2,58

Table 6. Simulation -1 Capacity Utilization Rates

	Current Capacity	Utilization Rate (%)
Triage Nurse	2	24,07
Registrar	2	19,04
Injection Nurse	1	1,2

The average waiting time of the patients according to the triage tag in the ED department is as in Table 7. The red-tagged patients do not wait in the examination and treatment queue. Given the patient urgency, the target time worldwide is immediate for life-threatening patients and a maximum of 10 minutes for very urgent patients. The waiting time for the first examination is well enough for life-threatening and very urgent patients in the ED examined. The average waiting time for the first examination of yellow-tagged patients was 39.39 minutes. Considering the number of yellow-tagged patients, the waiting time for the first examination, 39.39 minutes, was considered to contribute to the ED patient density.

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It is predicted that shortening this period will make a significant contribution to both increasing patient satisfaction and reducing the density of ED patients. For green-tagged patients, the waiting time to be seen by a doctor is generally more than an hour. Currently, the average waiting time of green-tagged patients is 0.017 minutes, and patients do not wait for examination. The waiting times of patients in each triage code for treatment or registration are negligible.

Table 7. Simulation -1 Waiting Times (Minutes)

	Examination	Treatment	Medical Secretary
Red Zone	0	0	0
Yellow Zone	39,39	0,31	0,035
Green Zone	0,017	0,02	0,003
Triage	0,15		
Hasta Kayıt	0,016		

The average waiting time of a patient in the triage queue was found to be 0.15 minutes in the queue and 0.016 minutes in the registration queue (Table.7). This shows that patients rarely wait for both procedures and go to the treatment area after having their procedures done.

Except for mandatory waiting periods (waiting for laboratory results, waiting for radiology results), red and green-tagged patients do not wait for examination, treatment, or registration. The yellow-tagged patients wait in the examination queue for a long time. It is foreseen that shortening this period will contribute positively to the functioning of ED.

In line with the information obtained from the simulation-1 study showing the current status of the ED, the system was simulated by creating two scenarios to increase staff utilization rates and to reduce the time for the first examination and stay in the system, especially for yellow-tagged patients.

Scenario-1

In Scenario-1, a different triage application was used without making any changes in the number of personnel working in the ED. According to the recommended triage practice, the patients get directed to the treatment areas. The new triage application designed is a hybrid model using the three-level triage system and the five-level triage system. The three-level triage system separates patients according to three different color codes according to their urgency. The five-level triage system, on the other hand, divides and prioritizes patients into five levels according to the number of resources to be used, and their urgency. When the ED data was examined, it was found that 69.23% of the yellow-tagged patients do not use resources other than doctors and nurses. The newly designed triage application categorizes the patients in three levels, like red, yellow, and green triage codes, according to their urgency. Yellow-tagged patients are divided into two categories those who use resources other than doctors and nurses and those who do not. According to the recommended triage practice, all patients who did not use yellow triage coded resources get directed to the green zone and receive treatment. Since the red-tagged patients are life-threatening patients, no change in the referral was considered for the patients with this triage code. The simulation-2 results created according to the new patient orientation are presented in Table 8-9-10.

According to Simulation-2, when all the patients who do not use the yellow triage coded source get directed to the green zone, the number of patients treated in the green zone is approximately 785. During the 24-hour shift, an average of 785/48 ≅ 17 patients per hour per doctor will be reduced. The number of patients treated in the yellow zone is 286. However, all of these patients will be re-evaluated by the doctor as they use at least one resource. Therefore, the doctors in the yellow area will have dealt with 286x2= 572 patients. In this case, the number of patients per working hour for doctors in the yellow area will be 572/72≅ 8. In other words, within an hour, a doctor in the green zone will deal with approximately twice as many patients as a doctor in the yellow zone. This situation might cause a loss of motivation among doctors. If 65% of the yellow-tagged patients are directed to the green zone according to the current doctor's working hours, then doctors working in both areas will care for an average of 12 patients per hour.

