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SIMULATION STUDY FOR IMPROVING PATIENT TREATMENT SERVICES

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ABSTRACT

This paper describes a simulation study conducted on patients' waiting time and the optimum use of doctors utilization at the Department of Medicine (MOPD) Hospital Alor Setar (HAS) with the aim of improving the operational performance of the hospital. It incorporates the use of *Arena* to help MOPD develop a model for the analyses of different alternatives to enhance the doctor utilizations and to improve on the patients"waiting time. Two different scenarios were considered. The first scenario, which was changing patients' scheduling capacity resulted in the reduction of patients' waiting time while the second scenario, which was increasing patients' appointment capacity by 10% resulted an increase in the use of doctors but at the same time increased patients' waiting time. Results of the analyses showed that management could reduce patients' waiting time and increase the use of doctors' by changing the scheduling strategy and by redefining the waiting time itself.

Keywords: simulation, hospital, health care, medical.

1.0 INTRODUCTION

*M*any hospitals are continuously on the quest for ways to improve . their quality of service and operational effectiveness. However, unlike other service companies, the quality o f health care services and operational effectiveness are more difficult to define, measure and control (Faltermayer, 1994). The.task becomes harder due to the dynamic nature and randomness of a hospital's operations.

There are many indicators of quality assurance in health care services. In the outpatient department for example, the main indicator of quality assurance for patients is patients' waiting time itself (Hyde, 1986). This means that patients should be attended to within an acceptable time period. For instance, the management of The Harry S. Truman Memorial Veterans' Hospital in Columbia Missouri, U.S.A. has set 30 minutes or less as the acceptable waiting time (Valdivia and Crowe, 1997). On the optimum use, the utilization of doctors and staff would be one of the main indicators of quality assurance for any hospitals management (Huang and Lee, 1996). Over utilization of staff leads to staff fatigue while underutilization of staff means that valuable resources are not used optimally.

Patients' waiting time and staff utilization can be measured in various ways. The two common approaches are through queuing models and simulation techniques (Babes and Sharma, 1991; Proctor, 1996).

This paper describes a simulation study conducted on patients' waiti ng time and the optimum use of doctors at utilization at the Department of Medicine (MOPD) Hospital Alor Setar (HAS) with the aim of improving the operational performance of the hospital. The following describes several related studies on section simulatio n in health services in general and patients' waiting time and the optimum use of doctors in particular. This is followed by, an overview of the operating environment at MOPD is given. The description of the data collection process for the simulation model of the system under study, and the discussion on the output obtained. Then, the effects of changing several variables on patients' waiting time and doctors utilizations are discussed. The paper ends with a summary of the entire study, and a list of sugges tions to improve the quality of service and operational effectiveness at MOPD.

2.0 PREVIOUS RELATED STUDIES

The power of simulation as an analytical aid to decision makers is growing in acceptance and importance. From a practical viewpoint, simulation is a process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give a better understanding of the behaviour of the particular system for a given set of conditions (Kelton and Sadowski, 2002). Simulation has an advantage over analytical or mathematical models for analyzing complex systems since the basic concept of simulation is easy to comprehend, and hence, often easier to justify to management or customers than some of the analytical models (Banks, Carson and Nelson, 1996).

