Jurnal Kejuruteraan 38(4) 2026: 1711-1719
https://doi.org/10.17576/jkukm-2026-38(4)-14

Development of Waiting Time Predictor System (WTPS) for Optimization on Patient Experience in Healthcare Centre

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Received 25 April 2025, Received in revised form 16 March 2026
Accepted 16 April 2026, Available online 30 July 2026

ABSTRACT

A Waiting Time Predictor System (WTPS) is designed in web-based system using Queuing Theory method to predict and provide average of waiting time that the patient was going to spend waiting, given the arrival rate, service rate and traffic intensity. This study addresses the uncertainty waiting times in outpatient clinics in Unit Kesihatan UiTM Campus Seremban. The system incorporates a real-time update for a patient to monitor their position in registration and triage, consultation, and pharmacy process. The system is built using Visual Studio Code and phpMyAdmin to enhance user experience and enables them to enter their data easily. A group of twenty-three students were encouraged to use the system and answered the questionnaire. A feedback survey has been conducted using System Usability Scale (SUS) resulting 83.45 that classify into excellent system meanwhile, the User Experience Questionnaire (UEQ) feedback forwarded high attractiveness, efficiency, and reliability but low novelty. The system can imply further improvement due to limitations such as introducing real-time notifications and supporting mobile application development that can approach bigger potential for broader applications.

Keywords: Queuing Theory; waiting time; system development; patient management

INTRODUCTION

Effective patient management was essential to ensure the best possible service delivery in contemporary healthcare facilities. However, the high workload, facility availability, and unexpected number of patients' arrivals led to dissatisfaction with healthcare services (Aburayya et al. 2020). Wireless networks are essential for real-time data collecting, patient monitoring, and interprofessional communication in healthcare institutions (Al-Hubaishia et al. 2024). Moreover, healthcare centres were often devastated by lengthy wait periods for appointments, which results in dissatisfied patients and inefficient use of available resources (Almomani & AlSarheed 2016). Inefficient healthcare centers with prolonged waiting times were a source of frustration for patients, staff, and administration (Robinson et al. 2020). The waiting time can be long and extended when patients who were walking in for consultation and those who already have an appointment come at the same time. It can also be stressful when patients do not know when they will be treated, which will cause patient frustration (Nasrudin et al. 2023).

Therefore, this study aimed to address this issue by developing a system that allows patients to estimate and acknowledge how long they will wait for a consultation. Hence, this innovative strategy can maximize the operations of healthcare centres by allowing patients to optimize and arrange their time while waiting for their turn. The project focused on developing a predicting waiting

times model using data analytics and predictive modelling approaches. Since outpatients were not informed of their waiting period until they receive treatment, most of them arrived concurrently at the healthcare facility during business hours under the impression that they will be attended immediately and experience shorter wait times (Chu et al. 2019). The waiting time prediction system has evolved time by time to provide accurate prediction of waiting times to the patients by using real-time and historical information, appointment schedules, patient arrival trends, and consultation lengths. From this waiting time predictor system, patients will be able to better manage their schedules and time, contributing to significantly less inconvenience and increased overall satisfaction with healthcare centre services.

The application of queue management system in the healthcare centres waiting room can increase patient satisfaction (Bidari et al. 2021). The healthcare centre operation management and patient experience enhancement has seen a promising queue management system. Positive relationship between general satisfaction of patients towards the waiting times achieved when queue management is being assessed (Sani Burodo et al. 2021). However, there is a lack of personalized wait time predictions leading to a significant deficiency in the outpatient department. Existing methods sometimes fail to consider individual patient characteristics and dynamic healthcare centres situations, despite delivering broad wait time figures. The objective of this project is to address the existing deficiency by developing a system that is specifically tailored for Unit Kesihatan UiTM Campus Seremban, considering the clinic's unique operational dynamic and patient demographics.

By filling this gap, the proposed solution would transform patient experience in Unit Kesihatan UiTM Campus Seremban and establish a new benchmark for outpatient clinic administration. Patients will no longer be misinformed about their waiting times for consultations, enabling them to organize their schedules accordingly. Additionally, the healthcare centre management will benefit from better resource allocation and workflow management, which will increase operational efficiency and service quality.

