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SUMMARIZING THE VARIOUS APPROACHES TO OPTIMIZE THE SCHEDULING PROBLEM IN HEALTHCARE

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ABSTRACT

In recent times, topics relating to healthcare optimization have attracted a large amount of attention in order to deliver services that are more appropriate at reduced costs. This article provides a summary of the most recent studies on various scheduling issues that arise in healthcare, such as problems with patients' admission scheduling, nurse scheduling, operation room scheduling, surgery scheduling, and other healthcare scheduling issues. The paper presents an extensive review of healthcare scheduling with a primary focus on the most recent research in this field. The advancement of research in healthcare scheduling plays an important part in the reduction of healthcare costs, the improvement of patient flow, the prompt administration of treatment, and the most effective utilisation of the resources that are both available in hospitals and that can be accessed by those hospitals. In recent decades, there has been a proliferation of healthcare scheduling approaches that make use of metaheuristics in order to automate the search for the most effective resource management in hospitals. The goal of these methods is to improve patient care. The published results, on the other hand, are inconsistent since the authors attempted to address each individual problem on their own, despite the fact that there are numerous different problem definitions and a wide variety of data sets accessible for each of these problems.

Key words: Patient, Scheduling approaches, Optimization.

1. INTRODUCTION

Basically, healthcare systems should ensure that all people may easily gain entry to high-quality medical care that doesn't break the bank. The goals of such scheduling can be broken down into four categories: reducing healthcare costs, improving patient experiences, reducing wait times, and bolstering fairness in the healthcare system. When a patient is admitted, they use the whole range of services available to them, and this policy equally divides those costs between ordinary patients, those with emergencies, and doctors. This is why equity in healthcare is so important. To further motivate employees, the division uses a revolutionary gain paradigm that has never been reported before and is not dependent on appointment scheduling fairness. Fixing individual schedule preferences, which means that every doctor has different availability requirements, is another crucial issue concerning fairness. As much as feasible, these should be taken into account when creating a schedule. Healthcare services that are both effective and efficient can lead to the development of appointment scheduling systems to help patients more easily gain access to necessary medical services. When appointments are scheduled in advance like this, patients are more likely to be pleased with the results. Different parts, first visits, individual visits, and extra procedures all make use of appointment scheduling. Depending on the number of patients scheduled to see a doctor at a first clinic, physicians may have to divide their time into many sessions. Both the urgency of a patient's condition and the quality of the services available influence the guidelines for gaining access to primary care. A few examples of this procedure are prioritising emergency cases and routinely checking in on patients.

Since healthcare is a service, hospitals can become more competitive by improving their quality and efficiency. Most patients evaluate hospitals based on the quality of care they receive and the quickness with which they receive it; long wait times are a common source of dissatisfaction. If patients perceive that they have saved significant time, this can boost productivity. Patients' wait times were found to have a negative correlation with their level of satisfaction with the hospital in a large-scale study conducted by Sun et al. from October 2014 to February 2017. Thus, it is essential to refine the appointment-setting process and the way patients are allocated to examination rooms (or clinical rooms). Appointment scheduling in hospitals and procedures for allocating patients to examination rooms are discussed in the literature, but the effects of these on patient wait times and the workload of radiological technologists are not. Further, several researchers looked at hospital abandonment and overcrowding by employing techniques from fields as disparate as system dynamics, finite machines, and Six Sigma.

