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# DISCRETE EVENT SIMULATION MODELING WITH ARENA FOR COMBINATION OF MANUAL QUEUE AND FAST TRACK QUEUE IN HOSPITAL

**Febrian Krisnawati[1], Dhoni M. R. Anugroho[2], Laura Yunita R[3], Muhammad Asrol[4]***

[*1,2,3]Industrial Engineering Department, BINUS Graduate Program – Master of Industrial Engineering, Bina Nusantara University
Bina Nusantara University 11480, Jakarta, Indonesia
Email: febrian.krisnawati@binus.ac.id, dhoni.muhamad@binus.ac.id, laura.rachmawati@binus.ac.id, muhammad.asrol@binus.edu*

## Abstract

In this study an analysis of the patient queuing system will be carried out by developing a queuing system, namely adding aspects of patient registration status and the registration process with a system or machine or through the hospital's web by downloading an application. This study aims to improve the efficiency of patient service management in clinics and develop a patient care management simulation model so that the number of patient rejections and patient waiting time in clinics. Discrete Event Simulation (DES) with ARENA and compare it with manual processes and with applications or machines in the registration process. The results show that patient rejection can be reduced to 1%, and the average patient time to be seen by a doctor is 0.7145 hours. If converted into minutes, each type of patient takes about 10 minutes in the doctor's office.

**Keywords***: Simulation; Queuing system; Hospital management; Discrete Event Simulation*

## INTRODUCTION

The hospital is a health service institution for the community with its own characteristics. Hospitals provide a place for healthcare Professional services, namely providing services provided by nurses, doctors, and staff other health professionals. The implementation of quality services often experiences a mismatch between expectations and perceptions such as the lack of outpatient service quotas that researchers have observed during observations and the flow of outpatient services that need to be improved and there are frequent complaints of patients experiencing long queues (A Santosa, M Sagathi, 2019).

To optimize the service operations of the queuing system at the hospital, a simulation system provides a systematic solution. In this research, the registration queuing system for doctor service is modelled. The researchers want to raise the problem of the queues that occur at the hospital from the time of registration to the doctor. In previous studies, scholars have largely described how hospital management provides improvements to reduce the percentage of patient refusal services and manage the workload or doctor's schedule and patient service flow in order to improve the quality of hospital services. It was concluded that there was sufficient waiting time to disrupt the quality of patient care and the high rate of patient refusal (Guseva et al., 2018). Hospitals are complex systems and modelling them requires simplification of their complexity. Three methods to reduce the complexity are discussed. First, framing hospital operations, to take the modeller’s attention to an area where modelling objectives can be achieved; second, to divide the hospital operations into smaller and manageable parts for modelling, and third to aggregate some of the processes in hospitals. The complexity, or the level of detail, is linked with data requirements and the

level of generality. The level of generality is a significant factor in determining a simulation model's reusability (Gunal, 2012).

The Emergency Department (ED) is a department within a hospital that is equipped to provide medical care to patients with acute and life-threatening medical conditions. Emergency Departments are typically open 24 hours a day, seven days a week, and are staffed by doctors, nurses, and other healthcare professionals who are trained to handle a wide range of medical emergencies (Parkinson et al., 2020). In the event of a serious medical emergency, patients are usually taken to the emergency department by ambulance or other emergency transportation services. Once there, patients are assessed and treated as quickly as possible to stabilize their condition and prevent further harm. To develop models of two EDs that could diagnose bottlenecks and evaluate performance improvement approaches using a generalized approach. The researchers used Discrete Event Simulation (DES) to model two EDs in Toronto, Canada, based on existing processes and empirical data. Model outputs include wait times, treatment times, and selected process durations. Management of both EDs used the models to evaluate performance and preview the effects of staffing and flow changes before committing to the improvement measures. Examples of successful performance improvement opportunities include a new triage flow for patients arriving by ambulance, merging of the treatment zones, and increases in staffing levels (S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, 2021)

There is an increasing need for services in the health sector, therefore hospital services must review the management system used to improve and maintain patient satisfaction. In this study, an analysis of the patient queuing system will be carried out by developing a queuing system by adding several factors including adding aspects of patient registration status and the registration process with the system or machine or via the hospital web by downloading an application. The benefits of this application are by using the outpatient registration application web- and wap-based paths assist patients in doing patient registration and access information about patient registration, by using the patient registration application web-based outpatient helps in managing registration data patient for registration staff (Kresnawati, 2011)

A queue is a waiting line of units that require service from one or more service facilities. This waiting line is a problem that usually occurs when the need for a service facility exceeds the available capacity (Siagian, 1987). The activity of waiting in the queue cannot be completely eliminated life, but various efforts have been made to reduce the effects of waiting to within a reasonable or tolerable limit (Robinson, 2005).

