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USING DISCRETE EVENT SIMULATION TO IMPROVE THE PATIENT FLOW OF A HEALTHCARE SYSTEM.

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ABSTRACT

Long waiting time in any process is a challenge for any healthcare system. As healthcare institutions are complex and busy system and various department interacts with each other any existing bottleneck can drive the whole system into failure in providing in time services. And that arises the need of use simulation to detect and eliminate the bottleneck faced in any process. In this paper, a model based on simulation aiming at patient flow optimization in a health care system been proposed. To achieve the goal, first, modeling of patients' workflow was created by using discrete-event simulation using Rockwell Arena Software. Afterward, alternative scenarios were analysis in the process analyze to iden-tify the best scenarios. Among defined scenarios Analytical Hierarchy Process method (AHP) scores the highest value to the most suitable one. The results of the simulation indicate that performing this scenario can decrease non served patient number almost zero by adding some resources while elimination few others. To get the maximum utilization form the resources at the end resource scheduling is presented.

1. INTRODUCTION

Healthcare is a diverse and complex system where different department interact with each other's in order to deliver service to the arriving patients. Although technology and medical advances are being made at an incredible rates, the process of providing care is still inefficient where waits, delays and cancelations is a regular phenomenon. By adding more resources such as large facilities, more beds and increased staff like doctor and nurse, hospitals have responded to mitigate the delays. But they have found this not the only answer towards delays. But the answer is believed to lie within understanding patients flow as a system and improving the ways patients are able to receive timely care [1]. Moreover understanding the interactions between patients, support service and resources will help to identify how different departments within the health care interact with each other [2].Because of high demand of services, high costs, limited budget and healthcare resources decision makers should be able to detect any existing bottlenecks and eliminate that. This paper focuses on the flow of the patients and changes in the system caused mainly for the different distribution of the resources. The designed simulation model developed in Rockwell Arena Automation 14 reflects the total interaction between a patient and the resources and facilities in a clinic in Bangladesh.

2. LITERATURE REVIEW

Waiting time is defined as the time spent by the customers in the queue before getting the service required. Waiting time is a critical factor for any health care system in determining its success to provide the health care service for the patients [3]. Longer waiting time not only regards as a financial burden but also imposes a greater risk of jeopardizing the quality of patient care. Unnecessary suffering, adverse medical outcome, further complication of handling delayed patients, added costs and reduced efficiencies of the resources all can be caused because of patients longer waiting time [4].

As the total service process in the clinic is a multi-factorial problem involving various patient arrival rate and process such as registration for admission, waiting for exam, treatment, doctor contact, different discharge unit rate, a discrete event simulation (DES) software was used. The use of DES provides a method to study and improve processes without affecting patient care or significant monetary investments [5].DES models comes with the greater flexibility and due to the complex nature of the health care industry. DES model is gaining popularity to be used in health care system [6]. The selected DES software is Arena version 14. Arena is a discrete event simulation and automation software developed by System Modeling and acquired by Rockwell Automation in 2000 [7].In 2008, Erik M.W. Kolb used Arena simulation software to study the operation of the health care institution. Where it is found that the major cause of overcrowding of the health care institution is the waiting tie patients spend in the emergency room waiting for the in-patient assistant [8].An Overview of discrete event simulation modeling application to the health care clinics and integrated health care system is presented by Sheldon H. J. and James R [9]. A simulation or optimization model by Blasak et al. (2003) focuses on the problem of resources based on the type of service and taking into consideration of the constraints imposed by the system limitations [10].Najmuddin and I. Islam (2010) proposed a approach to integrate multiple departments together [11]. Recently some studies has paved the way that a better solution for optimization can be done by integrating other method such as using OptQuest tool for optimal solution [12].