Uncertainty of waiting times is a global issue that can occur anywhere, and healthcare systems are no exception (Horwitz et al. 2010). In healthcare, particularly at Unit Kesihatan UiTM Campus Seremban, uncertainty waiting times had become a major challenge despite the implementation of appointment mechanisms. This inefficiency leads to patient frustration because it required time for them to reschedule appointments, leading to having a negative impact of their day-to-day activities, and reduced their trust in the system. The lack of real-time waiting times in each of the sections forces patients to wait without knowing how much time it will take before it reaches their turn.

Recent studies had only made research to enhance appointments procedures (Paul & Ojuawo, 2019; Yew Hui & Teo, 2024), but the creation of predictive algorithms for waiting time post arrival intuitive prediction system using queuing theory to analyse the waiting time for certain patients at Unit Kesihatan UiTM Campus Seremban remains a research gap. In addition, without an effective system to estimate and display waiting times, both patients and clinic staff faced challenges in managing expectations and optimizing workflow. Thus, this system had the capability of improving the level of satisfaction with the waiting times that patients receive and assist them in deciding to continue with the treatment or leave the system.

Previous studies on waiting time predictor show that the Waiting Time Estimation (WTE) system for smartphones determines the latest wait time for a new patient using the Message Queue Telemetry transport (MQTT) protocol in real – time (Mahāwitthayālai Phayao et al. n.d.). The system can optimize the resource allocation and expedite patient treatment procedures by the healthcare centre management. This study aimed to let patients use their smartphone to see the anticipated wait time in real-time for the outpatient department's line through the system. Thus, the patient may arrange their arrival at the outpatient clinic and help in reducing outpatient overcrowding by using this information, leading to improving both patient satisfaction and operational efficiency. Furthermore, queuing theory and the MQTT protocol have been used to help in improving patients' satisfaction and improve their experiences by shortening the wait times and providing high quality service. The basic factors used in this queuing model such as arrival rate, service rate, and queue length help the algorithm to provide accurate prediction that mostly have similar value with the real time durations. The result showed that the algorithm used in the developed system got positive feedback with a high average score for usability and the benefits. The systematic patient flow can be achieved by the system as the proposed system algorithm can present the waiting time for the new patients close to the real waiting time.

Moreover, Ansari1 et al. (2021) explores the major problem that healthcare facilities faced when trying to control patient lines efficiently, which leads to high wait times and traffic as patients need to go through different type of consultation at healthcare centre. The study aims to improve patient's satisfaction and maximize operational efficiency by using this algorithm. The study has used sophisticated Patient Treatment Time Prediction (PTTP) algorithm and a comprehensive Hospital Queuing-Recommendation (HQR) system to overcome the problem

and reduce the task of health facilities management. The HQR system is obligated to recommend effective treatment to minimize the overall waiting process. The PTTP method is suggested, which determines how long a patient must wait between treatments. The result in using PTTP algorithm and HQR system has effectively helped in minimizing patient waiting times and enhancing efficiency of service in healthcare centres.

In addition, Joseph et al. (2022) have conducted a study about the correlation between accurate waiting time information and improving patient satisfaction. Patients experience in waiting to be consulted is a significant factor to boost satisfaction in healthcare services. In order to help medical personnel effectively manage patient flow, an algorithm of machine learning is being developed to analyse and predict patient waiting time for a bigger dataset. The method used in this study is machine learning algorithms like Random Forest and XGBoost to forecast waiting time of patient before consultation. Because each of the models uses a different approach to predict wait time, it produces distinct results in predicting waiting time. By using machine learning algorithms specifically two models which are Random Forest and XGBoost, it successfully achieved high accuracy prediction waiting time before consultation and offering potential similar value for real-time estimation of patient wait times. The algorithms can effectively enhance patient care and improve healthcare management through advanced machine learning algorithms with the use of detailed analysis in predictive waiting time in healthcare centres.

