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# A Simulation Approach for Reduced Outpatient Waiting Time

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***Abstract*— Extended waiting time for treatment in National hospitals is very common in Sri Lanka. This situation has created several problems to patients, doctors and even to other health workers. The quality of service leaves a lot to be desired and is costly to the economy. This study analyses different queues which create bottlenecks in the Out Patient Department at national eye hospital in Sri Lanka and critically evaluate several appointment scheduling rules with the help of a simulation model to come up with a solution which minimises the total patient waiting time. Our results shows that total patient waiting time can be reduced more than 60% using proper appointment scheduling system with process improvement.**

***Keywords*— OPD, waiting time, simulation, scheduling.**

## I. INTRODUCTION

Waiting time in outpatient departments has become a problem in healthcare industry all over the world. In Sri Lanka most of the government hospitals have long queues in OPDs and this creates a high waiting time for the patient. The major cause for this problem is the assumption that doctor's time is more valuable than the patient's time. It seems that sufficient attention is not paid to this matter in the Sri Lankan context and no other studies have been undertaken so far. Most government hospitals don't use any appointment systems for Out Patient Departments. Patients come as early as possible and wait in the queue before the hospital work starts. From the time of registration until they leave the hospital, patients have to wait longer periods for every examination, test, and diagnosis they face.

This area of patient waiting time analysis has been chosen by many researchers in the world and important solutions have been introduced throughout the past. But most of these solutions cannot be directly adapted to other hospitals as the solutions are specific to the hospital which is considered for their analysis. Some of these studies are discussed in the literature review.

During this research the process of National Eye Hospital is thoroughly studied and possible appointment scheduling rules are proposed in order to minimize patient waiting time in the hospital. And we have focused on resecuring of the process such as introducing new workstations, reducing patient routing time in the hospital premises etc in order to improve the overall process.

## II. LITERATURE REVIEW

According to Kaandorp and Koole[1], all Appointment Scheduling (AS) literature is divided in to two main groups; evaluated schedules and evaluated algorithms to uncover improved schedules. Simulations are mostly used to test evaluated schedules, whereas analytical methods are used to test evaluated algorithms.A comprehensive literature review on appointment scheduling is found in Cayirli and Veral [2].

The types of appointment systems vary from single block appointment to individual appointments. Most systems are concentrated on modifying and combining these two appointment systems in different forms. An appointment rule is created using any of the following schemas:

- Single Block System – This allows all patients to arrive in a block at the beginning of the clinic session. This system allocates a date rather than allocating a specific appointment time. Babes and Sarma[3] introduced this system. Single block system creates long waiting times for patients but shortens idle time for doctors.
- Individual-block/fixed-interval system – This system calls patients individually at intervals equal to the mean consultation time Klassen, Rohleder,Cayirli,Veral, and Rosen has done research on this.[4],[5],[6].
- Individual-block/fixed-interval with an initial block system -This is similar to the above method, but the number of patients assigned to the initial block is greater than one. Bailey in 1952[7] introduced this rule to the Appointment Scheduling literature, setting two patients at the beginning of the session. Ho and Lau [8] evaluated and made additional amendments to the original Bailey rule. Many people used this system in their studies. Klassen and Rohleder[4]Yang, Lau, and Quek [8] Cayirli, Veral, and Rosen [5],[6], Wijewickrama and Takakuwa [17] evaluated these rules in their studies. Kaandorp and Koole [1] introduced initial block in their queuing model.
- Multipleblock/fixed-interval rule – This divides the patients in to m number of blocks and calls a fixed number of patients at the beginning of each block. Soriano[13] introduced this system to the Appointment Scheduling Literature. This system schedules two patients at a time with an interval of twice the consultation time. The two at a time rule was extensively studied with its original counterpart and its variations by Ho and Lau [8] and Cayirli, Veral, and Rosen [5], [6].
- Multiple block/Fixed-interval with an initial block rule - Cox, Birchall, et al.[14] investigated this rule with an initial block rule,introducing an initial block to the above rule studied by Soriano.

