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IMPROVING THE EMERGENCY DEPARTMENT PERFORMANCE USING SIMULATION AND MCDM METHODS

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ABSTRACT

The main purpose of this paper is to introduce a new framework to more efficiently investigate the patient flow of the Emergency Department (ED) of a governmental hospital in Tehran, Iran, in order to find out improving scenarios for reducing waiting times of patients. The proposed framework integrates the simulation model of patients flow process with the group AHP and TOPSIS decision models in order to evaluate and rank scenarios based upon desired performance measures. TOPSIS decision model takes the weights of performance measures from the group AHP and the values of performance measures from simulation model, and ranks the improving scenarios. The results analysis indicates that the average waiting time of non-fast-track patients by taking new policies with reasonable expenditure can be reduced by 42.3%.

1 INTRODUCTION

An Emergency Department (ED) is a medical treatment facility, specializing in acute care of patients who present without prior appointment, either by their own means or by ambulance. Due to the unplanned nature of patient attendance, the department must provide initial treatment for a broad spectrum of illnesses and injuries, some of which may be life-threatening and require immediate attention. The ED of a hospital is a complex unit where the fight between life and death is always a hair's breadth away, requiring a high degree of coordination among human and material elements (Yeh and Lin 2007). One of the common areas of concern in any ED is the reduction of waiting time or length of stay of patients. Most patients experience very lengthy waits before receiving care, and some leave without being treated. To overcome this issue which is also related to the benefits of a healthcare organization, different approaches such as simulation modeling have been adopted. The result of analyzing this kind of problem can be used to enhance the ED with better quality care.

Over the last decade, there have been fruitful efforts in developing simulation/optimization models for solving healthcare management problems (Ahmed and Alkhamis 2008). However, it is more than two decades that the simulation modeling approach has been used to solve healthcare problems in the US and UK (Meng and Spedding 2008). The objectives of most of the reviewed papers are to reduce waiting time

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and to maximize patient throughput. Presented solutions to meet these objectives are 1) adding resources, 2) process reengineering, and 3) improving the relationship between an ED and other relevant wards. A brief review of some of these papers is provided here.

Samaha et al. (2003) presented a simulation model of the operation in the ED at Cooper Health System. The objective of the model was to create a model which depicts the current operation and evaluate possible alternatives to reduce the length of stay. The alternative with fast-track centre allows the achievement of better performance by expediting noncritical patients through the system and shortening their length of stay in ED. Komashie and Mousavi (2005) discussed the application of Discrete Event Simulation (DES) for modeling the operations of an ED in the London area (Britain). The main objective was to determine the impact of key resources (doctors, nurses, beds) on key performances (patient total times, queuing time). The highest reduction in waiting time was obtained for a scenario where the system was assumed without blockage so that all patients could be admitted. The result shows a possible reduction of more than 20% in patient's waiting time. Ruohonen et al. (2006) presented a simulation model which described the operations in ED of special health care at Central Hospital of Jyvaskyla, Finland. The goal was to test the impact of a new triage approach called "triage-team" method on key performances (patient waiting times and especially patient throughput time). The results showed that this method improves the operations of the ED substantially (over 25%), if it is implemented properly and includes all the necessary tasks. Duguay and Chetouane (2007) described a DES study of an ED in Moncton (Canada). The objective of the study was to reduce patient waiting times and to improve overall service delivery and system throughput. The alternative with one physician and nurse added gave the best improvement level for waiting time. Yeh and Lin (2007) presented how patients' queue time at a ED at Show-Chwan Memorial Hospital in Central Taiwan can be minimized by utilizing simulation and a genetic algorithm (GA) to appropriately adjust nurses schedules without hiring additional staff . The computational results indicate that these near-optimal nursing schedules reduce the average queue time in the current staffing plan by 43.47% and 43.42% for two-shift and three-shift types, respectively. Meng and Spedding (2008) described a case study of a DES model of an Accident and Emergency Unit in a hospital in the UK. The scenario analysis illustrates that significant reductions in the waiting time of patients can be obtained by a reduction of waiting time for the consultant as well as an increase in the number of trolley beds. Ahmed and Alkhamis (2008) integrated simulation with optimization to design a decision support tool for the operation of an ED at governmental hospital in Kuwait. The optimization simulation model presented in this paper provides optimal staffing allocation that would allow a 28% increase in patient throughput and an average of 40% reduction in patients' waiting time with the same resources. Khurma et al. (2008) presented how a variety of Lean tools, such as Cycle Time Analysis, Work Combination Charts, Cause and Effect Matrix, Fish-bone Diagram, and Affinity Diagram, were utilized to assess and address the ED overcrowding. The outcome helps to understand why the process system is creating long waiting lines and overwhelming delays. In addition, simulation model software was used to convey this information in a visual form and perform comparative analysis.