Similarly, a study researched by Arias-Gómez et al. (2023) has shown that lengthy wait times at Accident and Emergency (A&E) departments have resulted in a devastating real- time situation. The lack of the existing method used by the department, like rolling average to predict waiting times was not significant enough to predict complex data such as in A&E department. This showed that the wait times forecasting needs to be improved to better manage the patient's flow. The existing method was such a lack; this study has focused on several techniques to create more accurate models to measure the waiting times that suited with the A&E department. The start of outpatient walks in and register at the department, the recent study used machine learning algorithm, Random Forest and XGBoost to predict waiting times for the patients. The study found that with lesser value of RMSE (Root Mean Square Error), MAE, and MSE (Mean Square Error), it showed that the XGBoost model outperformed the Random Forest model. The model provided an improvement in accuracy in forecasting wait time for the department. Highlighting the result, the algorithm offered an efficient method to control patient flow and minimize the resources and capacity in the A&E department.

Meanwhile, Bee et al. (2019) discovered that long wait times at clinic specifically in Pusat Sejahtera, University Science Malaysia correlate with patient dissatisfaction and showed the operation of clinic has been deficiency. Long wait times during peak hours are an issue that the study uncovered and that gave frustration to both staff and patients. The study makes an initiative approach by using a strategy that makes use of digital appointment systems and forecasting tools to improve patient experience and maximize clinic operations. A complete queue management system that used web-based appointments and Time-Series Extrapolation projection was offered in research undertaken after it was determined that a solution was required. The system was being favorably received by participants during testing. The system has been affordable and has intuitive user interface that were highly appreciated and compliments by many. The study has significant value as it has the potential to transform in its capacity administration procedures, enhance patient satisfaction by providing real time queue updates and web-based appointments with the added reminders. The solution not only suggests ways to enhance Pusat Sejahtera's patient queue flow, but it also demonstrates the potential value and significance of using such advanced analytical and informative tools to the healthcare industry.

Overcrowding in emergency departments (EDs) is a genuine issue for healthcare systems globally and the department should do better in controlling the resources (Benevento et al. 2023). Due to the elderly population and cut of cost policy in Italy, the inequality between supply and demand for the services happened. This study has solved the issue by using several approaches of machine learning such as Lasso, Random Forest, Support Vector Regression, Artificial Neural Network, and the Ensemble Method. By using the real data from two Italian hospitals, the researchers performed a comparison analysis of the several machine learning techniques to improve prediction accuracy. The results concluded that to boost accuracy and efficiency, the Ensemble Method outperformed better than any other method for forecasted waiting times. The Ensemble Method offered accurate forecasting of waiting times in EDs to enhance patient satisfaction, management efficiency and resources. From there, EDs can make accurate decision making with the help of a predictive system using machine leaning algorithms to better manage on controlling patient flow and activities in the department.

Therefore, the objective for this study is to develop an algorithm WTPS system for predicting waiting times based on several variables, including appointment scheduling and consultation lengths at Unit Kesihatan UiTM Campus Seremban. The results will guide the development of an interface system that will enable patients to efficiently manage their time when visiting the clinic.

METHODOLOGY

The adopted and modified methodology framework (Akanmu et al. 2020) describes the phases involved in the research study from preliminary assessment to analysis and evaluation. It consists of comprehensive methodological framework for conducting the study and it is divided into 5 phases as follows as show in Figure 1:

1. Preliminary Assessment
2. Research Study
3. Waiting Times Predictor System (WTPS) Development
4. Testing the Development
5. Analysis & Evaluation

PRELIMINARY ASSESSMENT

In this first phase, the activity involved brainstorming and idea aimed to identify the nature of the research. This phase resulted in the definition of research objective, scope and the significance of the research as documented through journals and articles. The focus at this stage was on establishing the overall framework of the research and ensuring its relevance.

