Increase the System Utilization by Adaptive Queue Management System with Time Restricted Reservation

V. Limlawan and P. Anussornnitisarn

***Abstract*—Traditionally, the ticket queue technology is implemented to manage queuing system, but the disadvantage of the ticket queue is losing queue information. The queue-length and the waiting time is often overestimated when some customer abandons from the queue. The overestimated waiting time intensify the customer abandonment problem which has negatively effects on business revenue and the resource utilization. Based on the problem, this paper aims to study the adaptive queue management system with the queue reservation system and also proposed the time restriction rule for the reservation. In the system the queue information such as queue-length and service time is constantly updated, and the system is allowed customer to reserve the queue if the waiting time is too long. Moreover, the time restriction rule prevents the reservation which affects the system performance. The result shows that the adaptive queue management system with the queue reservation and the time restriction rule outperforms the system without the queue reservation and the time restriction rule. In most cases, the resource utilization of the system is 0.9, and the percentage of customer completed service is more than 90%.**

***Index Terms*—Artificial neural network, exponential weight moving average control chart, queue management system, adaptive system.**

I. Introduction

Managing waiting line is important for service and customer because long waiting line affects the customer perception on service quality [1], [2]. Moreover, the long waiting time in queue also affects the customer loyalty. [3].

In order to manage the waiting line, many businesses traditionally implement the ticket queue technology. Arrival customer receive the ticket which contain queue number and waiting time. Moreover, the remote communication technology such as smartphone and internet also applied with the ticket queue technology. Customers comfortably register to the queue from anywhere.

However, the disadvantage of the ticket queue technology is losing queue information when customer abandon from the system before receiving service. The system does not update queue-length when a customer abandons. The losing queue information affects the accuracy of the estimated waiting time. The overestimate waiting time often provides to each customer and the overestimation intensify customer abandonment problem. Customer abandonment affect business revenue and the system utilization.

To solve the problem, the queue reservation is considered. Instead of abandonment, customer who think the waiting time is too long can reserve their queue. Customer can do other activities before coming back to the waiting area. The queue reservation reduces the abandonment rate and improve the business revenue and the system utilization at the same time.

However, the customer behavior which may affects the system performance has not been studied. Some customers reserved the queue although their predicted waiting time is very small or close to zero. The reserved customers automatically are late, and the late reserved customer affects the system performance.

Therefore, this paper aims to study the queue reservation system in the different customer behaviors in the reservation, and also proposed the time restriction rule for preventing the reservation with the small predicted waiting time. The remaining of this paper is organized as follows. Section II reviews the background of the queue management system. The adaptive queue management system will be explained in Section IIII. The experiments are explained in Section IV, and the result of the experiments are discussed in Section V. Finally, the conclusion of this paper is in Section VI.

II. Background

Submit your manuscript electronically for review. Recently, many businesses generally implement the ticket queue management system. An arrival customer arrives and receive the ticket which contain their queue number, queue-length and the estimated waiting time. After that, the customer comfortably waits for voice calling at the waiting area.

In the ticket queue, customers feel relax because they do not need to wait in the physical queue. They comfortably wait anywhere in the waiting area. Some business provides a luxury waiting area and some hospitality such as comfortable sofa, soft drink, WIFI to customers. Based on the waiting psychology, the queue-length and the estimated waiting time provided to each customer reduce the anxiety of customer [4].

Since the communication technologies such as smartphone and internet are developed, many queue management systems are developed by using remote communication devices. For example, the short message system (SMS) was implemented to the queue management system, so customers can get the ticket by using SMS [5]. LineKing system which use smartphone component and data in cloud was proposed and to estimate the waiting time in a coffee shop [6]. Internet of Things (IoT) was also applied to develop smart ticket

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queue system [7]. The smart queue management system using wireless device was proposed to manage the queue in hospitals [8]. In those system, customers can remotely join the queue and check queue status via their smart phone.

