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Changing the Patient Flow Process for the Green Area of Emergency Department: A Discrete-Event Simulation Approach

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Abstract

Aim: This study aimed to analyze patient waiting times and hospital stay times by developing a different approach to the current patient flow processes in the green area of a hospital emergency department.

Methods: Numerical and statistical results were obtained using a discrete event simulation model for the current and new situation of patient flow processes.

Results: The waiting time decreased from 12.91 minutes in the current simulation model to 12.81 minutes in the proposed simulation model. The length of stay time decreased from 54.72 minutes in the current simulation model to 53.90 minutes in the proposed simulation model. In this case, it is seen that the proposed model provides a reduction in the length of stay and patient waiting time.

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Conclusion: The result shows that the proposed model provides some improvement in both waiting and length of stay time. This study offers a different approach to patient flow, allowing emergency department personnel to use their resources effectively and minimizing the time spent on patients' treatment or waiting periods. Thus, this study concluded that the effective management of recommended patient flow processes increases the capacity of emergency departments to deal with emergencies and accelerates access to emergency medical services.

Keywords: Emergency Department, Green Area, Patient Flow, Discrete-event Simulation, Waiting time, Length of stay.

INTRODUCTION

Emergency services are considered an essential element of public health and play an important role in the capacity to deal with a variety of emergencies (Khan et al. 2018). These services provide the ability to deal with emergencies such as unexpected and sudden medical conditions, accidents, or disasters (Hugelius, Becker, and Adolfsson 2020). Emergency services, which have a critical role in terms of people's health and safety, alleviate vital situations by intervening in a timely and effective manner (Atalan, Dönmez, and Ayaz Atalan 2018). The importance of emergency services is related to their ability to respond quickly and professionally in emergencies (Scanlon, Helsloot, and Groenendaal 2014). In cases of sudden illness, heart attack, stroke, or respiratory problems, emergency services intervene without delay, increasing the patient's chance of survival (Mahmud et al. 2020). Emergency services also play a critical role in the overall safety of the community (Ung 2020). In cases of disaster, natural disasters, or major accidents, emergency services intervene at the scene and ensure the evacuation of the public. Therefore, the effective and orderly functioning of emergency services is of vital importance to ensure the safety and health of society (Murphy, Wankhade, and Lakoma 2020).

There are problems such as patient waiting time and patient length of stay in emergency departments (Hoot et al. 2008; Berg et al. 2010). Patient waiting time in emergency departments represents a significant problem in healthcare systems (Dönmez, Atalan, and Dönmez 2020). Although emergency departments are generally designed to handle emergencies, patient wait times can increase due to high patient volume, staff shortages, or other factors (Atalan 2021b). This situation reduces patient satisfaction and prevents rapid intervention, which is vital for critically ill patients. Additionally, long waiting times reduce the efficiency of emergency services, making it difficult to use medical resources effectively (McIntyre and Chow 2020).

Patient length of stay is another important issue (Clarke 2001). The process of patients applying to emergency departments to receive the medical services they expect, diagnosis, and treatment, affects the length of patient stay (Pak, Gannon, and Staib 2021). It occurs due to long patient stays, excess capacity in emergency departments, lack of beds, and other factors (Ahmed and Alkhamis 2009). This situation both reduces the efficiency of emergency services and prevents new patients from receiving service quickly. Additionally, this situation increases the burden on medical staff in emergency departments, causing healthcare workers to work under extreme stress. To deal with these problems, healthcare systems should adopt strategies such as increasing capacity in emergency departments, optimizing staffing, and making processes more effective (Kelen et al. 2021). Additionally, it is important to develop solutions to better manage patient flow and minimize such problems by collaborating with other healthcare services and primary care organizations that work in an integrated manner with emergency departments (Johnson, Burgess, and Sethi 2020; Atalan 2021a). In this study, the patient flow process of the green area of a hospital's emergency department was analyzed by simulation method.