The ED of a governmental hospital in Tehran, which is considered as the largest ED in Iran is studied in this paper. The major purpose of this study is to overcome the most important problem of the ED of the Hospital, which is the long waiting time of different patient types. A new framework is proposed to first identify bottlenecks of the ED and then to evaluate improving scenarios with the lowest possible expenditure developed for overcoming these bottlenecks.

In the present study, some wards with expensive medical equipment including X-Ray, MRI and CT Scan are investigated in details. Lab test is not covered in this research, because the patient does not refer to this ward individually whereas only the patient's sample is transferred to the laboratory. The waiting time for the test result is considered as delay process in the model. Working shift is not considered in this study as no human resource shortage was observed. In addition, due to considering nurse services to the patients, bed preparation was ignored. The application software used in this study is Arena. Here, for selecting the best scenarios, multi-criteria decision analysis approach is employed.

The paper is organized as it follows. In Section 2, system description of ED of a governmental hospital is presented. Then the methodology adopted for modeling and simulation is explained in Section 3. Experimental results including data collection and input analysis, model verification and validation, design of scenarios, and benchmark scenario are posed in Section 4. Finally, in conclusion, the paper concludes with a brief summary of findings and some recommendations for future studies.

2 SYSTEM DESCRIPTION

The ED of the Hospital operates round the clock and receives an average of 150 patients daily. The ED is of forty-bed capacity. The ED currently has fifty six nurses, twelve physicians, one paramedic, six technicians, three financial staff, one cash staff, one reception staff, twenty laborers, two X-Ray machines, two CT Scan machines and one MRI machine. There are two 12-hour shifts for physicians starting at 07:00 and 19:00 and three shifts for nurses starting at 07:00, 14:00, and 19:00 in the ED of a governmental hospital. Each shift of physicians includes two faculty members, three first-year residents, two second-year residents, and one third-year resident.

Here, patients are classified as per the Emergency Severity Index (ESI) standard in the triage (Gilboy et al., 2005). Triage codes assigned by triage nurses are critical to achieve a correct dispatch of patients (giving the right priority based on patient condition). ESI is a 5-level classification system which categorizes patients from 1 (most urgent) to 5 (least urgent) on the basis of acuity and resource needs. ESI standard classified the patients according to the Figure 1.

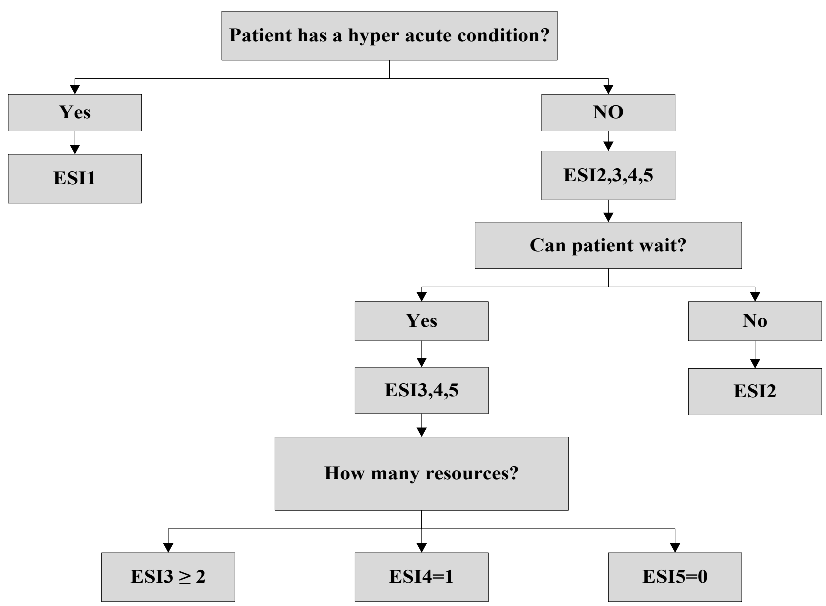

Figure 1: ESI standard for ED patients classification (Gilboy et al., 2005)

