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Original Article

Development of a Discrete Event Simulation Model to Minimize the Waiting Time of Patients in Hospitals

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Abstract

Introduction: Proper management of health systems requires the use of a suitable decision making logic. Simulation is a good tool for accurate and evidence-based decision making. The main objective of this study was to developing a simulation model to minimize the waiting time of patients in the cardiac subspecality clinic of Kowsar Hospital.

Methods: This is a cross-sectional study. The statistical population consisted of 576 patients, referring to Kowsar cardiac clinic in the morning and afternoon shifts. Data collection was conducted according to a designed timetable form. Scenarios were defined to receive the best answer. These scenarios were as follows: scenario A: decrease of the average of the service time; scenario B: increase of the mean time between the two entries; and scenario C: decrease of the service time and increase of the time between two entries. ARENA software was used to simulate and review the scenarios and General Algebraic Modeling System (GAMS) software was used to obtain a definite answer.

Results: Simulation results showed that in scenario A the mean time spent in the system was 85.55 minutes in the morning and 77.05 minutes in the evening shifts. In scenario B, the average time spent in the system was 65.95 minutes in the morning and 79.63 in the evening shifts. In scenario C, the mean time spent in the system was 73.90 minutes in the morning and 61.17 minutes in the evening shifts. The result of the final model showed that the average time spent in the system was 97.33 min in the morning and 86.85 min in the evening.

Conclusion: According to the results obtained from the use of the definitive and simulated models, it was found that the simulation model, due to its probability, faces a percentage of error. Comparison of the definitive and simulated models revealed that the best scenario to the definitive answer was scenario B (increasing the mean time between the two logs).

Keywords: Clinic, Waiting time, Queuing theory, Simulation

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Introduction

Hospitals are one of the most important providers of health care services and play an essential role in restoring the patients' physical and mental health, carrying out medical research and training the staff required by the health sector (1). Clinic is one of the most important sections in hospitals, where a large number of people refer to in orderto receive health care services (2). The waiting time of patients in the clinic of hospitals is very important. The purpose of waiting time is the length of the patients' entrance to a clinic and waiting in the clinic until the examination is performed by the physician. The waiting time indicates the level of access to hospital services and can be measured as one of the indicators of hospital performance (3). One of the ways to improve the quality of services and reduce the waiting time is increase in the work force of an organization. However, increasing the work force will enhance the cost of the organization. In fact, healthcare efficiency should be improved through evaluating the existing systems and using advanced solutions without increasing costs (4). Simulation is a good tool for accurate and evidence-based decision-making, which can help reduce the costs and prevent loss of resources by providing appropriate solutions (5). The discrete event simulation method, due to its high benefits, can be used to model a complex system such as a clinic. However, the implementation of simulation only is not sufficient. The use of hospital optimization model will reduce the waiting time and the number of visitors in the waiting queue and improve the quality of services (6). Various studies have been conducted in hospitals and medical centers to reduce the waiting time, using simulation models. According to the results of these studies, the use of software simulation models can help reduce the waiting time and increase the patient satisfaction (7-12). For instance, in study conducted by Moradi and Razavi, in one of the hospitals in Shiraz to simulate para-clinical services and evaluate the waiting time reduction scenarios, it was shown that the implementation of the proposed scenarios, compared to the current model, improved the quality of services and reduced the waiting time of patients to receive the first visit (12). Also, in another study, Ramazankhani et al. used queuing theory and simulation model to optimize the pharmacy performance in one of the country's hospitals. The results of study showed that the characteristics of the queue in the pharmacy in the study were undesirable during the morning and evening shifts, and decrease in the number of personnel at the stage of receiving the drug prescription did not change the queuing performance indices. However, increase in the number of personnel at the stage of delivery of the prescribed drugs reduced the average number of people waiting in the queue by 10. Furthermore, a decrease in the number of personnel from 2 to 1 at the stage of the delivery of prescribed drugs in the evening shift slightly changed the queuing performance indicators. However, adding one person to the personnel at the stage of drug delivery reduced the average number of the people in the queue by 50 (13). Another study was designed by Brandon to create a simulation model in one of the obstetrics and gynecology clinics affiliated with Arkansas University of Medical Sciences to reduce the waiting time of patients. In this study, a discrete event simulation model was used with the purpose of reducing the waiting time. The results of the scenario analysis showed that the optimal use of manpower could reduce the waiting time of the clinic patients. Additionally, by increasing the number of nurses and laboratory staff in the clinic, the average waiting time of patients reduced by about 40 minutes (14).