Over the past four decades, simulation has proven to be a significant tool in the analysis of a wide variety of health care delivery systems, mostly focusing on capacity planning and scheduling. It started as early as in the 1960's when Fetter and Thompson (1965) applied simulation to study the operating behaviour at a maternity suite, an outpatient clinic, and a surgical pavilion, followed by Robinson, Wing and Davis in 1968 by applying simulation to model patients' scheduling and other hospital operational problems. The use of simulation techniques continues with among others, the determination of the most appropriate number of operating rooms in a surgical suite through the use of various assumptions about surgical demand, average length of operations, and average length of stay (Hopkins, Gerson, Levin and Merchant, 1982), the study of the operations of the emergency room of the 600-bed Rashid Hospital in the United Arab Emirates (Badri and Hollingsworth, 1993), the allocation of resources in an emergency medical service system (Su and Shih, 2002). The prediction of the capacities required in cardiology units for heart failure patients (Groothuis *et al.,* 2003), and the modeling of an emergency medical services in a hospital in Taipei, Taiwan (Su and Shih, 2003). The power of simulation as an analytical aid to decision makers is growing in acceptance and importance. From a practical viewpoint, simulation is a process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give a better understanding of the behaviour of the particular system for a given set of conditions (Kelton *et al.,* 2002). Simulation has an advantage over analytical or mathematical models for analyzing complex systems since the basic concept of simulation is easy to comprehend and hence often easier to justify to management or customers than some of the analytical models (Banks *et al., 1996).*

Several studies on patients' waiting times and doctors' utilizations are also found in various literatures. This is verified by Jun, Jacobson and Swisher (1999) who stated that two main areas of the use of simulation in health services are in the management of patients' flo w and resource allocation. For example, Fisher (1971) evaluates the effectiveness of outpatient medical care in a hospital, Babes and Sharma (1991) compare the advantages and disadvantages of using queuing models and simulation techniques on the study of t he out-patient queues of Ibn-Rochd Health Centre, Garcia, Centeno, Rivera and DeCarlo (1995) presents a simulation model focused on the reduction of waiting time in the emergency room at Mercy Hospital in Miami, and Bowers and Mould (2002) study ways of re ducing patients' waiting lists in orthopedic departments in UK hospitals.

Our study resembles the study conducted by Huang and Lee (1996) who study the utilization of doctors and staff in the out-patients department, the time spent in the hospital by the out patient, and the length of the out-patient queue at a small local hospital in Taiwan. We describe the operating environment of the system under study in the next section.

3.0 THE OPERATING ENVIRONMENT AT THE DEPARTMENT OF MEDICINE, HOSPITAL ALOR SETAR

MOPD started its operation in 1907. At present, it has a total of 178 beds and provides health care services to the population of Kota Star, which comprises of approximately 400,000 residents. It also serves as a referral hospital for various he alth clinics in the district of Kota Star and other hospitals in the state of Kedah, which has an estimated population of about 1.5 million residents.

Briefly, MOPD operates as follows:

Firstly, the department opens only on Sunday, Monday, Tuesday, and Wednesday. On any particular day, only certain types of treatments will be rendered. The types of treatments provided on each day are summarized in Table 1.

Table 1: Types of treatments provided daily at MOPD

Day	Type Of Treatment
Sunday	General MOPD Nephrology Clinic
Monday	NeurologyRheumatology
Tuesday	Anti-Coagulant Clinic Nephrology Clinic
Wednesday	General MOPD

Although the department opens at 8:00 a.m. and closes at 2:00 p.m. during its operating day s (except for Sunday when it opens at 1':00 p.m. and closes at 5:00 p.m.), treatment will only start at 9:00 a.m. (except on Sunday when treatment starts at 1:30 p.m.).
Secondly, patients come for treatment based on an appointment system. The appointment time obtained by patients depends on the category of patients. There are three categories of patients:

- Type 1 - Scheduled Follow-Up with appointment time between 9:00 a.m. to 11:00 a.m, or 1:30 p.m. to 3:00 p.m.
- Type 2 - Scheduled Follow-Up with appointment time between 11:00 a.m. to 1:30 p.m. or 3:00 p.m. to 4:30 p.m.
- Type 3 - New Patient.

During each appointment period, there is a limit set by the management on the number of patients of each type that can be treated. The summary of the appointment ti me and the maximum allowable number of patients of each type to be treated is given in Table 2.

Thirdly, on any particular day, 2 specialists, 8 senior doctors, and 5 junior doctors will be put on duty from a pool of 2 specialists, 15 senior doctors, and 15 junior doctors. Junior doctors give treatment to patients under the supervision of either a specialist or a senior doctor, while only specialists or senior doctors are allowed to treat new patients.