- Variable-block/fixed-interval –This rule assigns a different number of patients in a fixed appointment interval during the clinical Lang Khiong et al. [11] Using a dynamic programming approach, Lin (2000) optimized a quota AS.
- Individual-block/variable-interval rule - Calls patients individually with unequal appointment intervals. Ho and Lau [8] introduced this rule by concluding that the variable-interval system, which sets an increasing appointment intervals rate towards the latter part of the session. This system works well in most environmental conditions. Many scholars have tested this rule using either analytical method or applying simulations Cardoen, Brecht et al. [12] identified the some pattern of inter-arrival times which optimized the solution. This pattern made inter-arrival times shorter at the beginning and the ending part of a session and longer in the middle, which represents a slight variation of variable interval rule.
- Multiple-block/variable-interval rule - Cayirli, Veral, and Rosen [5] introduced this method to the Appointment Scheduling literature. They modeled the multiple-block/variable-interval rule by combining the dome pattern of inter-arrival to "the two-at-a time rule" and Bailey rules.

Most of the above studies concentrated only on appointment rule disregarding the patient characteristics in designing the appointment systems. A number of studies considered the use of patient classification to sequence patients by classifying consultation time or type of procedure into groups based in order to design the Appointment Scheduling [5], [6].

Klassen and Rohleder [4] proposed a sequencing rule in scheduling based on the consultation time variance, whether a patient was considered "low variance" or "high variance." The empirical research showed that setting low variance patients at the beginning of the session and high variance patients at the end of the session would minimize both patient waiting time and doctor idle time in most instances.

Later they [4] identified that this rule is still effective when the scheduler is unable to identify the low variance and high variance patients proportionately. Incorporating patient classification into AS (Appointment Scheduling) rules, a number of AS rules were designed under a wide range of clinical environments by Cayirli, Veral et al.[5] by grouping patients as new and returning. They concluded that "sequencing decisions have a more definite impact on performance than the choice of an appointment rule"

By extending the scope of their previous research, Cayirli, Veral, and Rosen [6] introduced well-designed ASs, with adjusting appointment intervals to match the consultation time characteristics of different patient classes.

We have focused on implementing schedule rules to minimize total waiting time not only considering the patient types but also the routing times inside the hospital. In the Sri Lankan context doctor's idle time is not a matter. In our work we have done modifications to prevailing Appointment Scheduling rules.

## III. MODEL CONSTRUCTION

This section provides an introduction to the processes that were considered in building the simulation model. The OPD process of the hospital includes patient registration, eye checking, searching for previous diagnosis receipts, and finally the doctor's examination. In the later part of this section it describes how the simulation model was built using the gathered information with the help of Rockwell Arena simulation software [15].

### *A. Description of OPD*

*1) Patient Registration*: There are two types of patients at the OPD. They are the first time and follow up/second visit patients. Patient registration process starts at 6.00 am every Monday to Saturday. Any first time patient has to visit Room No 10 and get the ticket after registering there before 10 a.m. An attendant at the counter takes basic details from the patient and assigns him/her a unit and a registration number. First patient in a Monday morning receives K1, second one receives K2. Third patient is assigned with unit B1 and fourth one is B2. Fifth patient gets unit F1 and sixth one gets unit F2. The seventh person starts the cycle by having unit K1 again. This pattern is same for other days and the only difference is that on Mondays, Wednesdays and Fridays they assign patients with units K, B, F and on Tuesdays Thursdays and Saturday the operating units are MP, G, and S. These units have been named according to the consultant at the clinic on that day. A patient receives two different receipts after the registration process. One receipt is consisted with the details of the patient and he has to keep it securely during the stay in the hospital.