3. DESCRIPTION OF PROCESS FLOW IN THE HOSPITAL

With the arrival of the patient the process flow of the hospital begins. All patient need to check in the hospital though the reception center. After following the triage process with the help of triage nurse all patients divided into two group based on the severity of the treatment. Patients identified as "critical" move through the traumatic room, where a physician and nurse associate to provide treatment before preceding to the resident doctor. On the other hand "non-critical" patient's size nurse in the waiting room before get access to the traumatic room. In the queue of the traumatic room and resident doctor the "critical" patients always get priority than others. After observation the doctor decide whether the patient needs to have any test or be allowed to go home without any test. When the prescribed test can be done in the hospital Lab then the patient goes thought the hospital exam lab otherwise they leave. In hospital lab, patients usually use some times to get themselves ready for the followed up test with the help of a nurse and a physician. The kind of test is performed in the lab are X-Ray, CT scan, ECG, Radiography and Blood test. When the test is over he or she waits for getting the test results. Having the test result the patient consult with the resident doctor as final diagnosis, where the doctor decide the departure of the patients or refers to the specialist doctor for further investigation. Followed by that the patient finally leaves the hospital marked as being served with the service.

Leaving the* system *without service

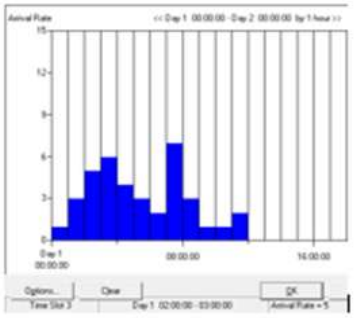
Non critical decide whether they stay in the queue and wait or leave base on the length of the queue and waiting time. To identify the number of patient leaving the clinic without service based on the previous data, it is assumed that a non-critical patient tends to leave the clinic if he/she would have to wait more than 30 minutes in queue without service before started his/her treatment in clinic.

4. PATIENT ARRIVAL

The patient arrival followed a schedule which captured on average, the number of patient arriving per hour. The arrival rate of the patient is accumulated using descriptive data analysis. Which is illustrated in the figure 1 indicates that the arrival rate of the patients is minimum at the end of the day. However the distribution of the patient is busiest from 10 am to 4 pm, where this figure rocketed up to 7 in the 3 pm. The hospital is open from 8 am. Moreover there assumed no regular break in the clinic. The medical stuff and nurses will relax in turns as appropriate and considering the number of patients waiting in the queue. Based on the observation it is obvious that the clinic operates for around the day until the all patients is discharged. However, it is important to note that there is still patient arrive after 8 pm, but for the purpose of this study those part is excluded from the observation as that time the arrival is too minimum. Figure also indicate how those arrival rate is codded in the arena software.

Time	Arrival Rate
8-9	1
9-10	3
10-11	5
11-12	6
12-1	4
1-2	3
2-3	2
3-4	7
4-5	3
5-6	2
6-7	1
7-8	2

Arrival Rate of the patient



Setting Arrival Rate through Schedule Module in Arena

Figure 1: Table of Patient Arrival rate based on hours

5. WAITING TIME

The distribution of the waiting time of the patients in the hospital are: a) Patients waiting time for registration in the check in b) Patients waiting time in triage c) Patients waiting time in waiting room d) Patient waiting for the treatment by the resident doctor e) Patients waiting time for being ready for the prescribed test f) Patient waiting tie for getting the test result g) Patients waiting for final diagnosis and h) Patient waiting in check out. The results and discussion may be combined into a common section or obtainable separately. They may also be broken into subsets with short, revealing captions.

6. METHODOLOGY

The study was carried out in one of the small clinic in Bangladesh. The main steps of the methodology are shown in the figure below. Starting with the indication of the problem then previous studies are observed. The behavior of those data was identified using ARENA INPUT ANALYZER. Formulation a model in Arena Software to mimic the real scenario help to get valuable information. Various alternative scenarios were discussed in Process Analyzer. AHP method was used to find suitable one situation and recommendation is proposed.

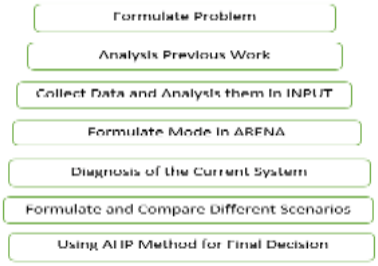


Figure : The Major Steps of the Present Research Work.

7. STATISTICAL ANALYSIS OF THE COLLECTED DATA

After the date has been collected, an attempt was made to understand the behavior by applying the statistical analysis with the help of Arena Input Analyzer [13].The appropriate distribution of the collected data is showed in the table below.