The use of the simulation method with discrete event simulation followed Harrell's procedure. The model is expected to be implemented after the results are obtained. The results obtained are a process for mapping needs and accommodating environmental demands to increase customer satisfaction (Varga, 2001). Discrete event simulation supports hospital management efforts in increasing patient satisfaction. Discrete event simulation can also be used as a forecasting tool to assess or predict the impact of changes on patient enrollment flows and investigate what factors have a relationship to improving the quality of hospital management such as how long it takes patients in the clinic to get treatment.

Data on the number of patients who arrive, their wait times, and the length of their services are required for this study. Depicted in table 1, the data before development (manual Registration).

Table 1. Time Spent In The Clinic By Manual Registration

| Patient Type | Waiting Time For Registration | Registration Time | Waiting Time for Doctor | VA Time | Total Time |
|---|---|---|---|---|---|
| Patient1 | 15 | 15 | 15 | 10 | 55 |
| Patient2 | 15 | 15 | 15 | 8 | 53 |
| Patient3 | 15 | 15 | 15 | 10 | 55 |
| Patient4 | 15 | 15 | 15 | 12 | 57 |

The purpose of this research is to improve the efficiency of patient care management in hospitals and to develop a patient care management simulation model. The simulation model can reduce the number of patient rejections and patient waiting time in the hospital. Therefore this study was conducted to see the possibility of reducing registration queues and waiting time for doctor visits at the hospital as a development from previous research. In previous studies, researchers found causal factors that could affect hospital quality management, but researchers have not proven these factors to be true or cannot affect hospital quality management in previous studies researchers did not provide solutions or improvements that could be made to improve hospital quality management. The author in his research is currently trying to create a simulation by developing a registration system with applications and machines to improve the quality of hospital services.

## LITERATURE REVIEW

Healthcare system is a pure service system that is characterised by a high human involvement both at resource level (doctor, nurses, etc.) and entity level (patients). Such system can be challenging to design, control or improve when facing the variability resulting from this human involvement. Furthermore, patient diagnosis result depends on several subjective factors and often leads to variability on the amount of resource and on the process route dispatched to patients. This variability leads to longer waiting times and low throughput (Branch, 2015).

Simulation modelling in healthcare is an effective approach to understanding the interdependency between human-oriented and infrastructure-oriented variables in complex systems of systems (SoS), and to explore scenarios of decision-making from different stakeholders or practitioners. However, the knowledge that underlies the best practices in designing and developing simulation models in healthcare, either Discrete Event Simulation (DES) or Agent-Based Modelling (ABM), is unfortunately scattered throughout the computing and operational research literature. Though there were early attempts to formalize the process by developing framework as introduced (Almagooshi, 2015).

Discrete event simulation is a technique used to model the behavior of a system over time (Seay & You, 2016). In a discrete event simulation, the system is represented as a series of events that occur in a specific order, with each event having the potential to affect the state of the system. This technique is commonly used in fields such as engineering, business, and computer science to evaluate the performance of a system, test new designs, and make predictions about the system's behavior. Discrete event simulation is useful because it allows researchers to analyze complex systems in a controlled, virtual environment, and make predictions about how the system will behave in the real world.

Agent-based modeling is a technique used to simulate the behavior of complex systems. In an agent-based model, the system is represented as a population of agents, each of which has its own characteristics, behaviors, and interactions with other agents and the environment. This technique is commonly used in fields such as economics, sociology, and

biology to study the behavior of individuals or groups and the emergent properties of the system as a whole. Agent-based modeling is useful because it allows researchers to study the behavior of complex systems in a controlled, virtual environment, and make predictions about how the system will behave in the real world (Karima & Sopha, 2020).

Discrete event simulation and agent-based modeling are similar in that both are techniques used to simulate the behavior of complex systems. The main difference between the two is the level of abstraction at which they operate. Discrete event simulation focuses on the sequence of events that take place in a system, while agent-based modeling focuses on the behavior and interactions of individual agents within the system (Arini et al., 2021).

According to (Hillier, F. S., & Lieberman, 2013) queuing training is a phenomenon that occurs when demand becomes greater than the ability to deliver a service over a given period. For example, if the number of servers is less than necessary at a restaurant during lunch time, the customer may end up waiting longer than he or she is willing, resulting in dissatisfaction or even discontinuance of service usage.

However, it is equally crucial to analyze the alternative scenario. The cost of maintaining them rises if more servers are allocated than are required. The conditions of the institution, including office hours, the amount of customers requesting the service, and peak hours, must be considered for these analyses.

Simulation model is an ideal tool to cope with the diversified and dynamic nature of a hospital's registration department. The model developed for this work allowed the evaluation of various schedules for the nurses, technicians, and doctors with respect to such performance measures as average length of stay of the patients. There are many extensions to this work which are currently being investigated. Examples of these extensions would include the development of an "optimization module" which would interface with the simulation model to optimize over a large number of potential schedules. Such an optimization module would consider several objectives simultaneously, such as length-of-stay, personnel costs, and desirability of various schedules as considered by the nurses, technicians, and doctors (Evans et al., 1996).