It is now generally accepted that all patients should be able to gain quick and simple access to healthcare facilities as part of a well-designed healthcare process. As a result of Appointment Scheduling (AS), medical facilities and their pricey staff can better serve their patients and reduce wait times for patients. The purpose of appointment scheduling is to develop a system for scheduling work in the healthcare industry under uncertainty in order to optimise for a desired quality standard. In public healthcare settings, one of the key goals of healthcare management software is to reduce patient wait times while simultaneously raising levels of contentment among those receiving treatment. There may be a variety of issues for healthcare providers to deal with when dealing with a big volume of outpatients. Long wait times, for example, can have a negative effect on both the patient's experience and the quality of care provided. The need for services at healthcare facilities like hospitals and clinics continues to rise. In order to attract new patients and maintain their current clientele, hospitals must provide efficient and timely healthcare infrastructure. They need to pinpoint the bottlenecks, predict how diversity will affect demand, and calculate the best way to divide up available resources. When assessing healthcare facilities, it is important to look for those that can identify the best practises, use quantifiable methodologies, and acknowledge a responsibility to constantly better their services. Clinics can maintain a high standard of treatment while keeping costs low by employing decision support tools. Decision support systems for the administration of outpatient clinic services are one approach proposed in the literature to lessen patients' lengths of stay. Over the past few years, healthcare organisations have struggled to meet the needs of their patients while operating with inadequate resources. Improved quality and timely access to healthcare facilities is one of the most pressing challenges in healthcare today, thanks in large part to ASP. Time is a critical factor in determining whether or not patients are happy with the care they have received.

2. LITERATURE REVIEW

System simulation was utilised by Asgary et al. [1] to build a drive-through mass vaccination model, which was then used to allocate medical resources in order to minimise wait times for patients receiving vaccinations at the drive-through.

With the help of the AnyLogic agent-based simulation tool, Wu et al. [2] developed a patient evacuation strategy for the case hospital to more efficiently distribute medical personnel and shorten the time it took to evacuate patients.

Priority and avoidance criteria were implemented by Zou et al. [3] in the modified cellular automata model. The findings revealed that by giving wheelchairs top priority, waiting times and evacuation times were drastically cut.

Knowledge of process mining techniques, as demonstrated by Tamburis and Esposito [4], can give a solid foundation upon which to construct a discrete event simulation model of a healthcare process.

Drum-buffer-rope (DBR) scheduling was developed by Huang et al. [5] to determine which medical resource was the bottleneck resource in order to maximise operating room efficiency. This was followed by a Monte Carlo simulation to ensure the DBR approach worked as intended in a variety of hypothetical scenarios.

In order to accommodate patients who are chronically late, Deceuninck et al. [6] presented a control variate approach to appointment scheduling. Through strategic use of control variates, their method significantly outperformed the Monte-Carlo simulation in terms of the accuracy of the simulation estimations.

Three types of orthopaedic outpatients and various visiting times were examined in a study by Baril et al. [7]. In order to maximise physician use, decrease patient waiting times, and maximise patient examinations, they established how to allocate patient appointment schedules and the placement of nursing personnel in three examination rooms.

The patient flow pattern was first described by Bhattacharjee and Ray [8], who accounted for factors such the unpredictability of patients' arrival times, the frequency with which they would be absent, the likelihood that their care would be diverted, and the length of their visits. They polled a variety of healthcare settings for data on performance indicators, including ERs, ORs, ICUs, and diagnostic centres. Discrete event simulation is well-suited to this study because the properties of the problem best fit the characteristics of discrete event simulation, which are as follows: a) intricate patient flows There are three issues here: (2) scheduling and resource allocation; (3) transient study of system performance.

3. PATIENT ADMISSION SCHEDULING PROBLEM (PASP)

Patients are placed in hospital rooms over a period of time using a method called Patient Admission Scheduling (PASP). The scheduling of patient admissions is an example of a combinatorial optimization problem that is drawing the attention of academics in the medical field. In healthcare facilities, PASP helps long-term (strategic), medium-term (tactical), and short-term (operational) decision-makers assess whether or not the available resources can meet the needs of the patients.