Although customers in those system are convenient, the drawback of the ticket queue system and those systems is losing queue information when customer register and abandon from the queue without receiving service [9]. The system does not update queue-length when the abandonment occurred. The queue-length known by the system is always larger than the actual waiting time. Furthermore, the losing information also affects the waiting time estimation. The waiting time provided to customer is often overestimated.

In order to solve the problem, the adaptive queue management system which use Artificial Intelligence (A.I.) has been applied to monitor and update queue information such as the number of people in queue, the service time of the system [10]. Once the queue information was updated, the updated queue information is used as the input of the waiting time predictor in the system. The system can provide the accurate waiting time to each customer, so customer can plan their activities during waiting.

With the accurate estimated waiting time, the system also provides the reservation option to each arrival customer because customer can choose to stay in the shop or do other activities outside the shop based on the estimated waiting time [11]. Comparing to the system without the queue reservation. The system with the queue reservation improves the revenue and the utilization of the system.

Based on the advantage of the queue reservation system, this research extends the study of the queue management system with queue reservation by investigating the robustness of the system in different scenarios. Many customer behaviors in the queue reservation are studied for improving the queue reservation system. Moreover, the time restriction rule which prevent the reservation with small waiting times is also proposed in this research.

III. Adaptive Queue Management System

In this section, adaptive queue management system with the queue reservation is explained moreover; the time restriction in the reservation is also presented. The adaptive queue management system in this research is based on [11]. In that work, Artificial Intelligence (A.I) has been applied to update and predict the waiting time. Moreover, the queue reservation is implemented to the queue management system.

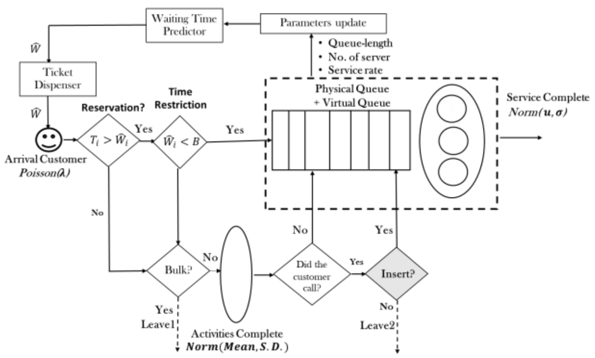

Fig. 1. Diagram of the adaptive queue management system with the queue reservation.

As illustrated in Fig. 1, arrival customer received the ticket which contains the estimated waiting time predictor from the system, and then the customer can choose to stay in the shop or do other activities outside the shop based on the estimated waiting time. The detail of each system component is explained in the following subsection.

A. Waiting Time Predictor

The predicted waiting time provided to each customer is predicted by Artificial Neural Network (ANN). ANN is inspired by the neural network in human brain, and is a powerful tool for solving many problems such as pattern recognition, clustering, prediction [12], [13]. The architecture of ANN in the model is a single hidden feedforward as shown in Fig. 2. In order to predicted the waiting time, the inputs of ANN are average service time, the queue-length and the number of servers. Let **p** be the inputs vectors of ANN, $\mathbf{a}^0$ is the input vector of the hidden layer, $\mathbf{w}^1$ the weight vector of the hidden layer, $\mathbf{b}^1$ is the biased vector of layer 1, $\mathbf{a}^1$ is the input vector of the output layer, $\mathbf{w}^2$ the weight vector of the output layer, $\mathbf{b}^2$ is the biased vector of the output layer $\mathbf{a}^2$ is the output vector of the output layer, f^1 be the activated function of the hidden layer, f^2 be the activated function of the output layer. *u(t)* is the average service time at time t, *Q(t)* is queue-length at time *t*, *s(t)* is the number of servers at time *t*. The calculation of the predicted waiting time ($\hat{w}_i$) is as follows.