The service name	Expression (minutes)
All Patient Check In	Uniform (4,6)
TRiage	Triangular (4,5,7)
Traumatic Room	Critical Patient Triangular(8,10,15) Non Critical Patient Uniform (10,18)
Waiting For Exam Room	Non Critical Patient Uniform (4,6)
Contact with the Resident Doctor	Critical Patient Uniform (10,15) Non Critical Patient Uniform (10,15)
Being Ready for the Exam	Uniform (10,15)
Delay For CT	Triangular (15,20,25)
Delay For X RAY	Triangular (10,15,20)
Delay For ECG	Triangular (30,32,35)
Delay For Radiography	Triangular (10,20,25)

Delay For Blood Test and Others	**Uniform (15,20)**
Test Result	**Uniform (20,25)**
Final Diagnosis	**Uniform (10,15)**

Figure 2: Table of statistical analysis for data distribution by Input Analyzer

8. MODELING AND DIAGNOSTIC OF THE CURRENT SYSTEM

Below figure identify a simulation model which is presented using the data from the observation in Rockwell Automation's Arena 14 software.

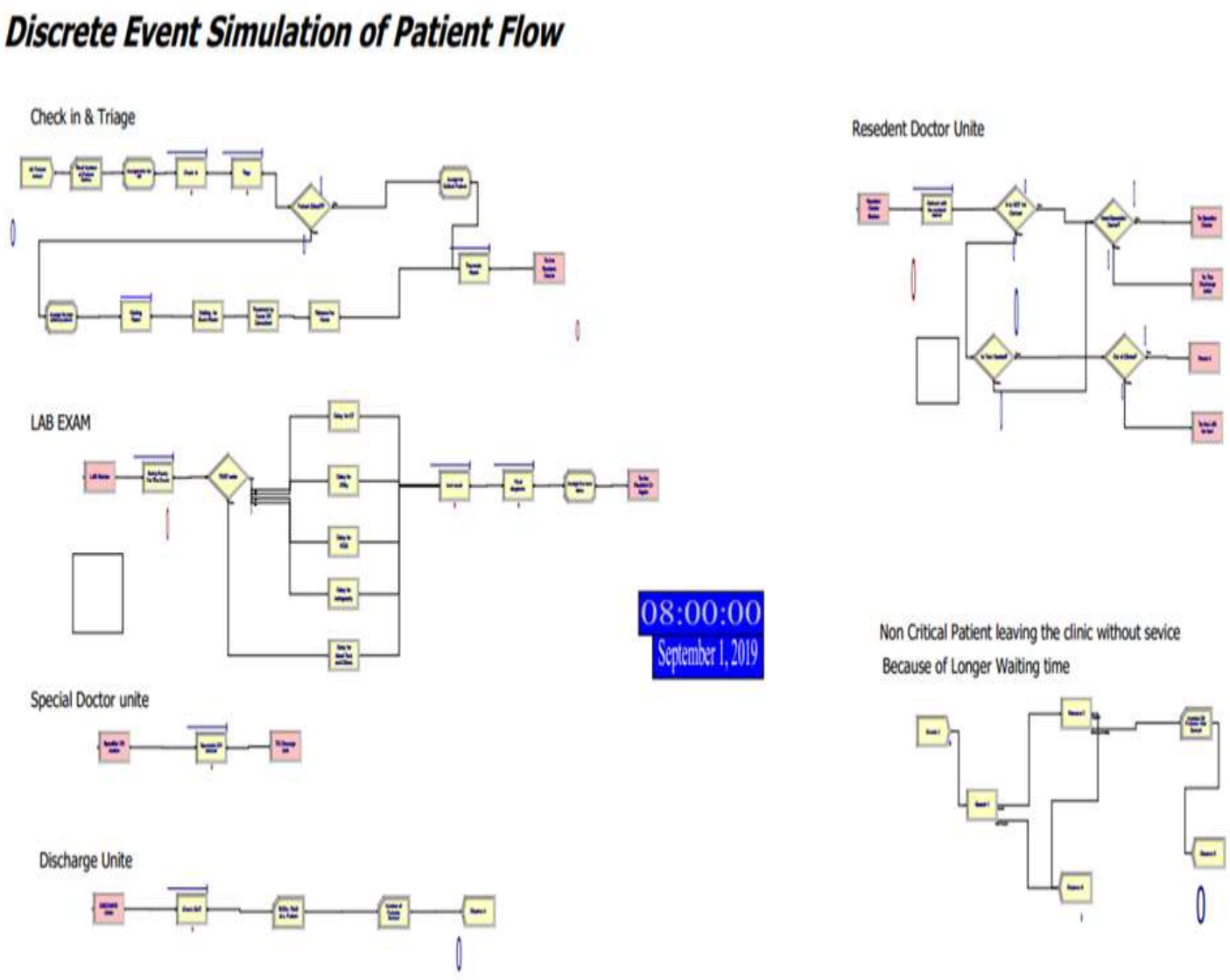


Figure The model presented in the ARENA for simulation.