Which in addition to patient dissatisfaction increases the costs One of the most important and prevalent problems in the hospitals of the country is the long waiting time for receiving health care and treatment services in clinics. Therefore, the use of scientific methods that reduce the waiting time can have a significant impact on reducing the costs and increasing patient satisfaction. The purpose of this study was to develop an optimization and simulation model, using simulation software to investigate the current situation and identify the problems in cardiac clinic of Kowsar Hospital in Shiraz and to implement the optimization model, using GAMS software; we also aimed to compare the simulation model with the optimization one and select the closest answer to the optimal answer.

Methods

This is a cross-sectional study. The statistical population consisted of 576 patients referring to the Clinic number 1 (cardio-vascular sub-specialty clinic) of Shiraz Kowsar Hospital. All participants signed an informed consent before the commencement of the study.

This study was performed in seven steps:

1. Developing a timetable form, including the time of arrival of the patient to the hospital, the time of arrival of the patient into the examination room and the time of exit from the hospital
2. Identifying and defining the type of the service system in the clinic
3. Designing the basic simulation model
4. Developing a mathematical model for minimization of the waiting time of the patients referring to the clinic
5. Implementing the model
6. Implementing various scenarios in simulation software and analyzing the results
7. Comparing the results of the model of minimization and simulation as well as providing suggestions for improving the clinic performance and reducing waiting time.

In order to collect data about waiting time, including admission time, arrival time to the clinic and waiting time in the clinic, we prepared some forms to record the timetables. After collecting the data, the type of service system was identified and defined. Based on the research background, a basic simulation model was designed. The input variables of the model included the arrival time and service receiving time. In order to analyze information, we used the Excel software and the analytical information was separated. Then, initial evaluation of the data and estimation of distribution function were performed, using SPSS software. After estimating the distribution function, the parameters were extracted, using the queue model. Then, these parameters were used as the target function and the limitations of the definitive model. The optimal answer was obtained, using The General Algebraic Modeling System (GAMS) software. In order to design and implement a discrete simulation model, we used arena software, and eventually the definitive and non-deterministic (probabilistic) answers were compared; with the implementation of different scenarios, the closest answer to the definitive answer was selected. Figure 1 shows the basic model designed in simulation software.

After designing the basic model and its implementation, the results of the mean waiting time of patients were determined. Additionally, the system behavior was reviewed without any changes in the system itself. In order to improve the process according to the system performance criteria, different scenarios were defined and by running each scenario on the simulation model, their effect on the functional measures of the system was examined. These scenarios have been able to be defined and discussed from a variety of perspectives and aspects. In order to highlight the role of scenarios and their importance in simulation studies and consider different aspects of the problem, three categories of scenarios were defined. These scenarios are considered as potential alternatives for making changes in departmental processes.