Arriving at the ED follows a logic process as depicted in Figure 2. The process begins when a patient arrives through the ED entrance door and ends when a patient is either released from the ED or admitted into the Hospital for further treatment. Having been determined the patient status according to the ESI standard in the triage, if the patient has a hyper acute condition (ESI1), he is entered to CPR (Cardio Pulmonary Resuscitation) ward so that he can be resuscitated. If CPR action is effective, the patient is transferred to emergency department 1 (ED1); otherwise (if deceased), patient is discharged. On the other hand, if the patient doesn't need to be admitted to CPR ward initially, he is transferred to one of the below wards according to ESI level.

a. Emergency department 1 (ED1): this subdivision is exclusive to acute patients (ESI1, ESI2) and they should be treated in the least time. Twenty two beds available exclusively for this division.
b. Emergency department 2 (ED2): this subdivision is exclusive to patients who are in a better condition in comparison with the patients in subdivision ED1, but they need inpatient facilities and further evaluations (ESI3, ESI4). Eighteen beds are available exclusively for this division.
c. Fast-track: this subdivision is exclusive to patients with normal conditions who don't need to be inpatient and only need to be visited by the physician. This type of patients are discharged from ED after being visited in ED (ESI5).

The patients of ED1 and ED2 may need other resources in addition to the physician; physicians will decide if the patient needs further tests such as X-rays and clinical lab tests, performed by a patient care lab technician. According to what decision made, they will be transferred to MRI, CT Scan, radiology wards, lab and so on for further investigations. After these investigations have been done, the patient will be returned to the related ward. After the patient revisited by the physician, he will either be transferred to the Hospital inpatient ward or he will be discharged according to the patient status. If the patient is sent to the fast-track ward, he has to attend the reception initially and after booking his turn and paying his visit, he should remain in the physician fast-track waiting list.

Due to the lack of expensive MRI and CT Scan machines within the Hospital, these machines are shared between the ED patients and all other patients coming from different departments of the Hospital (shown by dotted line in Figure 2), called non-ED patients.