The results of the Simulation-1 study revealed that the staff utilization rates are very low in the current situation and new staffing is required. According to the new personnel plan to be designed, it is estimated that the balance between the number of patients that the doctors working in the treatment areas will deal with per hour can be achieved by directing 70% of the patients who do not use yellow triage code resources to the green zone. According to the Simulation-3 and Simulation-4 studies, which involves directing 70% and 65% of the patients who did not use yellow triage coded resources to the green zone, in a way to stabilize the average number of patients per hour per doctor, the emergency service performance criteria are presented in Table 8-9-10.

Considering the mean duration of stay of the patients in the ED, the mean duration of stay in the ED of red-tagged patients showed a slight decrease compared to the current situation in three simulation studies conducted under Scenario-1. Although there was no change in the patient flow in the red zone, it was interpreted that the shortening in the duration of stay in the ED of red-tagged patients was due to the decrease of patients leaving the system. While the duration of stay in the ED of yellow-tagged patients was 66.34 minutes in the current situation, this time was shortened in the three simulations created in Scenario-1. For yellow-tagged patients, the best results were obtained with Simulation-4. However, the number of yellow-tagged patients leaving the system in Simulation-3 is higher than in Simulation-4.

Although there were more patients in the yellow triage zone in the Simulation-4 study compared to the Simulation-3, the shorter duration of stay of yellow-tagged patients can be explained by the fewer patients leaving the system. On the other hand, for green-tagged patients, the average duration of stay in ED found as a result of the three simulations created in Scenario-1 is longer than the current situation. However, Simulation-3 gave better results for green-tagged patients compared to Simulation-2 and Simulation-4. Scenario-1 simulations showed that the duration of stay in ED was shortened for yellow-tagged patients, while it was longer for green-tagged patients (Table 8).

Table 8. Length of stay of the patients in ED

Simulation	Treatment Area	Number of Patients Leaving the System	Patient Staying Time in the System (Minutes)			
			Min	Max	Mean	Change (%)
Simulation-2	Red Zone	52	8,88	385,19	94,87	-3,27
	Yellow Zone	870	5,73	261,01	46,2	-30,36
	Green Zone	139	3,35	127,62	28,35	534,23
Simulation-3	Red Zone	53	9,13	293,14	93,864	-4,3
	Yellow Zone	946	5,79	249,04	32,113	-51,59
	Green Zone	138	3,46	19,33	7,187	60,78
Simulation-4	Red Zone	52	7,85	402,75	96	-2,12
	Yellow Zone	938	6,09	316,72	29,26	-55,38
	Green Zone	144	3,27	40,72	9,93	122,15

Considering the capacity utilization rates, it is currently the best for the doctors in the yellow zone. However, according to the current situation, the capacity utilization rate for doctors working in the green zone is very low. While the Simulation-2 study decreased the capacity utilization rate of the doctors working in the yellow zone, it increased to 68.77% for the doctors in the green zone. Simulation studies have shown that as the percentage of patients who do not use yellow triage code resources directed to the green zone increases, the capacity utilization rates of the yellow zone doctors decrease, while the capacity utilization rates of the green zone doctors increase. The Simulation-4 study brought the capacity utilization rates of yellow and green zone doctors to the closest to each other. According to simulation-3 and simulation-4 studies, the capacity utilization rate of doctors working in treatment areas is around 50%. When patient referrals are made according to the patient referral percentages used in both simulation studies, the working hours of the doctor in charge of the treatment areas can be adjusted.

When the nurse utilization rates were examined, the simulation-2 study gave better results than the simulation-3 and simulation-4 studies. However, the capacity utilization rates of the nurses working in the yellow zone in the simulation-2 study are lower than the current situation. The low utilization rate of nurse use showed that the number of nurses in all three treatment areas could be reduced at certain times of the day.

The Simulation-1 study is the best for the medical secretary capacity utilization rate in the yellow zone. However, Simulation-2 is better than other simulations in balancing the use of medical secretaries in the green and yellow zone. Again, simulation studies have shown that the number of medical secretaries in treatment areas can be reduced (Table 9).