3.1 Definition of patient admission scheduling problem (PASP)

The goal of solving the Patient Admission Scheduling Problem (PASP) is to improve medical care in the hospital while also optimising managerial competence, patient comfort, and safety. The problem of determining when to admit patients is a difficult combinatorial one. Since the problem is first established, the solution permits the scheduling of patients assigned to specific beds in specific relevant departments, satisfying in an ideal way to the needs of the patients, and ensuring all the necessary medical constraints. In most hospitals, a central admissions office is responsible for assigning patients to available beds by coordinating with other departments several days in advance. Some hospitals don't have a centralised admissions office and instead have their individual divisions handle patient admissions independently. For the same reason as in the second scenario, departments may not be using their resources to their full potential if they lack the necessary level of overall knowledge and information. Depending on the department, there may be a lack of available beds for patients while there are extra beds in the other.

3.2 PASP Formulation

The first variant, Patient Admission Scheduling version (1), or the "basic problem," assumes that admission and discharge dates are known in advance. There should also be a minimum time commitment of one bed per patient. The problem's rudimentary lexicon can be described as follows:

1. Nigh: Each hospitalised patient's time horizon is represented by a set of variables.

2. Admitted patients are those who have been formally admitted to the hospital and given a private room and bed.

3. Patient: A patient who needs to receive medical care in a hospital and who is assigned a room and given a specific admission and discharge date.

4. Room: Each division has its own dedicated room, the capacity of which is determined by the number of beds present (which may be single, double, or ward beds).

5. Specialism: Each and every one of the hospital's wards is assigned to a specific treatment. In addition, each room within a given department offers its own unique degree of care, ranging from (1-3) according to the distinct needs of each patient.

6. Transfer: Transferring an inpatient from one room to another during their hospital stay.

4. METHODOLOGY

4.1. Research Problem

This study's research challenge is comparing the efficacy of three simulation models in lowering patients' waiting times on the day of their ultrasound examination, achieving work-life equilibrium among radiology technologists, and keeping equipment utilisation rates high. Appointment scheduling for ultrasound exams is the focus of this study's research challenge, which also includes the assignment of patients to exam rooms, the assignment of patients to patient types, and the assignment of patients to body regions. The distribution of patient arrival times varies depending on the patient type. Each ultrasound examination room is considered to have identical testing equipment in order to make the research challenge more manageable. In addition, the distribution of the time spent on an examination varies depending on which body component is being checked. This research takes these considerations into account to build a more efficient appointment scheduling system for patients undergoing ultrasound examination, which includes allocating them to examination rooms, determining a more suitable time interval, and recommending a new method for allocating patients. There are a few caveats to the research problem in this investigation. It is standard practise to have a male radiologist examine a male patient for scrotal and prostate ultrasounds, and for a female radiologist to examine a female patient for a deep vein thrombosis ultrasound.

4.2. Research Procedure

The following steps were taken to collect data for this study: first, interviews were conducted with radiology technologists and appointment schedulers working in ultrasound examination rooms at the radiology department of the case hospital to gain insight into the process of appointment scheduling for patients undergoing ultrasound examination; second, the data regarding time intervals for the arrival of different types of patients and the time taken to perform ultrasound examination on dummies was collected; and third, a chart review was conducted to identify any discrepancies between the Probability distributions were calculated using data fitting based on the observed patterns.

The second part of this investigation was to build a simulation model and compare its performance to that of the real system. To fix the simulation model, statistical tests must return a significant result. A simulation model can stand in for the real system to conduct further research into the appointment scheduling time interval for patients undergoing ultrasound examination if statistical tests show no significant differences. In this research, the number of simulation model replications (n) is calculated using the following Equations (1)-(3).