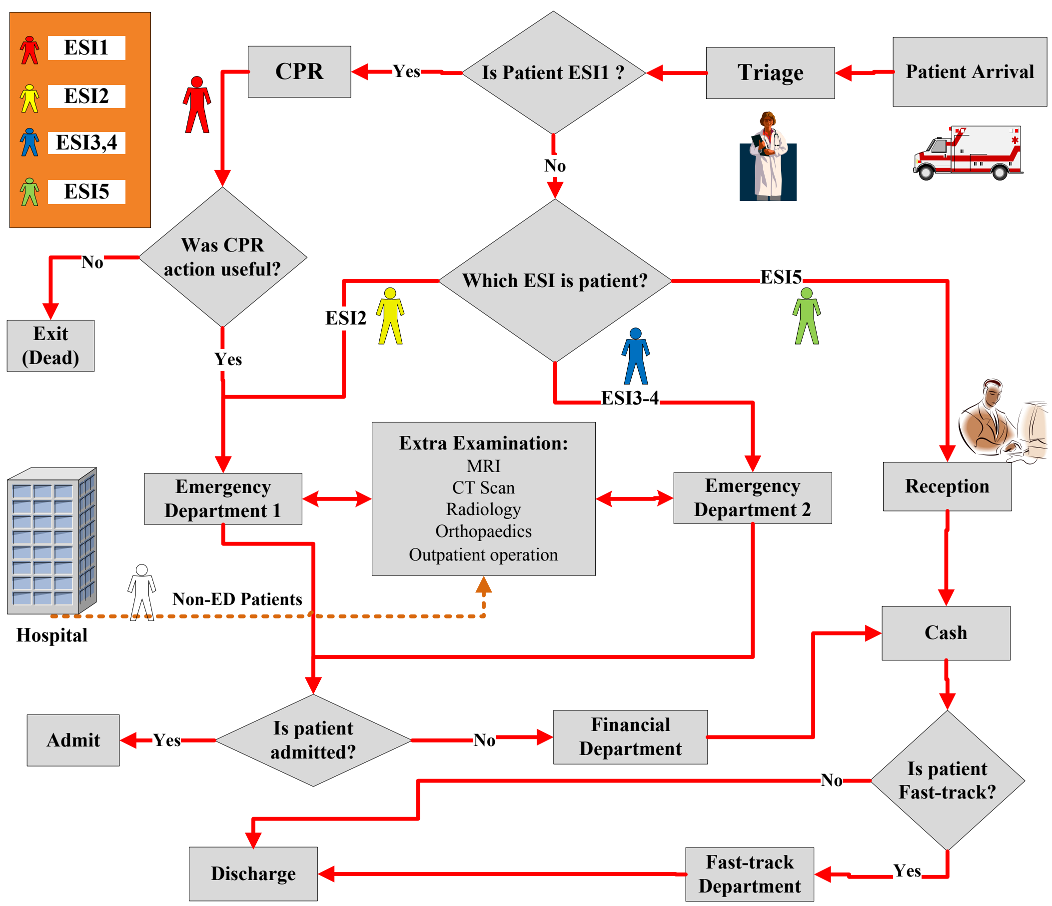

Figure 2: Conceptual model of the ED of a governmental hospital

3 PROPOSED METHODOLOGY

In this study our goal was to improve the care process by reducing waiting times. There are three main steps of the proposed methodology, as shown in Fig 3, to achieve the target of the present study:

1- Data collection and developing a databank
2- Real system modeling and verifying and validating the simulation model
3- Selection of the best scenario

In the first step the data of ED patients including arrival rate and different service times should be gathered and stored in a databank. By using this data, statistical distributions can be developed for the simulation model. Then in the second step the real system modeling can be done as per the developed conceptual model. The simulation model is verified by animation and validated by executing the model and comparing the produced outputs with the real system outputs.

In the last step, decision makers should define performance measures and by using Group AHP method their relative weight can be identified and the performance measures can be prioritized consequently. Finally by applying the TOPSIS method the best scenario can be selected.

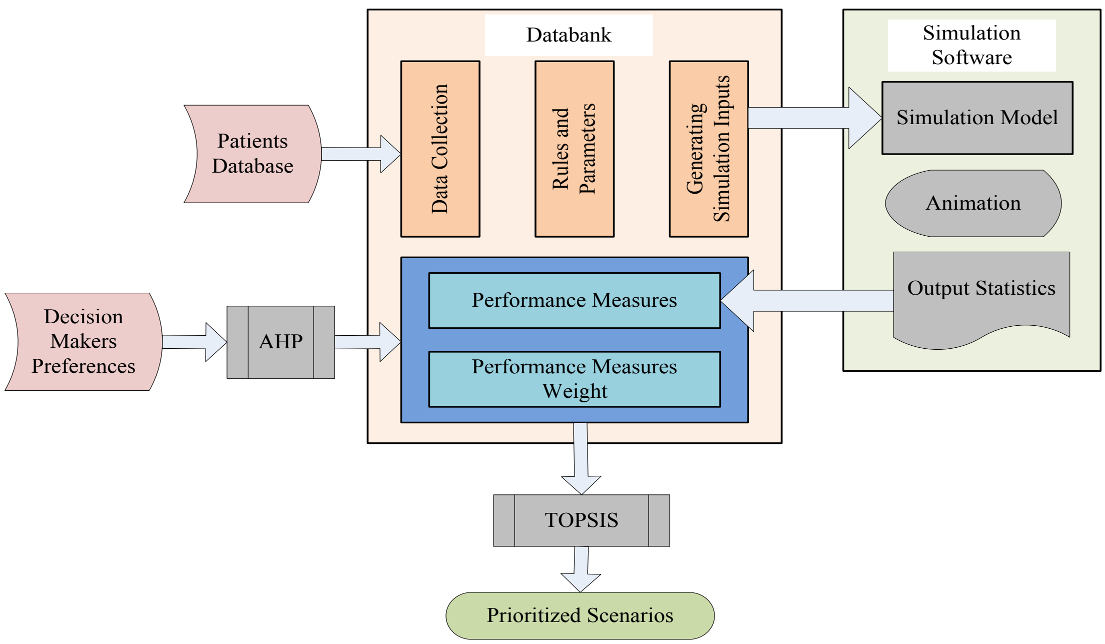

Figure 3: The main steps of the proposed methodology

3.1 Simulation

Simulation is a powerful tool for experimenting with a detailed model of a real system to determine how the system will respond to changes in its structure, environment or underlying assumptions. The real power of simulation is fully realized when it is used to study complex systems. Healthcare is a dynamic system with complex interactions among various components and processes. Furthermore, healthcare management operates in an environment of aggressive pricing, tough competition, demanding patients, and rapidly changing guidelines. To meet these challenges, healthcare management must respond quickly to identify critical system processes, recognize all relevant resources, access real-time information, and analyze "what if" cases.