The basic formula for a queuing system is the formula for the number of customers in the system, which is often represented as L or N (Vinogradova-zinkevič, 2021). This formula is:

$$L = \lambda W \tag{1}$$

Where $\lambda$ is the arrival rate of customers,
W is the average time that a customer spends in the system
L is the average number of customers in the system.

The logic of a queuing system is that as the arrival rate of customers increases, the average number of customers in the system also increases. This can lead to congestion and delays, as there are not enough resources (such as servers or machines) to handle the influx of customers. To prevent this, organizations may need to add more resources or implement other strategies to manage the flow of customers and improve the efficiency of the system.

## RESEARCH METHODOLOGY

### 1. Research Framework and Flow

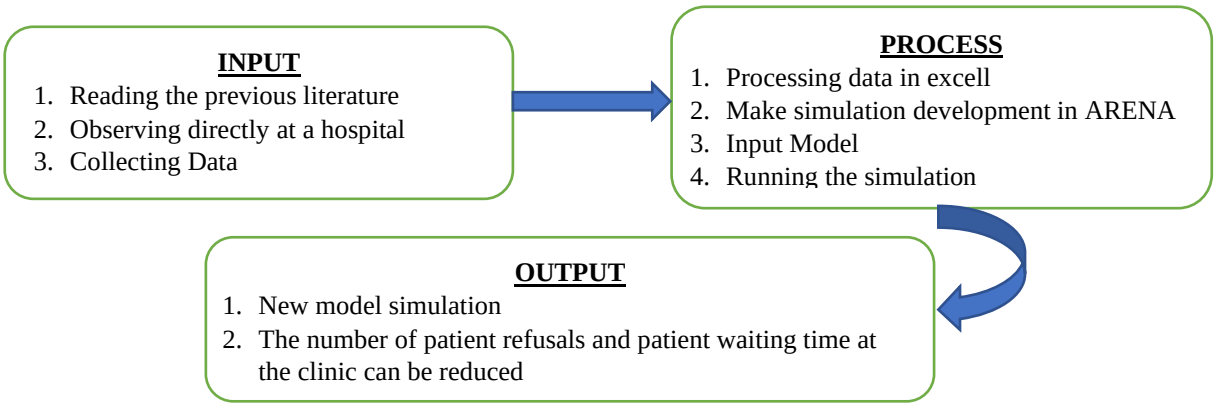


Figure 1. Research Framework and Flow

The researcher conducted a literature review on several papers to find out what could be developed for this research. Then make direct observations of the location of the place that is the object of research to get the data needed. Then the data is processed in excel to get a more realistic description. Start making simulations with ARENA software according to block diagrams that become a real description of patient flow in the hospital. After the model has no errors, it can be run and the results will be visible. The research framework and procedure is depicted at Figure 1.

### 2. Data Analysis

The data used by the author is quantitative data obtained from the results of observational data collection procedures. By observing and trying their own patient registration activities until they meet the intended doctor. Asking the health workers who are on duty about some things that are needed in Table 2 can be seen in the data obtained for the next simulation.

The data is then validated and verified to see if the results of the simulation model are close to the reality of the system in the field (valid).

Table 2. Registration Data for XYZ Hospital

| No | Data Based On Site | Value | Unit |
|---|---|---|---|
| 1 | Incoming Patient 1 | 150 | Persons per day |
| 2 | Incoming Patient 2 | 150 | Persons per day |
| 3 | Incoming Patient 3 | 150 | Persons per day |
| 4 | Membership Status | 75% | Persons per day |
| 5 | Reception Desk | 15 | Minutes |
| 6 | Waiting | 15 | Minutes |
| 7 | Web Registration Machine | 1 | Minute |
| 8 | Refusal Patient | 1% | |
| 9 | Serviced Patient | 99% | |
| 10 | General Practitioner (Patient 1) | 45% | 10 Minutes |
| 11 | Waiting Time for General Practitioner | | 15 Minutes |
| 12 | Specialist 1 (Patient 3) | 20% | 8 Minutes |
| 13 | Waiting Time for Specialist 1 | | 15 Minutes |
| 14 | Specialist 2 (Patient 4) | 10% | 10 Minutes |
| 15 | Waiting Time for Specialist 2 | | 15 Minutes |
| 16 | Surgery (Patient 2) | 25% | 12 Minutes |
| 17 | Waiting for Surgery Doctor | | 15 Minutes |

For data on the number of patients who came, we obtained data on the average arrival of patients at three different times assuming the same magnitude. Then it can be seen in Table 2 that manual registration takes about a total of 30 minutes due to waiting time for registration calls and then registering. Meanwhile, those who use the application only take about 1 minute, before they can register with the doctor in question. Then, the average length of time they visit each doctor is listed.