Table 9. Capacity Utilization Rates

Simulation	Treatment Area	Doctor		Nurse		Medical Secretary	
		Utilization Rate (%)	Change (%)	Utilization Rate (%)	Change (%)	Utilization Rate (%)	Change (%)
Simulation -2	Red Zone	13,95	1,45	7,79	4	3,18	-0,6
	Yellow Zone	38,21	-44,61	26,63	-44,97	9,89	-36,56
	Green Zone	68,77	816,93	33,14	4702,9	10,81	318,99
Simulation -3	Red Zone	13,8	0,36	7,37	-1,6	3,25	1,56
	Yellow Zone	50,76	-26,41	37,76	-21,97	12,69	-18,6
	Green Zone	54,89	631,87	25,62	3613	9,25	258,5
Simulation -4	Red Zone	13,83	0,58	7,7	2,8	3,16	-1,25
	Yellow Zone	51,69	-25,07	37,49	-22,53	12,8	-17,9
	Green Zone	52,12	594,93	23,71	3336,2	8,95	246,9

Currently, yellow-tagged patients have to wait 39 minutes on average before they can be examined by a doctor. Considering the number of yellow-tagged patients, it can be said that this period causes patient density in ED. In the Simulation-2 study, this duration was less than one minute. Based on yellow-tagged patients, the best results were obtained from the Simulation-2 study. However, while the Simulation-2 study shortened the waiting times of the yellow-tagged patients in the examination queue, it caused the green-tagged patients to wait in the examination queue for approximately 25 minutes. The durations found in simulation-3 and simulation-4 studies are more acceptable than both the current situation and simulation-2 studies.

It has been observed that the patients hardly wait to get treatment from a nurse. Therefore, all three of the simulation studies gave positive results. The same is valid for the waiting times in the medical secretary processing queue (Table 10.).

Scenario-1 simulation results showed that the proposed triage practice significantly improved the duration of stay in the ED of yellow-tagged patients, who constitute the most intensive patient group. It has been evaluated that this situation will contribute positively to the patients' getting better service by reducing the patient density in ED. On the other hand, hospitals are also businesses. Although public hospitals are non-profit, hospital managers still need to reduce costs, as in every business. Personnel costs are among the major cost items of hospitals.

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Table 10. Waiting Time of Patients in Operation Queues

Simulation	Treatment Area	Examination		Treatment		Medical Secretary	
		Time (Minute)	Change (%)	Time (Minute)	Change (%)	Time (Minute)	Change (%)
Simulation-2	Red Zone	0	0	0	0	0	0
	Yellow Zone	0,33	-99,2	0,15	-51,6	0,033	-5,7
	Green Zone	24,73	143017,6	0,2	900	0,038	1166,7
Simulation-3	Red Zone	0	0	0	0	0	0
	Yellow Zone	3,91	-90,07	0,25	-19,4	0,021	-40
	Green Zone	6,92	40605,9	0,085	325	0,02	566,7
Simulation-4	Red Zone	0	0	0	0	0	0
	Yellow Zone	4,21	-89,3	0,22	-29	0,024	-31,4
	Green Zone	5,69	33370,6	0,11	450	0,024	700

The current situation and scenario-1 simulations have shown that the employment rates of ED personnel are low and a new personnel work program should be established. For this purpose, a new personnel work plan was made and the proposed triage application was tested according to the percentages used in the scenario-1 study.

Scenario-2

In Scenario-2, changes were made in the number of personnel working in the ED. Simulation-5 is a simulation of the current patient flow. In the simulation-6, simulation-7 and simulation-8 studies, the patient flow was modified and the system was simulated according to each patient flow.

New Personnel Plan

The previous four simulation studies showed that the rates of staff working in the treatment areas, triage nurses, registrars, and injection nurses were low. According to graph.5 created according to MIS records, there is not much fluctuation in the number of red and green-tagged patients who come to the ED especially at night, while there is high variability in the number of yellow triage coded patients. While there is a significant decrease in the number of yellow-tagged patients at night, the number of patients increases continuously from 8:00 onwards, and there is a density between 18:00 and 24:00. This has also been confirmed by ED employees. The results of both graph.5 and Simulation-1 show the current status of the ED that new personnel planning is required to make the ED more efficient. The number of personnel to be assigned according to the work plan created is given in Table 11.