The 95% confidence interval =

$$\left[\bar{X} - t_{n-1,1-\frac{\alpha}{2}} \times \frac{s}{\sqrt{n}}, \bar{X} + t_{n-1,1-\frac{\alpha}{2}}, \times \frac{s}{\sqrt{n}},\right] \quad (1)$$

$$h_o = t_{n-1,1-\frac{\alpha}{2}} \times \frac{s}{\sqrt{n}} \quad (2)$$

$$n \approx n_0 \times \frac{h_0^2}{h^2} \quad (3)$$

5. METHODS AND MATERIALS

5.1 Description of the sequential appointment scheduling process.

Once the hospital begins to generate outpatient appointment service, the hospital administrator is confronted with the constant challenge of determining how many patients to accept and allocating slots for these patients within the facility's physical constraints. Individual patients are phoning in one after another to schedule appointments for the next week. Regular hospital patients are distinguished from those admitted due to an emergency situation. In many cases, urgent outpatients can be admitted if they follow the same protocol as regular patients. The idea of justice is upheld. Patients at either level of emergency care should not have to wait in line when they visit the triage, doctors' offices, pharmacy, laboratories, or imaging departments. On the other hand, it's reasonable to expect that there is another emergency patient waiting in line. When a new emergency patient arrives, they will wait in the emergency service queue behind the current patient who is being screened. Also taken into account in the model is the possibility that regular patients need be treated in an emergency during the appointment. The resource (the starting point for patient servers) is the default slider number at each step of the procedure. NormalEnt and EmergenctEnt indicate regular and emergency patients, respectively, who are logged into the model using the distribution functions given in the tables in the previous figure. Multiple patients of each category were currently registered, as shown by the accompanying numbers. There were 77 scheduled visits and 1 unexpected visit from a patient in need of immediate attention. As can be seen, all 76 patients admitted to the hospital went to the admissions department, while 51 were sent to the triage area. The model operates under the assumption that those receiving services are not affected by the new fairness policy. If a number is specified, it will be in the upper left. The high accuracy rate likely reflects the large volume of patients undergoing checks by doctors at the present time. That's the maximum amount of workers allowed in each division. In the above illustration, the doctor is evaluated after a patient has been diagnosed in the triage area (FirstPhysicianCheck1 station).