3.2 Group AHP

The Analytic Hierarchy Process (AHP) technique is a popular approach used in determining the relative importance of a set of attributes or criteria (Saaty 1990). By applying this technique, we can identify various criteria, sub-criteria and assess their relative importance in order to make tradeoffs and to determine priorities among them for making good decisions by choosing the best scenario.
AHP has also been modified for group decision making. As outlined by Forman and Paniwati (1998), there are several ways of aggregating individual responses into a group response. In this paper, each participant generates their own pair wise comparison matrix for each node of the hierarchy, then geometric mean of all comparisons was used to aggregate same pair wise comparison for each person.

3.3 TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a linear weighting technique which was developed by Hwang and Yoon (1981). It is based on the concept that the chosen alternative should have the shortest *weighted* distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS) for solving a multiple criteria decision making problem. Briefly stated, the PIS is made up of all best values attainable of criteria, whereas the NIS is composed of all worst values attainable of criteria. After the PIS and NIS solutions are identified, the distance of each alternative from the PIS and NIS solutions, denoted by D_i^+, D_i^-, are calculated. Finally, for each alternative the relative closeness to the ideal solution is calculated by $R_i = \frac{D_i^-}{D_i^- + D_i^+}$, where R_i denotes the final performance score in TOPSIS method. The chosen alternative has the maximum value of performance score.

4 SIMULATION RESULTS

4.1 Data Collection and Input Analysis

Historical data acquisition is crucial because the results and findings of a simulation study, in the best case, are as good as the input information. Data were collected for the eight scheduled weeks from Mid December to Mid February. December, January and February are ones of the few regular months in the hospital year in Iran. The patients were observed 24 hours a day and seven days a week. The total number of visits was about 6500 patients. Around 70% of data was used for input data analysis and fed into the simulation model and other 30% was used for model validation.

In order to use the historical data as the useful input information for simulation model, it is necessary to identify what statistical distributions the various data sets well fitted to. For input modeling, Arena input analyzer is used and statistical distributions with the highest p-values larger than 0.1 are selected as the most appropriate distributions. In this study, all datasets were well fitted and there was no need for employing an empirical distribution.

Based on the collected data, 6% of the patients are ESI1, 16% of the patients are ESI2, 33% of the patients are ESI3 and ESI4 combined, and 45% of the patients are ESI5. Here, there are two stages for the nurse and physician visits. In the first stage, the nurse or physician visits the patient before sending her/him for the extra examination and in the second stage, they visit the patient after extra examination.

The patients arrival process to the ED follows a non-homogenous Poisson process with rate $\lambda(t)$. $\lambda(t)$ denotes the arrival rate of patients to the ED at time t. Figure 4 shows patient arrival pattern based on data collected from the study.

It is seen that the one-hour arrival time intervals starts from 0:00-1:00 and ends at 23:00-24:00 in the midnight. The pick hour is between 23:00 and 24:00 arrival rate of about eight patients. The hours from 20:00 to 24:00 are among the busiest hours because the other Emergency Departments in the area are getting closed within this period. However high arrival rate can be seen in the period between 09:00 and 16:00 which is typically expected.

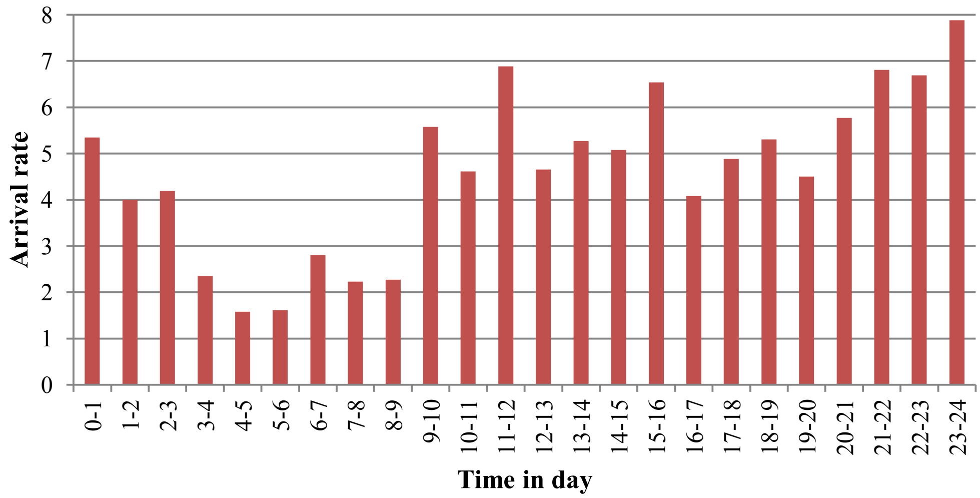

Figure 4: Plot of the estimated rate function λ (t) in patients per hour for the arrival process