Table 11. New Personnel Plan

	Red Zone			Yellow Zone			Green Zone		
Hours	Doctor	Nurse	Medical Secretary	Doctor	Nurse	Medical Secretary	Doctor	Nurse	Medical Secretary
08:00-18:00	2	3	1	2	2	1	2	2	1
18:00-24:00	2	3	1	3	2	1	2	2	1
24:00-08:00	2	2	1	1	1	1	1	1	1

The number of personnel working in the triage and patient registration departments was also reduced from two to one. Since the injection procedure was deemed appropriate by the nurse in charge of the green zone, a separate nurse was not assigned for the injection procedure.

The simulation results created according to the new personnel plan are given below. The percentages of change are based on the current situation in ED.

Table 12. Duration of Patients' Stay in ED According to Scenario-2

Simulation	Treatment Area	Number of Patients Leaving the System	Patient Staying Time in the System (Minutes)			
			Min	Max.	Mean	Change (%)
Simulation -5	Red Zone	55	8,96	497,71	102,58	4,59
	Yellow Zone	667	6,26	426,14	132,12	99,16
	Green Zone	137	3,47	17,14	6,41	43,4
Simulation -6	Red Zone	53	9,19	411,78	100,09	2,05
	Yellow Zone	866	6,24	324,79	48,61	-26,73
	Green Zone	122	3,38	133,54	34,07	662,19
Simulation -7	Red Zone	54	8,94	487,02	101,77	3,76
	Yellow Zone	947	6,09	217,21	36,85	-44,45
	Green Zone	139	3,62	50,09	15,91	255,93
Simulation -8	Red Zone	55	9,03	382,08	101,18	3,16
	Yellow Zone	935	5,97	232,73	41,62	-37,26
	Green Zone	140	3,54	37,96	11,83	164,65

When the simulations were compared for the duration of the patients' stay in the system, the best results for yellow-tagged patients were obtained from Simulation-7. Compared to the current situation, the duration of stay in ED was reduced by 44.45% for yellow-tagged patients. For green zone patients, Simulation-5 gives the best results. Considering the number of patients, simulation-7 gave the best results for reducing ED patient density (Table 12).

When the simulations are compared according to the doctor capacity utilization rates, the best results for yellow zone doctors are obtained in Simulation-5. Compared to the current situation, there has been an increase of 32.18%. For green zone doctors, the best results were obtained in Simulation-6. The utilization

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rate of green zone doctors, which is currently very low, increased by 829.4% and became 74.43%. Similar results were obtained in all simulations for red zone doctors. Simulation-7, where the capacity utilization rates are closest to each other for doctors, was seen as a suitable scenario.

When the simulations were compared according to nurse capacity utilization rates, the best results for yellow zone nurses were obtained from Simulation-5. For green zone nurses, the best results were obtained from Simulation-6. The results were close to each other in all simulations for the red-zone nurses. Simulation-7, where the capacity utilization rates are closest to each other, is seen as an acceptable scenario.

When the medical secretary capacity utilization rates were examined, it was seen that the Simulation-6-7 and Simulation-8 studies yielded close results. As an acceptable scenario, the Simulation-7 study, which is close to each other and relatively higher than other simulation studies, was seen as the appropriate scenario for medical secretaries working in the yellow and green zones (Table 13).