A: decrease in the average service time

B: increase in the average time between two entries

C: decrease in the service receiving time and increase in the time between two entries

In order to select the best scenario for implementation in the clinic in the study, we compared the results of the implementation of the proposed scenarios with those of the base model. Then, the best scenario was selected based on how much each scenario decreased the waiting time. Through GAMS software, version 24.1, the mathematical modeling was implemented. For this purpose, the parameters were first obtained based on the basic model developed and implemented by ARENA software. The parameters were considered as the target function and the constraints, and finally the model was implemented. In the proposed model, y represents the average service rate, yy the average customer entry rate and Ws the average time spent by each client in the system. Also, WQX (i) the average waiting time of clients in the queue, LQX (i), the average number of clients in the queue and LSX (i), the average number of clients in the system have been defined as the variables.

$$MIN\ W = \sum_i WQX_i$$

s.t.

$$WQX_i \geq LQX_i * y \qquad \forall i$$

$$LQX_i \geq LSX_i * ws \qquad \forall i$$

$$LSX_i \geq yy \qquad \forall i$$

Results

In this study, the data for both morning and evening rotations were simulated. According to the information obtained from the statistical population, more than 70% of the patients referred to specialists, 20% to sub-specialists, and 10% to surgeons (data not shown).

Figure 2 displays the distribution function of the client arrival time, service distribution, and time distribution between the two entries. The average time between the two entries (λ) was 5.57 in the morning and 6.75 in the evening. The average service time (μ) was 8.15 in the morning and 9.11 in the evening. The morning productivity was 65% and the unemployment rate was 35%. The evening productivity was 69% and the unemployment rate was 31%.