Table 3. Time Spent In The Clinic By Machine or Application Registration

| Patient Type | Waiting Time For Registration | Registration Time | Waiting Time for Doctor | VA Time | Total Time |
|---|---|---|---|---|---|
| Patient1 | 0 | 1 | 15 | 10 | 26 |
| Patient2 | 0 | 1 | 15 | 8 | 24 |
| Patient3 | 0 | 1 | 15 | 10 | 26 |
| Patient4 | 0 | 1 | 15 | 12 | 28 |

## 3. Simulation Modelling

The simulation method requires real data to complete this study. Therefore, this study uses observation, interviews, and time study to gather all the information. The information obtained is original data specific to the study. The data taken is related to time and volume (Mohamad & Filza Saharin, 2019).

In this paper, the addition of aspects of patient registration status and the registration process with the system or machine or through the hospital web by downloading the application, where these two additional aspects can help hospital management shorten the waiting time for patients to get health services with the help of facilities that make it easier for patients. registering services and consulting complaints also reduces the number of patient refusals.

Then the flow of registration at the Hospital to meet the intended doctor is as follows, patients come divided into 3 times in the morning, afternoon and evening, then there are those who register by web, which can be done from home or onsite at the hospital, this can directly book a doctor who will be directed to the following time slot, then only by scanning the barcode from the registration via the application, the patient can immediately wait at the destination doctor's poly in a short time because the patient arrives based on the time slot that has been booked. This reduces the potential for patients to be rejected (refusal patients) because, for example, doctor's practice hours end, or patients cancel visits due to long queues. The other option is manual registration at the hospital, which requires waiting in a queue at the registration desk, then getting a doctor's slip and having to wait again. Even patients may wait a long time because they haven't got a time slot to go to the doctor. This condition allows the high rate of patient refusal.

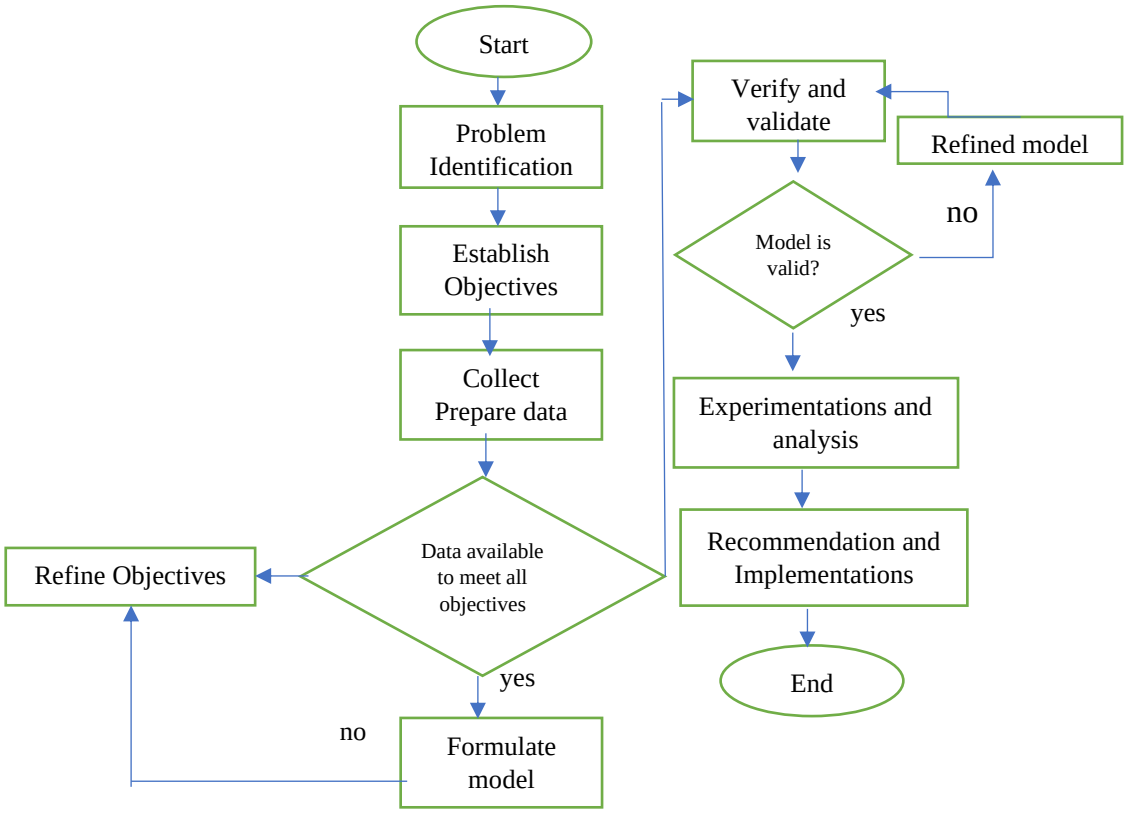


Figure 2. Simulation Modelling Process (Centeno & Carrillo, 2001)

Before creating a queuing simulation model, a block diagram as the basis for modeling is described in Figure 3.