Table 13. Capacity Utilization Rates According to Scenario-2

Simulation	Treatment Area	Doctor		Nurse		Medical Secretary	
		Utilization Rate (%)	Change (%)	Utilization Rate (%)	Change (%)	Utilization Rate (%)	Change (%)
Simulation -5	Red Zone	13,86	0,8	8,2	9,5	3,1	-3,1
	Yellow Zone	91,18	32,18	51,05	5,5	28,69	84
	Green Zone	7,66	2,1	0,96	39,1	4,97	92,6
Simulation -6	Red Zone	13,95	1,45	7,93	5,87	3,62	13,1
	Yellow Zone	50,73	-26,5	28,34	-41,4	18,46	18,4
	Green Zone	74,43	892,4	36,94	5253,6	21,83	746,1
Simulation -7	Red Zone	14,01	1,9	8,26	10,3	3,51	9,68
	Yellow Zone	71,26	3,3	38,93	-19,55	24,45	56,83
	Green Zone	65,39	771,8	30,97	4388,4	19,26	646,5
Simulation -8	Red Zone	13,92	1,2	8,12	8,4	4	25
	Yellow Zone	68,95	-0,04	39,53	-18,3	24,85	59,39
	Green Zone	59,33	691,1	27,7	3914,5	18,27	608,1

According to the new personnel plan, the utilization rates of the registrar and triage nurse increased by 99.89% and 103.4%, respectively, compared to the current situation, and became 38.09% and 48.96% (Table 14).

Table 15 shows the duration of the patients in the operation queues according to the simulation results.

Table 14. Capacity Utilization Rates According to Scenario-2

	Current Capacity	Utilization Rate (%)	Change (%)
Triage Nurse	1	48,96	103,4
Registrar	1	38,09	99,89
Injection Nurse	0	0	

Table 15. Waiting Time of Patients in Operation Queues According to Scenario-2

Simulation	Treatment Area	Examination		Treatment		Medical Secretary	
		Time (Minute)	Change (%)	Time (Minute)	Change (%)	Time (Minute)	Change (%)
Simulation -5	Red Zone	0	0	0	0	0	0
	Yellow Zone	98,47	149,98	0,28	-9,67	0,058	65,7
	Green Zone	0,018	5,88	0,06	200	0,013	333,3
Simulation -6	Red Zone	0	0	0	0	0	0
	Yellow Zone	0,86	-97,8	0,15	-51,6	0,04	14,28
	Green Zone	27,4	161076,5	0,1	400	0,1	3233,3
Simulation -7	Red Zone	0	0	0	0	0	0
	Yellow Zone	6.52	-83,44	0,15	-51,6	0,06	71,4
	Green Zone	9.06	53194,1	0,11	450	0,071	2266,7
Simulation -8	Red Zone	0	0	0	0	0	0
	Yellow Zone	10,99	-72	0,23	-25,8	0,09	157,1
	Green Zone	3,7	21664,7	0,23	1050	0,061	1933,3

Based on the inspection queue average waiting time, Simulation-7 gave the best results. However, although Simulation-7 is not the best in terms of waiting time in the green zone examination queue, it still has a waiting duration of fewer than 10 minutes. Considering that the waiting time of fewer than 10 minutes is the target time for red-tagged patients, the Simulation-7 study did not give a waiting time for red-tagged patients, while it increased the waiting time in the examination queue of yellow and green-tagged patients to less than 10 minutes.

All simulations yielded positive results, as the average waiting time in the treatment queue was less than one minute in all simulations. The same is valid for the waiting time in the medical secretary processing queue.

In Scenario-2, the waiting times of the patients in the triage and patient registration queues increased compared to the current situation, but the average waiting time in the patient registration queue was 0.14 minutes and the average waiting time in the triage queue was 2.02 minutes (Table 16).

Table 16. Waiting Time of Patients in Operation Queues According to Scenario-2

	Waiting Times (Minutes)	Change (%)
Triage	2,02	1246,7
Patient Registration	0,14	775

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9. Discussion

With an irregular and busy patient flow, EDs are the most dynamic locations of hospitals. Medical interventions at all levels, from life-threatening cases to minor complaints, are performed in EDs whose primary objective is to stabilize the patient. In ED facing extreme cases, patients should receive the necessary treatment and care as soon as possible. A patient who comes to the ED goes through processes such as triage, registration, examination by a doctor, laboratory tests, radiological tests, treatment, observation, referral to another health institution, hospitalization, or discharge. The duration of stay of patients in the ED is prolonged due to patient density, lack of personnel to perform the procedures or inability to perform appropriate triage. The prolongation of the patients' stay in the ED may cause the patient density in ED and cause disruptions in the treatments that endanger the patient's health.

