The Simulation of Queuing Model for Bangkok Rapid Transit Train Ticket System Using Python

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Abstract

This paper proposes the simulation model for ticket system of Bangkok rapid transit train. The proposed analysis model is applied by using queuing theory to analyze main queuing delay problem rapid transit train ticket machines. This analysis model has been developed by using python programing language to create software tool for analyzing the existing ticket system comparing with the desire variable condition or redesign the ticket system. Since, proposed software tool use for analyze the effect of existing ticket system by modification to visualize the queuing, delay time, waiting time and etc. The software tool with the simulation model can visualize the 2D animation results and graph for analyzation. The proposed analysis model could be used to any rapid transit train ticket system for impact analysis own existing ticket system.

Keywords: Simulation Model, Queuing Theory, Bangkok rapid transit, train ticket system, software tool

1. Introduction

Bangkok is the capital of Thailand and has a population near to ten Million in 2019. Like all other large cities in the world, road traffic congestion is a common and very serious problem. The government of Thailand came to realize that mass rapid transit is necessary to serve as a public transportation system for moving passengers, thereby reducing road congestion. It was not until 19 November 1996, just before the Thailand economic crisis in 1997, the construction of a massive rapid transit system in Bangkok commenced which spans over 19.8 kilometer, covering 18 stations from Bang Sue to Hua Lamphong. After several delays, on 3 July 2004 the line was officially opened. Over the last decades, the number of passengers using mass rapid transit is increasing so significantly that more construction of mass rapid transit lines soon follow using underground, elevated or surface trains. At present, mass rapid transit in Bangkok consists of three networks, the Bangkok Mass Transit System (BTS), the Metropolitan Rapid Transit (MRT) and the Airport Rail Link (ARL). According to the statistics in 2017, this Chaloem Ratchamongkhon (Blue) line carries more than 360,000 passengers daily. This huge number of passengers has indeed caused negative impact on the ticketing system at each station. At peak hours, passengers face difficulties in purchasing ticket due to inadequate ticket machines resulting long queueing delay. This causes unsatisfaction particularly among tourist travelers. In response to this problem, reference [1] applied some basic queueing model to approximately analyze and able to roughly identify the main causes of delay. An analysis model or simulation model of the ticket machine was proposed [2,3]. They discuss issues that focus on specific criteria in each country. In this paper, we propose to develop a more accurate simulation model that incorporates actual traffic data from major stations during peak hours. While collecting real traffic, we observe that congested and long queues can build up at the entrance/exit gates between the ticket system and the trains. Therefore, this nontrivial observation has been included in to our simulation model to achieve more realistic investigation. The proposed simulation model has been implemented in python and extensively tested with real traffic data. Our developed software tool provides graphical visualization for the queuing analysis with 2D Graph and animation.

2. Queuing Theory

In this paper, we apply queuing theory to analyze the impact of queuing time or services time. At first of the normal condition of analysis model, we define the primary ticket system model by M/M/1 Poisson Distribution process in arrival rate λ person/minute and service rate μ person/minute. The expected number of users or L in queue is

$$L = \frac{\rho^2}{(1-\rho)} \tag{1}$$

where

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

$$W = \frac{L}{\lambda} \tag{3}$$

and where W is average of the waiting time.

Typically, if we would like to increase the service rate for reducing the queuing delay, number of ticket machines must be expanded. Therefore, a model of M/M/1 would be replaced by M/M/c model. Therefore, the expected number of users L in queue is

$$L = \frac{\rho}{(1-\rho)^2} P_c \tag{4}$$

where

$$P_c = \frac{(c\,\rho)^c}{c!} P_0 \tag{5}$$

$$P_0 = \left(\sum_{k=0}^{c-1} \frac{(c\,\rho)^k}{k!} + \frac{(c\,\rho)^c}{c!} \sum_{k=c}^{\infty} \rho^{k-c} \right)^{-1} \tag{6}$$

and where c is the number of machines, P_c is the probability that there are c users in the system and P_0 is the probability that there is no user in the system.

3. The Simulation of Queuing Model

From the theoretical model by previous section, we propose the simulation model of ticket system by making propose simulation model using python programming. The propose simulation model could be defined by number of machines of the ticket system. The simulation tools can make the comparison of the previous system or the newer system by own designating the parameter. The examples of the simulation tools were shown in Figures 1 and 2.