The discrete-event simulation method is a powerful tool for assessing patient waiting times and the effective use of resources in healthcare systems (Vázquez-Serrano et al. 2024). The discrete-event simulation method mimics real-world scenarios by modeling the time-varying states of a system. In terms of analyzing patient wait times, discrete-event simulation is used to understand delays and disruptions in the process from emergency departments to hospital admissions (Molnar 2023). In this way, bottlenecks in the process are identified and improvements are made at these points. Reducing patient waiting times allows patients to be treated more quickly and effectively (Atalan 2022).

At the same time, discrete-event simulation also plays an important role in evaluating the effective use of resources (Ouda, Sleptchenko, and Simsekler 2023). Simulation models increase efficiency by showing how resources (personnel, equipment, facilities) can be allocated at an optimal level (Chang et al. 2023). Workforce planning optimizes resources to ensure adequate use. Thus, cost-effectiveness in healthcare delivery increases, and resources are managed more effectively (Atalan and Dönmez 2020). Discrete-event simulation helps make strategic decisions for the design and implementation of operational improvements in healthcare systems, promoting more effective healthcare delivery by reducing patient wait times and optimizing resource use (Rau et al. 2013).

This study consists of five main sections. The first section contains important information about the subject of the study, and the second section contains a literature review regarding the method of the study. The second part of the study includes the theoretical explanation of the method proposed for the study and information about the developed model. In the third part of the study, numerical results of the model are discussed. General conclusions about the study and the contribution of this study to the literature are mentioned in the last section of the present research.

LITERATURE REVIEW

Patient flow charts serve as an important mapping for the operation of hospitals. Cost and time factors are involved in creating the patient flow method. Many scientific studies have mentioned the importance of patient flow methods and discussed the benefits of these methods for hospitals. The importance of patient flow and how it is created has been discussed in some studies. In one study, a computer-based planning system called Opti-TRANS increased the efficiency of patient transportation services in German hospitals, reducing costs and increasing patient satisfaction (Hanne, Melo, and Nickel 2009). Another study describes a centralized Patient Flow Management Center-integrated approach to managing inpatient services at a multi-campus academic health system. It reports successes in the first year of operations (Lovett, Illg, and Sweeney 2016).

Obtaining the results of changes in patient flow charts in health systems simulated in the computer environment is faster than in real systems. One study reported the effects of implementing a split-flow process using discrete event simulation modeling to support process improvements in a hospital emergency department, and that this new approach provided significant improvements in patient wait times and overall patient length of stay (Konrad et al. 2013). One study took an ethnographic approach to how emergency department clinicians behave in the field to manage work pressures and efforts to optimize patient flow in environments such as delayed patient admissions and emergency room crowding (Nugus et al. 2011). Gharahi et al., based on the fact that long waiting times in a hospital negatively affect the performance of the emergency department, suggested that a 6% reduction in waiting times could be achieved by modeling the patient flow with methods such as discrete event simulation and analytic hierarchy process, identifying bottlenecks and applying the best scenario (Gharahi et al. 2014).

The importance of the patient flow chart in terms of cost and time factors is increasingly emphasized to increase effectiveness and efficiency in healthcare. Many studies show that improving patient flow can reduce costs and use resources more effectively (Gualandi, Masella, and Tartaglini 2020). In particular, reducing the number of waiting patients by ensuring a more fluent patient flow has helped to use personnel and resources more efficiently and thus reduce costs (Alowad et al. 2021). However, creating and implementing an effective patient flow chart can take time and require extra resources. However, in the long run, spending these efforts and resources provides benefits such as improving hospital functioning, increasing patient satisfaction, and improving the quality of healthcare services.

Regarding the time factor of patient flow, one study emphasized that time is a critical factor and it is important to manage patient movement quickly and effectively (Saghafian, Austin, and Traub 2015). Especially in emergency departments, fast and regular patient flow accelerates the treatment process of patients and reduces the time required for situations requiring urgent intervention (Jarvis 2016). Additionally, a study emphasized that timely diagnosis and treatment provide patients with better outcomes and fewer complications (Mercer, Singh, and Kanzaria 2019). Therefore, it is vital that the time factor is taken into account during the creation and implementation of the patient flow chart and that all stages of the process are optimized in terms of time.