4.2 Model Verification

Verification is the task of ensuring that the model behaves as intended (Kelton et al., 2007). It is concerned with building the model correctly according to the conceptual model and its assumptions. Verification checks whether a model was built correctly. In fact, the logic of the proposed model is examined. In this research, tracing the animation of the simulation model regarding the conceptual model made it possible to verify the model logically. Observing overall operations in the simulated hospital and tracking different types of patients assures that the conceptual model is reflected accurately in the simulation model.

4.3 Model Validation

Validation is the process of determining whether the simulation model is a useful or reasonable representation of the real system. Absolute validation is usually impossible because the simulation is at best an approximation of the real system, and the most definitive method is to compare the output data from the simulation with the actual data from the existing system using formal statistical analyses such as confidence intervals. In the validation process the average patient sojourn time in the ED (time spent in the system from entrance to discharge) categorized by patient type was used as the measure of the model validity. The actual average sojourn time was compared to the output of the simulation model.

The model was simulated for 58 days plus two initial days that were discarded as warm-up period. The warm-up period is set for the simulation run to eliminate any bias at the early stages of the process (Law 2007). Twelve replications of 24 hour were performed for each day. The system was always initialized between replications. We calculated the confidence intervals of the simulation outputs at 95 percent (α = 0.05) confidence level and compared them to the actual values – 30% of the data which were retained for validation of the model. The comparison is summarized in Table 3. In all cases there were no significant differences between results at a 95% confidence level.

Table 3: Comparison between actual and simulated patient sourjan time

Patient Type	Actual Mean	Simulated	
		Mean	Confidence Interval
ESI1	597	614	[594.61 , 636.43]
ESI2	906	879	[840.18 , 917.82]
ESI3-4	743	711	[677.25 , 744.75]
ESI5	35	34	[33.71 , 35.32]

4.4 Simulation model results

For each patient type, Table 4 depicts the average time elapsed in the ED, the average time elapsed in all queues, and the average waiting times for each emergency ward. As it is shown, the waiting time elapsed in Radiology, Orthopedic, and Outpatient Operation can be easily ignored. There is the same situation for Beds, Physician, and Nurse. On the other hand, the waiting time for MRI, CT Scan, Inpatient, and Discharge are very significant and should be considered in designing scenarios for reducing waiting times. Surprisingly, the average waiting time for ESI2 and ESI3-4 patients are more than four days which implies a very high demand for a single available MRI machine within the whole hospital. In other words, the sole MRI machine available in the hospital is located in the ED and it is shared between the ED patients and all other patients coming from different departments of the hospital, called non-ED patients. Based upon the current policy of the ED, only ESI1 patients have higher priority over non-ED patients resulting in a long waiting time for ESI2 and ESI3-4 patients. Having discussed with the panel of ED experts, these results are close to what they observe in practice.

Table 4: Average waiting time for each Patient type in the “as is” system (min)

Patient type	Average time in the ED	Average waiting time for all queues	Average waiting time for									
			MRI	Inpatient	CT Scan	Discharge	Beds	Orthopedic	Radiology	Nurse	Physician	Outpatient Operation
ESI1	614.5	388.4	18.2	1140.4	13.8	73.1	1.6	1.2	0.1	0.1	0.0	0.0
ESI2	879.1	617.7	5948.3	1170.4	309.6	74.4	1.6	2.0	0.2	0.1	0.0	0.0
ESI3-4	712.4	630.9	5976.7	2010.4	314.7	71.8	3.6	3.0	0.4	1.5	1.1	0.0
ESI5	34.6	15.0									4.9	

5 SYSTEM IMPROVEMENT

5.1 Design of scenarios

The patients waiting time is too long during three following stages which have been identified after twelve replications of the model for sixty 24-hour days:

1. The patients waiting time in entering to the MRI and CT scan wards,
2. The patients waiting time in entering to the inpatient ward,
3. The patients waiting time in entering to the CT scan ward, and
4. The patients waiting time for financial department when they are discharged.