$$\mathbf{p} = \begin{bmatrix} u(t) \\ \mathrm{Q}(t) \\ s(t) \end{bmatrix} \tag{1}$$

$$\mathbf{a}^0 = \mathbf{p} \tag{2}$$

$$\mathbf{a}^1 = f^1(\mathbf{w}^1\mathbf{a}^0 + \mathbf{b}^1) \tag{3}$$

$$\mathbf{a}^2 = f^2(\mathbf{w}^2\mathbf{a}^1 + \mathbf{b}^2) \tag{4}$$

The average service time in the system is constantly monitored and updated by Exponential Weight Moving Average Control Chart (EWMA). EWMA is a control chart which monitor and update a small shift in mean [14]. Let *u* be the average service time, σ be the standard deviation of service time, $\hat{b}_i$ be the estimated service time of customer *i*, x_i be the actual service time of customer *i*, λ and *L* be EWMA parameters.

Firstly, the upper bound (UB) and lower bound (LB) of control chart are calculated by using (5) and (6).

$$LB = u_0 - L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{5}$$

$$UB = u_0 + L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{6}$$

The system collects the actual service time, x_i and calculates the estimated service time by using (7).

$$\hat{b}_i = \lambda x_i + (1-\lambda)\hat{b}_{i-1} \tag{7}$$

If $\hat{b}_i < LB$ or $\hat{b}_i > UB$, then the average service time (u) is equal to $\hat{b}_i$

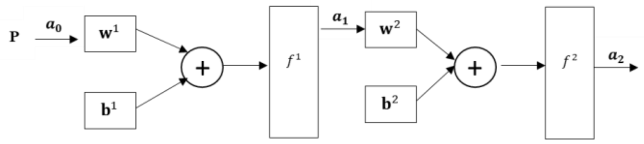

Fig. 2. Diagram of the adaptive queue management system with the queue reservation.

B. Queue Reservation System

Instead of abandonment, the queue management system with the queue reservation allowed customers to reserved their queue as illustrated in Fig. 1. Let the tolerance time of customer i be T_i and the predicted waiting time of customer i be $\hat{W}_i$. If $T_i < \hat{W}_i$, the customers will reserve the queue, otherwise customer will stay at the waiting area.

In the original version of the queue reservation, customers are allowed to reserve the queue although the estimated waiting time of customers is small. The reservation with small waiting time may affects the system performance. The customers who reserve the queue with small waiting time will always be late, and the insert algorithm does not insert all the customers who are late. The utilization and the business revenue might decrease from the reservation. Therefore, the time restriction rule for queue reservation is proposed for managing the reservation of customer. The customers are not allowed to reserve if their waiting time is less than B minutes.

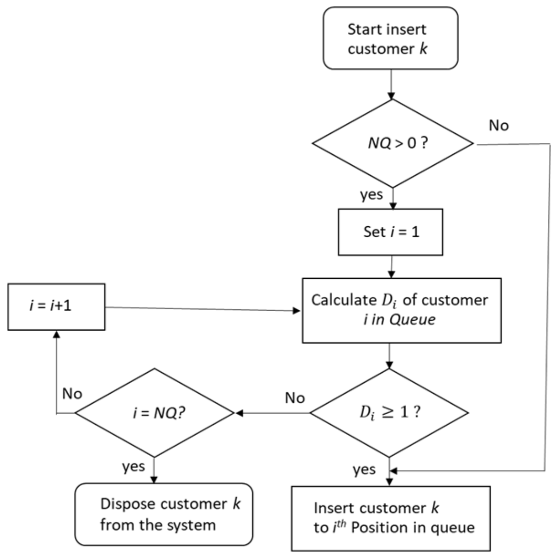

Fig. 3. Steps of the insert algorithm.

For the reserved customers who come back and found that their queue has been called, the system has the insert algorithm which may insert the late customer to the queue. The idea of the insert algorithm is to insert the customers in the available slot which is indicated by the available time of customer in queue. The step of insert algorithm is illustrated in Fig. 3. Let $\hat{W}_i$ be the predicted waiting time of customer i provided by the system, E_i be the elapsed time from the arrival time of customer i, $\hat{R}_i$ is the remaining waiting time of customer i. D_i be the available time slot of customer i in queue. The available time of customer i in queue is calculated by using (8)

$$D_i = \hat{W}_i - E_i - \hat{R}_i \tag{8}$$

The algorithm calculated D_i from the head of the queue to the last of the queue. If $D_i > 1$, then the customers are inserted in front of customer i in queue. With the insert algorithm, the system expected to gain some customers from the abandonment and increase the revenue and the system utilization. Moreover, customers who are inserted back to the queue will be pleased that they will not join the queue at the back of the queue.