When a patient arrives at the clinic, the patient p uts his/her appointment card into one of the appointment boxes that are divided according to the blocked appointment times. This means that patients should arrive before their

Table 2: Appointment schedule and maximum number of patients to be treated

Session	Patient Categories	Appointment Time	Number Of Patients Allowed
Monday, Tuesday, and Wednesday	Type 1	9:00 a.m. – 11:00 a.m.	50
	Type 2	11:00 a.m. – 2:00 p.m.	50
	Type 3	9:00 a.m. – 1:30 p.m.	15
Sunday	Type 1	1:30 p.m. – 3:00 p.m.	50
	Type 2	3:00 p.m. – 4:30 p.m.	50
	Type 3	1:30 p.m. – 4:15 p.m.	15

appointment time. Next, the clerk on duty, assisted by nurses and medical assistants collects the patient's card and record the patient's particulars in the daily report book. Then, the patient's profile is retrieved from the file rack. Once the profile is obtained, the patient's name is put on queue and the patient is asked to take a seat in the waiting area to wait for. When the time comes, the patient is called in to the doctor's room for treatment. After receiving the appropriate treatment, the patient is either directed to the counter for a follow - up appointment, if necessary, or is free to go home without any further appointment. In some cases, the patient is issued with a list of prescriptions for medicine that can be purchased at any authorized pharmacists. As a summary, the whole process is as depicted in Figure 1.

In the following section, the data collected on patients' arrival time and doctors' service times are analyzed using a simulation software, *Arena.* The software is chosen because of its flexibility and ease of use. The model under study can be constructed witho ut any programming knowledge due to its use of dialog boxes. Furthermore, *Arena's Input* and *Output AnalYzers* provide excellent tools to fit input probability distributions based on actual data, and analyze output data using classical statistical measures.