9. DIAGNOSIS OF THE CURRENT SYSTEM

On average the total number of patients arrive at the hospital in 7 days is 280. Among them 226 pa-tients leave the hospital after service where 54 of the patients leave without being served because of the long queue before getting treatment. The average time a patient have to stay in the hospital is around 235 munities. The figure represent the output from report module in Arena software.

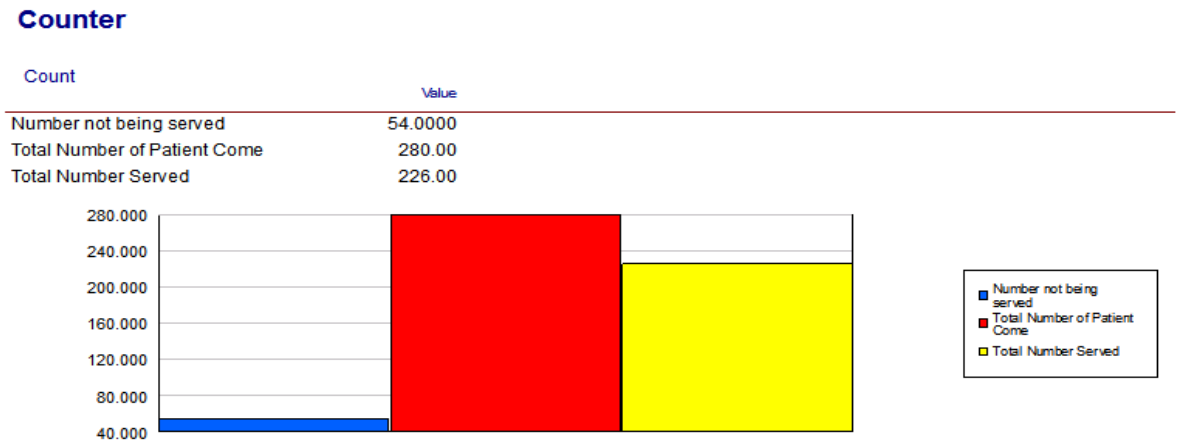


Figure 4: The number of patient status after the simulation.

Name of the Queue	Waiting Time average (minute)	Maximum Waiting Time	Maximum Patient wait In Queue
Check IN Queue	0.24	4.9	4
Waiting Room Queue	0.44	5.93	1
Traumatic Room Queue	45.8	175.95	16
Triage Queue	28.8	130.4	10
Contact with the Resident Doctor Queue	28.9	136.8	6
Being Ready for the Exam	0.42	6.25	1
Test Result Queue	20.43	20.5	3
Specialist Doctor Queue	2.43	20.5	1
Final Diagnosis Queue	29.69	98.34	2
Check Out Queue	0.03	3.7	1

Figure 5: Average and maximum waiting time in queue.

The average waiting time in queue is the time required for a patients to wait until get the service expected. Table represent the average waiting time and maximum waiting time in the queue indicated from SIMAN report, which identify the existence of longer queue in the traumatic room with an average of almost 46 minutes waiting for patients. The maximum time a patient have to wait in traumatic room is 175 minutes. On the other hand the lowest waiting time is in check out with almost no waiting time in queue. The maximum number of patient waiting in the traumatic room is 16.Whereas average waiting time in queue for triage, and resident doctor is same as around 29 minutes. So it is obvious from the table that there remains a bottleneck in the traumatic room queue.

Troumatic Room.Queue

Time	Average	Half Width	Minimum	Maximum
Waiting Time	45.7912	(Insufficient)	0	175.95
Other	**Average**	**Half Width**	**Minimum**	**Maximum**
Number Waiting	1.1902	0.581038853	0	16.0000

Figure 6: Traumatic room average and maximum waiting in queue.

