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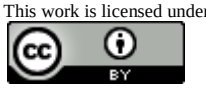

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IMPROVING CLINIC QUEUES IN MALAYSIA USING TIME-SERIES EXTRAPOLATION FORECAST AND WEB-BASED APPOINTMENT

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Abstract: In University of Science, Malaysia (USM), Sejahtera Centre is the main healthcare centre that provides medical care to the university students, employees and pensioners. Along the years, the increasing demand for these services has led to long queue problems in the clinic. As a result, the clinic becomes congested during peak hours, leaving both patients and healthcare staffs dissatisfied. Apart from Sejahtera Centre, long queue issue has been a common problem in many government outpatient departments across Malaysia. Therefore, this paper proposes a low-cost, user-friendly clinic management system that consists of a web application for clinic staff and a hybrid mobile application for patients. Real-time queue monitoring and queue forecasting using Time-Series Extrapolation is incorporated to help patients avoid peak hours and empower better clinic workforce management in handling different patient flow peaks. The web-based appointment approach allows patients to conveniently reschedule their appointments online and receive appointment reminders via the mobile application. To demonstrate the feasibility and effectiveness of the proposed system, a prototype is developed and evaluated based on several interviews. The prototype serves as a basic working model that outlines the feasibility of the proposed concepts to improve queue issues in other clinics across Malaysia.

Keywords: Queue Forecasts, Appointment System, Healthcare.

I. INTRODUCTION

In the healthcare sector, patients' satisfaction is generally accepted as one of the main indicators of the quality of care [1-3]. Reducing patients' waiting time and delays is also an important measure of access to healthcare [4-5]. However, many clinics in Malaysia are facing difficulties in coping with long queue issues.

Sejahtera Centre is a healthcare centre of a local university campus known as University of Science, Malaysia (USM). The centre was established in 1969 in the university's main campus to provide medical and dental consultations for the students. Today, the centre has about 66 staff members [1], led by the director Dr. Normala Abdul Wahid [2], with free healthcare services entitlement expanded to all students, employees and pensioners of USM. Over the years, the demand for medical services at Sejahtera Centre has been growing significantly. During peak hours, patients had to spend excessively long waiting time for a short consultation with the doctor. As a result, the clinics are often congested, leaving both staff and patients dissatisfied. The same situation is observed in the government outpatient departments in Malaysia that provide medical care to the residents at an inexpensive rate.

Although a number of virtual and mobile-integrated queue management solutions that allow patients to join a queue before physically arriving at the clinic were introduced into the market throughout the years, it can be seen that the implementation of these systems in Malaysia clinics remains low. The slow consumer adoption of the existing virtual queue systems reflects that the current solution could have certain

criteria that do not fulfil consumer needs. Since Sejahtera Centre and many government clinics have typically lower operational costs, the high implementation cost of virtual queue management solutions is one of the reasons why such solutions are not implemented. Moreover, a lot of consideration needs to be taken in order to cope with the complexity in handling situations where patients do not show up.

Surveys and interviews are conducted with the Matron and patients of Sejahtera Centre to determine the level of patient satisfaction in relation with waiting time and the possible causes of long queues. The reason queues form, in essence, is simply because there are more patients than doctors to serve them. When the number of patients visiting the clinic rapidly increases at a certain period of time, also called peak hours, the clinic becomes congested. Apart from that, the unpunctuality of appointment patients is also a contributing factor to long queues. Many of the patients who have appointments do not follow the pre-scheduled time slot, causing queues to develop among appointment patients.

In this study, a queue management system that incorporates Time-Series Extrapolation forecast and web-based appointment is presented. The system consists of a web application for healthcare staff and doctors, and a mobile application for patients. The forecast is calculated using Exponential Smoothing model, which places more weight on the most recent historical data, thereby making the forecast more sensitive to changes in queue flow. This feature will help patients avoid peak hours and empower better clinic workforce management in handling different patient flow peaks. Real-time monitoring feature is included in the mobile application as a form of information for patients to decide the best time to visit the clinic. Using a web-based appointment management approach, appointment rescheduling feature is developed to enable patients to reschedule their appointments conveniently via the mobile application. An automated appointment reminder is also included in the mobile application to reduce no-shows and promote appointment punctuality.

In order to demonstrate the feasibility and effectiveness of the proposed system, the design and prototype implementation of a fully-functional system is developed and evaluated based on several interviews. The prototype serves as a basic working model that outlines the feasibility of the proposed concepts to improve queue issues in other clinics across Malaysia.