RESEARCH STUDY

This phase involved two activities which are literature review and field study. The literature review activity focused on gathering information from academic journals and articles. It was a fundamental part of the research, aimed at exploring the queuing theory method and developing waiting time predictor system. Next, field study activity provided a deeper insight and understanding of the research environment which consist of 33 UiTM Seremban students as the respondent with average ages between 20-24 years old. It involved observing and collecting data in real-world settings such as Unit Kesihatan Campus Seremban 3. Valuable data including patient's arrival time, patient's interarrival time, average waiting time, the number of resources (nurses and doctors) were collected for the development of the system.

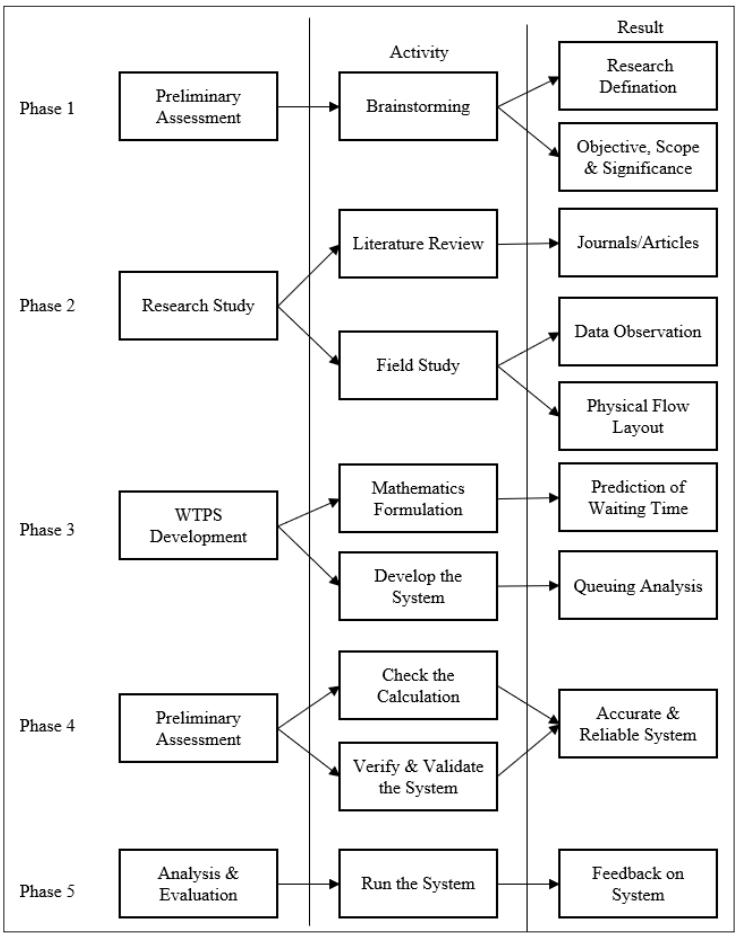

FIGURE 1. Research Framework

WTPS DEVELOPMENT

In this stage, the process is more focused on the mathematical formulation and system development. The mathematical formulation uses Queuing Theory that predicts waiting times based on the collected data. A widely recognized notation used to classify queuing system is Kendall's notation introduced by David G. Kendall in 1953 (Mahāwitthayālai Phayao et al. n.d.). Some basic properties used to analyze the queuing system are:

- Arrival Rate (λ): The average number of patient arrivals per unit as shown in (1)
- Service Rate (μ): The average number of patients that can be served per time unit.
- Number of Server (c): The total number of server (service section)
- Traffic Intensity(ρ) : The ratio of the arrival rate to the service rate. The Traffic Intensity is representing how much the server's capacity is being used as shown in (2)
- W_q is the average of time a customer spends waiting in queue as shown in (3)

There is only one server for each process hence, the average waiting time formula is established for M / M / 1 based on Little's Law Formula subjected to:

$$\lambda = \frac{N}{T} \tag{1}$$

$$\rho = \frac{\lambda}{c\mu} \tag{2}$$

$$W_q = \frac{\rho}{\mu(1-\rho)} \tag{3}$$

The system will be designed to handle user inputs, process data, perform calculations, and provide outputs in the form of queuing analysis. Initially, the system provided the input capability that enabled users to enter the necessary information. This data included waiting time history (hour), arrival of patients and other required parameters for the queuing analysis such as registration and triage service rate, consultation service rate and pharmacy section service rate. Then, the raw data was validated within the system to ensure that they are properly formatted and contain no errors. After validation, the system used the mathematical model to process the data. At this stage, important queuing formula used in queuing theory such as arrival rate, service rate and traffics intensity were applied as in Equation (1)-(3). It includes predicting the waiting time and number of patients in the queue.