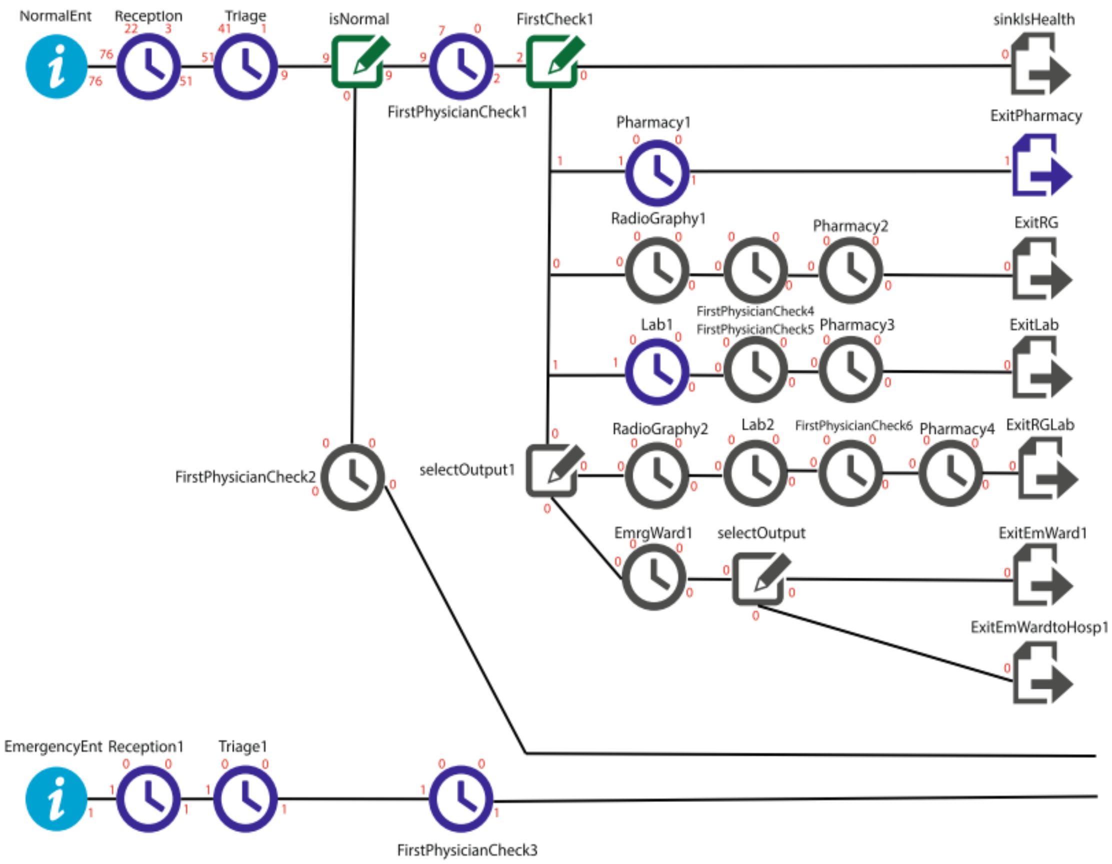

Figure 1. Simulation model of appointment scheduling for two different patient type.

5.2 Appointment Scheduling Process for Patients Undergoing Ultrasound

Examination A patient who has seen a specialist and needs to schedule an ultrasound exam must do so by bringing an examination appointment form to the radiology department's front desk, as depicted in Figure 2.

