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DISCRETE–EVENT SIMULATION OF QUEUING SYSTEMS

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ABSTRACT

The type of queuing system a business uses is an important factor in determining how efficient the business is run. In this project, we examine two types of queuing systems: the single-channel and the multiple-channels queues which are commonly seen in banks and fast food restaurants respectively. We use computer programs to simulate the queues and predict the *queue length*, *waiting time* and *wait probability*. The input to the simulation program is based on the statistics collected over a span of a week. The discrete–event simulation approach is used to model the queuing systems and to analyze the side effects when one system is changed to the other.

INTRODUCTION

As the size of the world's population increases so do the number of queues and their queue length. In the business world, more customers means more business transactions. Out of the many ways to attract customers, an efficient queuing system plays an important role as it reduces a customer's waiting time. As a result, the shorter waiting time makes customers happy, and one thing for sure is that a happy customer will come back for business again.

This paper begins with a description of the single-channel and multiple-channels queuing systems and their influence on a customer's waiting time and wait probability[1]. We use discrete-event simulation program to verify the live data, and predict the performance if the configuration of the existing queue is changed.

General Queue

In a queuing system, the calling population is assumed to be infinite [1]. That is, if a unit leaves the calling population and joins the waiting line or enters service, there is no change in the arrival rate[2]. Figure 1 shows the model used to analyze a general queue. The arrivals occur one at a time in a random order and once the customer joins the queuing system he will eventually receive the service.

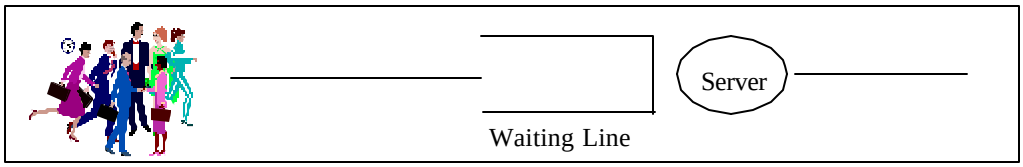

Figure 1: A Simple Queue

[1] The probability that a customer will have to join in a queue when he/she comes to a service station.
[2] The effect of this assumption is negligible if the size of calling population is large.

The arrival rate and services are modeled as variables which follow statistical distributions. If the arrival rate is greater than the service rate, the waiting line will grow without bound.

Single-Channel Queuing System

The single-channel queuing system can be seen in places such as banks and post offices, where one single queue will diverge into a few counters. The moment a customer leaves a service station, the customer at the head of the queue will go to the server. The disadvantage of a single-channel queue is that the queue length seems to be very long, thus it can discourage customers from joining the queue.

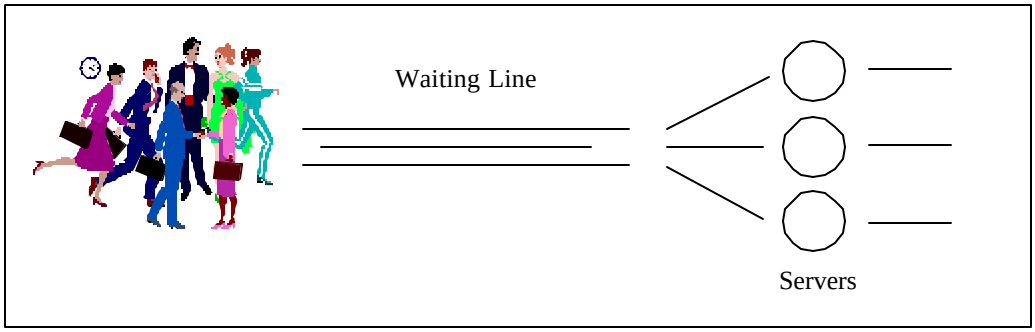

Figure 2: Single-Channel Queuing System

Multiple-Channels Queuing System

The multiple-channels queuing system is commonly observed in fast food restaurants like KFC, Burger King, McDonalds, etc. It is a system whereby the customers line up in rows directly in front of each server. They are arranged in relatively straight lines that do not converge. Generally, the customers in a multiple-channels queue feel happier because the queue length is shortened as they are distributed to different counters.

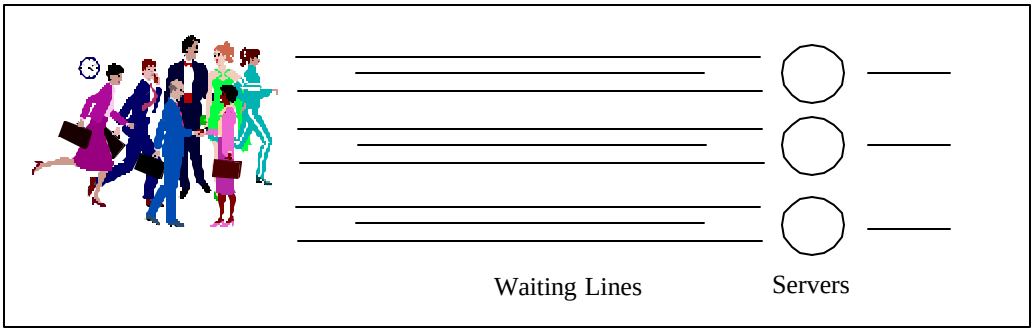

Figure 3: Multiple-Channels Queuing System

Example of a Single-Channel Queue

POSB is a banking service entity that uses the single queue system. Customers join one queue and when they reach the front they will go to a server that is idle. The main characteristic of a single-channel queue is the first-come-first-serve feature.