It is necessary to minimize the loss of time between processes and to ensure that patients leave the ED as quickly as possible so that patients can receive the necessary medical care in EDs where a large number of applications are made.

The first thing that comes to mind for the solution of the problem may be to increase the capacity. However, the capacity increase will cause a cost increase. In our country, public hospitals use the resources of the state as non-profit service enterprises. Therefore, the increase in hospital costs creates a burden on the country's economy. As a business, hospitals must take measures to reduce costs while providing safe and timely care to patients in EDs. For this reason, different strategies can be used in EDs that will both reduce the waiting time of the patients and reduce the costs.

This study, it was aimed to offer suggestions that would decrease the waiting times of the patients in the ED and increase the staff capacity utilization rate. For this purpose, the proposed strategy was tested by simulating a public hospital ED. Within the scope of the study, besides the Simulation-1 study, which shows a form of the current situation, seven more simulation studies were carried out according to two different scenarios, and the behavior of the system was monitored.

In the current situation, the average duration of stay in the ED of red-tagged patients was found to be 98.08 minutes. Considering the seriousness of the health conditions and the fact that the majority of these patients are kept under observation, the duration may be considered normal.

The mean duration of stay in the system for yellow-tagged patients was 66.34 minutes. This duration was considered long, taking into account that 69.23% of these patients did not use any resources other than the doctor. The mean duration of stay in the system for green-tagged patients was 4.47 minutes. When the waiting times of the patients in the procedure queues were analyzed, it was observed that red-tagged patients did not wait in any procedure queues. In addition, the observations showed that there was no queue in the operations performed in the red zone. The current situation is the targeted situation for red-tagged patients. Simulation-1 results showed that yellow-tagged patients waited an average of 39.39 minutes before being examined by a doctor. Observations made in the yellow zone have shown that long queues are formed especially in the evening when the patient density is the highest. It was concluded that this period, in which yellow-tagged patients had to wait for examination, could be the reason for the patient density in ED. No waiting queue formation was observed in the green zone. Patients leave ED by getting their treatment done without waiting in line. When the capacity utilization rates of the personnel working in the treatment areas are examined, the capacity utilization rates of the personnel working in the green zone were found to be quite low.

A different triage practice has been proposed to shorten the duration of yellow-tagged patients both staying in the system and waiting time until they are examined by the doctor. Management Information System records show that 69.23% of yellow-tagged patients do not use any source other than doctors and nurses, such as green-tagged patients in ED. Three different simulation studies were carried out under the title of Scenario-1 to see whether or not all or some of these patients who do not use resources can be directed to the green zone in triage will solve the problem and how it will affect the length of stay of the patients in the system. The system was simulated by directing the non-resource yellow-tagged patients to the green zone; 100% of the patients in the Simulation 2 study, 70% in the Simulation-3 study, and 65% in the Simulation-4 study.

In the Scenario-1 simulation studies, the best results were obtained from the Simulation-3 and Simulation-4 studies according to the duration of the patients' stay in the ED. Although the mean duration of stay in the system for red-tagged patients was shortened compared to the current situation, it was evaluated that this shortening was related to the number of patients leaving the system rather than the triage application. Compared to the current situation, the mean duration of stay in the ED of yellow-tagged patients decreased by 51.59 minutes to 32.113 minutes in Simulation-3 and decreased by 55.38% to an average of 29.26 minutes in Simulation-4. The duration of stay in the system of green-tagged patients increased by 60.78% to 7.187 minutes in Simulation-3, while it increased by 122.15% to an average of 9.93 minutes in the Simulation-4 study.

When the simulations were examined in terms of the duration of waiting in the procedure queues, it was seen that red-tagged patients did not wait in the procedure queues. While simulation-3 reduced the waiting time in the examination queue of yellow-tagged patients by 90.07% to 3.91 minutes, in Simulation-4 the decrease was 98.3% and the duration decreased to 4.21 minutes. The waiting time in the examination queue of green-tagged patients increased in both simulation studies compared to the current situation. While the average was 6.92 in the Simulation-3 study, it was found to be 5.69 minutes in the Simulation-4 study. The waiting time in the other procedure queues of both yellow and green-tagged patients was found to be less than one minute.