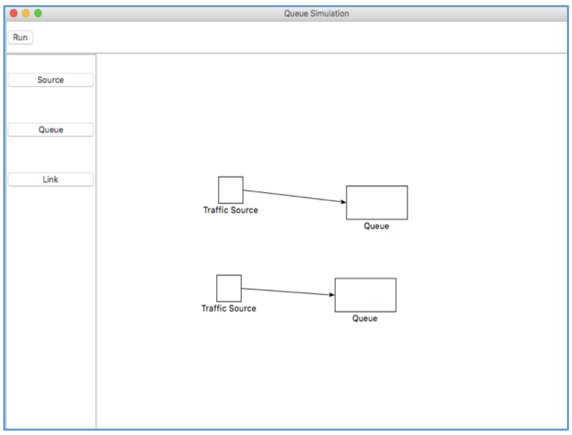

Figure 1 The simulation Tools Graphical User Interface

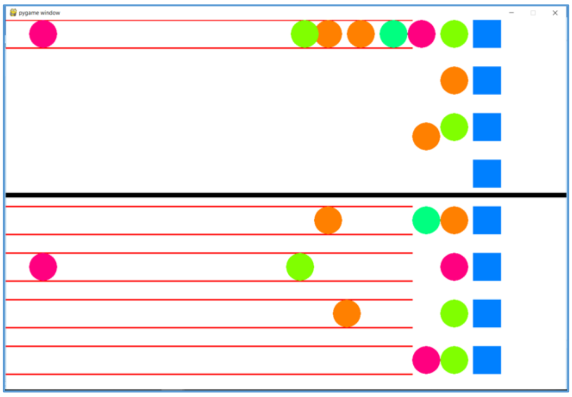

Figure 2 Comparison of 2 System in Animation

4. Experimental Results

In this section, first we present the arrival results of the ticket machine scenarios considered for both single queue and multiple queues. The simulated arrival rate is set at 0.4 passengers per second with 1000 seconds of seconds of simulation time. The average service time of ticket machine is 10 seconds. The number of ticket machine we study is 4. The simulation graphic for single queue and multiple queues is shown in Figure 3 and 4 respectively. These show the operation of ticket machine queuing. In figures, the circles and rectangles are the representation of arrival passengers and ticket machines. The numerical results of our simulation are measured with queue length for comparison of single and multiple queuing performances and illustrated with graph in Figures 5 - 7.

Figures 3-7 have confirmed that our developed software tool provides graphical visualization for the queuing analysis with 2D Graph and animation.

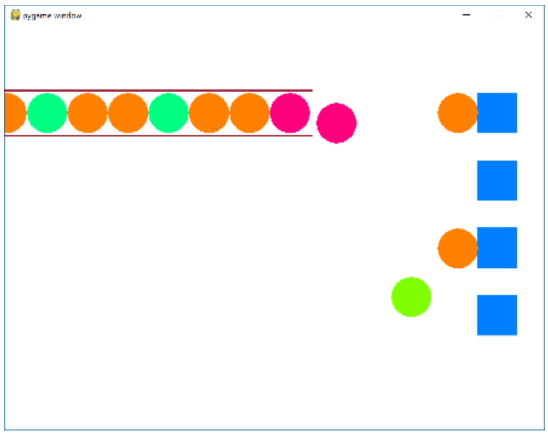

Figure 3 The simulation of single queue for 4 ticket machines

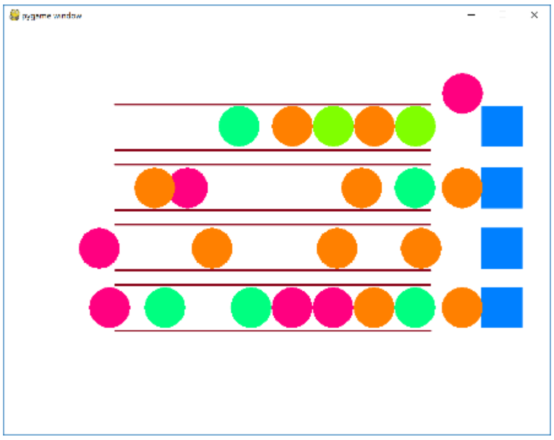

Figure 4 The simulation of multiple queues for 4 ticket machines

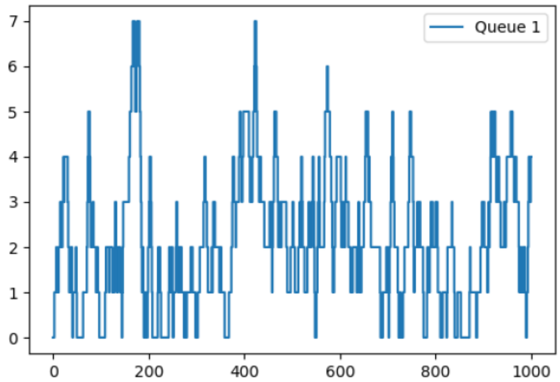

Figure 5 The numerical result of queue length for single queue

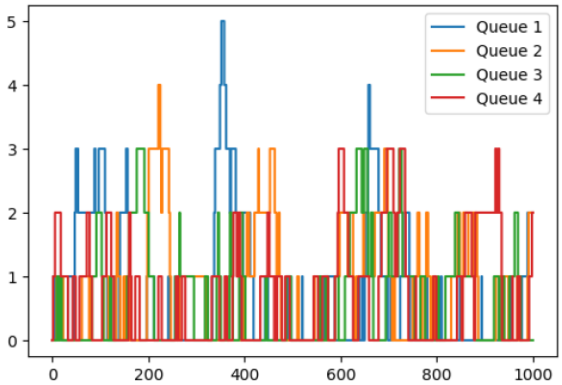

Figure 6 The numerical result of queue length for multiple queues

Figure 7 shows the comparison result of the average waiting time of users between single queue and multiple queues when different of the arrival rate in same service rate with 10000 users simulation.