On the other hand, waiting for MRI, CT Scan, Inpatient ward and being discharged make the ED beds too crowded as the patients do not leave their bed while they are waiting. In order to reduce the waiting time in ED in the above four stages and eventually in the total system, fourteen scenarios have been proposed by a panel of ED experts including the ED chief, ED Physician and Nurse chief. The scenarios from 1 to 14 have been shown in Table 5, where current system is considered as the scenario 1. The proposed scenarios were investigated in the virtual model in order to select the best scenario.

One scenario has been developed for each bottleneck except for CT Scan which two scenarios have been developed. For resolving both bottlenecks of MRI and CT Scan, seven scenarios have been developed. Another scenario, scenario No 14, has been developed to resolve all the bottlenecks simultaneously.

It includes scenario 12, 13, and 3 which the latter one is the least expensive scenario among the scenarios for resolving both MRI and CT Scan.

Table 5: Suggested scenarios for reducing bottleneck(s)

Bottleneck(s) Reduction	Scenarios No	Scenarios Description
	1	Current system
MRI and CT Scan	2	Considering priority for ESI2 patients in the MRI and CT scan wards over non-ED patients (patients coming from other departments of the Hospital)
	3	Considering priority for ED patients in the MRI and CT scan wards over non-ED patients.
	4	Establishing an exclusive MRI ward for ED patients and considering priority for ED patients in the CT Scan ward.
	5	Establishing an exclusive CT scan ward with one CT scan machine and considering priority for ED patients in the MRI ward.
	6	Establishing an exclusive CT scan ward with Two CT scan machine for ED patients and considering priority for ED patients in the MRI ward.
	7	Establishing an exclusive MRI and CT scan ward for ED patients with one CT scan and one MRI machine.
	8	Establishing an exclusive MRI and CT scan ward for ED patients with two CT scan and one MRI machine.
MRI	9	Establishing an exclusive MRI ward for ED patients.
CT Scan	10	Establishing an exclusive CT scan ward with one CT scan machine.
	11	Establishing an exclusive CT scan ward with Two CT scan machine for ED patients.
Inpatient	12	Adding five mobile beds in inpatient ward.
Discharge	13	Adding a resource in financial department.
MRI, CT Scan, Inpatient and Discharge	14	It includes scenarios 3, 12 and 13.

5.2 Ranking Scenarios

At first experts from the ED participated in the decision-making group to identify evaluation criteria and to establish evaluation criteria hierarchy. The members of the decision-making group include ED boss, ED physician, and ED head nurse. After a general consensus among experts, three groups of performance measures were identified. The first group focuses on waiting time for each type of patient. The second group consists of the utilization of resource in four areas: MRI machine, CT scan machine, financial department, mobile bed in Inpatient ward. The third group focuses on the cost of each scenario.

The group AHP methodology requires the pair wise comparisons of the criteria and sub criteria in order to determine their relative weights. An AHP survey questionnaire was designed in order to determine relative importance of performance measures. In the questionnaire, pair-wise comparisons were performed on the basis of nine scale of AHP. Questionnaires were filled by each group member. Then ranking of the performance measures can be determined via the greatest Eigen value of the matrix and the corresponding eigenvector. Then the consistency ratio is calculated for each matrix. As consistency ratio (CR) of the matrices is less than 10 percent, it indicates satisfactory consistency. Subsequently, this eigenvector is normalized to 1 by dividing all elements of the eigenvector by the sum of all the corresponding elements. Figure 5 indicates the weights of nine performance measures.

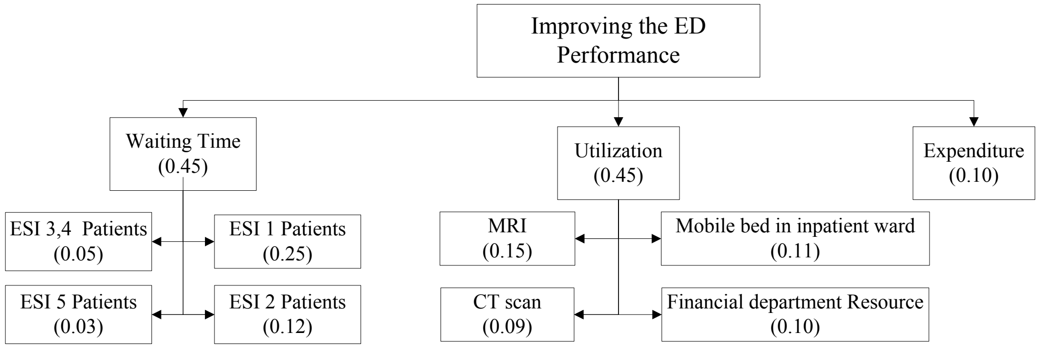

Figure 5: The weights of nine performance measures

To prioritize the fourteen scenarios, at first, the weighted normalized decision matrices of the alternatives are calculated by multiplying the normalized decision matrix and the weights which are calculated by Group AHP method.

