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Modeling and Simulation Analysis of Medical and Dental Clinic System using Arena

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Abstract
Enhancing sustainability for private clinics by balancing between the service provided and the expenditures incurred is a great challenge. This study observed the service performance of a clinic that offers medical and dental treatment, which was illustrated using a simulation model. Based on the observation, the overall utilization rate of staff is 48%, and the average waiting time in the dental consultation process is 12.141 minutes. Model 3, which reduces the number of staff at the registration counter, can improve performance by increasing the utilization rate to 55.35% and reducing the average waiting time to 10.5 minutes.

Keywords: clinic processing system; utilization rate; waiting time; Arena simulation model

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1.0 Introduction

Malaysia's healthcare system is running to a high standard and has won international accolades for its medical equipment and human resources (MT Webmaster, 2020). There are two parallel systems in primary health care service; the public clinic and the private clinic. Even though the number of private clinics is much higher than that of public clinics, about 65% of the Malaysian population receives medical treatment from public clinics. Because of that, private clinics need to work hard to improve their performance. Since the private clinics are independently funded, they must also ensure that the servicing process is cost-effective to stay competitive and sustainable. This study applied a simulation modeling approach to observe the embedded problems and enhance decision-making considering the problems. According to Britannica (2016), simulation is a study or teaching method that duplicates real-world activities in a controlled environment in business, science, and education. This method is being used to understand better how processes and systems work and how the particular system is affected when certain variable changes. It has been widely employed and proven helpful in healthcare by identifying problems, testing solutions in a risk-free environment, and confidently planning for a better system (Palmieri, 2013).

This study was conducted in a private clinic combining medical and dental facilities under one roof. This clinic has been operated in a rural district for about six years since 2018. Until now, this clinic remains focused on those two essential services even though numerous clinics have opened in that area. There are two dentists and one medical doctor in service. The clinic is open Saturday through Thursday from 9 a.m. to 10 p.m. The novelty of this study is the modeling and simulation analysis of clinical performance for both medical and dental treatments. This study started by constructing a verified and valid simulation model to observe the flow of the patients attending both treatment services.

Based on the observations, the processes that need to be improved can be identified. Several options will be introduced to provide better service to patients. The clinic's managers were concerned about providing the optimal service configuration to satisfy customers and service providers. The queue length and waiting time are two significant factors that play important roles in the customer's perception of the quality of service in the clinic. The objectives of the study are:

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1. To develop and analyze a Medical and Dental Clinic simulation model.
2. To identify potential problems with the current clinic operations through simulation modeling.
3. To propose an improvement model to enhance the clinic's performance and recommend the best solution.

2.0 Literature Review

Simulation modeling has been increasingly used to demonstrate various techniques using various software to maintain the best practices in various sectors, including healthcare.

2.1 Simulation

Simulation is model-based experimentation in that a physical or computational model is used in place of the system of interest. This model is conceptually very similar to doing field experiments. The method has proved beneficial in many applications to assist the management in understanding their current operations better and developing improved models to overcome the problems. This approach entails evaluating and testing different designs and confirming, explaining, and supporting simulation results and research suggestions to reduce waiting time (Alam et al., 2018).

Arena software is one of the most effective tools of simulation to develop models based on observations and suggest various options. The developed model can help reduce traffic flow in the traffic system (Yuniawan et al., 2018), improve efficiency in the outpatient department of a large public hospital specializing in cardiology (Chang et al. et al., 2019), and increase the performance of crossing docking operations ((Stanković & Božić, 2021). Atalan and Keskin (2023) apply Arena software to identify the utilization rates of dentists, orthodontists, assistants, and clerks in a dental clinic as 65.5%, 77.5%, 35.5%, and 45%, respectively.

2.2 Simulation in Healthcare System

There are numerous advantages for people nearby when the simulation is used daily. Applying simulation techniques in healthcare can enhance performance and guarantee the system at an optimum level because strong performance draws in more customers. A study has proposed a simulation technique to model a suitable queuing system in a clinic. Arena software was used to model and simulate the patient's current queue system based on the analyzed data using Microsoft Excel. The results showed that the clinic had met the Ministry of Health's patient charter's goal of having patients wait no longer than 60 minutes to see a doctor (Aziati & Hamdan, 2018). Ngor, et al., (2023) simulated the outpatient department of a public clinic for express and regular patients. The waiting time and total time patients need improvement to enhance the quality of healthcare. Yemane et al. (2021) simulated several scenarios in order to increase the service efficiency rate and relate it to the number of work-in-process (WIP) at a clinic. They found out that the combination of two scenarios is the best option.