*2) Eye Checking*: Registered patients visit Room No 13 where his/her eyes are checked. An attendant checks the left eye and right eye and measurements are written on the other receipt which was received by patients at the registration counter.

*3) Searching Previous Diagnosis Documents:* Second visit patients have to provide the receipt with their details to the counter and get the previous diagnosis from Room No 10.

4) *Doctor's Examination (OPD):* Patients wait in a waiting area according to the registration number order, until doctors arrive. Patients are taken in to the OPD room in a FIFO pattern. First visit patients are examined by a junior doctor and second visit patients are examined by a senior doctor. During the examination patients may receive diagnosis and leave, they may ask to go for test rooms, or have to visit OPD again in another day after using the medication.

### *B. The Performance Measures*

The performance measure considered under this study was the patient waiting time for each type of patient. Times are measured in seconds. The total waiting time of a patient was calculated using a spread sheet.

### *C. Data and Simulation Model*

Data was collected for a period of one month and the main source of information gathering was through observation since an electronic database was not available. Table I shows the distribution patterns of data, which was generated by the Arena Input Analyzer. Other than these waiting times routing times inside the hospital for various purposes were also considered in building the simulation model.

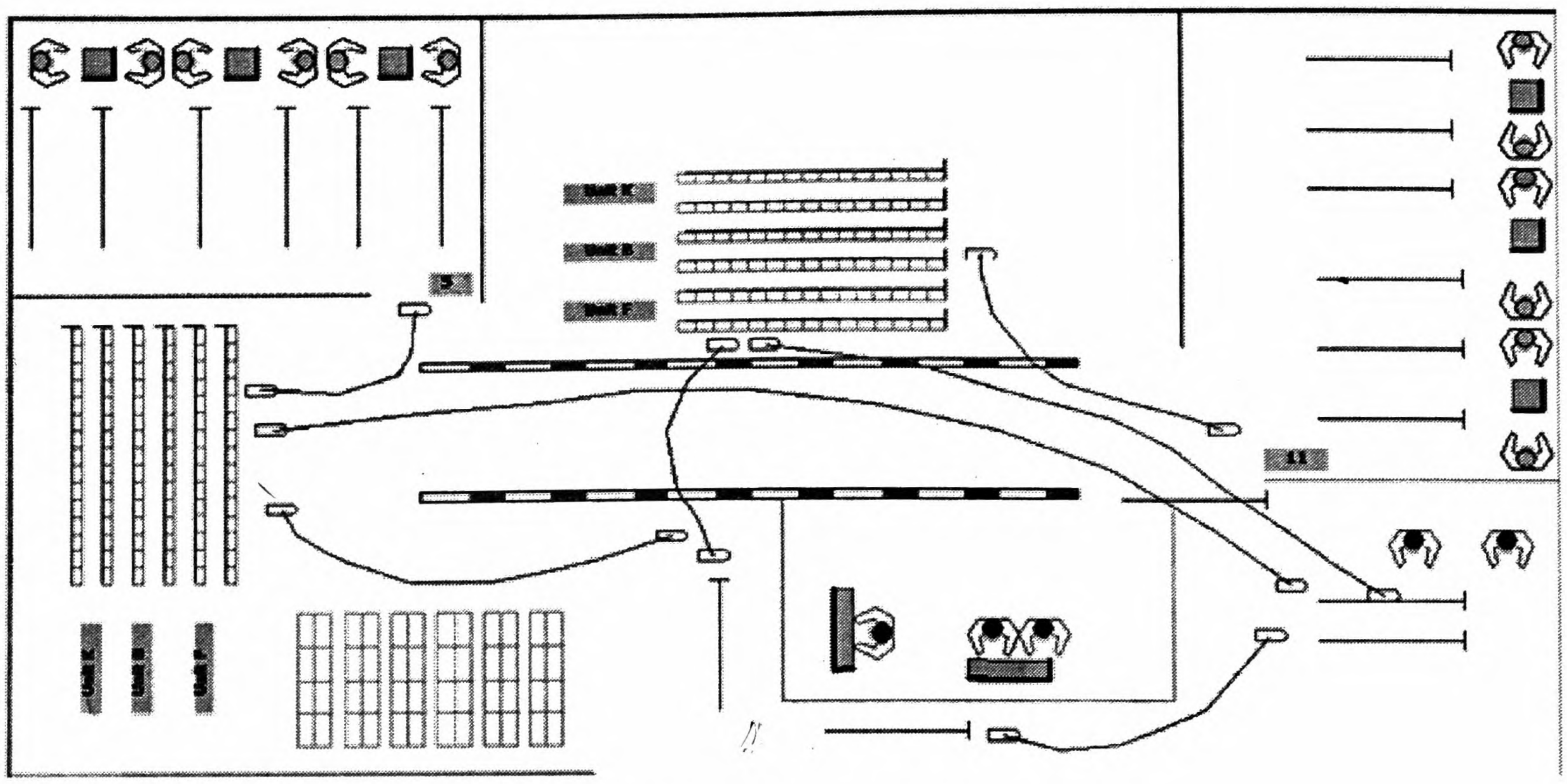

Fig. 1 The animation of the OPD process