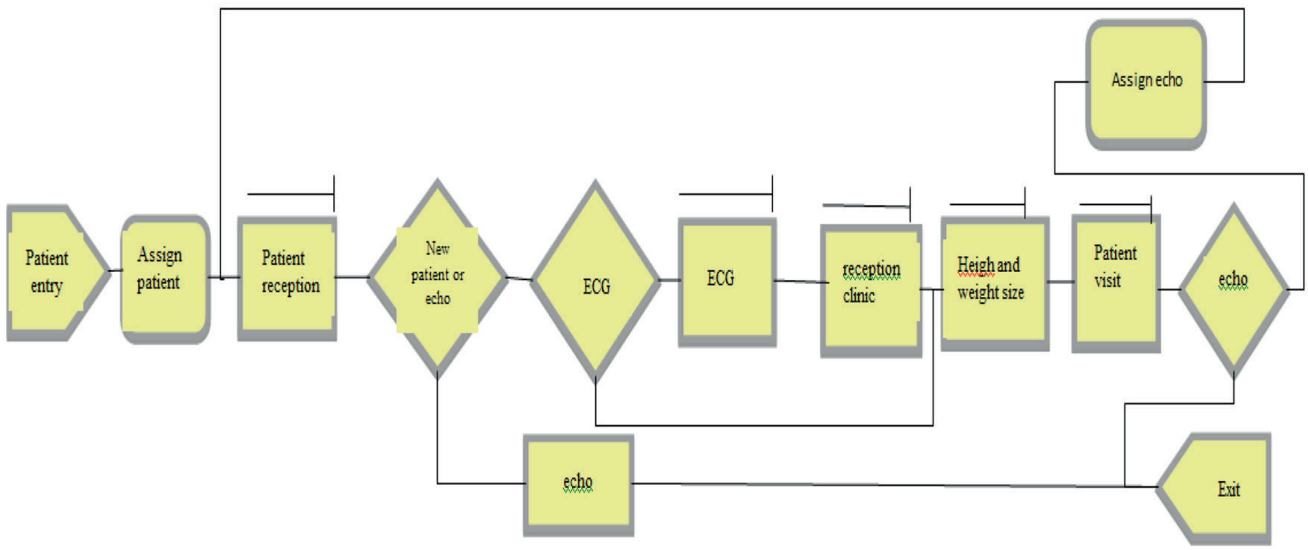

Figure 1: Basic model simulated with ARENA software

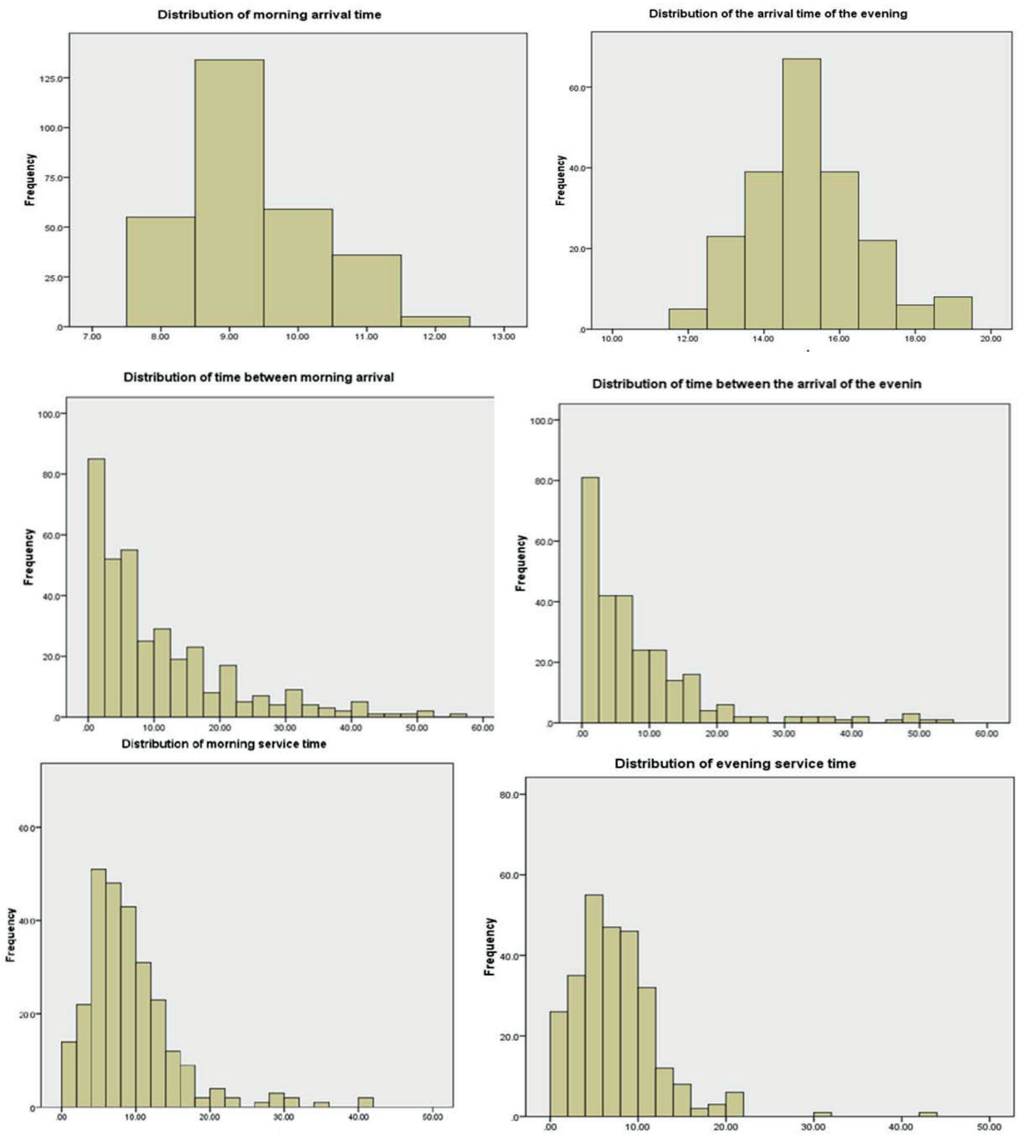

Figure 2: Time distribution functions

Table 1 shows the results of simulation model with the ARENA software. The average number of clients in the queue was 11.98 in the morning and 7.60 in the evening. The average number of clients in the system was 12.97 in the morning and 8.59 in the evening. The average waiting time in the queue was 98.17 in the morning and 70.53 in the evening. Also, the average time spent in the system was 106.33 in the morning and 79.64 in the evening.