3.0 Methodology

This study employed a simulation modeling approach using Simulation Arena Software. Nine stages were used in this study.

In the first stage, problems at the current clinic operations were identified, and three objectives were addressed for this study. In the second stage, the flow of patients into the clinic was constructed. Patients who arrive at the clinic will be processed systematically. The process starts when a patient arrives at the clinic and proceeds to the registration counter to start the process. After registering, the patient is given a number that indicates the type of treatment they will receive, either medical or dental. Currently, only one medical treatment room and two dental treatment rooms are available at the clinic. The patient waits in the waiting area until it is their turn to see the doctor. After the treatment, the patient will go to the pharmacy to take their medication and make payment at the counter before leaving the clinic. Figure 1 shows the flow of patients in the clinic.

The next stage is data collection. The data was collected during a one-day observation on November 24, 2022. Data collection templates are made for data collectors to record processing times for each process. The model requires data on the time the patient arrives at the clinic and the times the patient begins and ends each process, namely registration, medical treatment, dental consultation, pharmacy, and payment. In addition, the supporting staffs and doctors involved in each process will be recorded. Data were collected only for two sessions of nine hours each (9 a.m.–1 p.m. and 2 p.m.–5 p.m.). The limitation of the study was dental treatment; only dental treatment time was recorded and acquired. The types of treatment each patient might receive, such as root canal therapy and fillings, are not considered in this study. The Arena simulation software's input analyzer was then used to fit the collected data distribution used in simulation model development.

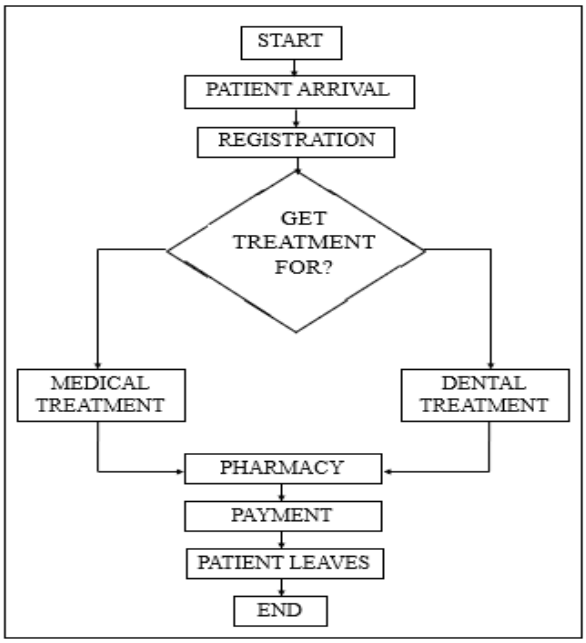


Fig 1: Illustration of the Clinic Flowchart.

Based on the observation, a clinic simulation model was created using Arena simulation software version 16.2. Figure 2 shows a snapshot of the existing simulation model in Arena. Four basic modules, create, process, decide, and dispose, and two advanced modules, route and station, with the analysis from the input analyzer, were included in the model. Several limitations and assumptions were made when creating the simulation model for this study.

1) The simulation model excludes patients who come to buy medication only.
2) The simulation model does not include patients who schedule or receive an appointment.
3) The simulation model excludes patients receiving medical and dental care in one day.