## D. Animation

In addition to the simulation model an animation was used to clearly identify and analyse the process and the behaviour of each entity. This animation model is shown in the Fig. 1.

TABLE I
ARRIVAL AND SERVICE TIME DISTRIBUTION

| Description | Distribution/Expression |
|---|---|
| Inter arrival time of first visit patients | 9 + GAMM(4.67, 3.23) |
| Inter arrival time of second visit Patients | TRIA(220, 398, 474) |
| Service time at Room no 10 | 7 + ERLA (7.3, 2) |
| Service time at Room no 13 | 10 + GAMM (10.5, 1.36 |
| Doctor service time at OPD Rooms | 35 + 385 * BETA (0.916, 0.97) |

## E. Verification and Validation of the Model

Model verification and validation is the most important and hardest activity in any simulation project. In this scenario several techniques were used to verify and validate the model. An animation view was created with dynamic statistics and graphs. This was used to examine whether the animation depicts the real system behavior. And statistics generated through the computer simulation model was examined against the statistics that were collected from the real system.

# IV. EXPERIMENTAL ANALYSIS

This section provides a comprehensive summary of schedule rules and results of each are discussed.

Fig. 2 depicts the average waiting time in each queue for the original model (the model generated with the data gathered from the current OPD process).

Average total waiting time of a first visit patient in the original model is about 13673.8 seconds. That is 3.79 hours. For a second visit patient it is about 6802.62 Seconds.

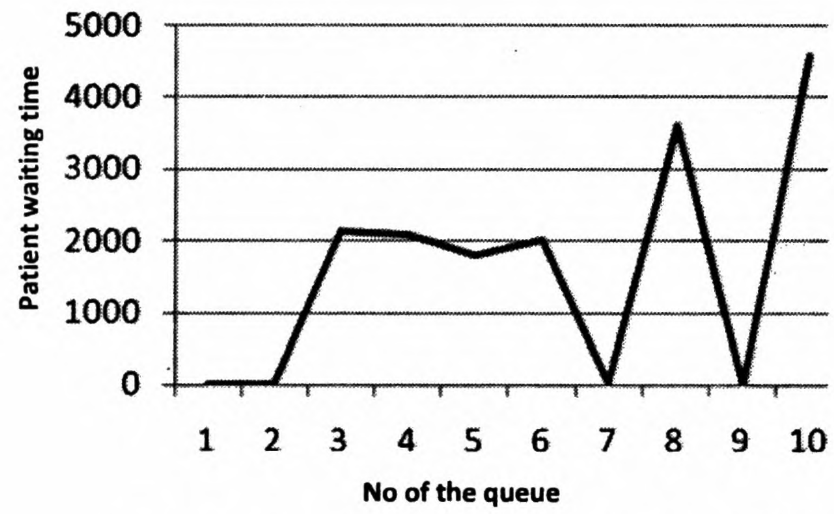


Fig. 1 Patient waiting time in queues for original model

To reduce the total waiting time of a patient four schedule rules were introduced.