The tables and bar charts below shows the resources utilization in percentage and the total number of patient sized. Based on the analysis the utilization rate for the resident doctor is maximum in com-pared with the others, while the specialist doctor and nurse having the lowest utilization.

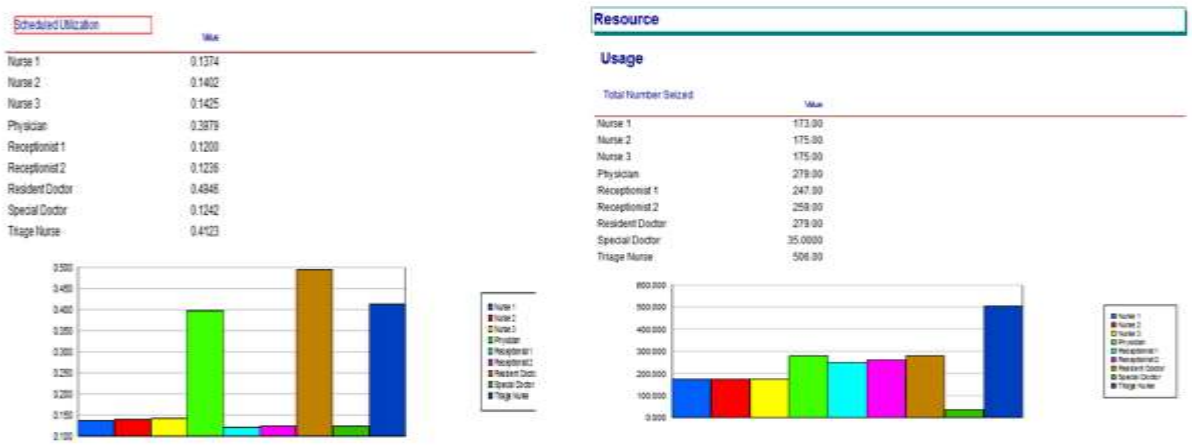


Figure 7: Table of the utilization of the resources.

10. ANALYSIS FOR IMPROVING THE CURRENT SCENARIO

The total performance of the clinic is measured with respect to the amount of patients it served while minimizing the loose of patients because of longer queue time. Different scenarios of the current system is test in the Arena Process Analyzer to get the best outcome. In the Arena process analyzer resource such as resident doctor, physician, triage nurse and nurse are set up as controls. Using 5 number of repetition is set for each different scenario. The result obtained from process analyzer module is showed in the figure below.

	Scenario Properties			Controls					Responses							
	S	Name	Program File	Reps	Physician	Triage Nurse	Resident Doctor	Nurse 1	Num Reps	Number not being served	TOTAL TIME ALL Patient	Troumatic Room.Queue. WaitingTime	Physician.Utilization	Resident Doctor.Utilization	Triage Nurse.Utilization	Nurse 1.Utilization	Total Number Served
1		Scenario 1	52 : DES of Hospital Patient Flow.p	5	1	1	1	1	5	46	235.512	46	0.39	0.49	0.42	0.14	214
2		Scenario 2	52 : DES of Hospital Patient Flow.p	5	2	2	1	1	5	0	288.437	7	0.25	0.61	0.25	0.15	273
3		Scenario 3	52 : DES of Hospital Patient Flow.p	5	2	2	1	0	5	0	254.765	5	0.23	0.58	0.24	0.00	264
4		Scenario 4	52 : DES of Hospital Patient Flow.p	5	2	1	2	0	5	24	203.019	39	0.22	0.26	0.44	0.00	234
5		Scenario 5	52 : DES of Hospital Patient Flow.p	5	1	2	1	1	5	27	247.967	38	0.44	0.55	0.23	0.14	240
6		Scenario 6	52 : DES of Hospital Patient Flow.p	5	1	2	1	2	5	23	238.240	35	0.42	0.52	0.22	0.08	232
7		Scenario 7	52 : DES of Hospital Patient Flow.p	5	2	1	1	2	5	45	236.440	43	0.21	0.51	0.44	0.08	227
8		Scenario 8	52 : DES of Hospital Patient Flow.p	5	1	1	2	2	5	51	189.602	47	0.40	0.25	0.44	0.08	222
9		Scenario 9	52 : DES of Hospital Patient Flow.p	5	1	2	2	1	5	25	169.956	41	0.44	0.27	0.23	0.14	242
10		Scenario 10	52 : DES of Hospital Patient Flow.p	5	1	2	2	0	5	27	188.647	39	0.45	0.27	0.23	0.00	239
11		Scenario 11	52 : DES of Hospital Patient Flow.p	5	1	2	2	2	5	28	159.964	38	0.41	0.25	0.22	0.08	230
12		Scenario 12	52 : DES of Hospital Patient Flow.p	5	2	2	1	2	5	0	299.968	7	0.26	0.63	0.26	0.09	281
13		Scenario 13	52 : DES of Hospital	5	1	2	1	0	5	25	240.881	38	0.42	0.52	0.22	0.00	233