1. RESEARCH METHODOLOGY

This study aimed to analyze the new and current situation in a discrete-event simulation model by developing a different approach to the existing patient flow processes of a hospital's emergency department. The healthcare system in Turkey has a structure with certain protocols and color coding regarding the functioning of emergency services. Emergency services, as an indispensable part of hospitals, are organized to provide rapid and effective intervention. Color coding is used in emergency departments to indicate the level of urgency of patients. Green, yellow, and red colors are generally used categories. These colors help prioritize patients based on their condition.

The green area represents those with the lowest urgency among patients applying to emergency departments. This category is generally used for minor injuries, simple illnesses, or routine examinations. Green area patients are cases that require intervention later than patients with other emergencies in the emergency department sequence. The yellow area indicates situations where the patient's condition is slightly more serious. This category includes situations that require immediate attention but are not life-threatening. Moderately urgent patients can expect a faster response than those in the green zone. The red area represents patients with the highest level of urgency. This category includes life-threatening situations and those that require the quickest intervention. Red zone patients are considered a top priority among other emergencies and are triaged immediately for emergency treatment.

The triage process in emergency departments aims to provide the most effective treatment by determining the urgency levels of patients, together with color coding. This system increases the capacity of healthcare personnel to deal with emergencies by providing them with priority intervention according to the patient's conditions. In this study, a model was developed using the discrete-event simulation method for the green area of the emergency department of a public hospital, taking into account patient flow processes. The simulation model of the emergency service unit is shared in Figure 1. In the simulation model developed for the emergency service unit, there are 2 doctors, 2 exam rooms,1 triage area, 1 triage staff (nurse or health trained), and an officer responsible for patient entry and exit procedures.