Following section demonstrates each schedule rule with the output statistics generated through the model. In the Fig1. No of the queue axis represent check eye sight.Queue1, check eye sight.Queue2, examine time-first visit11, examine time-first visit5, examine second-visit11, examine-second visit5,get ticket, wait until doctors arrive, search ticket, wait until getting space respectively.

## A. Schedule Rule 1(Equal intervals/Equal blocks)

TABLE II
SCHEDULE RULE 1

| Patient type | Time period (Seconds) | Number of patients | Total |
|---|---|---|---|
| First Visit Patient | | | |
| | 3600 | 50 | 50 |
| | 3600 | 50 | 50 |

| | | | |
|---|---|---|---|
| | ... | ... | ... |
| | 3600 | 50 | 50 |
| Second Visit Patient | | | |
| K1,K2,B1,B2,F1,F2 | 7200 | 10 from each type | 60 |
| K1,K2,B1,B2,F1,F2 | 7200 | 10 from each type | 60 |
| | ... | ... | ... |
| K1,K2,B1,B2,F1,F2 | 7200 | 10 From each Type | 60 |

Schedule Rule 1 has 50 first visit patients per half an hour and 60 second visit patients per hour. Second visit patients are 10 from each type.

According to the calculations Schedule Rule 1 gives an average waiting time of 1270.425 seconds for first visit patients and 1320.63 seconds for second visit patients. It is a very higher reduction of total patient waiting time when compared with the original model. Fig II shows variations of waiting time in the Schedule Rule 1.

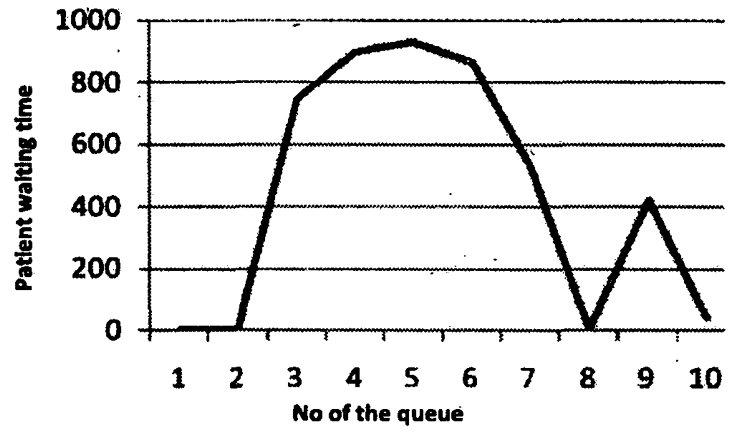


Fig. 2 Patient waiting time in queues for schedule rule 1

*B. Schedule Rule 2(Equal Intervals Repeating/Equal Blocks)*

TABLE III
SCHEDULE RULE 2

| Patient type | Time period (Seconds) | Number of patients | Total |
|---|---|---|---|
| First Visit Patient | | | |
| | 3600 | 100 | 100 |
| | 3600 | 100 | 100 |
| | ... | ... | ... |
| | 3600 | 100 | 100 |
| Second Visit Patient | | | |
| K1,K2,B1,B2,F1,F2 | 7200 | 20 From each Type | 120 |
| K1,K2,B1,B2,F1,F2 | 7200 | 20 From each Type | 120 |
| | ... | ... | ... |
| K1,K2,B1,B2,F1,F2 | 7200 | 20 From each Type | 120 |

Schedule Rule 2 is a variation of the Schedule Rule 1 with different block size and time intervals. The values for the first visit and second visit patients are shown in Table III. This rule also has reduced most of the waiting times and but it has a long waiting times in get ticket and search ticket queues compared to the original model.