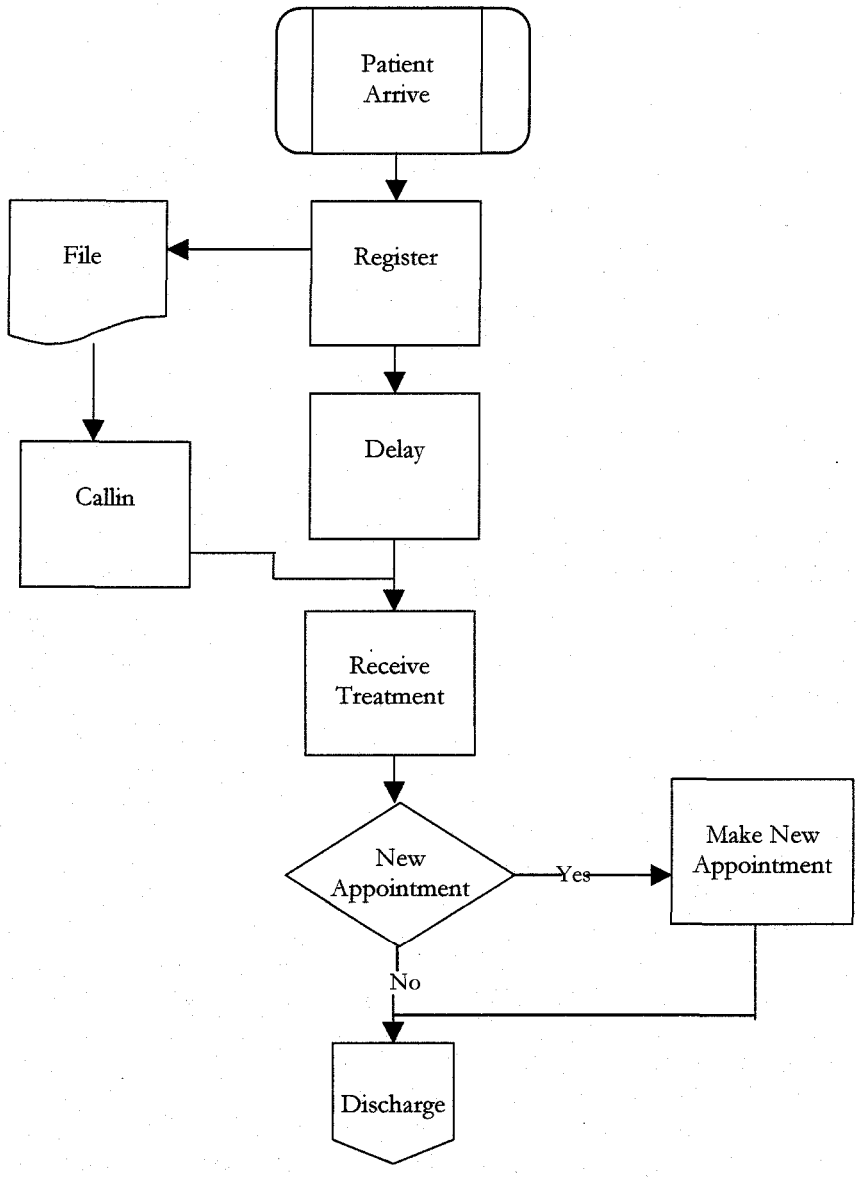

Fig 1: Schematic patient process at MOPD

4.0 DATA COLLECTION AND RESULTS

4.1 Data Collection

Data analysis provides the driving force for any simulation modeL Without input data, the simulation model itself is incapable of generating any data about the behaviour of the system it represents (Banks, 1990). In this study, there types of data were collected:

i) Patients' arrival times - collected from observation and the daily report book over a period of three weeks. Since it was difficult to record every patient's arrival time at the hospital, the arrival time for each patient was set at the time the patient arrived at the registration counter.

ii) Doctors' process times - collected from observation, the daily report book and interviews over a period of three weeks. The process time sta rted as soon as the patient was called for treatment and ended as soon as the patient left the doctor's room.

iii) Doctors' scheduling times - obtained from the staff manager.

4.2 Results

The data gathered was analyzed using *Arena*]- *Input* and *Output AnalYzers* and the output obtained for Sunday, Monday, and Wednesday (Tuesday was not included in the analyses because Tuesday was generally not a busy day) were as follows:

i) Since patients are already issued with appointment times, their arrival patterns are influenced by the appointment times. The patterns for patients' arrival times "for the three days are as described in Table 3.

ii) Treatment times of doctors vary depending on their experience, their specialization and the type of patients treated. The treatment times of doctors for the three days follow a certain distribution as shown in Table 4.

These distributions were then used as inputs for the simulation model developed based on the process described earlier in Fig. 1. The model was run for 10 replications and the average values for the number of patients treated, the doctors' process time, the patients' waiting time and the percentages of doctors' utilization were recorded. These values (sim) were then compared with the actual values (act) and the total differences (diff) in percentages were calculated using this formula:

$$Diff\ (\%) = abs[(act - sim) / act\} \times 100 \quad (1)$$

The detailed results are as discussed below:

4.2.1 **Number** of Patients **Treated**

The comparisons between the actual total and the simulation total of patients of each type treated on Sunday, Monday, and Wednesday are as shown in Table 5.

Table 3: The mean total patients' arrival for each patient type for Sunday, Monday and Wednesday