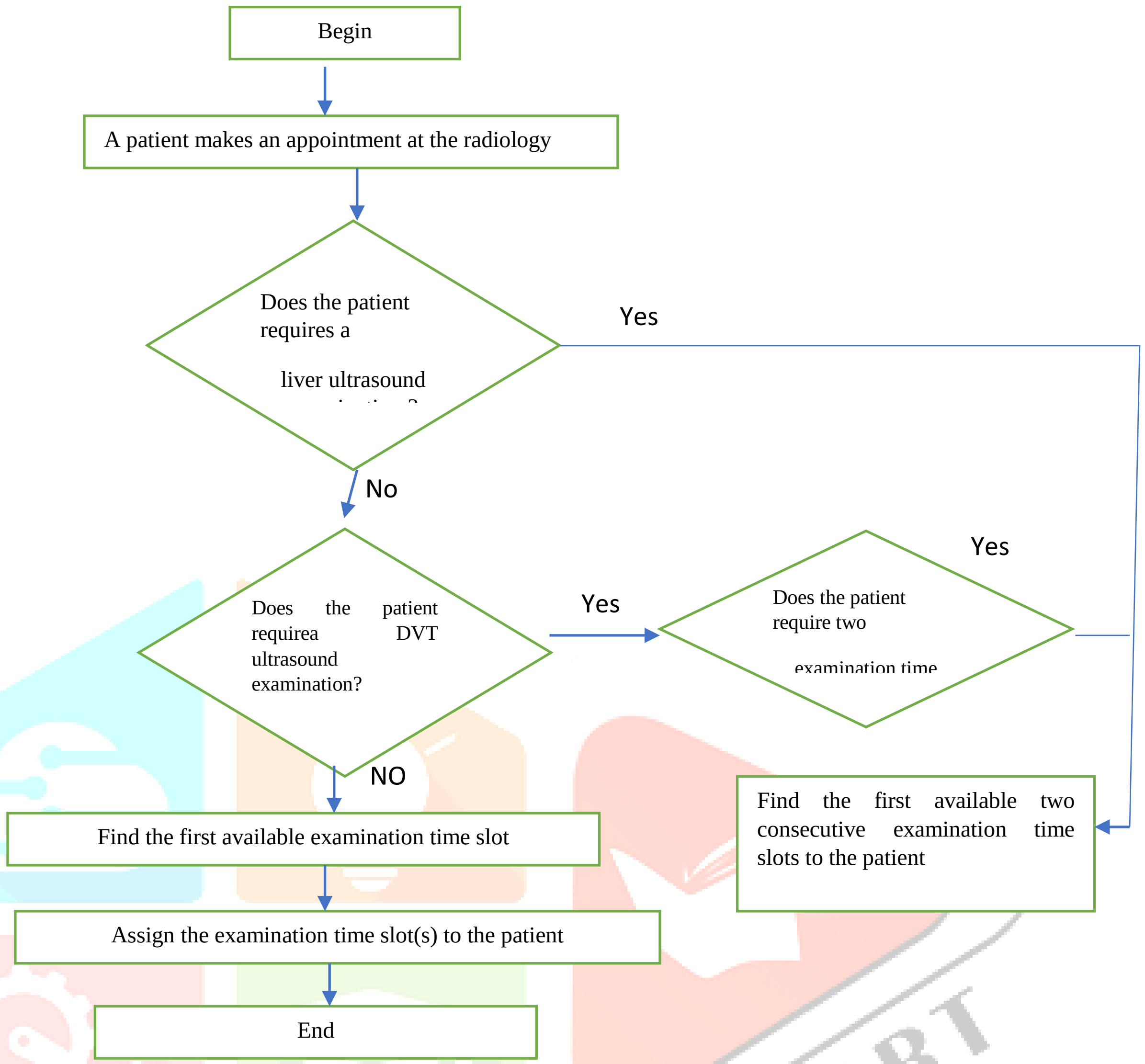

Figure 2. The flowchart of patient's appointment procedure at the radiology department

The ultrasound appointment scheduler first decides if a liver ultrasound is necessary. In that case, the patient will be given the first two available back-to-back appointments for the assessment. If that's not the case, the scheduler will decide if an ultrasound for deep vein thrombosis is necessary. The scheduler decides if two separate examination times are necessary for the patient based on whether or not they need the DVT ultrasound. If the patient needs to be seen at two separate times, the first two consecutive times that work will be given to the patient.

5.3 Heuristic/metaheuristics algorithms for OTR problem

The OTR scheduling problem has previously been addressed via heuristic techniques. Two types of such algorithms are taken into account based on the work of Cardoen et al. (2010b): (1) constructive heuristics, and (2) metaheuristics. First, we introduce some constructive heuristics, and then we talk about meta-heuristic algorithms like simulated annealing (SA) and tabu search (TS). We use them as a "sequencing generation engine" in the search algorithm (Figure 9) and then use CPH techniques to analyse the results. Both the Scheduling Assistant (SA) and the Traveling Salesman (TS) heuristics are well-known, constructive heuristics that have been reported to perform well in the OTR scheduling problem. Finally, we provide a theoretical upper bound on the efficiency of our search strategy.

6. ANALYSIS AND DISCUSSION

Based on data collected over the course of six months, this study included outpatients, inpatients, and emergency patients who had ultrasounds performed in Exam Rooms 5-10 in the radiology department of the case hospital. Ultrasound exams on all other body parts (excluding the breasts) were performed in Rooms 5–10. All six exam rooms featured an ultrasound machine, and each of the six machines was identical in terms of capabilities. After consulting a doctor and signing in at the radiology department's front desk, the patient was given a date and time for their evaluation.

6.1 Data Regarding Patients Undergoing Ultrasound Examination

As can be seen in Table 1, outpatients made up the vast majority of the 10,133 patients who were examined using ultrasound technology (72% of the total number of patients), followed by inpatients and emergency patients.

Table 1. Proportion of Patient Category at the Radiology Department.

Patient Category	Number of Patients	Percentage	Cumulative Percentage
Outpatient	10,133	72.46%	72.46%
Inpatient	2794	19.98%	92.43%
Emergency Patients	1058	7.57%	100.00%
Total	13,985	100.00%	

6.2 Data Fitting Analysis

In this study, Rockwell Automation Inc.'s Arena Input Analyzer was used to perform the data fitting analysis (Rockwell Automation, Coraopolis, PA, USA). Both the Chi-square and Kolmogorov-Smirnov (K-S) tests were run to determine the most suitable distribution of probabilities. A valid probability distribution was attained if and only if the data set passed the Chi-square and K-S tests. Otherwise, the number of categories used would have to be adjusted and a new study of how the data fit would have to be conducted. After adjusting the amount of data categories, the data set has a valid probability distribution if it passes the Chi-square and K-S tests.