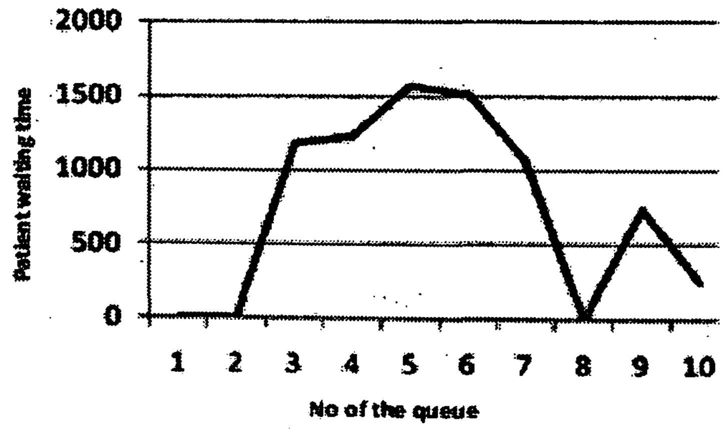


Fig. 3 Patient waiting time in queues for schedule rule 2

*C. Schedule Rule 3(Unequal Intervals Repeating/Unequal Blocks)*

TABLE IV
SCHEDULE RULE 3

| Patient type | Time period (Seconds) | Number of patients | Total |
|---|---|---|---|
| First Visit Patient | | | |
| | 1800(6.00) | 45 | 50 |
| | 3600(6.30) | 109 | 50 |
| | 1800(7.30) | 56 | |
| | 3600(8.00) | 92 | 50 |
| | 1800(9.00) | 49 | |
| | 3600(9.30) | 105 | |
| | 1800(10.30) | 56 | |
| | 3600(11.00) | 95 | |
| Second Visit Patient | | | |
| K1,K2,B1,B2,F1,F2 | 3600(6.00) | 9,10,8,12 10,11 | 60 |
| K1,K2,B1,B2,F1,F2 | 7200 (7.00) | 19,25,15,22 20,19 | 120 |
| | 3600 (9.00) | 6,15,9,12 10,8 | 60 |
| K1,K2,B1,B2,F1,F2 | 7200(10.00) | 20,16,27,19 12,26 | 120 |
| K1,K2,B1,B2,F1,F2 | 3600(12.00) | 5,9,17,12 8,9 | 60 |

Schedule Rule 3 is somewhat different from other two schedule rules discussed earlier. The schedule allows unequal amount of patients for each interval. These intervals are one hour and half an hour repeated. These intervals are repeating one after another.

The average waiting time for a first visit patient in Schedule Rule 3 is 2232.01seconds and for a second visit patient it is about 1904 seconds.