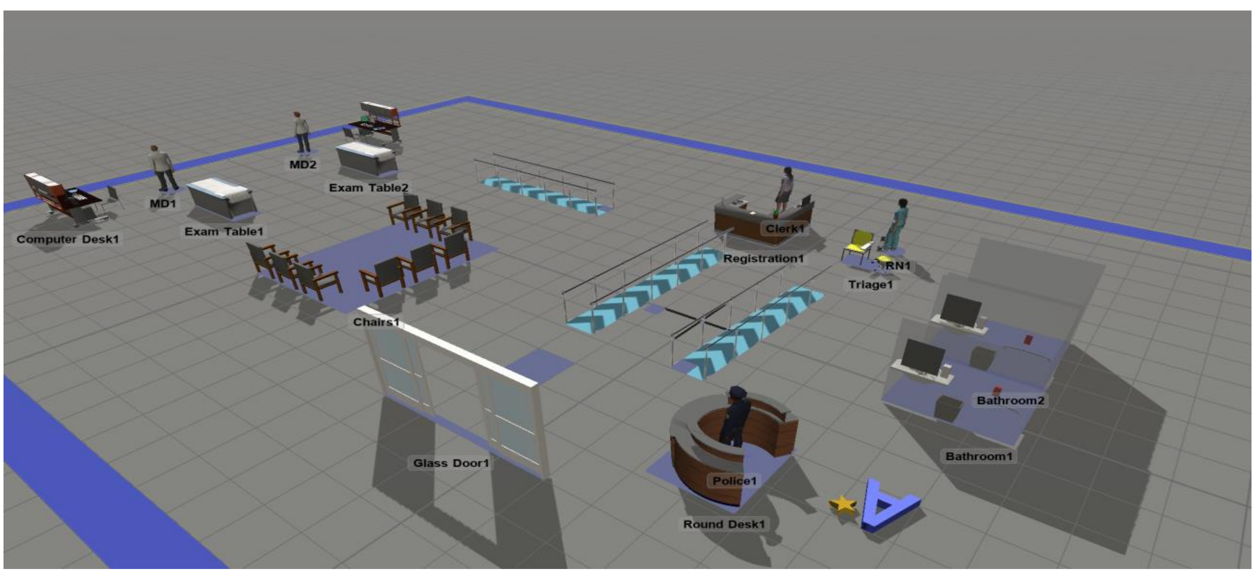
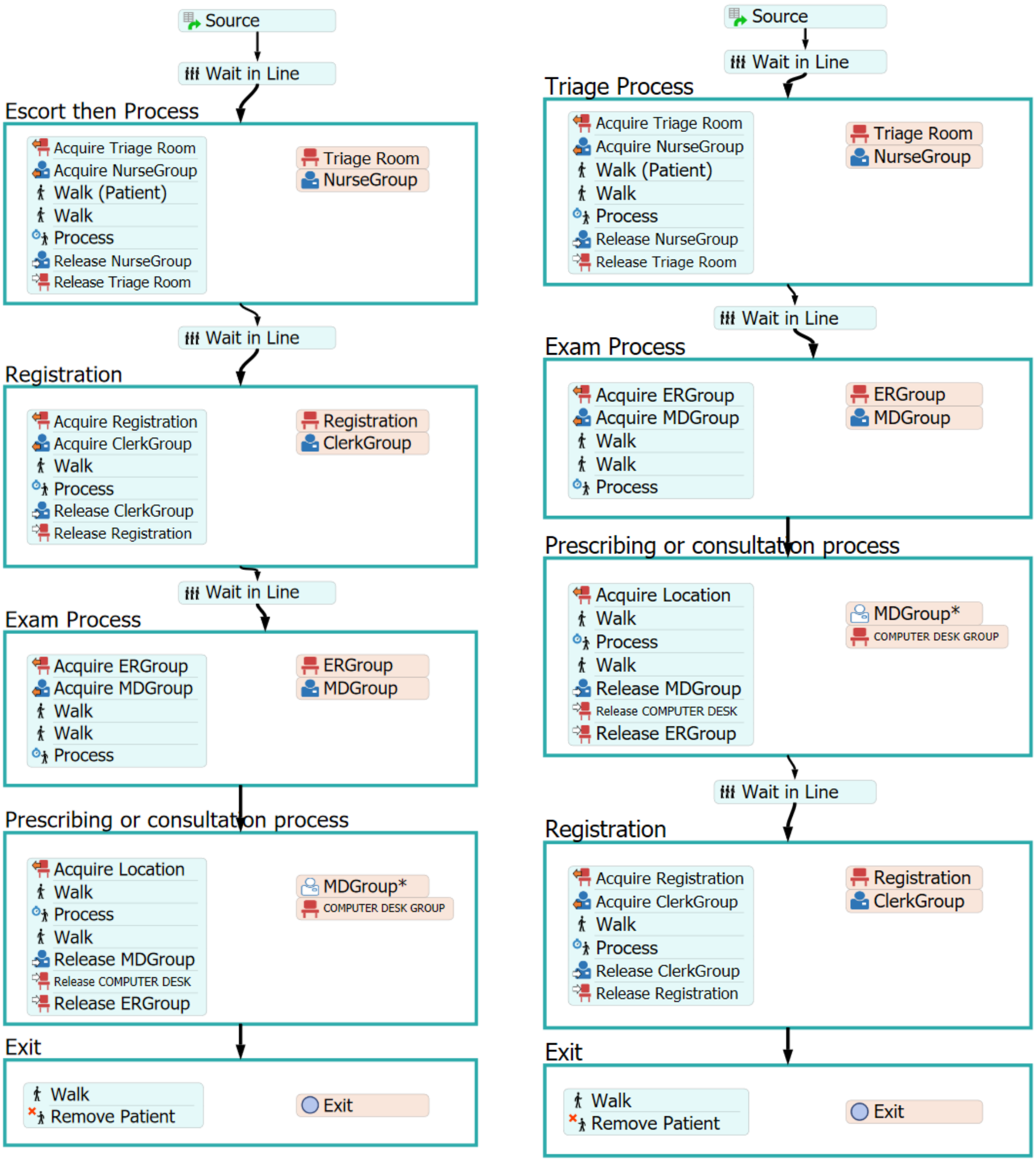


Figure 1. The simulation model of the emergency service unit

The current patient flow chart for patients transferred to the green area in the emergency department is discussed in **Figure 2-a**. The green-coded area of the emergency department is a section where patients with low-emergency situations generally receive service. The green area includes situations that do not require immediate attention, such as minor injuries, simple illnesses, or routine examinations. This area aims to maintain a certain order and speed in the patient flow process. When a patient applies to the green area, they are first directed to triage and then to the registration department. Here, the patient's basic information is recorded and the patient's emergency condition is evaluated by the triage nurse. Since the condition of greenfield patients is generally mild, immediate intervention may not be required, but treatment or referral may be needed.