DEVELOPMENT TESTING

This phase involved the process of checking whether the system development in the previous phases was accurate and reliable. It consisted of two critical activities: cross-checking the calculations from queuing theory method and verifying and validating the system. This process is to ensure that the system functions correctly and performs as intended when fully implemented. The first activity in this phase included verifying the calculations obtained from the queuing theory method.

The second activity was verification and validation of the system to ensure it met the specified requirements and performs as expected. The verification system was a process to check whether the system was built correctly according to the design specifications. The first step was to review the code to ensure it fit the design and is free from errors. Next, individual components of the system were tested to ensure they functioned correctly. Finally, integration testing was conducted to verify that the different components of the system worked together seamlessly.

The validation process checking whether the system satisfies the need of the user and could perform its intended functions in the specific environment. The process involves end-users to test the system in a real-world scenario to ensure it meets their needs and expectations. Next, it has assessed the system's performance under various loads to ensure it can handle the expected volume of data and users. Lastly, the reliability testing had been performed to ensure that the system performs consistently over time without failures.

ANALYSIS AND EVALUATION

This phase focused on running the system and carrying out a detailed analysis and evaluation. The main purpose was to maintain the stability of the system and evaluate the effectiveness of the system in meeting the research objective. Application in real-world settings involves subjecting the system to daily use scenarios and monitoring its performance to truly test the system's capabilities.

In order to ensure the system operated as intended, we encouraged at least twenty students to use the system (Lališová et al, 2024). Their feedback with a diverse range

of perspective and experiences that are different from the researchers had been gathered through a survey questionnaire. This allowed us to quantify and qualify data regarding the system's usefulness, the usability of its function, and level of its accuracy, and overall users' satisfaction. The method used for measuring user experience on Waiting Time Predictor System (WTPS) were System Usability Scale (SUS) and User Experience Questionnaire (UEQ) method as shown in Table 1.

This study chose SUS and UEQ because of SUS method has the advantage of being able to measure subjective view of users regarding system function and this can be done in a very short time without negating some measure of usability such as ease of use, time taken and perceived satisfaction (Sari & Rasio Henim, 2022). The advantage of the UEQ method is that the UX can be determined instantly providing both technical and non-technical evaluation of user's emotional responses and satisfaction.

RESULTS AND DISCUSSIONS

Table 2 shows the result of expected waiting time for each process calculated using Queuing Theory method. Number of staff on duty during the observation are three staffs and they only had one shift per day. As shown in the table, arrival rate per hour (denoted by lambda) is 8.6 patients per hour. This arrival rate was obtained by using (1). Furthermore, the average waiting time in queue (denoted by W_q) for each process is being calculated using M/M/1 in Queuing Theory method. Firstly, we compute the average waiting time for registration and triage process. The first step is to calculate the utilization factor (ρ) which measure how busy server is using (2). Next, Equation (3) is used to determine the average waiting time in queue (W_q). Similarly, the average waiting time in queue for the other two processes can be calculated using the same process as outlined earlier.