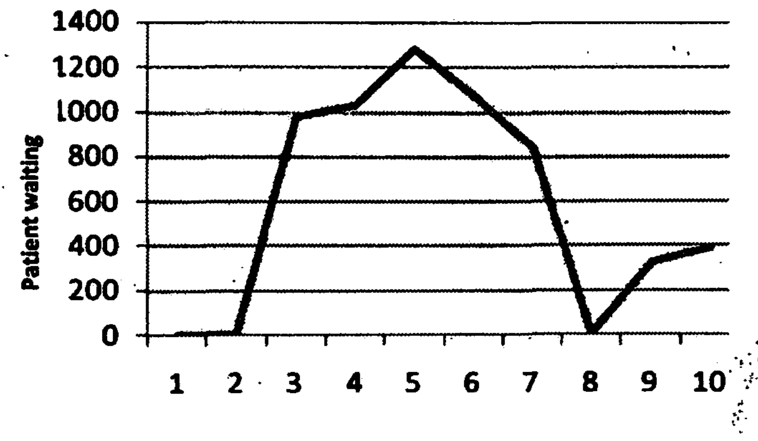


Fig. 4 Patient waiting time in queues for schedule rule 3

*D. Schedule Rule 4(Unequal Intervals Repeating/Unequal Blocks)*

TABLE V
SCHEDULE RULE 4

| **Patient type** | **Time period (Seconds)** | **Number of patients** | **Total** |
|---|---|---|---|
| First Visit Patient | | | |
| | 1800(6.00) | 50 | 50 |
| | 900(6.30) | 25 | 50 |
| | 2700(6.45) | 75 | |
| | 900(7.30) | 25 | 50 |
| | 900(7.45) | 25 | |
| | 900(9.00) | 25 | |
| | 2700(9.15) | 75 | |
| | 2700(10.00) | 75 | |
| | 3600(10.45) | 100 | |
| Second Visit Patient | | | |
| K1,K2,B1,B2,F1,F2 | 1800(6.00) | 10 From each Type | 60 |
| K1,K2,B1,B2,F1,F2 | 3600 (6.30) | 10 From each Type | 60 |
| K1,K2,B1,B2,F1,F2 | 7200 (7.30) | 10 From each Type | |
| K1,K2,B1,B2,F1,F2 | 1800 (9.30) | 10 From each Type | |
| K1,K2,B1,B2,F1,F2 | 1800(10.00) | 10 From each Type | |
| K1,K2,B1,B2,F1,F2 | 3600(10.30) | 10 From each Type | |
| K1,K2,B1,B2,F1,F2 | 1800(11.30) | 5 From each Type | 60 |

Schedule Rule 4 is also somewhat similar to Schedule Rule 3. The only difference is that it has a varying number of patients in different time intervals for both first visit and second visit patients. With schedule rule 4 first visit patients take 2639.05 seconds and second visit patients take 1913.32 seconds.

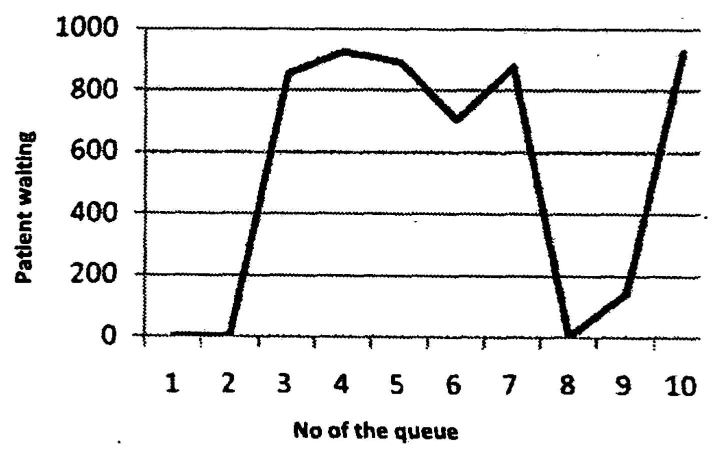


Fig. 5 Patient waiting time in queues for schedule rule 4

*E. Problems with Schedule Rules*

The main aim of this study was to find the method that could minimize total patient waiting time without creating other large queues. Although the Schedule Rules (SRs) 1, 2, 3 and 4 were successful in minimizing total waiting time they generated large queues in some other places. The next analysis was conducted with more attention focusing on reducing the total waiting time at the expense of particular queues. Since they are carried out based on the schedule rules they have been named as Experiment1 [SR1], Experiment2 [SR1]...etc.

Spreading the load in the various queues was achieved by modifying the number of agents in the get and search ticket counters at Room No 10. In the first two experiments it has been used the previous data that was gathered and for the next two an assumption has been made that service time in Room No 10 and 13 is equal to the half of the original data with increment of agents inside each room.