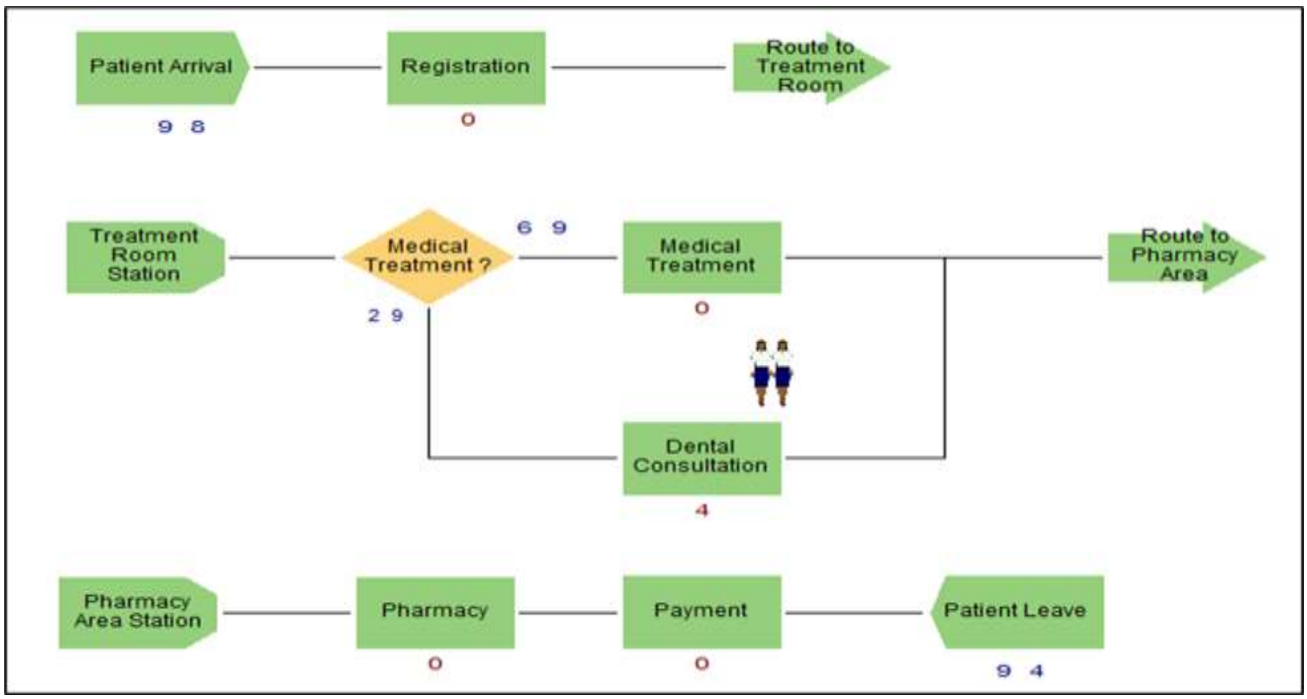


Fig 2: Snapshot of the existing simulation model in Arena simulation software

In stage five, the model was run for five replications to ensure accurate results. The schedule for clinic operations is 480 minutes or 8 hours. Several outputs are monitored to assess the efficiency of clinic processing processes. This output will be utilized to improve the model. The results are as follows:

1) Average processing time for each process
2) Average wait time for each process
3) Average processing total time for each process
4) Resource utilization rates
5) Average and maximum number of patients in the queue
6) Number of patients that enter and exit the system

Then, in stage six, this study performed verification and validation analysis to ensure the correctness of the development of the existing simulation model and to ensure the model is accurate enough to represent the existing clinical system (Chen et al., 2022). For the verification, process testing ensured that the model was free of functional and logical errors while it was running (Maslazim et al., 2022). For the validation process of the model, the simulation model's findings are compared with the clinic system's actual predictions. The difference between the output of the simulation and the actual data, which could not be more than 10%, is calculated using the following equation (Rani et al., 2021).

$$Difference = \frac{Simulation\ output - Actual\ data}{Actual\ data} \times 100 \quad (1)$$

In stage seven, several alternative models were generated to improve and solve the problems, enhance the clinic's performance, and provide better patient service. The next stage is running the suggested alternative models, and the results obtained from each model will be recorded and compared with the existing simulation model results to evaluate the performance of the clinic system. The last stage will be recommended with the best improvement model to improve the clinic's performance system.

4.0 Findings

4.1 Verification and validation of the model

For the verification of the existing simulation model, Figure 3 indicates that the clinic simulation model has been operating successfully and without logical mistakes. The comparison between actual data and that of the existing simulation model is shown in Table 1. With the assurance that results are less than 10%, the model is accepted and valid, and the development of alternative models can progress.