IV. Experiment

The objective of this research is to examine the robustness of the queue reservation system in various customer behavior and to propose the time restriction rule in the reservation. The customer behavior in the queuing system is uncontrollable and might affects the performance of the queue management system. Therefore, the adaptive queue management system without the queue reservation, the adaptive queue management system with the queue reservation and the adaptive queue management system with the queue reservation and the time restriction are compared in the test cases.

The simulation of queuing system explained in Section III are simulated by SIMAN ARENA® Rockwell software. The setting of the simulation is as follows.

- The system opens 8 hours a day
- The arrival rate of customer is Poisson distribution with mean λ
- The service rate is normal distribution with a mean of 1 minute and a standard deviation of 0.75.
- The arrival rate, the number of server and the load of the system is based on the schedule in Table I.

TABLE I: The Parameters of Test Systems

Time	Arrival Rate (λ) (min/customer)	Service Time	Resource	P(Load)
8.00-9.00	1.25	Norm(1,0.75)	1	0.80
9.00-10.00	1.05	Norm(1,0.75)	1	0.95
10.00-11.00	0.51	Norm(1,0.75)	2	0.99
11.00-12.00	0.45	Norm(1,0.75)	2	1.1
12.00-13.00	0.30	Norm(1,0.75)	3	1.1
13.00-14.00	0.51	Norm(1,0.75)	2	0.99
14.00-15.00	1.05	Norm(1,0.75)	1	0.95
15.00-16.00	1.25	Norm(1,0.75)	1	0.80

In order to examine the reservation system, the customer behavior such as the tolerance time is used to design the experiment. The tolerance time which is exponential distribution with mean of γ is adjusted to set the different level of customer abandonment. Moreover, the lateness of reserved customer is also varied because the lateness in reality is random and unpredictable. To set the lateness, the activity time outside the shop of customers is adjusted. The activity time is normal distribution with mean u_t and σ_t. u_t is calculated based on the estimated waiting time of each customer, denoted as $\hat{W}_i$, and σ_t is equal to $0.5\,u_t$.

The summary of test case is shown in Table II. Three queue management systems are compared in each case. The time restriction in the queue reservation is set to 5 minutes. The customers who the predicted waiting time is less than 5 minutes are not allowed to reserve the queue.

TABLE II: TEST CASE

Most Likely "On Time"	**Tolerance Time**	**Activity Time while waiting**	**Queue System Parameters**
Low Abandonment	Expo (30)	Norm $(\hat{W}_i - \sigma_t, 0.5\mu_t)$	Based on the Schedule
Medium Abandonment	Expo (5)		
High Abandonment	Expo (1)		
Most Likely "Late"	**Tolerance Time**	**Activity Time while waiting**	**Queue System Parameters**
Low Abandonment	Expo (30)	Norm $(\hat{W}_i + \sigma_t, 0.5\mu_t)$	Based on the Schedule
Medium Abandonment	Expo (5)		
High Abandonment	Expo (1)		

In order to examine the performance of the system, there are three main performance measurements which are the percentage of customer completed service, the utilization of the system, and the accuracy of the predicted waiting time.