In the following sections, related works by different authors are discussed and the advantages of their proposed concepts are highlighted. Next, the paper analyses the survey response among Sejahtera Centre patients. The details of the proposed system architecture are explained, followed by an evaluation of the proposed system. Lastly, the paper is concluded, and possible future works is discussed.

II. RELATED WORK

The A number of researches related to clinic queue forecast and appointment features were conducted in the recent years. In this section, research related to the Time-Series pattern recognition, computerized appointment system and appointment reminders are studied. The advantages and feasibility of their proposed concepts are highlighted.

2.1 Time-Series Pattern Recognition

Many medical organizations are not able to detect small changes in patient flow, which leads to longer waiting times and lower patient satisfaction rates. In 2005, a research presented a system for adaptive long-term ambulatory scheduling, where the time-series forecasting, and pattern recognition abilities is used to predict possible patient flow peaks [6]. This kind of intelligence is useful when there are constantly present patterns in patient flow. The patterns can actually be difficult to spot by just a personnel manager.

To implement the pattern recognition, the authors obtained the historical data on patient waiting times. The data should be updated and recorded constantly. Time-series extrapolation, also known as univariate time-series forecasting or projection was used and gave quite promising results. This method is quick, reliable, inexpensive and easily automated. This approach analyses data for the variable of interest using quantitative methods. The study extrapolated the hourly average waiting times and queue lengths from the past four weeks to forecast average waiting time and queue length for a few days in advance.

A similar approach will be used to forecast Sejahtera Centre's queue length as this approach is proven to be adequate for predictions of this sort.

2.2 Computerized Appointment System

According to an article discussion about the comparison between manual and computerized scheduling systems, the paper-and-pen manual appointment system can become untenable with large workgroups or very busy schedules [7]. On the other hand, a computerized system that uses scheduling algorithms and rules to help multiple people manage appointments tends to be more efficient than manual scheduling. The available service times on the main calendar are allowed to be publicly shared, while keeping specific appointments private.

In 2015, a web-based appointment system was developed for the Medical Officer of Health (MOH) area clinics in Sri Lanka. A study was conducted to identify the benefits and patient adoption of implementing the web-based appointment system [8]. The study concluded that the feasibility of web-based method is low in rural clinics such as the clinics at the MOH areas due to the lack of technological knowledge among the rural community. However, on the opposite, the web-based appointment system is proven to be useful and highly preferred in urban and semi urban areas, and among the younger people.

In this paper, a web-based appointment system that handles appointments will be provided as one of the proposed solutions for Sejahtera Centre. Since majority of the targeted system users are not computer illiterate, thus the system is expected to have a high feasibility.

2.3 Appointment No-Shows and Reminders

A research was carried out in 2010 about appointment patient no-shows [9]. The paper discusses on no-show

patients, their behaviors and ways to resolve it. Although the research was mainly focused on psychotherapy patients, the outcome of the research can also be related to clinic outpatients.

No-show patients are patients who do not show up for their scheduled appointments. This matter creates administrative difficulties, while the patients may not be receiving effective and proper treatment. The research identified that majority of the missed appointments were accounted by patients with occasional absences of approximately once per month, while only a small percentage of patients missed appointments frequently. No-shows happen for a number of reasons, which include negative treatment reactions, practical matters and motivational concerns. Administrative procedures at the clinic level such as reminder phone calls and improved scheduling management have been implemented and evaluated for the effectiveness in reducing no-shows. The interventions are proven to be effectively geared toward patients who occasionally miss appointments.

Although phone call reminder appears to bring effective result in reducing no-shows, but this approach requires extra operational resources. This paper proposes the use of automated mobile application push notifications as a form of low-cost reminder for appointment patients.

III. PROPOSED SOLUTION

A survey was conducted among USM students, the main patients of Sejahtera Centre, in the form of an online questionnaire to determine the level of patient satisfaction in relation with waiting time. A number of 80 respondents made up of a moderately well-balanced gender of males & females and of different ethnicities participated in the survey. Their age ranges from 19 to 29 years old and majority of them are degree students. From the results gathered, out of 80 patients, 33 of them are satisfied with the waiting time for doctor consultation, 18 of them are neutral, while 29 of them are not satisfied. Next, 52.5% of the patients normally waited for 0-20 minutes to see the doctor, 17.5% waited for 21-30 minutes, while 30% waited for 31-60 minutes and above.