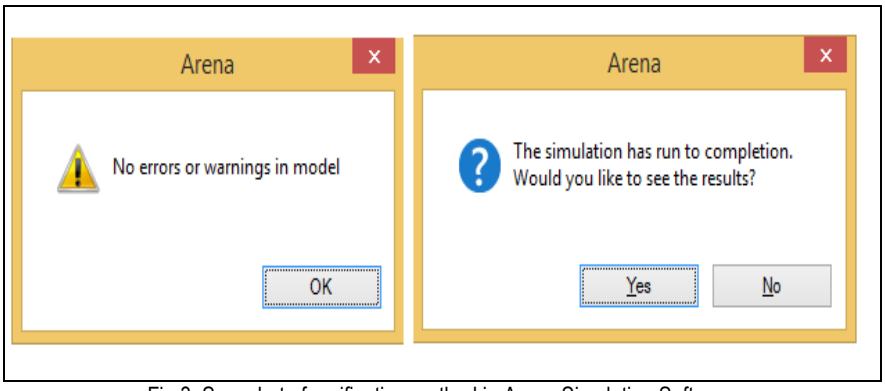


Fig 3: Snapshot of verification method in Arena Simulation Software

Table 1. The difference between simulation data and actual data

Process	Simulation output (minutes)	Actual data (minutes)	Difference (%)
Registration	2.7104	2.53	7.13
Medical treatment	8.6419	9.42	-8.26
Dental consultation	12.141	12.8	-5.14
Pharmacy	1.2836	1.41	-.8.96
Payment	0.20171	0.23	-9.55

4.2 Current simulation model results

Table 2 presents the simulation results for staff utilization rates. It shows that the utilization rate for all supporting staff is very low (less than 50%). The doctors are also not fully utilized, even though their utilization rates are higher (their utilization rate is lower than 80%). This situation will lead to high intangible costs for the clinic. These results of staff utilization might be one of the system's weaknesses.

Table 2. Staff utilization at various processes of the clinic

Process	Average Staff Utilization (%)
Registration Staff 1	22.56
Registration Staff 2	23.74
Medical Doctor	69.35
Dental Doctor 1	69.77
Dental Doctor 2	62.02
Pharmacy Staff	47.84
Payment Staff	40.71
Overall Average (%)	**48.00**

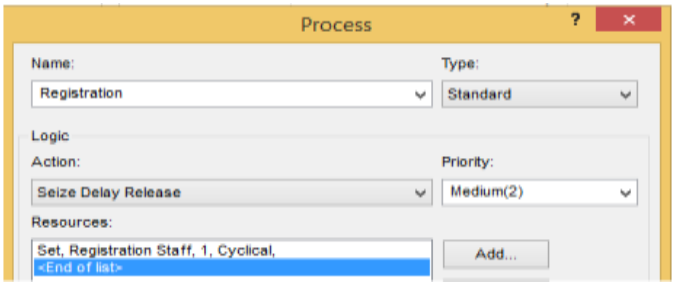
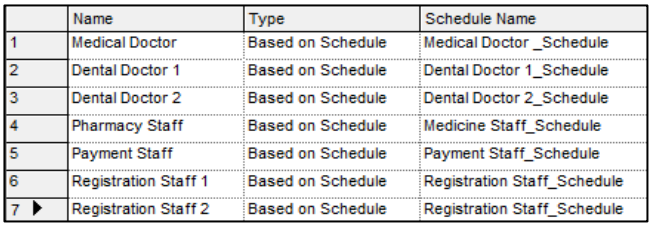
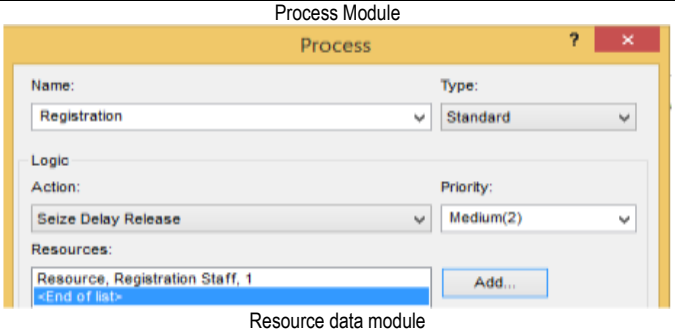
Table 3 displays the average waiting times and processing times for each process. Based on the average waiting time per patient, the bottleneck in the system is detected in the dental consultation process. The patients must wait, on average, 12.14 minutes to consult the dentist, even though the clinic has two dentists. This long waiting time might be due to the long consultation time. The average time to complete one consultation per patient is 42.341 minutes. Since each dental treatment takes at least 20 minutes, it is common that the time required for each patient to receive dental treatment is longer when compared to other processes. The lowest waiting time is at the payment process (0.20 minutes).