Example of a Multiple-Channels Queue

McDonalds is a chain of fast food restaurants that uses the multiple-channels queue. The restaurants are centrally located in areas where many people pass through daily like in Town Centres and around Orchard Road. In this type of queuing system the customers can feel a sense of "speed" when they see less people standing in front of them as compared to that in POSB.

MATERIALS AND METHODS

This project evaluates the performance of single-channel and multiple-channels queuing systems, specifically that of fast food restaurants like McDonalds and banks like POSB. To do this, we first went to both McDonalds and POSB to collect the statistical data. We spent a week recording inter-arrival times and service times at different locations and times.

Using the data collected as the input to the discrete-event simulation program, we set up two simulators for predicting the behaviour of a single-channel queue and a multiple-channels queue respectively.

The purpose of using simulation technique to analyze the collected data is to avoid costly design errors, and to analyze the behaviours of the existing systems. More importantly, simulation can be used to predict the performance of the existing system when the input parameters such as the arrival rate and service rate are changed. Simulation technique can also be applied to analyze the behaviours of system which has not even been created yet [2].

Materials Used

The first phase of this project is data collection. We used stopwatches to time the inter-arrival time and service time, and calculate the average timings as shown in Tables 1 and 2.

Table 1: Data collected at Choa Chu Kang and Clementi MacDonalds from 15:30 to 16:30 and 10:30 to 11:30

	Inter-Arrival Time (sec)	Service Time (sec)
Average	48	70

Table 2: Data collected at Taman Warna and Clementi POSB from 15:30 to 16:30 and 15:10 to 16:10 respectively

	Inter-Arrival Time/s	Service Time/s
Average	30	130

In the second phase, we used computer to analyze the collected data. A simulator programmed in C++ was used for this purpose.

Methods

Discrete–Event Approach

Discrete event is a technique used to model the real-world scenarios. In the queuing model two types of events are used, namely arrival and departure [2]. The arrival corresponds to the real-world event when a customer reaches a service station, and the departure corresponds to the event when the customer leaves. Due to the causality constraints, the arrival event for a customer must be executed before its departure event. Each event has a timestamp corresponding to the wall-clock time when it occurs. Discrete-event technique has been widely used in the simulation of communication and transportation systems, such as telephone networks, seaport and airport operations, etc.

The Question: What if POSB changes its queue to multiple-channels and McDonalds changes its queue to single-channel?

We first validate the data collected and compare the deviation of the observed and predicated queue length, waiting time and wait probability. As the simulation results follow closely the observed values, we brought up the question of whether McDonalds and POSB will benefit if they switched their queuing systems. The simulator was used to find out the answers.

The changes to the input data are as follows. To convert from a single-channel queue to a multiple-channels queue for n servers we will have to divide the arrival rate by n because the arriving customers are distributed to the n channels. Therefore, the arrival rate to each channel is scaled down by a factor of n. As for converting a multiple-channels queue to a single-channel queue, the arrival rate is multiplied by n due to the merging effect. The service rate remains unchanged for the conversions.

RESULTS

Tables 3 and 4 show the simulation results. As observed in both tables, the server utilization remains fairly constant as the total workload does not changed. As for converting from a multiple-channels queue to a single-channel queue, Table 3 shows that the queue length is reduced by 48%. More significantly, the wait probability is reduced from 0.68 to 0.35, and the average queue time is reduced from 106 seconds to 11 seconds. This implies that the probability that a customer coming to the McDonalds will have to wait for service is significantly reduced by half, and even if the customer is not immediately served the waiting time is reduced by 9 folds. As such, the change from a multiple-channels queue to single-channel will make a substantial improvement in the queuing performance.

Table 3: Comparison of Queuing Performance for McDonalds

Queue Type	Average Queue Length	Ave. Queue Time (sec)	Wait Probability	Server Utilization
Multiple-Channels (existing)	1.52	106.36	0.68	0.69
Single-Channel	0.78	10.86	0.35	0.68

On the other hand, Table 4 shows that the average queue length, average queue time and the wait probability all become worse if the POSB is to convert its single-channel queue to multiple-channels.

Table 4: Comparison of Queuing Performance for POSB

Queue Type	Average Queue Length	Ave. Queue Time (sec)	Wait Probability	Server Utilization
Single-Channel (existing)	4.25	127.34	0.68	0.86
Multiple-Channels	5.91	883.63	0.87	0.84

CONCLUSION

This paper has evaluated the performance of single-channel and multiple-channels queues using the discrete-event simulation technique. The input to the simulators is based on live data collected at McDonalds Fast Food Restaurant and POSB. Our simulation results show that a single-channel queue is more efficient than a multiple-channels queue. If so, why does McDonalds still want to use the multiple-channels queuing system? From our observations, one reason is that in a multiple-channels queue the customers can hop from one queue to another. Another reason is the impression of shorter waiting time but our simulation result has proven it wrong. While hopping queues may seem to allow customers to get to the server faster, it is not always true. A customer can hop to a shorter queue but the service time needed by the customers in the queue may be longer thus resulting in an even longer waiting time. Another side effect is that it can lead to disorder during the crowded hours and the most recent incident is the fight at McDonalds during their Hello Kitty promotion.

POSSIBLE FURTHER STUDIES

The simulation of queuing system can be applied to many real-world applications from car parking in multiple-storey carparks to ship docking at seaports. If it were possible to improve the queues, there would be more profits made and more time to carry out business than ever before, which would be very useful in this fast paced world.

ACKNOWLEDGEMENTS

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