Double-click here to add a new scenario.

Figure 8: The evaluating scenarios with Process Analyzer (PAN).

The table below is generated through the Process Analyzer which indicate the resource (Physician, Resident Doctor, Triage Nurse and Nurse) usage in different scenarios. According to the Table scenario 2, scenario 2 and scenario 12 are best in terms of utilization.

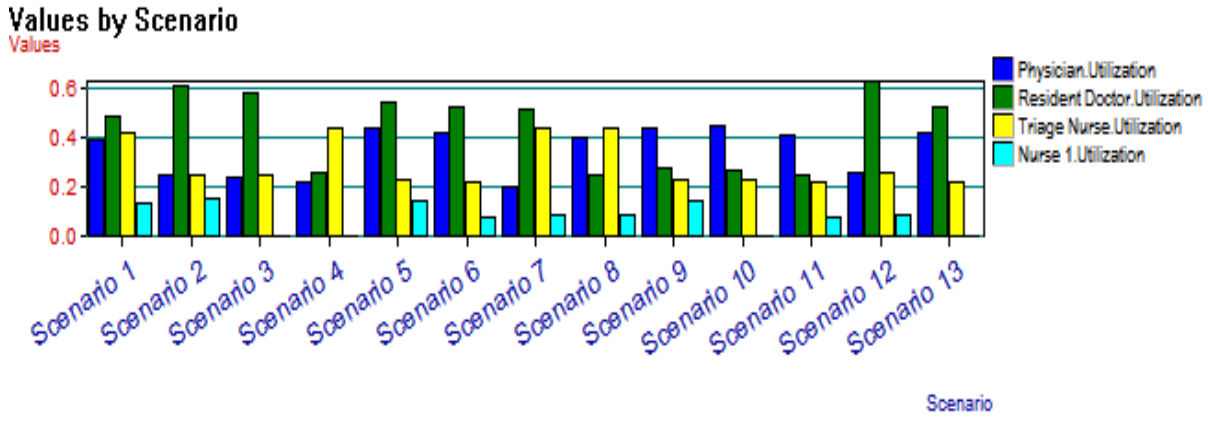


Figure 9 : The comparison bar chart of the resource utilization

The box and whisker plot below compare different traumatic waiting time in various situation. According to the box and whisker plot with error tolerance 10% the best scenario with respect to the minimum traumatic waiting time is scenario 3.