Time	Mean Total Patients' Arrivals								
	Patient Type 1			Patient Type 2			Patient Type 3		
	Sun	Mon	Wed	Sun	Mon	Wed	Sun	Mon	Wed
7:30-8:00	0	7	8	0	0	0	0	0	0
8:00-8:30	0	10	8	0	0	0	0	1	1
8:30-9:00	0	13	11	0	1	1	0	4	3
9:00-9:30	0	11	11	0	5	4	0	6	5
9:30-10:00	0	5	7	0	8	8	0	3	3
10:00-10:30	0	1	2	0	10	11	0	1	2
10:30-11:00	0	0	0	0	10	12	0	0	1
11:00-11:30	0	0	0	0	9	8	0	0	0
11:30-12:00	0	0	0	0	3	3	0	0	0
12:00– 12:30	1	0	0	0	1	0	0	0	0
12:30-1:00	9	0	0	1	0	0	0	0	0
1:00-1:30	18	0	0	5	0	0	3	0	0
1:30-2:00	13	0	0	5	0	0	6	0	0
2:00-2:30	6	0	0	7	0	0	4	0	0
2:30-3:00	1	0	0	15	0	0	1	0	0
3:00-3:30	0	0	0	14	0	0	0	0	0
3:30-4:00	0	0	0	2	0	0	0	0	0
4:00-4:30	0	0	0	0	0	0	0	0	0
Total	**48**	**47**	**47**	**49**	**47**	**47**	**14**	**15**	**15**

Table 4: The distributions of doctors' service times for Sunday, Monday and Wednesday

Treatment	Treatment Distribution	Expression
Specialists		
Sunday	Normal	NORM(17.1, 2.29)
Monday	Triangular	TRIA(10.5, 20.6, 28.5)
Wednesday	Erlang	10.5 + ERLA(2.09, 4)
Senior Doctors		
Sunday	Beta	14.5 + 11 * BETA(2.13, 2.06)
Monday	Triangular	TRIA(14.5, 24.6, 35.5)
Wednesday	Normal	NORM(22.3, 4.22)
Junior Doctors		
Sunday	Beta	18.5 + 11 * BETA(2.23, 1.83)
Monday	Weibull	21.5 + WEIB(9.46, 2.77)
Wednesday	Triangular	TRIA(16.5, 31, 38.5)

Table 5: Comparisons of number of patients for each type treated

	Sunday			Monday			Wednesday		
Patient Type	Sim	Act	Diff (%)	Sim	Act	Diff (%)	Sim	Act	Diff (%)
Type 1	43.4	48	9.6	45.2	49	7.8	12.9	14	7.9
Type 2	43	47	8.5	47.2	48	1.7	13.6	14	2.9
Type 3	44.4	47	7.7	45	48	6.3	13.7	14	2.1

The table shows that, the differences between the simulation outputs and the actual data are between 1.7% and 9.6%. The differences are less than 10%, which is within the standard total differences than can be allowed if a simulation model is to be considered as acceptable and valid (Carson, 2002).

4.2.2 Doctors' Process Time

The comparisons between the actual total and the simulation total of the doctors' process times for Sunday, Monday, and Wednesday are as shown in Table 6.

Table 6: Comparisons of mean doctors' process time

Day	Type of Doctors	Act	Sim	Diff (%)
Sunday	Specialists	17.1	17.6	2.9
	Senior Doctors	20.1	20	0.5
	Junior Doctors	24.5	24.4	0.4
Monday	Specialists	19.9	19.6	1.5
	Senior Doctors	24.9	24.8	0.4
	Junior Doctors	30	29.5	1.6
Wednesday	Specialists	18.8	18.8	0
	Senior Doctors	22.2	22.3	0.5
	Junior Doctors	27.9	28.7	4.3

From the table, it can be seen that the largest difference is only 4.3%. Again, the small differences between these values show that both the actual and simulated data seem to closely correspond to one another are in good agreement.

4.2.3 Patients' Waiting Time

The comparisons between the actual total and the simulation total of the patients' waiting time for Sunday, Monday, and Wednesday are as shown in Table 7.

Table 7: Comparisons of patients' waiting time for each type of patients

Day	Mean Patients' Waiting Time (in minutes)								
	Type 1			Type 2			Type 3		
	Act	Sim	Diff (%)	Act	Sim	Diff (%)	Act	Sim	Diff (%)
Sunday	40.8	39.6	2.5	97.7	98.8	1.1	98	99.2	1.2
Monday	56.6	58.1	2.7	106.5	104.7	1.7	121.8	125.1	0.8
Wednesday	18.5	18.9	2.1	23.9	23.1	3.3	24.24	25.9	6.8

Once again, the differences are all below 10%.