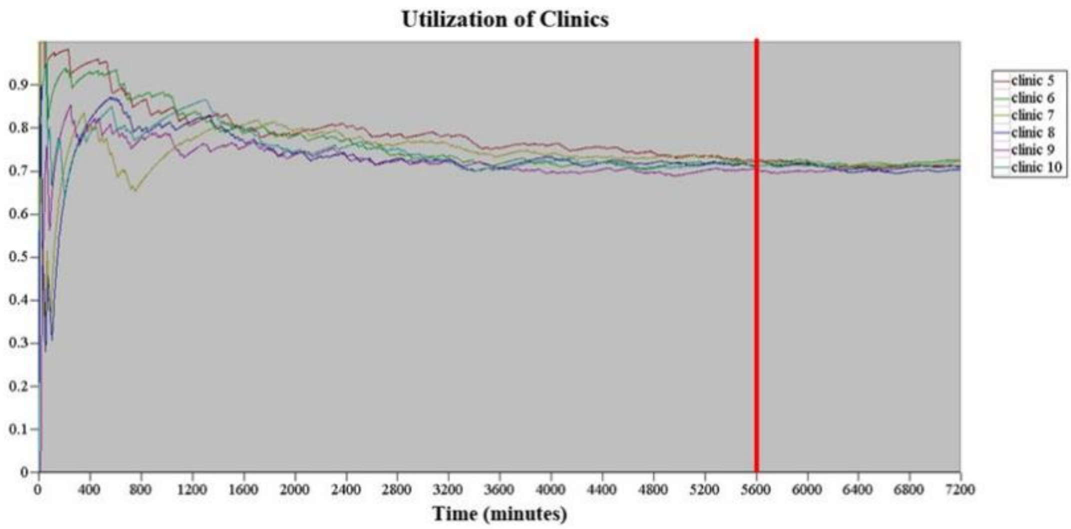

Figure 3. The warm-up period of the simulation model in this study

This study only focused at one part of the ultrasound exam schedule: Monday through Friday, from 8 a.m. to 5 p.m., with a break from 12 p.m. to 1 p.m., for a total of 8 hours a day. 6.8% of the total time spent on exams was spent on ultrasounds for outpatients, inpatients, and emergency patients, no matter what part of the body was being looked at. So, the actual time spent on simulations each day was 93.2% of the total time for the test, or 447.36 minutes (480 93.2%). The length of each simulation was five days (i.e., 2236.8 min). Figure 3 shows that the simulation model used in this study ran for 7200 minutes before the steady-state rate of equipment use was looked at. When the simulation time reached 5600 minutes, there were no big changes in how much equipment was being used. In this study, the simulation model's warm-up time was set to 5600 min, and the length of a replication was set to 7836.8 min (5600 + 2236.8).

CONCLUSION

The purpose of this study was to show and then solve a model of the hospital's appointment scheduling problem using the fairness technique. All scheduling systems aim to optimise resource use while minimising costs and patient wait times. The cost function used to aggregate the soft constraints has a significant impact on the final solution's quality. In addition, this analysis enumerated all healthcare scheduling systems and how they are supported by the most effective algorithms that have employed various sorts of search techniques. Several of the most recent high-tech solutions, we found, achieved noteworthy results. Metaheuristics algorithms used in local search and the population-based technique are also discussed at length in this study. The most prominent successful algorithms, however, are from the category of nature-inspired algorithms and have demonstrated success in solving the challenging N/P problem. This is because of the search space exploration capabilities of certain algorithms, especially swarm-based algorithms.

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