The results of implementing scenarios, using the Arena simulation software, are presented In Table 2. Scenario A with a decrease of 0.13% in the afternoon and 0.8% in the morning and scenario B with an increase of 0.01% in the evening and 0.07% in the morning were tested. The results of implementing scenarios A and B showed that with a decrease in the average service time and with an increase in the average time between the two entries respectively, the coefficient of operation increased and the unemployment percentage decreased. Furthermore, the parameters of waiting time and queue length decreased. Additionally, Scenario C was tested based on the combination of A and B scenarios. The results of scenario C showed that by decreasing the average service time and increasing the average time between the two entries, the coefficient of operation increased and the unemployment percentage decreased; also, the waiting time and the length of the queue decreased.

Table 3 shows the results of implementing the definitive model, using GAMS software. As shown, the average time spent in the system in the morning was 97.33 and in the evening it was 86.85. The average waiting times in the queue were 85.32 and 80.55 in the morning and evening, respectively. As shown, the average time spent in the system (W_s) and the average

Table 1: The result of simulation model in the morning and evening, using ARENA software

	Parameter	Afternoon	Morning
Average waiting time in the queue	W_q	70.53	98.17
Average time spent on the system	W_s	79.64	106.33
Average number of clients in the queue	L_q	7.60	11.98
Average number of clients in the system	L_s	8.59	12.97

Table 2: The results of scenario implementation using Arena software

		ρ	ƛ	µ	W_q	W_s	L_q	L_s
Scenario A	Morning	0.69	5.57	8.07	77.48	85.55	9.54	10.53
	Evening	0.75	6.75	8.98	68.07	77.05	7.33	8.31
Scenario B	Morning	0.69	5.64	8.15	87.50	95.65	10.59	11.57
	Evening	0.75	6.76	9.11	70.52	79.63	7.60	8.59
Scenario C	Morning	0.69	5.64	8.07	82.66	90.73	10.04	11.02
	Evening	0.75	6.76	8.98	52.19	61.17	5.62	6.5

Table 3: The results of implementation of definitive model using GAMS software

Parameter	Evening	Morning
Average between two entries (ƛ)	6.75	5.57
Average service rate (µ)	9.11	8.15
Functional rate (operating factor), (P)	0.69	0.65
Unemployment percentage (1-ρ)	0.31	0.35
Average number of clients in the queue (L_q)	6.75	5.570
Average number of clients in the system (L_s)	8.43	10.026
Average waiting time in the queue (W_q)	80.55	85.32
Average time spent in the system (W_s)	86.85	97.33

Table 4: Similarity coefficient and equivalence factor of the results of minimization and simulation model in the morning and evening shifts

Morning shift					Evening shift			
	Definitive answer	Scenario A	Scenario B	Scenario C	definitive answer	Scenario A	Scenario B	Scenario C
Definitive answer	1	0.32	0.77	0.46	1	0.73	0.78	0.51
Scenario A	-	1	0.42	0.70	-	1	0.93	0.69
Scenario B	-	-	1	0.59	-	-	1	0.65
Scenario C	-	-	-	1	-	-	-	1

waiting time in the queue (W_q) in the base Arena model were 106.33, 98.17 in the morning and 79.64, 70.53 in the evening. In scenario A, W_s and W_q were 85.55 and 77.48 in the morning and 77.05 and 68.07 in the evening, respectively. In scenario B, W_s and W_q were 95.65 and 87.50 in the morning and 79.63 and 70.52 in the evening, respectively. In scenario C, W_s and W_q were 90.73 and 82.66 in the morning and 61.17 and 52.19 in the evening, respectively. Additionally, in the definitive model W_s and W_q were 97.33 and 85.32 in the morning and 86.85 and 80.55 in the evening.

Table 4 illustrates the results of similarity and homogeneity coefficient of minimization and simulation model. In the morning shift, similarity coefficient in scenario A was 0.34, in scenario B it was 0.77 and in scenario C it was 0.46. Additionally in the evening shift, similarity coefficient in scenario A was 0.73, in scenario B it was 0.78, and in scenario C it was 0.51.