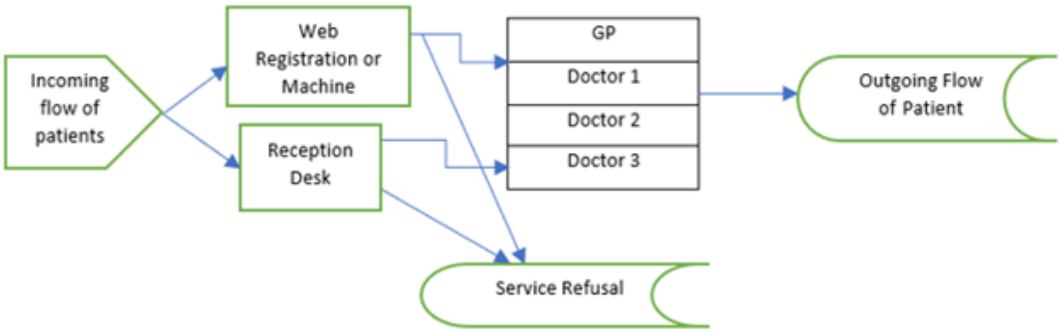


Figure 3. Block Diagram Modeling

A Discrete Event Simulation (DES) with ARENA software describes the running of the queue that occurs and a comparison of the manual process with the application or machine in the registration process. The simulation model is depicted at Figure 4.

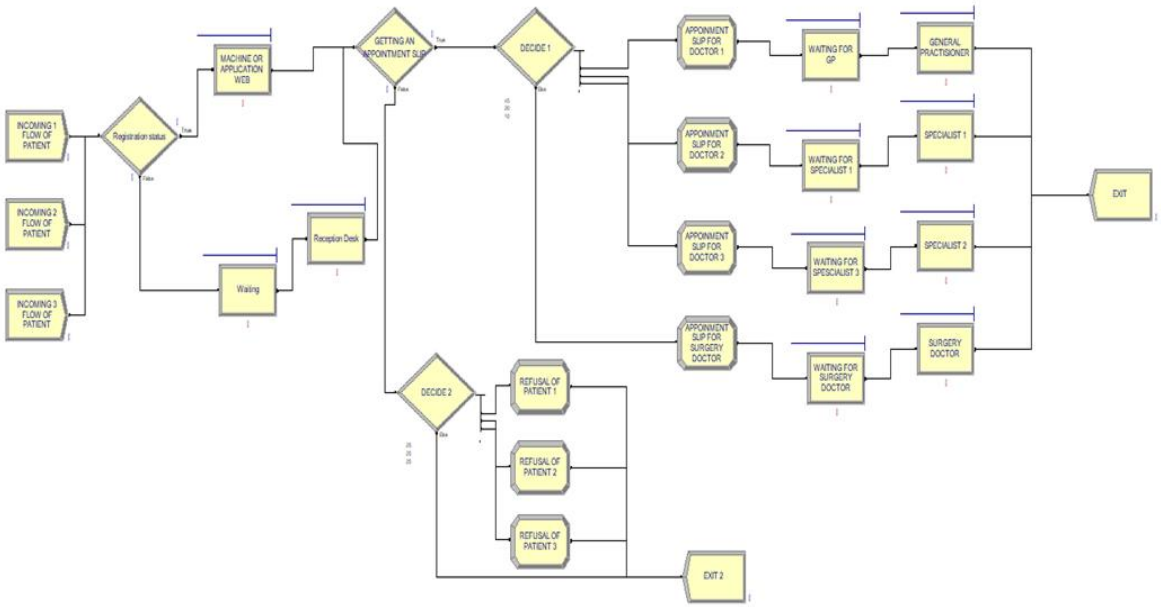


Figure 4. DES Model Design with ARENA Software

## RESULT and DISCUSSION

The definition of the problem in this study is that patients who come to the clinic have problems/complaints which are divided into 4 categories. For the time of arrival, patients are divided into 3 categories, namely P1, P2, and P3 (S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, 2021). The time period ($T_3$) between two patients is exponentially distributed. Each patient requires specific medical treatment ($a_1$, $a_2$, $a_3$, $a_4$) with probability $pa_1$, $pa_2$, $pa_3$, $pa_4$. The first step of patient arrival at the clinic is divided into two processes, namely manual and machine processes. The manual process is a process where the patient comes and the patient goes directly to the receptionist which later in this process the patient must register by filling out documents, printing an appointment card, and getting the first identification of what problems/diseases they are experiencing. As for the machining process, namely, patients only need to register and complain directly via the web/machine which will later be a system that will assist in registration, problem identification, and ordering clinic services. The clinic's resources consist of one general practitioner, two specialist doctors, and one doctor who specializes in surgery.

Table 4 and 5 are the result of the validation and verification of the ARENA simulation data, the following results are obtained.