After triage, the patient who is directed to the registration department completes the registration process, and then the green area patients are directed to the waiting area. In this section, the patient is subjected to an initial evaluation by the doctor while waiting for his turn. If the condition does not require urgent intervention, the patient is told to proceed to the examination room or outpatient clinic area in the specified order. However, usually, the patient leaves the hospital after medication or consultation. Green area patients generally use emergency department resources less intensively, so treatment/examination procedures are shorter. However, the number of patients referred to the green area and the active patient flow processes, cause long waiting times. For this reason, a new approach to green space is presented in this study. Patient flow processes of the new approach are shown in **Figure 2-b**.



a- Current Situation b- Proposed Situation

Figure 2. Patient flow for patients transferred to the green area in the emergency department

In the new process, when a patient applies to the green area, they are first directed to the triage department. Here, the patient's basic information is recorded and the patient's emergency condition is evaluated by the triage nurse. Afterward, after the patient is directed to the registration department and completes the registration process, green area patients are directed to the waiting area. In this section, the patient is subjected to an initial evaluation by the doctor while waiting for his turn. If the condition does not require urgent intervention, the patient is told to proceed to the examination room or outpatient clinic area in the specified order. After the medication or consultation procedure, the patient is directed to the registration process before leaving the hospital to ensure that the emergency service process is completed. In the registration area, the procedures performed on the patient are recorded and the patient is informed about the next procedure.

In this study, the results of two different simulation models created according to existing and proposed patient flow charts were obtained and these results were shared in the third part of the study.

2. ANALYSIS

In this study, a discrete-event simulation model was created by considering the patient flow of a hospital's emergency department. This study, which offers a new approach to the harvest flow chart of the emergency service unit, has created a new model by improving the existing simulation model. Waiting and length of stay times values obtained for both models are given in **Table 1**.

Table 1. The descriptive statistics for Waiting Time and Length of Stay

Variable	Current Model		Proposed Model	
	Length of Stay	Waiting Time	Length of Stay	Waiting Time
Total Count	111.00	330.00	110.00	330.00
Mean	54.720	13.260	53.900	13.060
SE Mean	2.4600	1.1900	2.5100	1.2000
StDev	25.890	21.590	26.290	21.720
Variance	670.51	466.25	691.19	471.65
CoefVar	47.320	162.82	48.780	166.25
Minimum	7.7200	0.0500	7.9200	0.0500
Maximum	99.400	86.150	101.38	85.230
Range	91.680	86.100	93.470	85.180
Skewness	-0.1600	1.7000	-0.1100	1.6900
Kurtosis	-1.1800	1.5700	-1.1500	1.5100

The average waiting time was measured as 330.00 units. The average waiting time is 13.260 minutes. The standard error (SE Mean) is 1.1900, which indicates the estimated amount of error regarding the mean. The standard deviation expressing the distribution of waiting time data is 21.590 minutes. The total length of stay was measured as 111.00 units. The average length of stay is 54,720 minutes. The standard error of the length of stay is 2.4600. The standard deviation is 25.890 units. The variance between hospital stays is 670.51 units.

Several metrics can be used to compare waiting time and length of stay. The variance for wait time (466.25 units) is lower than for length of stay, which may indicate that waits are more consistent overall. However, since the average length of stay is higher than the average waiting period, it can be said that patients stay in the hospital longer after treatment. To evaluate the distribution of the data, minimum and maximum values can be looked at. The minimum is 0.0500 and the maximum is 86,150 minutes during cooldown. During the hospitalization period, the minimum is 7.7200 minutes and the maximum is 99.400 minutes. These values show that there is a wider distribution in waiting time and a more limited distribution in hospitalization time. The skewness value of the waiting time is 1.7000 and the lying time is -0.1600. Positive skewness in the waiting time indicates that the distribution is skewed to the right, while negative skewness in the length of stay indicates that the distribution is skewed to the left. Kurtosis values may indicate that both variables are close to a normal distribution, but there are some outliers.