Table 3. Simulation results about the processing time for all processes

Process	Average waiting time per patient (minutes)	Average processing time per patient (minutes)
Registration	2.7104	5.126
Medical treatment	8.6419	13.491
Dental consultation	12.141	42.341
Pharmacy	1.2836	3.918
Payment	0.20171	2.469

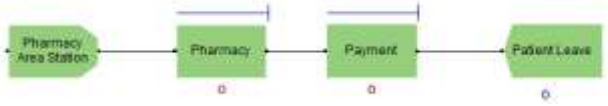
5.0 Discussion

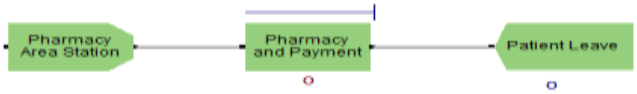
Table 4. Changing Resource Capacity for Improvement Model 1

Activity	Capping the resource capacity
Actual Model	Process Module  Resource data module 
Improvement Model	Process Module  Resource data module

	Name	Type	Schedule Name
1	Medical Doctor	Based on Schedule	Medical Doctor _Schedule
2	Dental Doctor 1	Based on Schedule	Dental Doctor 1_Schedule
3	Dental Doctor 2	Based on Schedule	Dental Doctor 2_Schedule
4	Payment Staff	Based on Schedule	Payment Staff_Schedule
5	Registration Staff 1	Based on Schedule	Registration Staff_Schedule
6	Pharmacy Staff	Based on Schedule	Pharmacy Staff_Schedule

Table 5. Changing in Process Module and Spreadsheet for Improvement Model 2

<table>
<tr><th>Activity</th><th>Capping module and processing time</th></tr>
<tr><td>Actual Model</td><td>Process Module
 

Spreadsheet process module
<table>
<tr><th></th><th>Name</th><th>Action</th><th>Expression</th></tr>
<tr><td>1</td><td>Registration</td><td>Seize Delay Release</td><td>TRIA(1.5 , 1.95 , 4.5)</td></tr>
<tr><td>2</td><td>Dental Consultation</td><td>Seize Delay Release</td><td>Dental Treatment</td></tr>
<tr><td>3</td><td>Pharmacy</td><td>Seize Delay Release</td><td>1.5+WEIB(1.57 , 1.87)</td></tr>
<tr><td>4</td><td>Payment</td><td>Seize Delay Release</td><td>0.5+2*BETA(1.41 , 1.56)</td></tr>
<tr><td>5</td><td>Medical Treatment</td><td>Seize Delay Release</td><td>5.5+4*BETA(1.48 , 1.5)</td></tr>
</table></td></tr>
<tr><td>Improvement Model</td><td>Process Module:
 

Spreadsheet process module
<table>
<tr><th></th><th>Name</th><th>Action</th><th>Expression</th></tr>
<tr><td>1</td><td>Registration</td><td>Seize Delay Release</td><td>TRIA(1.5 , 1.95 , 4.5)</td></tr>
<tr><td>2</td><td>Dental Consultation</td><td>Seize Delay Release</td><td>Dental Treatment</td></tr>
<tr><td>3</td><td>Pharmacy and</td><td>Seize Delay Release</td><td>3.5+5*BETA(0.692 , 0.834</td></tr>
<tr><td>4</td><td>Medical Treatment</td><td>Seize Delay Release</td><td>5.5+4*BETA(1.48 , 1.5)</td></tr>
</table></td></tr>
</table>

Based on the observed result, the clinic is given three suggested improvement models to increase resource utilization rates by reallocating staff to the relevant sections or procedures. This model's outcomes are compared to the original simulated model. The three suggested improvement models are as follows:

1) Improvement Model 1 (IM1): Reducing one staff in the registration process.