According to the Table 6, the major difference can be seen between the utilization of MRI machine in scenarios 4, 7, 8, and 9 and in other scenarios. As described in Section 4.4, the reason is that the Hospital utilizes one MRI machine for the whole patient which makes the utilization of the machine 100%, but in scenarios 4, 7, 8, and 9 one extra MRI machine is provided just for the ED patients and as the number of ED patients is much lower than the number of all patients in the Hospital, the utilization of second MRI machine is very low. On the other hand as it can be seen from the Table 6, the same major difference exists for the utilization of CT Scan machine between the scenarios 5, 6, 7, 8, 10, and 11 and other scenarios because of the same reason. One should note that in reality the resource utilization of 100% is not true. However, it is possible to get the resource utilization of 100% in simulation modeling due to the real world system simplifications and/or number round up.

Table 6: Decision matrix for fourteen scenarios and nine performance measures

Scenarios	Waiting Time (min)				Utilization (%)				Expenditure (Cost Unit)
	ESI1	ESI2	ESI3-4	ESI5	MRI machine	CT Scan machine	Financial Dept.	Inpatient ward	
Scen. 1	388.34	617.71	630.91	15.21	100	95	95	100	0
Scen. 2	391.22	413.65	660.43	15.21	100	96	95	100	0
Scen. 3	397.27	419.08	494.27	15.21	100	97	95	100	0
Scen. 4	392.93	419.24	504.25	15.21	3	96	95	100	750
Scen. 5	391.98	425.85	508.93	15.21	100	34	95	100	400
Scen. 6	388.84	421.63	503.39	15.21	100	17	95	100	800
Scen. 7	379.82	414.17	494.75	15.21	3	34	95	100	1150
Scen. 8	377.61	411.62	492.73	15.21	3	17	95	100	1550
Scen. 9	387.88	476.46	546.25	15.21	3	95	95	100	750
Scen. 10	384.46	498.18	627.31	15.21	100	34	95	100	400
Scen. 11	388.05	510.35	585.23	15.21	100	17	95	100	800
Scen. 12	337.34	567.94	557.95	15.21	100	95	95	96	10
Scen. 13	334.19	585.08	675.34	15.21	100	95	81	100	7
Scen. 14	275.26	309.30	367.12	15.21	100	95	81	95	17

The ranking of the fourteen scenarios according to the TOPSIS final performance score (R_i), *i.e.* their relative closeness to ideal and negative ideal solutions, is shown in Table 7. It is seen that scenario 14 has the highest performance score and it is selected as the most desirable policy among fourteen alternatives. By performing this scenario, there will be reduction in:

1. The waiting time of ESI1 patients by 29%.
2. The waiting time of ESI2 patients by 50%.
3. The waiting time of ESI3-4 patients by 41%

Finally, the waiting time is reduced by 42.3% and 21.8% for non-fast-track (not ESI5) and all ED patients, respectively. It is worth mentioning that applying this scenario has no effect on the waiting time of ESI5 patients.

Table 7: Ranking of scenarios

Scenarios	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TOPSIS final performance score (R_i)	0.724	0.775	0.773	0.426	0.652	0.545	0.246	0.163	0.417	0.642	0.531	0.787	0.773	0.909
Rank	6	3	4	11	7	9	13	14	12	8	10	2	5	1

6 CONCLUSION

The goal of this study was examination of processes in ED of a governmental hospital in Iran and identifying bottlenecks that lead to long waiting times. Simulation was used first to identify bottlenecks of the process and second to evaluate different scenarios developed for overcoming these bottlenecks in order to decrease waiting time of the patients in the ED. Fourteen scenarios have been developed and evaluated and the last scenario was selected as the best one. This scenario is a combination scenario (includes suggestions taken from scenarios 3, 12 and 13) which recommends considering priority for ED patients in the MRI and CT scan ward over non-ED patients whilst adding five mobile beds in inpatient ward and a new staff in financial department.. By applying scenario 14 it is forecasted that waiting time of ED patients will be reduced by 29%, 50%, 41% and 0% for ESI1, ESI2, ESI3-4 and ESI5 patients, respectively.

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