According to the findings, the patients who waited for 0-20 minutes are satisfied. These patients probably visited the clinic during off-peak hours and do not have to wait behind a long queue. The patients who were neutral waited for 21-30 minutes which is still considered as a reasonable waiting time. Lastly, the patients who waited for 31-60 minutes or more are unsatisfied. This group of patients probably visited the clinic during peak hours. Having an almost equal number of unsatisfied patients (29 patients) with satisfied patients (33 patients) reflects the need for Sejahtera Centre to better manage queue peaks.

According to the interview conducted with the Matron of Sejahtera Centre, also known as the Head Nurse, the clinic considers the option to forecast queue peaks and adapt its service according to the queue flow, but relying on the personnel alone without a proper mechanism is very difficult to forecast this data accurately. Besides that, the current manual appointment system is hard to manage as many appointment patients are not punctual to the given date and time. Many patients tended to queue up early in the morning before the clinic is opened to avoid long waiting queues, but this eventually caused the clinic to be crowded at the clinic's opening time at 7.00am. There are also many patients who showed-up on other dates without prior notice for appointment rescheduling, which is the root cause for appointment patients' queue.

As a conclusion to the findings, there is a common recognition by both the staffs and patients that a solution is needed to improve the current queue flow and appointment system of the clinic. As mentioned by the matron, this issue has occurred for a long time, but there were no practical solutions given to effectively overcome it.

Therefore, a queue management system that caters the need of Sejahtera Centre is proposed. The system consists of a mobile application for the patients and a web application for healthcare management staffs and doctors. The solution comprises of four main modules as illustrated in Figure 1.

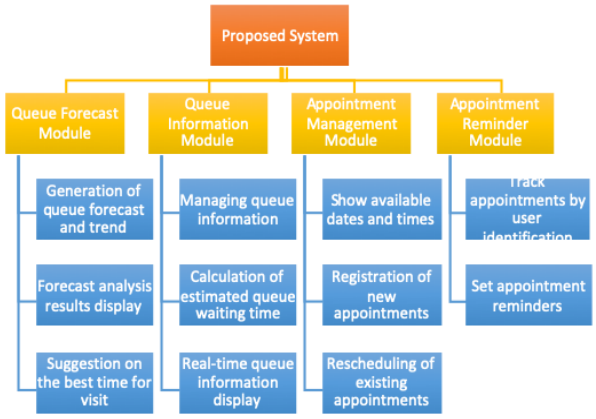


Figure 1: Modules of Proposed System

3.1 Queue Forecasts and Analysis

The queue forecast is calculated using a time-series extrapolation method. Among the common 7 extrapolation forecast methods [10], exponential smoothing technique is chosen to be incorporated in the proposed system. The reason exponential smoothing technique is selected is because it involves little historical record and is sensitive to changes [11]. This technique forecasts trends better than other common approaches such as naive approach, moving average, weighted moving average, etc.

The exponential smoothing approach requires a smoothing constant (α) that ranges from 0 to 1. The smoothing constant is subjectively chosen. A high value of α will be used when the underlying average is likely to change. On the other hand, a low value of α will be used when the underlying average is stable. The smoothing constant is generally $0.05 \leq \alpha \leq 0.50$. The formula to calculate the forecast using exponential smoothing approach [11] is as shown in Figure 2 below.

New forecast = Last period's forecast + α (Last period's actual value - Last period's forecast)

$$Ft = F(t-1) + \alpha(A(t-1)-F(t-1))$$

where F_t = new forecast

F_{t-1} = previous period's forecast

α = smoothing constant ($0 \leq \alpha \leq 1$)

A_{t-1} = previous period's actual demand

Figure 2: Forecast Formula of Proposed System

For more accurate projection of the clinic queue forecast results, a high value of α, which is 0.50, is chosen for the proposed system. This is because the clinic queue flow is relatively inconsistent, and it depends on climate changes and the chances of exposure of virus and bacteria in a particular region. The forecast is calculated by day (Sunday, Monday, Tuesday, etc.) and time (8.00am, 9.00am, 10.00am, etc.). Using this forecast data, the proposed system provides suggestion on the best time to visit the clinic by identifying the shortest waiting time for the day. The algorithm for the queue forecast is further explained using the Program Design Language (PDL).

```
Get the day's queue information
For (i = 0; i < length of day queue; i++)
    Count number of queues for each hour
End for
```