Descriptive statistics data regarding patient waiting times and discharge times (Length of Stay) of the proposed simulation model were obtained. For patient discharge times (Length of Stay), in the analysis conducted on a total of 110 patients, the average discharge time was found to be 53,900 minutes. The standard deviation, which is the measure of the distribution of the data, was calculated as 26.290 minutes and the variance was calculated as 691.19 minutes.. This shows that the data has wide dispersion. While the minimum discharge time was 7,920 minutes, the maximum discharge time was determined as 101.38 minutes. The difference between this distribution indicates that the data set has a wide range.

As for patient waiting times, in the analysis conducted on a total of 330 patients, the average waiting time was found to be 13,060 minutes. Lower waiting times are expected because the patient waiting time should generally be shorter than the discharge time. The standard deviation was calculated as 21.720 minutes and the variance was calculated as 471.65 minutes. While the minimum waiting time is 0.0500 minutes, the maximum waiting time is 85.230 minutes. The difference between waiting times shows that patient waiting times also have a wide distribution. Since the standard error (SE Mean) values of the mean values are low for both variables, it can be said that these statistics are quite reliable compared to the estimated mean values. Additionally, when the skewness and kurtosis values for both variables are examined, the skewness is negative and kurtosis is low for discharge times, while the skewness is positive and kurtosis is high for waiting times. The results of the simulation model run for 24 hours are given in **Table 2**.

Table 2. The results of the discrete-event simulations model run 24 hours a day

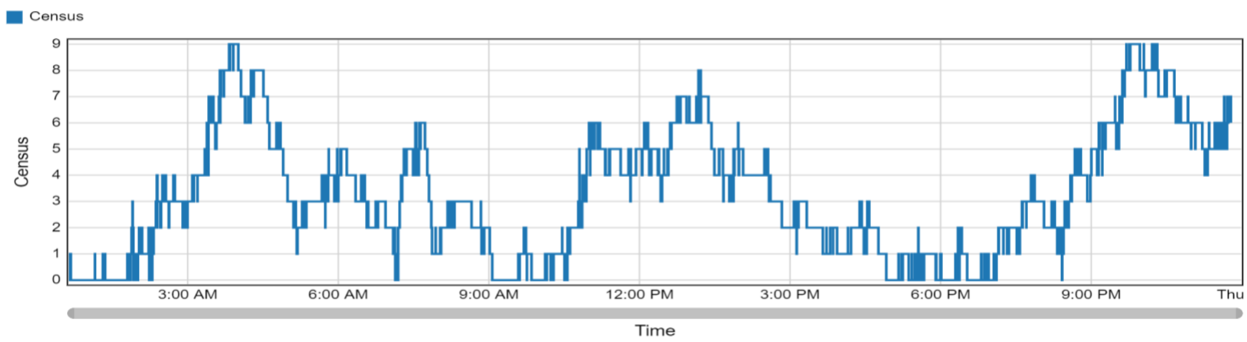
Outputs	Current Simulation Model	Proposed Simulation Model
Waiting time (minute)	12.91	12.81
Length of stay (minute)	54.72	53.90
Patient number	110	110
Clerk(utilization) (%)	16	15
Physician (utilization) (%)	88	88
Nurse (utilization) (%)	25	25

Table 2 shows the results of the discrete event simulation model run for 24 hours. These results compare the current simulation model with the proposed simulation model. First, when the "WT (minute)" output is examined, it is seen that the waiting time is 12.91 minutes in the current simulation model, and this time decreases to 12.81 minutes in the proposed simulation model. This shows that the proposed model provides a slight improvement in waiting time.