Table 4. Validation Test

| Validation | $r_{Count}$ | $r_{table}$ | Validation Status |
|---|---|---|---|
| Reception Desk | 0.89461 | 0.1898 | Valid |
| General Practitioners (Patient 1) | 0.887464 | 0.1898 | Valid |
| Specialist 2 (Patient 3) | 0.633748 | 0.1898 | Valid |
| Specialist 3 (Patient 4) | 0.525598 | 0.1898 | Valid |
| Surgery (Patient 2) | 0.339704 | 0.1898 | Valid |
| **Conclusion** | **The simulation model is close to the real system** | | |

Table 5. Verification Data

| **Verification** | |
|---|---|
| Outcoming Patient | Create |
| Registration Status | Decide 1 |
| Machine or Web Application | Process 1 |
| Waiting | Process 2 |
| Reception Desk | Process 3 |
| Getting an appoinment | Decide 2 |
| Appoinment Slip for GP (Patient 1) | Assignment 1 |
| Appoinment Slip for Specialist 2 (Patient 3) | Assignment 2 |
| Appoinment Slip for Specialist 3 (Patient 4) | Assignment 3 |
| Appoinment Slip for Surgery (Patient 2) | Assignment 4 |
| Waiting for General Practitioners (Patient 1) | Process 4 |
| Waiting for Specialist 2 (Patient 3) | Process 5 |
| Waiting for Specialist 3 (Patient 4) | Process 6 |
| Waiting for Surgery (Patient 2) | Process 7 |
| General Practitioners (Patient 1) | Process 8 |
| Specialist 2 (Patient 3) | Process 9 |
| Specialist 3 (Patient 4) | Process 10 |
| Surgery (Patient 2) | Process 11 |
| Outcoming Patient | Dispose 1 |
| Refusal Patient 1 | Assignment 5 |
| Refusal Patient 2 | Assignment 6 |
| Refusal Patient 3 | Assignment 7 |
| Outcoming Refusal Patient | Dispose 2 |
| **Conclusion simulasion can run** | |

After doing DES modeling with ARENA software, we will get the simulation results as depicted in Figures 5 and 6.

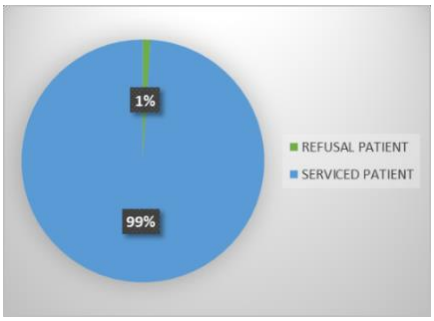


Figure 5. Accepted and Unaccepted Patient

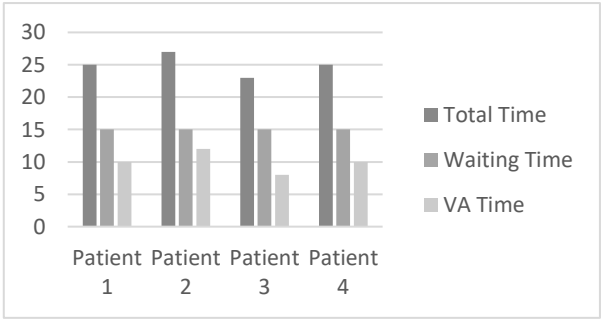


Figure 6. Time Spent in The Clinic

The results are shown in the simulation model development where patient refusal can be reduced to 1%, and the graph next to it depicts the time spent by patients in the clinic or hospital for each patient according to the doctor's visit destination category. We also try to display the results from ARENA, as found at Table 6:

Table 6. Arena Report

| Time | Average | Half Width | Minimum | Maximum |
|---|---|---|---|---|
| VA Time | 0.7145 | 0.0525677 | 0.0166667 | 1.7083 |
| NVA Time | 0 | 0 | 0 | 0 |
| Wait Time | 0.000111 | (Correlated) | 0 | 0 |
| Transfer Time | 0 | 0 | 0 | 0 |
| Other Time | 0 | 0 | 0 | 0 |
| Total Time | 0.7146 | 0.052537121 | 0.0166666 | 1.7083 |

From Table 6 the average visit time, waiting time, and total time spent for treatment at the hospital can be seen. In this case to the intended doctor's poly. Where the average patient time to be examined by a doctor is 0.7145 hours. If we convert it into minutes, it is about 40 minutes for 4 types of patients (according to the intended doctor). This means that for each type of patient about 10 minutes in the doctor's room.

The average waiting time spent waiting for the queue to enter the room is 0.00011111 in hours equal to 0.00666 minutes. This waiting time is very small, meaning there is no accumulation of patients because patient registration is mostly done by the application. So that the patient comes according to the time slot that has been promised. This can reduce the impact of patient refusal because the doctor's practice hours end, or there is an accumulation of one doctor.