The results of simulation model scenarios, mathematical model and similarity coefficient are exhibited in Figure 3.

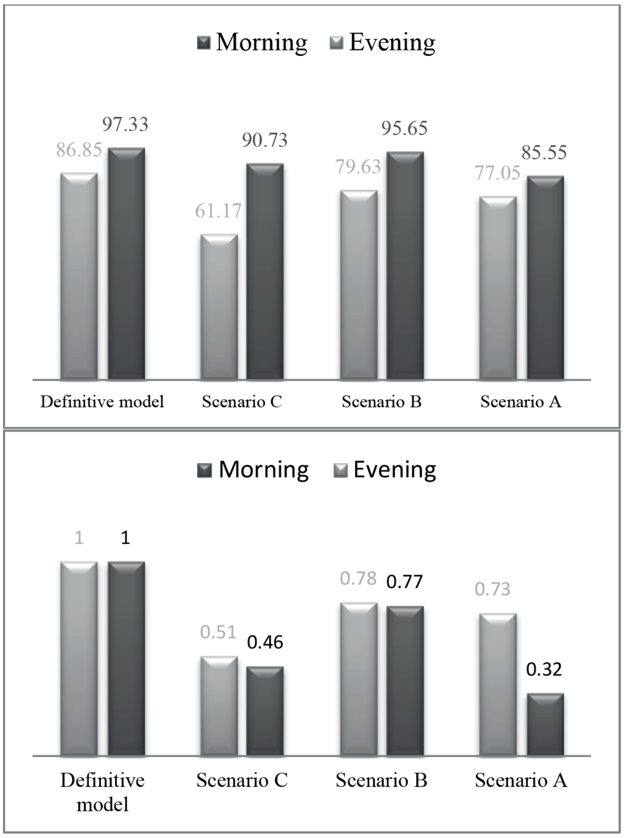

Figure 3: Results of simulation model scenarios and mathematical model

Discussion

The results of this study showed that the distribution of clients, arrival time, patient distribution, as well as the distribution of service time and time distribution between the two logs follow an exponential distribution. Considering that the morning productivity was 65% and the unemployment rate was 35%, in the evening shift, the coefficient of productivity and the unemployment rate were 69% and 31%, respectively; it can be said that the system does not use all its potentials. These issues indicate the importance and the necessity for further dstudies to be conducte.

Based on the results obtained from the scenarios, the best scenario in the morning shift was Scenario A, reducing the average service time. In this scenario, the service rate reduced by 13% in the morning and 08% in the evening. After running the model, the average waiting time was 77.48 in the morning and 68.07 in the evening; as also, the average time spent in the system was 85.55 in the morning and 77.05 in the evening. However, in the evening shift the best scenario, scenario C, was the combination of both scenarios (reducing the service time and increasing the time between the two entries). The result of this scenario showed that the average waiting time was 82.66 in the morning and 52.19 in the evening; also, the average time spent in the system was 90.73 in the morning and 61.17 in the evening.

According to the results of the definitive and simulation model, it was observed that the simulation software gives a non-deinitive answer in which there is the probability of error. Implementing different scenarios and comparing those with the definite answer can help the clients in reducing the waiting time and increasing satisfaction. After the implementation of the mathematical model and obtaining the definitive answer, the best answer of the proposed scenario, compared to the definitive answer, was selected. Based on the comparison between the simulation and mathematical models, scenario B (average time increase between two entries) was selected as the best scenario. The average time spent on the definitive model was 97.33 and in scenario B it was 95.65. Therefore, scenario B was selected as the best scenario. Additionally, in the evening shift, the closest scenario to the definitive model was scenario B. The average time spent on the definitive model system was 86.85 and in scenario B it was 79.63. Therefore, scenario B was selected as the best scenario. The results of calculating the similarity coefficient showed that scenario B was the best answer.