The utilization is calculated by SIMAN ARENA® Rockwell software at the end of each run [15], and the percentage of customer completed service is calculated using (9).

$$PC = \frac{1}{N}\sum_{i=1}^{N} r_i \times 100 \qquad (9)$$

where

$$r_i = \begin{cases} 1 & ,customer\ completed\ service \\ 0 & ,otherwise \end{cases}$$

where PC is the percentage of customer completed service, N is the number of arrival customers, r_i is the binary variable which indicate that which customers completed the service.
The percentage accuracy of the waiting time predictor is calculated by (10) – (12).

$$e_i = w_i - \hat{w}_i \qquad (10)$$

where e_i is error of the waiting time prediction of customer i w_i is the actual waiting time of customer i, $\hat{w}_i$ be the actual waiting time of customer i.

$$c_i = \begin{cases} 1 & ,e_i \in [-l, l\,] \\ 0 & ,otherwise \end{cases} \qquad (11)$$

$$\text{Percentage of the Accuracy within } \pm l = \frac{1}{N}\sum_{i=1}^{N} c_i \times 100 \qquad (12)$$

where N is the number of arrival customers, c_i is the accuracy indication of customer i, l is the acceptance tolerance.

In the experiment, ANN is trained by MATLAB R2016a. The tan-sigmoid function and the pure linear function are the activated function of the hidden layer and the activated function of the output layer respectively. The number of neurons of the hidden layer is 5. Backpropagation algorithm is used to trained ANN. The learning rate is 0.05.

For implementing ANN and EWMA control chart in the simulation, ANN and EWMA control chart are programmed by Microsoft VBA for SIMAN ARENA® Rockwell software.

V. RESULT AND DISCUSSION

In order to validate the model, the percentage of customer reservation of the queue management system with the queue reservation and the percentage of the reserved customers of who are late of the queue management system with the queue reservation is presented in Table III.

TABLE III: PERCENTAGE OF CUSTOMER RESERVATION AND PERCENTAGE OF THE LATE RESERVED CUSTOMER

"Most Likely on Time"		
Case	% Reservation	% Late (Reserved Customer)
High Reservation	80.41%	29.12%
Medium Reservation	58.81%	23.37%
Low Reservation	16.79%	19.54%
"Most Likely Late"		
	% Reservation	% Late (Reserved Customer)
High Reservation	58.08%	83.91%
Medium Reservation	28.91%	85.67%
Low Reservation	11.43%	85.50%

The percentage of the reservation for both "Most Likely on Time" and "Most Likely Late" increases based on the tolerance time setting, and the percentage of the late customer in both cases follows the setting in the simulation. In addition, the percentage of the reservation in "Most Likely Late" cases are less than the percentage in "Most Likely on Time" because the waiting time and the load of the system in "Most Likely on Time" is more than the waiting time and the load in "Most Likely on Time" due to the lateness of the reserved customer. The system cannot insert all the customers who are late in the queue.

Moreover, the predicted waiting time of the reserved customer is reported in Table IV for verified the time restriction model. The result shows that the predicted waiting time for all reserved customer is more than 5 minutes in the queue reservation with time restriction.

The result of percentage of customer completed service is shown in Table V. The queue management system with the queue reservation outperforms the queue management system without the queue reservation in all cases, and the time restriction rule for the reservation can improve the percentage of the customer completed service in all cases. For the reservation with time restriction rule, the percentage of customer completed service in "Most Likely on Time" cases are more than 95%. The percentage of customer completed service is a bit lower in "Most Likely Late", but the percentage is more than other models.

TABLE IV: THE STATISTICS OF PREDICTED WAITING TIME FOR THE RESERVED CUSTOMER

"Most Likely on Time"						
	Reservation without Time Restriction			Reservation with Time Restriction		
Case	Mean (min.)	Min (min.)	Max (min.)	Mean (min.)	Min (min.)	Max (min.)
High Reservation	4.12	0.15	24.89	8.11	5.00	27.73
Medium Reservation	7.22	0.05	33.42	10.00	5.00	56.74
Low Reservation	14.76	0.40	58.46	12.02	5.00	33.44
"Most Likely Late"						
	Reservation without Time Restriction			Reservation with Time Restriction		
Case	Mean (min.)	Min (min.)	Max (min.)	Mean (min.)	Min (min.)	Max (min.)
High Reservation	2.18	0.11	14.72	6.47	5.01	20.16
Medium Reservation	3.29	0.11	12.19	7.30	5.00	19.47
Low Reservation	8.23	0.44	24.05	14.01	5.02	46.65