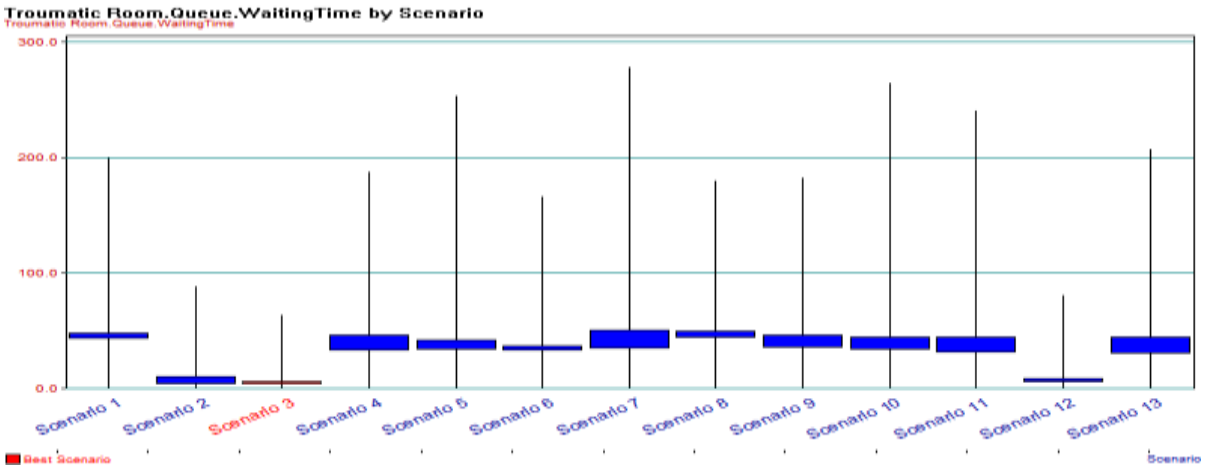


Figure 10 : Box and whisker plot addressing the best scenario.

11. DECISION MAKING WITH ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions [14]. For the classification of those alternative to choose the suitable scenario, it is necessary to identify the relative importance of the criteria in the form of a decision matrix. Then, measured the weight of those each scenario. Those weights are taken from interview with the nurses and the authorities of the clinic who are responsible for making decision. Fol-lowing those interviews, comparisons were made on the bases of nine scale of AHP. At the end the criterion "Total number Served" is more important than the criterion "Utilization of Resource". Whereas "Utilization of Resource" is little important compared with the "Total Aver-age time". "Waiting in the Triage" is equal to the criterion ""Utilization of Resource".

Among the 13 scenarios, 5 best scenarios are selected for the AHP analysis. Using excel matrix has been developed and their relative weighted is used to make comparison. The classification of the scenarios by AHP method is presented in the table below.

Scenario No.	Final Score
Scenario 2	0.224
Scenario 3	0.258
Scenario 6	0.150
Scenario 9	0.151
Scenario 12	0.217

Figure 11:Table presents the score obtained from AHP method.

The "scenario 3" is marked with the biggest score of importance. So it is selected as the suita-ble solution for the clinic. The application of the AHP has showed that t improve the current patient flow one physician and a triage nurse has to be implemented and elimination of a nurse is suggested.

12. RECOMMENDATION

After the AHP method decision analysis it is proposed that the scenario 3 is best possible situation for the current sys-tem. Beside that to increase the utilization of the resources in the proposed scenario the resource server should also be reschedule. Overall eliminating a nurse form the present process and adding one physician and one triage nurse is proposed. Table below represent the recommendation of resources schedule so that maximum number of patient can get service while minimizing the unsatisfied patient number**.**

Name of the Resources	8am-10 am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm
Receptionist	2	2	2	2	2	2
Nurse	1	2	2	2	2	1
Triage Nurse	1	2	2	2	2	1
Physician	1	1	2	2	2	2
Resident Doctor	1	1	1	1	1	1
Special Doctor	1	1	1	1	1	1

Figure 12: Scheduling of the resources.

13. CONCLUSION

In this study a discrete event simulation was used to improve the patient flow in the clinic. To achieve this purpose first data has been collected with the help of clinic administrative authorities. Following that to better understand the data behavior a statistical analysis is done. By using Arena software, the stochastic distribution function of the processes were identified. Afterwards some alternative scenarios were analyzed in Process Analyzer. Among the five best solution with the help of AHP method a best change is proposed. To implement the chosen improvement scenario, the participation of the final users in the simulation process is considered as a success factor. Another important point for a manager in implementing a research's output in the real word is considering cost measures. It is necessary to consider cost measured in the suggested scenario and then implementation can be done. But unfortunately the in-formation related to the cost were not available when the research is carried out as a result comparing those by using performance measured related to the cost was not possible.

If the proposed scenarios are economical, the manager will be ready to spend required money for improving efficiency in his or her surgical suite. Therefore, for implementing the superior scenario examined by this study, after meetings of counseling with hospital management, it is necessary to consider cost measures in suggested scenarios and then implementation will be done the in the surgical suite. But unfortunately the information related to the costs of implementing each scenario were not available when the research was carried out, and thus comparing those by using performance measure related to cost was not possible. Some key suggestion for the further study includes: a) adding cost measures for evaluating each scenario b) Considering the layout of the each processes c) optimizing the flow of equipment and materials.

14. ACKNOWLEDGEMENTS

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