4.2.4 Utilization of Doctors

The comparisons between the actual percentages and the simulation percentages in the utilization of doctor are as illustrated in Table 8.

Table 8: Comparisons of percentage for utilization of doctors

Type of Doctors	Average Utilization (%)		
	Act	Sim	Diff
Specialists	75.5	74.5	1.3
Seniors	76.9	78.5	2.1
Juniors	81.4	79.5	1.3

Similarly, the differences are less than 10%, well within the acceptable limit.

In summary, for the entire comparisons, the differences between the actual data and the data obtained from the simulation output are below 10%. This means that the simulation output can be considered as valid. The simulation results show:

i) On the average, almost 99% of patients turn up for their appointment.

ii) Junior doctors take the longest time while the specialists take the least time to treat patients. The differences between their treatment times are between 6.8 minutes and 9.9 minutes.

iii) If 30 minutes or below is set as the standard patients' waiting time, as suggested by Valdivia and Crowe (1997), then the patients' waiting time is u nsatisfactory where patients have to wait between 39.6 minutes and 125.1 minutes, except for Wednesday where the patients' mean waiting time is less than 25 minutes for all cases.

iv) The average utilization rate of doctors is 74.5%, 78.5 %, a nd 79.5% for the specialists, senior doctors, and junior doctors, respectively. The utilization of each type of doctors is below the desired level set by the hospital management, which is 85%.

Since patients waiting time is unsatisfactory and doctors are not fully utilized, several measures have to be taken by the hospital management. We discuss several options in Section 5.0.

5.0 MODEL EXPERIMENTATION

In order to improve the current situation, different configurations in terms of the number of patients issued with appointment times and the number of doctors on duty can be simulated in expected conditions. **In** this experiment, we considered two scenarios.

5.1 Scenario 1: Changing Scheduling Capacity for Each Block

Here, we analyzed the impact of changing scheduling appointment capacity of patients for each time block. The intention was to reduce the crowd of patients in the waiting area at the early period of treatment sessions. To do so, the number of patients scheduled for an appointment in block 1 (9:00 a.m. - 11:00 a.m. on Monday and Wednesday, and 1:30 p.m. - 3:00 p.m. on Sunday) was reduced from 50 to 25, while the number of appointments for patients in block 2 (11:00 a.m, - 2:00 p.m. on Monday and Wednesday, and 3:00 p.m. - 4:30 p.m. on Sunday) was increased from 50 to 75 patients. This new arrangement did not change the total number of patients allowed for treatment for that day. Table 8 shows the effect of the new arrangement in the scheduling system on patients' waiting time, while Ta ble 9 shows the effect of the changes in the scheduling system on utilization of doctors.

Table 8: Comparisons of patients' waiting time between the current system and scenario 1

Patient Category	Waiting Time (minutes)								
	Sunday			Monday			Wednesday		
	Current	New	Diff (%)	Current	New	Diff (%)	Current	New	Diff (%)
Type 1	40.8	22.1	45.8	97.7	73.5	24.8	98.0	78.0	20.4
Type 2	56.5	32.3	42.8	106.5	77.3	27.4	121.8	96.9	20.4
Type 3	18.5	18.3	1.1	23.9	22.5	5.9	24.2	22.4	7.4

The simulation output as a result of this new arrangement shows that although patients' waiting times were reduced by as high as 45.8%, the waiting times are sti ll considered as unsatisfactory in general. On the other hand, the results for doctor utilization rates are mixed. While in some cases, doctor utilizations are increased, there are also cases where the utilizations are decreased. However, in both cases, th e utilization rates are still below 85%.