TABLE V: PERCENTAGE OF CUSTOMER COMPLETED SERVICE

"Most Likely on Time"			
	Percentage of Customer Completed Service		
Case	Without Reservation	Reservation without Time Restriction	Reservation with Time Restriction
High Reservation	57.8%	89.2%	96.1%
Medium Reservation	72.7%	93.2%	96.6%
Low Reservation	91.6%	97.9%	98.8%
"Most Likely Late"			
	Percentage of Customer Completed Service		
Case	W/o Reservation	Reservation without Time Restriction	Reservation with Time Restriction
High Reservation	57.8%	76.1%	87.8%
Medium Reservation	72.7%	84.1%	86.6%
Low Reservation	91.6%	93.1%	92.7%

TABLE VI: RESOURCE UTILIZATION

"Most Likely on Time"			
	Resource Utilization		
Case	W/o Reservation	Reservation without Time Restriction	Reservation with Time Restriction
High Reservation	0.78	0.80	0.91
Medium Reservation	0.88	0.87	0.92
Low Reservation	0.89	0.91	0.94
"Most Likely Late"			
	Resource Utilization		
Case	W/o Reservation	Reservation without Time Restriction	Reservation with Time Restriction
High Reservation	0.78	0.80	0.89
Medium Reservation	0.88	0.88	0.91
Low Reservation	0.89	0.91	0.94

Based on the result, the revenue is related to the percentage customer completed service. The more the customers complete service, the more business gain the revenue. The queue reservation with time restriction can improve the revenue of the business in any customer behavior in reservation.

The comparison results of the resource utilization are presented in Table VI. Again, the queue management system with the queue reservation performs better than the queue management system without the queue reservation in all cases, and the time restriction rule for the reservation also improve the resource utilization in all cases. The resource utilization of the system with queue reservation with time restriction is more than 0.90 for 5 out of 6 cases. The queue reservation with time restriction can improve the resource utilization in any customer behavior in reservation.

In order to investigate the effect of the time restriction rule on the waiting time prediction, Table VII shows the percentage of accuracy of the queue management system with the queue reservation plus time restriction rule. The result shows that 95% of predicted waiting time is accurate within 5 minutes for all cases. Based on the result, the time restriction rule does not affect the accuracy of the waiting time prediction.

TABLE VII: PERCENTAGE OF ACCURACY OF THE QUEUE RESERVATION WITH THE RESTRICTION RULE

"Most Likely on Time"				
Case	%Accuracy within 1 min	%Accuracy within 3 min	%Accuracy within 5 min	%Accuracy within 10 min
High Reservation	62.9%	94.1%	98.3%	99.7%
Medium Reservation	61.2%	94.1%	98.7%	100.0%
Low Reservation	56.0%	91.5%	97.4%	99.3%
"Most Likely Late"				
Case	%Accuracy within 1 min	%Accuracy within 3 min	%Accuracy within 5 min	%Accuracy within 10 min
High Reservation	62.7%	90.1%	96.0%	99.8%
Medium Reservation	57.1%	87.4%	95.2%	99.6%
Low Reservation	48.0%	84.6%	95.0%	98.6%

VI. CONCLUSION

In this paper, the adaptive queue management system with the queue reservation has been studied. The system allows customer to reserved their queue and do other activities outside the waiting area. Customers decide to reserve their queue based on the predicted waiting time provided by the system. Sometimes a customer reserves the queue with the small waiting time such as 1 minutes and go outside the waiting area. The reserved customer is automatically late and affects the resource utilization. the time restriction rule of the reservation has been introduced for preventing the reservation with a small waiting time.

The system was tested with the various behavior of customer such as the tolerance time of customer, the lateness of the reserved customer because the behavior of customer is unpredictable. The adaptive queue management system without the queue reservation, the system with the queue reservation and the system with the queue reservation plus the time restriction rule were compared in the difference level of the customer reservation and the lateness of the reserved customer.