Then comparing the time spent coming to the clinic or doctor's clinic between patients who register manually and those who register through the application, the results are depicted at Figure 7:

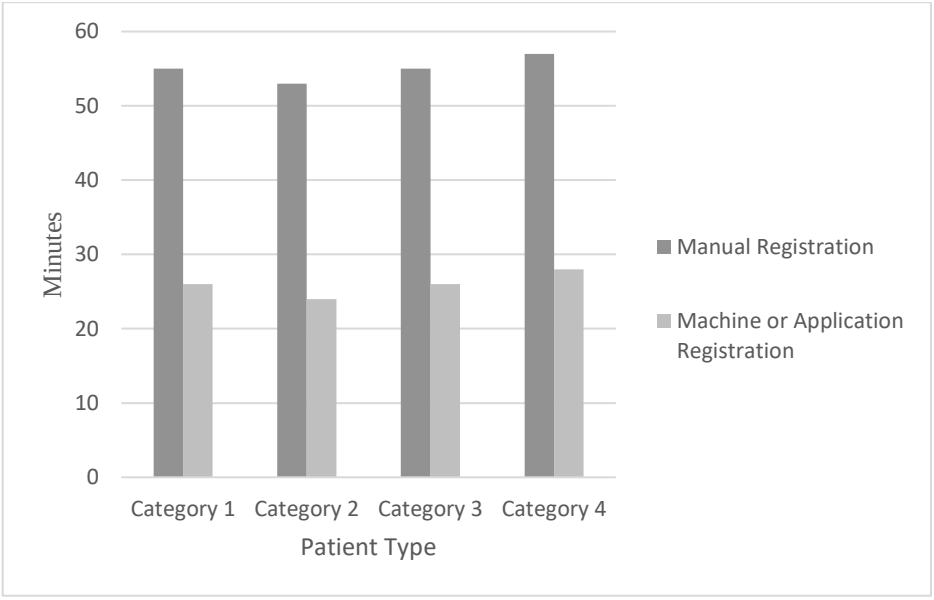


Figure 7. Comparison Graph of Total Time spent at the Clinic by Type of Registration

Then we can also see the results of the use of a resource from this simulation. In the simulation that has been made, there are several resources that are described in the process with a description of the seized delay release. These resources are shown at Table 7:

Table 7. Resource

| | |
|---|---|
| Resource 1 | Machine or Application Web |
| Resource 3 | Reception Desk |
| Resource 8 | General Practitioner |
| Resource 9 | Specialist 1 |
| Resource 10 | Specialist 2 |
| Resource 11 | Surgery Doctor |

Table 8. Number Busy of Resource

| Usage | | | | |
|---|---|---|---|---|
| Number Busy | Average | Half Width | Min | Max |
| Resource 1 | 0.00000966 | correlated | 0 | 1 |
| Resource 10 | 0.00000395 | insufficient | 0 | 1 |
| Resource 11 | 0.00000838 | insufficient | 0 | 1 |
| Resource 3 | 0.00004916 | insufficient | 0 | 1 |
| Resource 8 | 0.00005143 | insufficient | 0 | 1 |
| Resource 9 | 0.0000098 | insufficient | 0 | 1 |

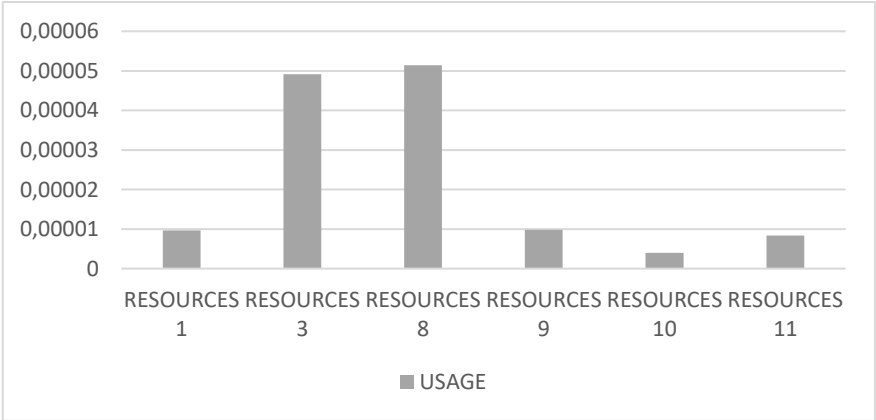


Figure 8. Graph of Usage

The simulation result is described in Table 8 and Figure 8. The simulation result shows that resource no. 8, namely General Practitioners, who looks the busiest serving patients, followed in the second position, is the registration desk which serves patients directly, namely patients who do not register via web applications or machines.
For proposed improvements, several things can be done as shown in the following table 9.

Table 9. Proposed Improvement

| Problem | Improvement |
|---|---|
| Patients are not familiar with web applications | Socialization of the use of the application and placing a service ambassador in the registration section to help patients who cannot use the application. |
| There are still queues when paying and at the pharmacy | This system or application will be better if it is expanded with payment facilities and patient medical records. |
| Maintain continuous quality | The web-based patient registration system is equipped with a user forum, so that users can submit suggestions and criticisms |

## CONCLUSION

The author has simulated the development model from the simulation model that has been in the previous paper. By using a combination registration system manually or by machine. When registering with the machine, the simulation results show a reduction in patient waiting time by up to 50% and can reduce the patient's refusal value by 1%.