TABLE 1. Evaluation table

Evaluation	Description
System Usability Scale (SUS)	John Brooke developed the System Usability Scale in 1986 (Lewis & Sauro, 2009). System Usability Testing (SUS) is a method for conducting usability that serve to assess software interfaces and testing on applications (Wulandari et al. 2023). SUS is a reliable usability measurement tool that is popular, effective, and easy to use. The SUS assessment uses a Likert scale 1 to 5. It consists of 10 items of questions with odd number that worded positively and even number that worded negatively. SUS is used for tests that includes the views of end users and will produce evaluations that are more appropriate to the actual situation.
User Experience Questionnaire (UEQ)	User Experience Questionnaire (UEQ) is a more subjective approach since it aims at giving a rating of the user's experience of the product. This method is widely used because it can quickly measure user experience on a product. UEQ measurement method is used to handle survey data about UX by identifying two part which is usability aspects and experience aspects (Alisya et al. 2023). UEQ carried out using 6 rating scales that named attractiveness, perspicuity, efficiency, dependence, stimulation, and novelty (Schrepp et al. 2017)

Figure 2 shows the login page for the Unit Kesihatan Campus Seremban. The system consists of space for users to enter their name and student ID. There is no password field, which suggests an easy user interface and since there is no protection from attempts or guessing of the ID, the websites is intended to be suitable use if no confidential information is being stored. After that, the user will press submit button, which will direct them to the main page interface.

TABLE 2. Expected waiting time for each process

No	Process	Rate Values (patient/hour)	Utilization Rate ($\rho < 1$)	Waiting Time in Queue (minutes)
1	Arrival Rate	8.6	-	-
2	Registration and Triage Service Rate	17.54	0.490	3.29
3	Consultation Service Rate	25.09	0.342	1.25
4	Pharmacy Section Service Rate	15.08	0.570	5.28

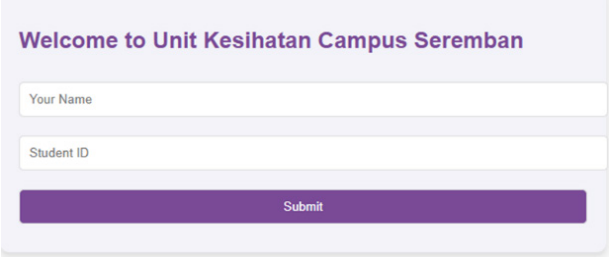

FIGURE 2. Login page of the WTPS

Figure 3 shows the main page of the system where users can see and keep updated their expected waiting time.

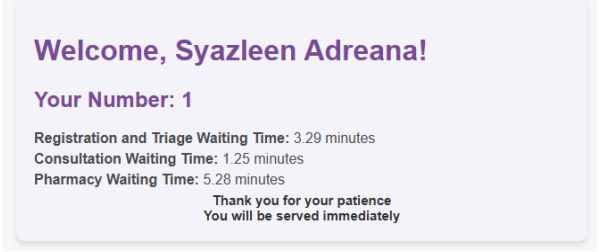

FIGURE 3. Output page of the WTPS

This page displays personalized queue information screen for each unique user. The interface acknowledges the user by name and provides unique turn numbers based on student ID data. It shows "*Your number: 1*", indicating the position of patient in queue. Next, the system lists specific waiting times for each process which the waiting time will increase as the arriving patient enter the system is also increasing. At the bottom of the text box, a closing note "*Thank you for your patience. You will be served immediately*" is designed to reassures the user about the process. The interface is styled focusing on user's experience that providing information tailored to the individual. By breaking down the waiting times for each process, it sets clear expectations and helps the user feel informed and reducing potential frustration associated with uncertainty.

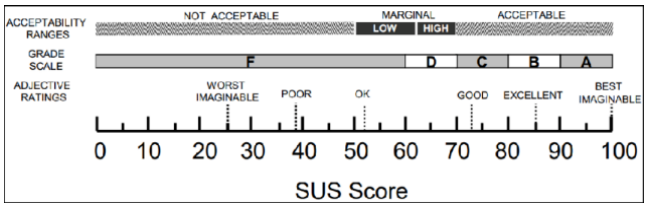

FIGURE 4. SUS score percentile rank

TABLE 3. SUS Score

SUS Score	Interpretation
0-25	The worst imaginable
24-37	Poor
38-52	Fair
53-72	Good
73-84	Excellent
85-100	The best imaginable

The average result is 83.45 and has an adjective rating of 'Excellent' category as presented in Table 3 and Figure 4. This means that users found that the system is efficient and pleasant to use. Additionally, the score corresponds to a grade scale of 'B. it can be interpreted as the system reflects strong performance but still has a gap from achieve the 'A' category. The score is also included in the acceptable category that hints for improvement that could enhance the system further.