The result shows that the queue reservation with the time restriction rule outperforms other models, so the queue reservation with the time restriction rule can improve the business revenue and the resource utilization in all cases. For further study, the limit of time restriction rule should be studied for provided the appropriate restriction time for the system.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

P. Anussornnitisarn and V. Limlawan devised the main conceptual ideas. P. Anussornnitisarn provided the technical support and the direction for this research. V. Limlawan. worked out the technical details, and performed the numerical calculations for the suggested experiment. P. Anussornnitisarn verified and approved the experiments, and supervised the findings of this work. P. Anussornnitisarn and V. Limlawan wrote the paper. All authors had approved the final version.

REFERENCES

[1] S. Tarloy, "Waiting for service: The relationship between delays and evaluations of service," *Journal of Marketing*, vol. 52, no. 1, pp. 56-69, 1994.

[2] K. L. Katz, B. M. Larson, and R. C. Larson, "Prescription for the waiting-in-line blues: Entertain, enlighten, and engage," *Sloan Management Review*, vol. 32, no. 2, pp. 44-53, 1991.

[3] F. Bielen and N. Demoulin, "Waiting time influence on the satisfaction-loyalty relationship in services," *Managing Service Quality: An International Journal*, vol. 17, no. 2, pp. 174-193, 2007.

[4] D. Maister, "The psychology of waiting lines," in *The Service Encounter: Managing Employee/Customer Interaction in Service Businesses*, J. A. Czepiel, M. R. Solomon, and C. F. Surprenant, Eds. Lexington, MA: D. C. Heath and Company, Lexington Books, 1985.

[5] K. Ramasamy and F. Chua, "Queue management optimization with short message system (SMS) notification," in *Proc. International Conference on Economics, Business Innovation (IPEDR 38)*, 2012, pp. 49-53.

[6] B. M. Fatih, Y. S. Yilmaz, M. Demirbas, N. Ferhatosmanoglu, and H. Ferhatosmanoglu, "LineKing: Crowdsourced line wait-time estimation using smartphones," *Mobile Computing, Applications, and Services*, vol. 110, pp. 205-224, 2012.

[7] M. Ghazal, R. Hamouda, and S. Ali, "An IoT smart queue management system with real-time queue tracking," in *Proc. 2015 the Fifth International Conference on e-Learning (econf)*, 2015, pp. 257-262.

[8] M. Ngorsed and P. Sueaowaluk, "Hospital service queue management system with wireless approach," *Lecture Notes in Electrical Engineering*, vol. 375, pp. 627-637, 2016.

[9] S. H. Xu, L. Gao, and J. Ou, "Service performance analysis and improvement for a ticket queue with balking customers," *Management Science*, vol. 53, no. 6, pp. 971-990, 2007.

[10] V. Limlawan and P. Anussornnitisarn, "Design of advanced queue system using artificial neural network for waiting time prediction," *Revista Espacios*, vol. 41, no. 40, pp. 111-124, 2020.

[11] V. Limlawan and P. Anussornnitisarn, "Enhance system utilization and business revenue with AI-based queue reservation system," *International Journal of Machine Learning and Computing (IJMLC)*, vol. 11, no. 3, 2021.

[12] M. T. Hegan, H. B. Demuth, M. H. Beale, and O. D. Jess. (November 2019). *Neural Network Design*, 2nd ed. [Online]. Available: https://hagan.okstate.edu/NNDesign.pdf

[13] O. I. Abiodun, A. Jantan, A. E. Omolara, K. V. Dada, and N. A. Mohamed, "State-of-the-art in artificial neural network applications: A survey," *Heliyon*, vol. 4, no. 11, 2018.

[14] D. C. Montgomery, *Introduction to Statistical Quality Control*, 7th ed. John Wiley & Sons, Inc., 2012, ch. 8, pp. 405-416.

[15] W. D. Kelton, R. Sadowski, and N. Zupick, *Simulation with Arena*, 6th ed. Boston: McGraw-Hill, 2015.

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