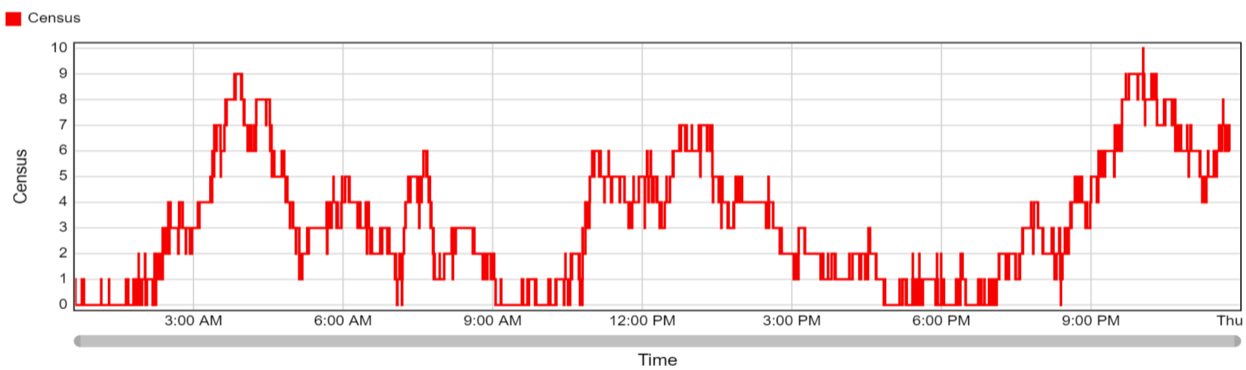
Secondly, when the length of stay output is evaluated, it is seen that the treatment time is 54.72 minutes in the current simulation model, and this time decreases to 53.90 minutes in the proposed simulation model. In this case, it appears that the proposed model provides a reduction in treatment time. Thirdly, when the patient output is examined, it is seen that both simulation models show the number of patients as 110. This shows that the proposed model does not bring any change in the number of patients compared to the existing model.

Fourthly, looking at the clerk (utilization %) outputs, it is observed that the civil servant utilization rate is 16% in the current simulation model, and this rate drops to 15% in the proposed simulation model. This shows that the proposed model provides some reduction in officer usage. Fifthly, looking at the utilization of physicians' outputs, it can be seen that the doctor utilization rate is 88% in both simulation models. This shows that there is no change in the rate of doctor usage. Finally, looking at the utilization of nurse's outputs, it is seen that the nurse utilization rate is 25% in the current and proposed simulation models. In this case, we can say that there is no change in the rate of nurse utilization.

As a result, the table shows that the proposed simulation model brings slight improvements in waiting time and treatment time, but decreases in officer utilization rate. No change was observed in the utilization rates of both doctors and nurses. In the simulation model, there are 3 waiting areas in 3 different areas. The first waiting queue is for the triage process of patients. The second waiting queue is for the registration process. The last waiting queue is for patients to be treated or examined, depending on the availability of doctors or appropriate exam rooms. The numbers of patients waiting in all three areas are shown in **Figure 3** for both the current and proposed situation.



a) the simulation model based on the current situation



b) the simulation model based on the proposed situation

Figure 3. The number of patients waiting in all three waiting areas (or lines)

According to Figure 3, which analyzes the number of waiting patients in the healthcare institution, various changes are observed between the current simulation model and the proposed simulation model at different periods during the day. During night hours, between 00:00 and 02:59, the expected number of patients remains constant at 4 in both models. In the early morning hours, between 03:00 and 05:59, while 9 patients were expected in the current model, this number decreased to 8 in the proposed model, which shows that the proposed model performs more effectively during these hours. As the hours progressed, while 6 patients were expected in the current model between 06:00-08:59, this number decreased to 5 in the proposed model. Similarly, the expected number of patients remains constant at 6 in both models between 09:00 and 11:59. While 8 patients were expected in the current model between 12:00 and 14:59 at noon, this number decreased to 7 in the proposed model. However, the expected number of patients remains constant at 3 in both models between 15:00 and 17:59. While 5 patients were expected in the evening hours between 18:00 and 20:59 in the current model, this number decreased to 4 in the proposed model. However, while 9 patients were expected in the current model between 21:00 and 23:59, this number increased to 10 in the proposed model, which shows that the proposed model needs more patient capacity in this time zone.