Table 9: Comparisons of doctor utilization between current system and scenario 1

Type of Doctors	Utilization Rate (%)								
	Sunday			Monday			Wednesday		
	Current	New	Diff	Current	New	Diff	Current	New	Diff
Specialists	73.7	76.3	3.5	77.5	76.0	1.9	69.2	68.4	1.2
Senior	77.1	78.4	1.7	80.2	77.9	2.9	69.5	80.1	15.3
Junior	78.4	82.6	5.4	81.0	77.8	3.9	70.1	68.6	2.1

5.2 Scenario 2: Increase Patients by 10%

Since doctors are under utilized, for the second scenario we increased the number of patients in each time block by 10%. The effects of these changes on doctor utilizations and patients' waiting times are as shown in Table 10 and Table 11 respectively.

Table 10: Comparisons of doctor utilization between current system and scenario 1

Type of Doctors	Utilization (%)								
	Sunday			Monday			Wednesday		
	Current	New	Diff	Current	New	Diff	Current	New	Diff
Specialists	73.7	77.1	4.6	77.5	83.4	7.6	69.2	74.4	7.5
Senior	77.1	81.8	6.1	80.2	87.5	9.1	69.5	76.7	10.4
Junior	78.4	81.9	4.5	81.0	88.1	8.8	70.1	77.3	10.3

By increasing the number of patients by 10%, the doctor utilization rates are increased by 4.5% up to 10.4%. With these changes, the desired level of 85% for certain types of doctors are met while for the remaining doctors, their utilization rates are approaching the desired level. However, as expected, patients' waiting times increased by as low as 1.2% and as high as 18.8%.

Table 11: Comparisons of patients' waiting time between the current system and scenario 2

Patient Category	Waiting Time (minutes)								
	Sunday			Monday			Wednesday		
	Current	New	Diff (%)	Current	New	Diff (%)	Current	New	Diff (%)
Type 1	40.8	41.3	1.2	97.7	104.4	6.9	98.0	105.7	7.9
Type 2	56.5	62.5	10.6	106.5	120.1	12.8	121.8	131.4	7.9
Type 3	18.5	20.4	10.3	23.9	28.4	18.8	24.2	25.2	4.1

6.0 CONCLUSION

One-way of achieving better levels of patients' satisfaction is by reducing the time and discomfort of patients' waiting periods. Realizing the advantages of simulation techniques to mimic a real-world system, this study incorporates the use of *Arena* to help MOPD develop a model for the analysis of different alternatives to enhance doctor utilizations and to improve on the patients' waiting time. Two different scenarios were considered. The first scenario which was changing the scheduling capacity resulted in the reduction of patients' waiting time; while the second scenario, which was increasing appointment capacity by 10% resulted in an increased in doctor utilization, but at the same time increased patients' waiting time.

Based on this study, we would like to put forward a few suggestions. Firstly, the management has to set a satisfactory standard patients' waiting time to be used as a standard in quality. Once the standard assurance has been set, the management can utilize the simulation model by experimenting with different scenarios to obtain the best combination of doctors' schedule and the appointment capacity for each time block. As a result both standards for patients' waiting time and doctor utilizations can be realized.
Secondly, our observations revealed that although patients are already issued with appointment times, they tend to arrive earlier than they should. Also, many physicians are late due to the rounds that they have to make on a regular basis elsewhere. Although these two phenomena are indeed common as reported by Rising, Baron and Averill (1973), management has to educate patients so that they would not turn up too early for their appointment, and find ways to rectify the way appointment schedules are made both for patients and doctors. As an example, Jackson (1964) proposes two main principles for

scheduling patients in out patient departments. First, the scheduled time slot between two patients depends on the average consultation time of each doctor. The best ratio of average consultation time to scheduled time slot between two patients is from 0.85 to 0.95. Second, it is better for the time point to be in multiple of five minutes.

Thirdly, the output obtained from this study was based on the data collected over a period of three weeks only. Therefore, the numbers might not be accurate. For better accuracy, the data should be collected for aperiod longer than three weeks.

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