Seven experiments were carried out to identify the best appointment scheduling method. Schedule rule 1 was checked for four experiments with changes to the number of servers. Experiment1 [SR1] has two attendants at the first visit patient registration and one attendant at the search ticket for second visit patients. Experiment 2[SR1] has two attendants for both counters in the Room no 10. In the experiment 3 another two attendants were added to the first visit patient registration counter. The same model was tested assuming the service time would reduce to half when the appointment system is introduced.

TABLE VI
DATA ANALYSIS

| *Model* | *Total Waiting time* | | *Difference* | | *Percentage Difference* | |
|---|---|---|---|---|---|---|
| | *FV* | *SV* | *FV* | *SV* | *FV* | *SV* |
| Original | 13673.81 | 6802.62 | | | | |
| SR1 | 1270.43 | 1320.63 | 12403.38 | 5481.99 | 91 | 81 |
| SR2 | 2436.13 | 2610.91 | 11237.68 | 4191.71 | 82 | 62 |
| SR3 | 2232.01 | 1903.99 | 11441.79 | 4898.63 | 84 | 72 |
| SR4 | 2639.05 | 1913.32 | 11034.75 | 4889.3 | 81 | 72 |
| Ex1-SR1 | 4450.29 | 2910.3 | 9223.52 | 3892.32 | 67 | 57 |
| Ex2-SR1 | 1234.41 | 1256.06 | 12439.4 | 5546.56 | 91 | 82 |
| Ex3-SR1 | 1325.79 | 1247.97 | 12348.02 | 5554.65 | 90 | 82 |
| Ex4-SR1 | 1399.44 | 1973.76 | 12274.37 | 4828.86 | 90 | 71 |
| Ex5-SR2 | 2142.17 | 1867.57 | 11531.64 | 4935.05 | 84 | 73 |
| Ex6-SR3 | 1948.29 | 2421.63 | 11725.52 | 4380.99 | 86 | 64 |
| Ex7-SR4 | 1856.67 | 2421.63 | 11817.14 | 4380.99 | 86 | 64 |

With the first four experiments it was clear that experiment 2 reduced the both first and second visit patient waiting time in a higher rate. Therefore the next 3 experiments were carried out based on this, which is to include two servers for both get ticket and search ticket counters. Schedule Rule 2, 3, 4 were analysed according to the model shown in figure 8.

All statistical out puts were collected and imported to a spread sheet using the arena simulation model. This data was used to calculate the percentage reduction compared with the statistics for the original model.

Table VI summarizes the final analysis of the output generated by the model. Experiments are shown as "Ex". It shows that the introduction of schedule rules helps to reduce the total waiting time to a great extent and that the reduction rate of most of the rules are greater than 80%. According to the observations first visit patients have the major problem of a high waiting time for the treatments. It is obvious that "Ex2"decreases the waiting time of a first visit patient by 91% and 82% from a second visit patient. Therefore the final analysis suggests that the best schedule rule for the national eye hospital to implement is E2 [SR1]; that is an appointment system of 50 patients per half an hour for the first visit patient type and 10 patients from each K1,K2,B1,B2,F1,F2 per an hour as second visit patients. There should be two counters for the registration of first visit patients and two counters to search tickets of second visit patients.

## V. CONCLUSIONS

This research has focussed on reducing extended waiting times in queues of National Eye Hospital in Sri Lanka. Different types of appointment scheduling rules have been tested. According to the simulation model it is obvious that significant amount of total patient waiting time has been reduced. The optimum solution which is proposed by our findings for the hospital is 50 patients per half an hour for the first visit patient type and 10 patients from each K1,K2,B1,B2,F1,F2 per an hour as second visit patients

The importance of this work is, it has considered both reducing waiting times and routing times in the hospital premises while improving the whole process. And also experiment schedules show how resources can be allocated in order to achieve efficient and effective service.

As for the future work these improved schedule rules can be implemented to see how they operate in the practical world. This model can also be used by the internal staff to test new scenarios in future.

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