The highest personnel cost in EDs is the doctor's cost. Simulation-3 and simulation-4 studies gave similar results in terms of doctor utilization rates for yellow and green zones. There was no significant change in the rate of usage of the doctor in the red zone. The same is current for other personnel in terms of capacity utilization rates. While the capacity utilization rates of the personnel working in the yellow zone decreased, an increase was observed in the capacity utilization rates of the personnel working in the green zone. Simulation studies conducted within the scope of Scenario-1 have shown that the capacity utilization rate of the ED personnel is low in the current situation, and new personnel planning is necessary without compromising patient health and safety in the ED.

Taking into account the patient density, a new personnel plan was created and scenario-2 simulations were repeated according to the percentages of patient referrals used in scenario-1 simulations. In the Simulation-7 study, the duration of stay in the ED for yellow-tagged patients decreased by 44.45% compared to the current situation and averaged 36.85 minutes, and it increased by 255.93% compared to the current situation and averaged 15.91 minutes for green-tagged patients. In the Simulation-8 study, the duration of stay in the ED for yellow-tagged patients decreased by 37.26% compared to the current situation and averaged 41.62 minutes, and for green-tagged patients, it increased by 164.65% compared to the current situation and averaged 11.83 minutes. Considering the number of patients, Simulation-7 gave more positive results than Simulation-8.

In terms of resource utilization rates, both Simulation-7 and Simulation-8 studies have better resource utilization rates than other simulations. However, Simulation-7 is preferable as it gives closer results for all sources.

When the duration of waiting in the procedure queues was evaluated, it was observed that when the percentage of yellow-tagged patients who were directed to the green zone increased, the waiting time in the examination queue of yellow-tagged patients decreased, while the waiting time in the examination queue of green-tagged patients increased. However, considering the number of patients according to the triage tags, the waiting time for the examination was 0.86 minutes in Simulation-6 for yellow-tagged patients, which made a major contribution to ED density, while it was 27.4 minutes on average for green-tagged patients. The waiting time was found to be 6.52 and 9.06 minutes in the Simulation-7 study, respectively, it was 10.99 and 3.7 minutes in the Simulation-8 study. The waiting times of the patients in other procedure queues are less than one minute. According to the new staff plan, the waiting times in the registration and triage queues were found to be 0.14 and 2.02 minutes, respectively.

Conclusion And Recommendations

Although it did not give the best results in all of the performance criteria examined, Scenario-2 of Simulation-7 application, which balanced the performance criteria observed in the yellow and green zones, was recommended to the examined ED. Although the proposed model increases the mean duration of stay in the ED for green-tagged patients by about 10 minutes, it shortens the mean time of stay in the system for yellow-tagged patients, which is the most intensive patient group in ED, by 44.45%, and shortens it by approximately 30 minutes.

With the new staff plan and the recommended patient referral, 20.24% savings in doctor working hours, 30% in nurse working hours, 40% in medical secretary working hours, and 50% savings in registration staff working hours can be achieved in the ED, according to the current situation.

In the study, it was suggested that 70% of yellow-tagged patients who did not use resources should be directed to the green zone. However, it would be appropriate for other EDs to make referrals in different percentages according to their patient structure and priorities.

In this study, the system was simulated by changing only the number of personnel working in the treatment, triage and patient registration department, keeping the other variables constant. In future studies, strategies to shorten the waiting times in queues in procedures such as patient flow, laboratory and radiological imaging, or the recommended triage practice can be developed by using the number of beds in observation rooms as variables. In addition, with the pandemic process, the HES code query, which questions the fever measurement of the patients during the application and the risk of Covid-19 transmission, has been started to be made in the ASs. During these processes, simulation studies can be conducted to examine the effect of patients on the duration of their stay in the ED.

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