Figure 3: Algorithm to Get Last Week's Actual Number of Patients

Figure 3 above shows the algorithm implemented to get the previous week's actual number of patients by day and hour. For instance, the result to obtain from the algorithm is the number of patients who visited last Monday at different hourly blocks. Further explanations are as below:

i. Get from database last week's queue records of the particular day (e.g. Monday)
ii. Create a loop on the retrieved actual queue data
iii. Count the number of patients for each hourly block (e.g. 8.00am-8.59am has 5 patients; 9.00am-9.59am has 7 patients; etc.)

```
Get the day's forecast from database
For (i = 0; i < length of day forecast; i++)
    If day forecast hour matches a defined hour
        Set day queue count of the hour as oldActual
    End if

    Set day forecast data of the hour as oldForecast
    Calculate newForecast of the hour
    Post newForecast of the hour to database
End for
```

Figure 4: Algorithm to Get Last Week's Forecasted Number of Patients

Figure 4 above shows the algorithm implemented to get the previous week's forecasted number of patients. Further explanations are as below:

i. Get from database last week's forecasted queue records of the particular day
ii. Create a loop on the retrieved forecasted data
iii. Assign the count of the number of queues for each hour as oldActual
iv. Assign the values of the forecast data for each hour as oldForecast
v. Calculate the new forecast using the formula: newForecast = oldForecast + alpha * (oldActual - oldForecast)
vi. Submit the new forecasts to the database

3.2 Queue Information Updates

The queue information is retrieved based on the data entered by the clinic staff and doctor. Each day when the clinic opens, the staff will enter the number of doctors available for the particular day. Subsequently, when patients begin to visit the clinic, the clinic staff will perform registration by entering patient details into the system via the web application. A list of common treatments that the clinic provides, and its estimated consultation duration is added in the proposed system as shown in Figure 5 below. When it is the patient's turn to enter the doctor's room for consultation, the doctor will first identify the treatment required for the patient and enter into the system before he or she begins the consultation.

treatmentType	estDuration
Diabetes	8
Dyslipidemia	10
General Sickness	5
Gout	10
Gynecological	10
Heart Diseases	10
Hypercholesterolemia	10
Hypertension	8
Hyperuricemia	10
Medical Checkup	5

Figure 5: List of Common Treatment Types and the Estimated Duration

The formula used to get the estimated waiting time is by using the number of doctors available for the day, divided by the number of patients multiplied by the estimated treatment duration. The mobile application displays the current number of patients in the waiting queue and the estimated waiting time in real-time to empower patients to make better decisions and plan the best time to visit the clinic, suited with their personal schedule.

3.3 Web-Based Appointment Management

The appointment management system is design in the form of a web application for the use of clinic staff and doctors. The system is designed using an open calendar concept via computerized scheduling that can show available time slots for each day. If compared to the traditional pen-and-paper approach that requires a manual appointment log with all scheduling funneled through an appointments secretary, the web-based appointment system can help to save time and effort needed to arrange appointments and maintain high resource utilization by optimizing manpower resources. Apart from that, the system is designed to allow patients to conveniently reschedule an appointment. If a patient could not make it on the appointed date due to sudden urgent issues, he or she can select a new available time slot via the mobile

application and reschedule the appointment to another date or time. This will help Pusat Sejahtera as well as other clinics to reduce no-shows.

3.4 Appointment Reminders

A reminders feature is included in the proposed system on the mobile application. This is to encourage patients to be punctual for their appointments and avoid developing queue due to delays in appointments. The reminders are prompted using push notification and will notify the patients a day before the appointment date and 30 minutes before the appointment time.

3.5 System Design

Since the design goal is to increase app usage flexibility, the mobile app is designed as a hybrid app that operates in multiple operating system platforms such as Android, iOS and Windows. Such apps can be developed with just a single development code base, which saves development time and increase efficiency of the project development. The cost of implementation will also be greatly reduced.

The web application can run across computers, tablets or phones of any operating systems that are able to support the access of common web browsers such as Internet Explorer, Google Chrome and Mozilla Firefox.