Since the average utilization for the registration process is low for Staff 1 and Staff 2, the resource usage will be reduced to only one staff for the registration process, which is Registration Staff 2. Therefore, the resource utilization rate is expected to increase. Table 4 shows the changing capacity for the improvement model in the resource data and process modules.

2) Improvement Model 2 (IM2): Merge the pharmacy and payment processes.

The payment process will be assigned to pharmacy staff by merging those two processes. The pharmacy and payment processes will be combined to get a new distribution. Table 5 shows the changing process module and distribution for Improvement Model 2.

3) Improvement Model 3 (IM3): Combining Improvement Models 1 and 2

Combining those two models will assign only one staff member to the registration process and another to the pharmacy and payment processes.

6.0 Conclusion & Recommendations

The simulation model given in this study is utilized to help the medical and dental clinic's management better comprehend their existing operations. This model is designed to evaluate potential improvements to the current system that can be made using existing resources. The simulation model findings demonstrate that supporting staff utilization rates are less than 50%, and the utilization rates of dentists are between 60% and 70%. These findings are in parallel with those done by Atalan and Keskin (2023). System bottlenecks might occur in the dental consultation process.

Among the three improvement models proposed, Model IM3, which combines the other two models, IM1 and IM2, is the best alternative solution due to its higher utilization rate in the registration and pharmacy/payment processes. The outcomes from each improvement model are displayed in Table 6 alongside the original simulated model. Based on the comparison results, IM3 is

recommended to the management as an alternative model for operation improvement because the overall utilization rates increase from 48% to 55.35% by using three supporting staff instead of the original number of five. IM3 will lead to the lowest average waiting time (33.80 minutes) among those three improvement models. To accommodate the higher average waiting time, especially in the pharmacy and payment processes, extra staff will be assigned to help reduce the occurrence of bottlenecks in any of the two adjusted processes. In conclusion, the alternative with a combination of several strategies will always be the best option. These findings parallel those made by Yemane et al. (2021). However, this study discusses utilization rates with waiting times to balance workers' cost efficiency and customer satisfaction.

Table 6. The comparisons of the improvement model

	Identification	Existing Model	Improvement 1	Improvement 2	Improvement 3
Average processing time (minutes)	Registration	5.1261	13.165	8.519	7.986
	Medical Treatment	13.491	12.448	15.124	6.7324
	Dental Consultation	42.341	55.567	42.484	28.863
	Pharmacy	3.9177	4.3469	-	-
	Payment	2.4686	3.4107	-	-
	Pharmacy and Payment	-	-	21.479	20.889
	Total average processing time	67.344	88.9376	87.606	64.470
Average waiting time (minutes)	Registration	2.7104	10.668	6.035	5.504
	Medical Treatment	8.6419	7.6057	10.334	1.9703
	Dental Consultation	12.141	25.407	11.684	10.463
	Pharmacy	1.2836	1.7317	-	-
	Payment	0.20171	0.84249	-	-
	Pharmacy and Payment	-	-	16.593	15.86
	Total average waiting time	24.979	46.255	44.646	33.800
Utilization of Rates (%)	Registration Staff 1	22.56	53.35	22.46	41.37
	Registration Staff 2	23.74	-	19.98	-
	Medical Doctor	69.35	72.65	59.87	52.02
	Dental Doctor 1	69.77	80.63	68.63	52.5
	Dental Doctor 2	62.02	83.96	64.09	51.00
	Pharmacy Staff	47.84	52.85	74.34	79.89
	Payment Staff	40.71	51.2	-	-
	Overall Utilization Rates (%)	48.00	65.77	51.56	55.35

Based on the limitations of this study, more detailed data should be inserted for future studies to get more accurate results. The suggested data would be the type of treatment the patients received during dental consultation, the possibility that patients come to the clinic only to purchase medicines, and the type of payment (cash or credit card). It is also encouraged to gather weekly data to observe the clinic's flow process instead of just referring to data from one particular day. The busiest times for doctors and staff should also be identified to get more justified results of utilization rates.

Paper Contribution to Related Field of Study

This paper contributes to the field of management and business planning.

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