This study proves that the addition of registration outlets using machines and the web can improve the quality of hospital management by shortening queue times and reducing the possibility of patient refusal.

The shortcoming of this study is that it did not take into account and map the time of the registration process for new patients whether they were at the same registration counter as old patients or differentiated.

For further research it is recommended to examine in more detail this queuing system by mapping new patients and old patients so that improvements can be made in order to improve the quality of hospital queuing services.

## REFERENCES

A Santosa, M Sagathi, M. R. S. (2019). Simulation of First Level Health Care Facilities to Reduce Patient Flow Time Simulation of First Level Health Care Facilities to Reduce Patient Flow Time. *IOP Conf. Series: Materials Science and Engineering 662 (2019) 042004 IOP Publishing*. https://doi.org/10.1088/1757-899X/662/4/042004

Almagooshi, S. (2015). Simulation Modelling in Healthcare: Challenges and Trends. *Procedia Manufacturing*, *3*(Ahfe), 301–307. https://doi.org/10.1016/j.promfg.2015.07.155

Arini, H. M., Lathifah, N., Maharani, L. D., & Masruroh, N. A. (2021). *Proceedings of the Operational Research Society Simulation Workshop 2021 (SW21) M. Fakhimi, D. Robertson, and T. Boness, eds. 2021*(1995), 200–209.

Branch, N. (2015). *Analysing the performance of emergency department by simulation : the case of Sirjan Hospital Zahra Sepehri S . Mohammad Arabzad * Seyed Mojtaba Sajadi*. *20*(3), 289–301.

Centeno, M., & Carrillo, M. (2001). *Challenges of introducing simulation as a decision making tool* (Vol. 1). https://doi.org/10.1109/WSC.2001.977241

Evans, G. W., Gor, T. B., & Unger, E. (1996). patients . It includes assessingpatient conditions , taking vital signs , applying dressin ~ hanging IV ’ s , patient treatment etc . Whereas indirect time apent by the staff of the ER includes coordinating patient care with other departments , prcessing . *Simulation*, 1205–1209.

Gunal, M. M. (2012). A guide for building hospital simulation models. *Health Systems*, *1*(1), 17–25. https://doi.org/10.1057/hs.2012.8

Guseva, E., Varfolomeyeva, T., Efimova, I., & Movchan, I. (2018). Discrete event simulation modelling of patient service management with Arena. *Journal of Physics: Conference Series*, *1015*(3). https://doi.org/10.1088/1742-6596/1015/3/032095

Hillier, F. S., & Lieberman, G. J. (2013). *Introdução à pesquisa operacional*. MCGRAW HILL BRASIL.

Karima, H. Q., & Sopha, B. M. (2020). *Pengembangan Model dan Simulasi Berbasis Agen untuk Adopsi Layanan Bank Sampah di Kota Semarang*. *5*(3), 111–120.

Kresnawati, D. (2011). *Aplikasi Pendaftaran Pasien Rawat Jalan Berbasis Web dan Wap*. 1–201.

Malik, A. A. (2019). Implementasi kebijakan diskresi pada pelayanan kesehatan badan penyelenggara jaminan kesehatan (bpjs). *Jurnal Ilmiah Kesehatan Sandi Husada*. https://akper-sandikarsa.e-journal.id/JIKSH/article/view/62

Mohamad, F., & Filza Saharin, S. (2019). Application of Discrete Event Simulation (DES) for Queuing System Improvement at Hypermarket. *KnE Social Sciences*, *2019*, 330–346. https://doi.org/10.18502/kss.v3i22.5059

Parkinson, B., Meacock, R., Checkland, K., & Sutton, M. (2020). Clarifying the concept of avoidable emergency department attendance. *Journal of Health Services Research & Policy*, *26*(1), 68–73. https://doi.org/10.1177/1355819620921894

Robinson, S. (2005). Discrete-event simulation: from the pioneers to the present, what next? *Journal of the Operational Research Society*, *56*(6), 619–629. https://doi.org/10.1057/palgrave.jors.2601864

S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, E. (2021). USING DISCRETE EVENT SIMULATION TO IMPROVE PERFORMANCE AT TWO CANADIAN EMERGENCY DEPARTMENTS. *Proceedings of the 2021 Winter Simulation Conference*, 6.

Seay, J. R., & You, F. (2016). *Discrete Event Simulation - an overview ScienceDirect Topics*.

Siagian, P. (1987). *Universitas Indonesia Library >> Buku Teks*. Jakarta: UI-Press, 1987.

Varga, A. (2001). The OMNET++ discrete event simulation system. *Proc. ESM’2001*, *9*.

Vinogradova-zinkeviˇ, I. (2021). *On Little ’ s Formula in Multiphase Queues*. 1–14.