IV. PROTOTYPE IMPLEMENTATION

A fully-functional prototype is developed in order to demonstrate the feasibility and effectiveness of the proposed solution. The three-layer architecture diagram of the proposed system is depicted in Figure 6. As illustrated, there are two main types of system user. The first type of user is the clinic staffs, which includes the doctors and administrators. The staffs will access the web application using the clinic's computer devices via any common web browser such as Internet Explorer, Google Chrome, Firefox, and so forth. Next, the second type of user is the clinic patients. This includes students, lecturers, pensioners and anyone entitled to visit the clinic. Patients will be able to access the mobile application via their mobile devices, with prior installation of the application on their devices.

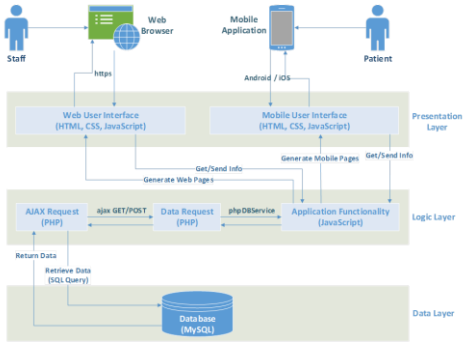


Figure 6: Three-Layer Architecture Diagram

The server used to host the system is called the WAMP server. It is a local server package for Windows that allows developers to host applications with Apache, PHP, and the MySQL database [12]. Currently, the system is hosted by a personal laptop computer as the server for prototyping purposes. As for the database, the MySQL database, an open source relational database management system (RDBMS) based on Structured Query Language (SQL) [13], is implemented. The phpMyAdmin which comes with the WAMP server is also used to easily handle the databases. It is a software tool written in PHP, intended to manage the administration of MySQL over the web [14].

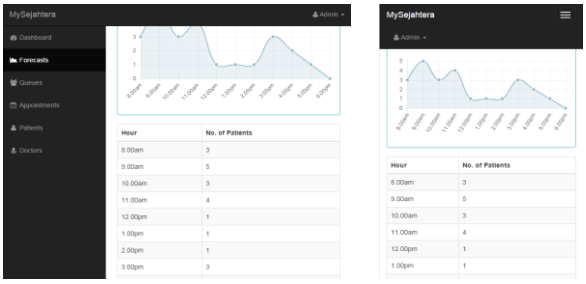
The presentation layer consists of the user interfaces for both the staff in the form of a web application, and the patient in the form of a mobile application. Next, the logic layer comprises of the application functionality, the data request and AJAX request that handles all the information sent by users and data retrieved from the database. Finally, the data layer is made up of a MySQL database that stores all of MySejahtera's data.

A few important aspects were taken into consideration when designing the user interface of the web and mobile application. First, the pages are designed with consistency using CSS and Bootstrap. Labels and headings, fonts and colors are used with consistency and harmony. Figure 7 below illustrates the design consistency in terms of fonts and harmonized.

(a) Web App (b) Mobile App

Figure 7: Screenshots of MySejahtera Consistent Design

Next, the interface has a responsive design and aligns itself to any screen sizes without hassle. The web application can be opened in any window size of the web browser while the mobile application can be accessed in mobile devices of different sizes and still fit in properly. Figure 8 and Figure 9 below shows some examples of the responsiveness of the user interface design.



(a) Medium-Sized Window (b) Small-Sized Window

Figure 8: Screenshots of MySejahtera Web App Responsive Design

Such design implementations provide greater flexibility in terms of usage among patients due to the usability of the mobile application in common mobile operating systems. Moreover, this allows much lower implementation cost and thus increasing the change for better consumer adoption of the system.

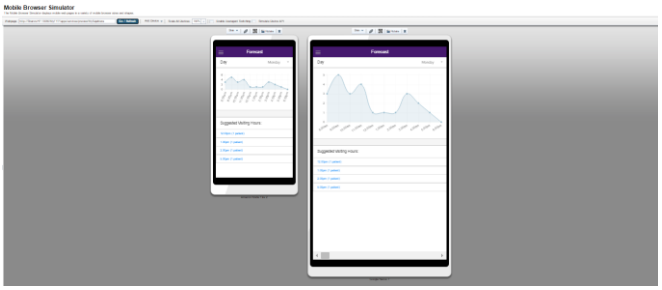


Figure 9. Screenshot of MySejahtera Mobile App Responsive Design

V. EVALUATION

Along the proposed system's development life cycle, test and evaluation are consistently performed to ensure that the system satisfies the specified requirements. Table 1 below shows the tests conducted on the main functions of the proposed system.