The results of the UEQ Benchmark graph in Figure 5 shows a value of 'Excellent' on attractiveness, perspicuity, efficiency, dependability, and stimulation which proves the advantages of the proposed system in different points of view concerning usability and users' satisfaction. An 'Excellent' score of attractiveness means that the users appreciating the visual appeal of the system and enjoy interacting with it. Next, perspicuity reflects how easily users can understand the system's design, that allows users to understand the operation of the system within a short period of time while effectiveness and reliability meaning that the system not only performs activities efficiently but also provides a dependable performance. Lastly, the 'Excellent' score in stimulation highlight that the system offers users an exciting and positive experience.

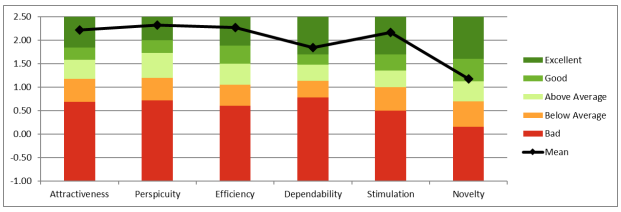

FIGURE 5. WTPS UEQ benchmark

Conversely, the dimension of novelty received a 'Good' rating. This implies that although the users perceived the system as mildly distinct from traditional systems and innovative, there is still room for improvement in introducing more unique features. This score indicates

the creativity of the system correspondence to the need of users, but it seems that the system is not yet at a level that amazes its users in coming out with new ideas. Overall, the results of the UEQ demonstrate that users are highly satisfied with the system, which performs exceptionally well in almost all tested aspects. However, there is potential to enhance the novelty of the system to make it more unique and creative.

CONCLUSION

Waiting Time Predictor System (WTPS) is a web-based system that designed people to estimate their waiting times in clinic system. This system was designated to solve the uncertainty waiting time problem that faced by outpatient's clinic. The main issue being addressed is that patients frequently encounter uncertainty about how long they will need to wait when visiting a clinic, which can disrupt their daily routines. The method that was implemented in this system is Queuing Theory. Queuing Theory is a method that use arrival rate of customer, service rate and traffic intensity to calculate average waiting time for a customer. It is necessary to make sure all the variables being calculated correctly to ensure that accurate waiting time can be shown to the user of the system.

Based on the analysis of the survey through questionnaire, the system has been analysed to be in an acceptable category with score 83.45. The survey also reveals that, overall, this project is a success as the majority user experience feedback received is positive. Users have expressed satisfaction with the system's functionality, ease of use, and the accuracy of the waiting time predictions, indicating that they system effectively meets their needs and expectations.

Although the study objectives were met, many limitations were found. The system only covers registration and triage, consultation, and pharmacy, which may limit its application to clinics with various operational structures or other services. In addition, the system does not update queue numbers and waiting periods when patients finish their processes.

The results suggest several recommendations for future work especially in term of user's experience. First, the system should support varied operating models in different clinics by offering a flexible workflow where processes can be added or eliminated based on operational needs. Second, technologies like Firebase could offer real-time system-patient device updates and SMS, email, or in-web warnings when a patient's turn is approaching. Third, a mobile app might make the system more accessible for smartphone users. Finally, more interactive features could allow patients to update their information and receive queue progress reminders. It is also suggested in future to involve testing with a larger and more diverse sample, comparing with other systems, and conducting longer-term evaluations to strengthen the study's validity.

ACKNOWLEDGEMENT

The authors would like to thank the Universiti Teknologi MARA Cawangan Negeri Sembilan and Faculty of Computer and Mathematical Sciences for the supports and Unit Kesihatan Kampus for the facilitated in the completion of this project.

DECLARATION OF COMPETING INTEREST

None.

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