It is understood that the patient flow process suggested in this study is consistent compared to other studies. In one study, it was observed that changing the patient flow management approach resulted in a 6% improvement in the waiting rate of patients (Gharahi et al. 2014). In another study, as a result of the suggested change in the patient flow chart, a decrease in patient length of stay of up to 48 minutes was achieved (Konrad et al. 2013). Batt and Terwiesch's study showed that reducing variability in patient flow resulted in more efficient use of resources in the cardiac surgery intensive care unit, resulting in a 15% reduction in patient waiting times. Holroyd et al. found that the use of a triage-affiliated physician in the emergency department contributed to reducing patient wait times by an average of 20%. (Holroyd et al. 2007). Fagbuyi et al. showed that implementing a rapid medical screening process in the emergency department reduced the average wait time per patient from 20 minutes to 12 minutes, thereby increasing patient satisfaction by 25% (Fagbuyi et al. 2011).

As a result, it seems that the proposed simulation model generally provides an improvement in reducing the number of waiting patients, but there are differences between time intervals. This analysis highlights the potential for a healthcare organization to optimize capacity management by hours.

3. CONCLUSION/DISCUSSION AND RECOMMENDATIONS

This study used a discrete event simulation model to analyze patient flow processes in the green area of a hospital emergency department and recommend changes. The importance of emergency services in dealing with various medical situations and ensuring the safety of the community is emphasized. Patient waiting time and length of stay have been identified as significant challenges in emergency departments, impacting patient satisfaction and affecting the overall efficiency of services. To address these issues, the study proposed a new approach that aims to simulate triage, registration, and treatment procedures by focusing on the patient flow process of the green area.

The method involved developing two simulation models based on existing and proposed patient flowcharts. The results are presented by comparing waiting time, length of stay, and resource usage between the two models. One of the most notable results of the study is that the proposed simulation model provides a slight improvement in waiting time. While the average waiting time for waiting patients in the current model is 12.91 minutes, this time has decreased to 12.81 minutes in the proposed model. Similarly, a reduction in treatment time was also observed. While the treatment time is 54.72 minutes in the current model, this time decreased to 53.90 minutes in the proposed model. This contributes to increasing the efficiency of emergency department processes and allowing patients to receive service faster.

Another important result of the study is that the proposed model leads to a decrease in the use of clerks. While the clerk utilization rate is 16% in the current model, this rate has decreased to 15% in the proposed model. However, no change was observed in the utilization rates of doctors and nurses. This shows that the proposed model provides more effective use of officers at certain points, but there is no significant change in the use of doctors and nurses. Another finding of the study is that the proposed model does not bring any change in the number of patients compared to the existing model. The number of patients remained at 110 in both models.

It revealed that the proposed model provided a slight improvement in waiting time and a reduction in treatment time, which contributed to the increase in overall efficiency. The analysis also showed the potential for optimizing capacity management by hours, pointing to various changes in the number of patients waiting in different periods. With the positive results obtained in this study, it will be more obvious that there will be significant decreases in long patient waiting times and length of stay in hospitals where emergency department visits are much higher.

Although the proposed simulation model has caused positive changes, it should be acknowledged that certain parameters, such as doctor and nurse utilization rates, have not changed. The study highlighted the importance of adopting strategies such as increasing capacity, optimizing staffing, and improving processes to effectively address challenges in emergency departments. Overall, the findings of this study provide valuable insights for healthcare organizations seeking to improve the performance of their emergency departments and improve patient outcomes through strategic process improvements in patient flow processes.

This study provides important recommendations in the field of healthcare management. First of all, it is emphasized that simulation models should be used effectively to improve patient flow in hospital emergency departments. Suggestions for future work include more comprehensive testing of the simulation model, examining the effects of different policy and procedure changes, validating simulation results with real-world data, and evaluating the economic impacts of the model. These recommendations provide an important road map to develop applicable strategies to increase efficiency in healthcare services and increase patient satisfaction.

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