Table 1. Test Results for the System Main Functions

Unit/Function	Test Scenario	Expected Results	Actual Results
User login	Login with correct combination of ID and password	Login success	Login success
	Login with incorrect combination of ID and password	Login fail	Login fail
Submit doctor availability	Select a status for each doctor for a particular day	Status stored and shows in the dashboard	Status stored and shows in the dashboard
Add new queue	Submit form with all fields completed	Add queue success	Add queue success
Add new appointment	Select a date in the form and see the available slots	Only slots that are available are listed out	Only slots that are available are listed out
	Submit form with all fields completed	Add new appointment success	Add new appointment success
View forecast	Select a day of the week to check the day's forecast	Forecast of the selected day is shown	Forecast of the selected day is shown
New patient account registration	Register with all valid data input	Registration success	Registration success
	Register with some invalid data input	Registration fail	Registration fail

In order to demonstrate the feasibility and effectiveness of the proposed system, the prototype developed was evaluated using both quantitative and qualitative methods. For performance testing, each stated function was tested 10 times and the system reacts within 3 seconds for all the functions. For usability testing, the applications were tested by 8 random students of USM and they were able to use the system without much guidance. For security testing, tests were done on the login module and only authorized users are able to access the system, with different functions accessible for different roles. Finally, for compatibility testing, the web and mobile application were tested on different operating systems and browsers. The mobile application is tested on Android 4.4.2 and Android 5.0 and works the same. Further testing on iOS and Windows devices could not be conducted as these resources are not available. On the other hand, the web application is tested on Google Chrome, Internet Explorer, and Mozilla Firefox. The results show a consistent performance and display on all web browsers, only with some slight deviations that do not affect the overall system. For instance, the form handling of different browsers deviates slightly. Internet Explorer has a view password characters feature while Google Chrome and Mozilla Firefox do not.

For the qualitative analysis, interviews were conducted with the main stakeholders of Pusat Sejahtera, which are the Matron of Pusat Sejahtera and 8 students from USM who frequently visit Pusat Sejahtera. The objective of the interviews is to evaluate end users' perspective of the proposed system and obtain feedback for future work ideas.

The Matron of Pusat Sejahtera tested out the web application whereas the 8 students of USM tested out the mobile application. From the comments received, majority of the participants felt that the web application and mobile application is easy to understand and use without much guidance. Only one participant felt that the implementation of push notification for appointment reminders is not as effective as using alarm reminders as users may miss out the push notification. The proposed system is estimated to cost about MYR 1500 in order to implement in clinics, and all participants agreed that the system is considered low-cost and

easy to be installed.

VI. CONCLUSION

This paper briefly analyses existing queue solutions and highlights the need for a better queue management system especially for outpatient clinics as the queue flow is unpredictable. This paper also presented an analysis on the survey conducted to identify the needs of clinic staff and patients in Universiti Sains Malaysia. It is deduced that long queues form during peak hours, leaving both patients and staff dissatisfied.

A low cost, secure, user-friendly, easily installed and flexible queue management system that caters the needs of Malaysians is proposed and implemented. The system consists of a web application and a mobile application, and it incorporates a Time-Series Extrapolation forecast, real-time queue updates and web-based appointment with added reminders. Such features help patients to make better decisions of when to visit the clinic, and help staffs promote appointment punctuality. The web-based appointment system also provides convenience for both patients and staffs to set and reschedule appointments.

The feasibility and effectiveness of the proposed architecture has been successfully evaluated using both quantitative and qualitative methods through tests and interviews. The evaluation has highlighted the stability of the proposed system. The potential of the proposed system has been practically proven with the implementation of the prototype. Interviews conducted have shown a positive attitude towards the developed queue management system.

The future works may be to further improve the system by implementing the routing of web pages without any page refreshes to enhance performance, the improvement of the appointment reminder feature with alarm reminders and the enhancement of the graphical user interface.

The proposed solution does not only offer recommendations for improved patient queue flow at Pusat Sejahtera, but also shows that the use of such sophisticated analytical and informative techniques in the healthcare field can be something valuable and impactful. Thus, the proposed system does not limit to the use of Pusat Sejahtera USM, but can be implemented for other clinics and hospitals' outpatient departments that have a similar situation as well.

In conclusion, quality healthcare delivery is essential for every healthcare provider, as well as Pusat Sejahtera. With the efforts carried out to solve current queue and appointment issues at Pusat Sejahtera, clinics in Malaysia will be able to advance to a higher level of healthcare delivery, with improved patient satisfaction and staff productivity.

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