Various studies have been conducted to reduce the waiting time of the patients, using simulation methods (1-3, 6-8, 15-18). For instance, Duguay and Chetouane conducted a study to reduce the waiting time in department systems, using discrete event simulation with ARENA software. The simulation results showed that the waiting time from the time of registration to presence in the examination room had the most problems (3 to 4 h at times). Finally, the results showed that increasing the number of physicians and nurses would improve the waiting time, but increasing the number of examination rooms did not have an effect on the waiting time without increasing work force (19). Moradi and Razavi conducted a simulation model for para-clinical services at Hafez hospital of Shiraz and evaluated the waiting time reduction scenarios. The aim of their study was to identify the factors affecting the waiting time of patients and reduce it to the extent it would have the least difference with the waiting time standards. The results of those studies showed that the implementation of the proposed scenarios, compared to the current model, improved the service quality and reduced the waiting time of patients in the first visit (12). Additionally, Salimifard et al. conducted a study to improve the hospital emergency department processes, using computer simulations. Their aim was to improve the patient flow processes in the emergency department. Colored petri dishes and CPN tools were used to make a model of patient flow processes and to simulate and examine improvement scenarios, respectively. The results of their study showed that in choosing a superior scenario, the mission of the emergency department, namely, saving the terminally ill patients, should be taken into account. Therefore, a scenario with this characteristic, even if it costs a lot, is superior to other scenarios (20). Previous studies have focused more on waiting time calculations. Most of these studies that focus on reducing the waiting time, using simulation techniques, have addressed just simulation and implementation of the scenario. The difference between the present study with other studies was the use of both simulation model (probable) and mathematical model (definitive) techniques and comparison of the definitive and the probable, as well as selection of the best answer considering the definitive answer.

Conclusion

The results of this study can help the hospitals to plan programs to reduce the waiting time of patients. Based on the results of the study, it was concluded that according to the simulation model in the morning, scenario A, considering the reduction of the service time, was the best scenario, in which an assistant helps the physician to reduce the service time. Based on the results obtained from the simulation model scenarios in the evening, scenario C, a combination of both scenarios A and B, was selected as the best scenario. As to this scenario, it is suggested that the time of the presence of patients should be more precise in order to prevent the untimely presence of patients in the clinic; moreover, physicians should attend in the clinic on time to prevent the crowding of patients in the clinic. Based on the results of the definitive model, the best scenario was scenario B. Therefore, it is suggested that an internet turn system should be used to prevent the presence of patients in the hospital for receiving their turn number and staying in the waiting queue until receiving their service. Using this system can lead to a decrease in the patients' waiting time, thus reducing their satisfaction. Additionally, suggestions for future studies include simulating other queues (height and weight measurement, electrocardiogram, echocardiography), ranking the factors which reduce the patients' waiting times, using multi-criteria decision-making techniques, developing non-linear optimization models to reduce the waiting time of patients, and employing hyperburial algorithms to minimize the waiting time of patients.

Among the main limitations of this study and in general was access to most simulation and optimization methods in therapeutic systems and collection of data. In other words, data collection was time consuming due to crowding of patients as well as insufficient number of the staff.

Conflict of Interest: None declared.