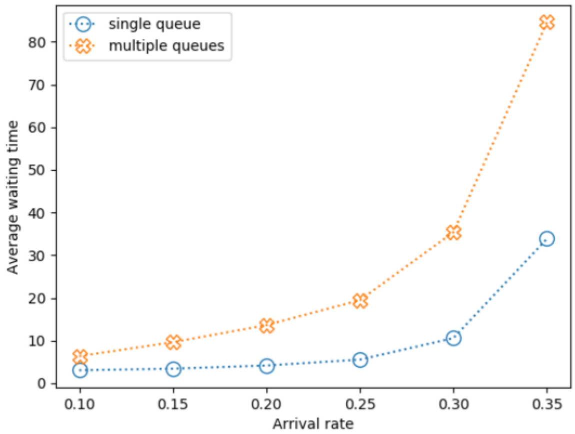

Figure 7 Average waiting time comparison between single queue and multiple queues

Next, we would confirm the experimental results between the propose simulation model and theoretical model. The comparison of simulation model and theoretical model was investigated by comparing the average users waiting time in different arrival rate and same service rate with 10000 users simulation. The results were shown in Figures 8-9.

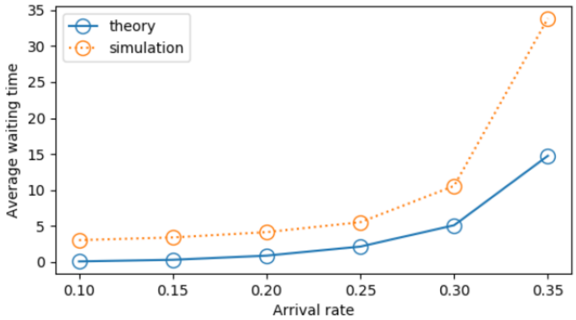

Figure 8 arrival rate comparison the propose simulation model and theoretical model in single queue

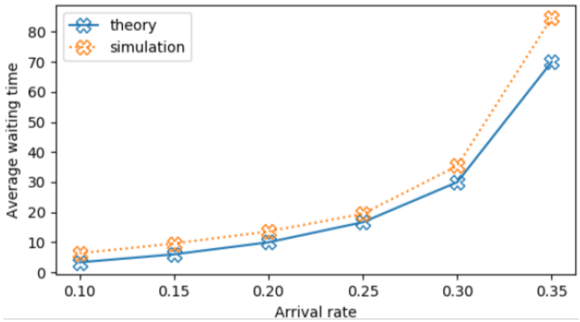

Figure 9 arrival rate comparison the propose simulation model and theoretical model multiple queues

Figures 8 and 9, the results has confirmed that propose simulation model and theoretical model has similarly trend when evaluation in different of arrival rate. However, the simulation average waiting time is much more than the theoretical model because the average waiting time of simulation model was included users walking time to service node.

5. Conclusion

The proposed analysis model can be used to evaluate the service time of railway companies, which enables for the operators to form a proper policy and decide on different ticket system operations based on cost requirements. The proposed simulation model has been implemented in python software tool for analyzing the effect time delay of queues or average waiting time for passengers by comparing ticket existing system and desire modification system. Since, the proposed simulation of queuing model presents the results to show the impact of time delay in queue of passengers when ticket machines are modified by number or feature upgrading. The proposed analysis model could potentially be used to any rapid transit train ticket system for impact evaluation on the existing ticket system.

6. Acknowledgement

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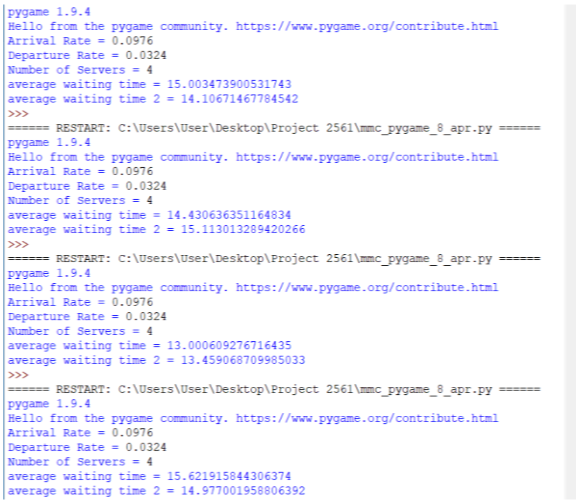
Appendix

Figures 10 - 12, we observe that congested and long queues by collecting real traffic and simulate the mean arrival time to investigate the output of waiting time in real traffic and simulation traffic.

Figure 10 Single queues in non-peak time

Figure 11 Single queues in peak time



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pygame 1.9.4
Hello from the pygame community. https://www.pygame.org/contribute.html
Arrival Rate = 0.0976
Departure Rate = 0.0324
Number of Servers = 4
average waiting time = 15.003473900531743
average waiting time 2 = 14.10671467784542
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Hello from the pygame community. https://www.pygame.org/contribute.html
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Departure Rate = 0.0324
Number of Servers = 4
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Figure 12 Real traffic and simulation traffic observation