References

1. Masoumpour S, Rahimi S, Kharazmi E, Kavousi Z, MOSALAH NH, Abedi Z. Assessing waiting time in emergency department of Shahid Faghihi hospital, Shiraz and presenting appropriate strategies using quality function deployment (QFD) method, 2011-2012. *Hakim Research Journal*. 2013;16(2):159-68.
2. McDougall GH, Levesque T. Customer satisfaction with services: putting perceived value into the equation. *Journal of services marketing*. 2000;14(5):392-410. doi: 10.1108/08876040010340937 .
3. Zare Mehrjardi Y, Hoboubati M, Safaee Nik F. Improvement of waiting time for patients referring to emergency room using discrete event simulation. *SSU_Journals*. 2011;19(3):302-12.
4. Ibrahim IM, Liong C-Y, Bakar SA, Ahmad N, Najmuddin AF, editors. A proposed simulation optimization model framework for emergency department problems in public hospital. AIP Conference Proceedings; 2015: AIP Publishing. p. 1-9. doi: 10.1063/1.4937030.
5. Jun J, Jacobson SH, Swisher JR. Applicationcrete-event simulation in health care clinics: A survey. *J Oper Res Soc*. 1999;50(2):109-23. doi: 10.2307/3010560 .
6. Weng S-J, Cheng B-C, Kwong ST, Wang L-M, Chang C-Y, editors. Simulation optimization for emergency department resources allocation. Proceedings of the Winter Simulation Conference; 2011: Winter Simulation Conference.
7. Babashov V, Aivas I, Begen M, Cao J, Rodrigues G, D'Souza D, et al. Reducing Patient Waiting Times for Radiation Therapy and Improving the Treatment Planning Process: a Discrete-event Simulation Model (Radiation Treatment Planning). *Clin Oncol*. 2017;29(6):385-91. doi: 10.1016/j.clon.2017.01.039 .
8. Ibrahim IM, Liong C-Y, Bakar SA, Ahmad N, Najmuddin AF, editors. Minimizing patient waiting time in emergency department of

public hospital using simulation optimization approach. AIP Conference Proceedings; 2017: AIP Publishing.
9. Almomani I, AlSarheed A. Enhancing outpatient clinics management software by reducing patients' waiting time. *Journal of infection and public health*. 2016;9(6):734-43. doi: 10.1016/j.jiph.2016.09.005.
10. Riff M-C, Cares JP, Neveu B. RASON: A new approach to the scheduling radiotherapy problem that considers the current waiting times. *Expert Systems with Applications*. 2016;64:287-95. doi: 10.1016/j.eswa.2016.07.045 .
11. Kozlowski D, Worthington D. Use of queue modelling in the analysis of elective patient treatment governed by a maximum waiting time policy. *European Journal of Operational Research*. 2015;244(1):331-8. doi: 10.1016/j.ejor.2015.01.024 .
12. MORADI H, RAZAVI M. The simulation model for paraclinical services in Hafez hospital in Shiraz, Iran, and evaluation of scenarios to reduce waiting time. 2016;13(1):8-11.
13. Bahadori M, Mohammadnejhad SM, Ravangard R, Teymourzadeh E. Using queuing theory and simulation model to optimize hospital pharmacy performance. *Iranian Red Crescent medical journal*. 2014;16(3):e16807. doi: 10.5812/ircmj.16807.
14. McVay BC. Waiting time analysis of patient flow in an outpatient OB/GYN clinic-A simulation approach: University of Central Arkansas; 2014.
15. Hu X. Optimization analysis of patient waiting time and resource utilization in an OB/GYN clinic-A simulation approach: University of Central Arkansas; 2013.
16. Pianykh OS, Rosenthal DI. Can We Predict Patient Wait Time? *Journal of the American College of Radiology : JACR*. 2015;12(10):1058-66. doi: 10.1016/j.jacr.2015.04.010.
17. Lade IP, Sakhare V, Shelke M, Sawaitul P. Reduction of Waiting Time by Using Simulation & Queuing Analysi. *International Journal on Recent and Innovation Trends in Computing and Communication*. 2015;3(2):55-9.
18. Vass H, Szabo ZK. Application of queuing model to patient flow in emergency department. Case study. *Procedia Economics and Finance*. 2015;32:479-87. doi: 10.1016/s2212-5671(15)01421-5.
19. Duguay C, Chetouane F. Modeling and improving emergency department systems using discrete event simulation. *Simulation*. 2007;83(4):311-20. doi: 10.1177/0037549707083111.
20. Salimifard K, Hosseinee S, Moradi M. Improving emergency department processes using computer simulation. *Journal of Health Administration (JHA)*. 2014;17(55).