Queuing of Café de Coral during weekday lunch hour

Introduction

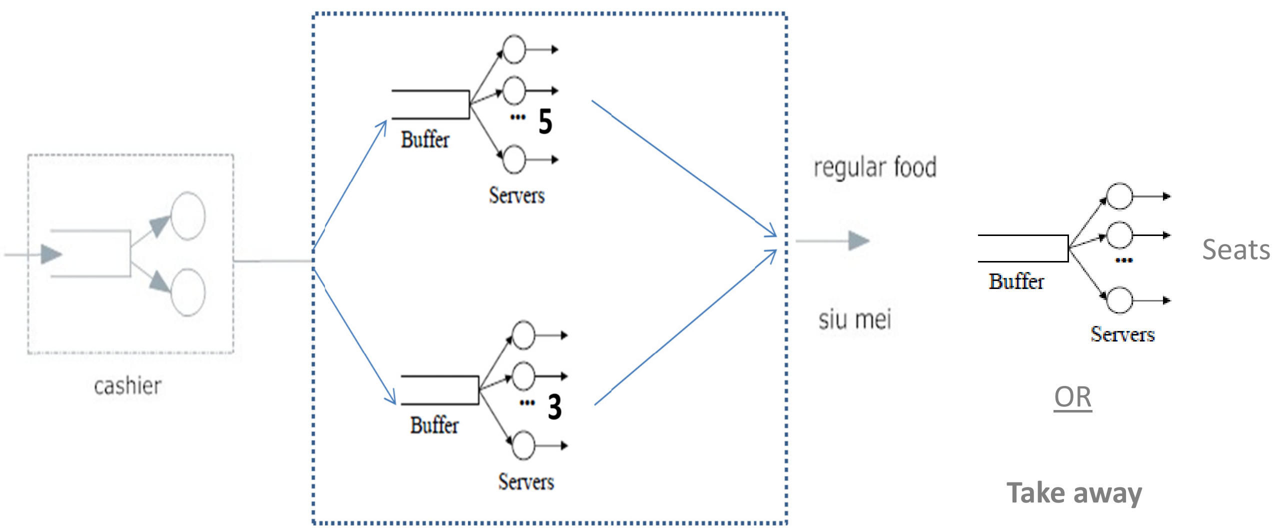
Background

In this project, we were asked to simulate a model that truly exists in the reality regarding to the queuing system. And the topic that we focus on is the Queuing of Café de Coral during weekday lunch hour. Café de Coral is a leading fast food chain in Hong Kong. Currently it operates over 120 restaurants and caters to about 300,000 people on an average day.

As Café de Coral is a big scale fast food chain in Hong Kong, it seems impossible to visit all of the branches of it. Therefore we would prefer to visit one of the branches with crowed population in a certain period which is lunch time from 1:00pm to 2:00pm.

System modeling

Before simulating the model of Café de Coral, we must need to know how the fast food runs in real situation. Hence, we have been to the one of the branch nearby Tai Po market MTR station for the investigation during lunch period. We noticed that actually the whole process of Café de Coral can be represented by three components and they are indicated in the following diagram.



As the diagram shown above, the first component, cashier is the area that provides customers a foods order list and also makes the payment for ordering foods. And the cashier can be presented as a single buffer, two servers queuing system. After that, according to the preference of foods that the customers ordered, they would go to either the queue of regular foods or the queue of “Siu Mei”. By our observation, we are aware of the rule that the maximum number of tray placed on the bench for the queues of regular foods and “Siu Mei” are five and three respectively. And they also can be presented as single buffer, five servers queuing system and single buffer, three servers queuing system correspondingly. Finally, after the foods that they ordered are delivered, they probably either looking for a seat or taking away.

During the investigation, we discovered a phenomenon that the queue of regular foods was always longer compared with other queue of “Siu Mei” during the lunch hour. As we were also in the period between lunch time and tea lunch, we noticed that there was a transformation between the queues of regular foods and “Mei Siu” that the queue of “Mei Siu” became longer than the queue of regular foods.

Based on our observations, we are curious about what we had found. So, we decided to focus on the main component which is composed of the queues of regular foods and “Siu Mei” and start the processes of the model simulation.

Input data analysis

During the investigation, we also collected the data that we use to simulate by using the software program such as stopwatch due to the limited memory of human being. We took around sixty of customers as our sample and record down the inter arrival time and service time of each customer.

Data type

As mentioned above, the data we took are inter arrival time and service time and both of them are belong to continuous data that result from infinitely many possible values that the observations in a set can take on. The term "infinitely," however, does not refer to the "countable" term we have seen with discrete date types. Continuous data types involve the uncountable or non-denumerable kind of infinity, which is frequently referred to as the number of points on a number line. In other words, the observations of this data type can be associated with points on a number line, where any observation can take on any real-number value within a certain range or interval.

Selecting input distributions

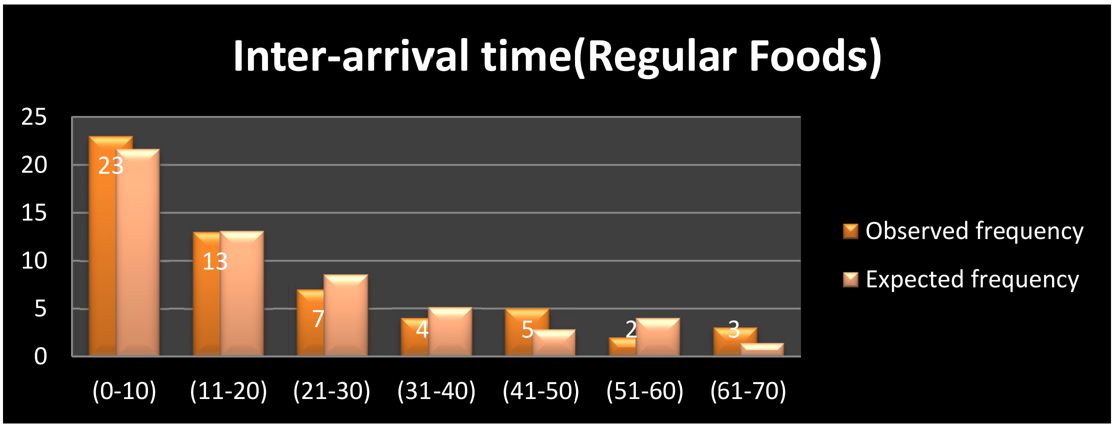
When selecting an input distribution that that can fit with the data sample that we took, we had to do the analysis in the data first. We would like to describe as a table showing the values of observed frequency and expected frequency, calculated by using chi square goodness fit test, in respect to the sample data. What is more, we also indicate the histograms that illustrate the comparison between observed frequency and expected frequency.

Regular foods

Inter-arrival time

For the inter arrival time, we choose exponential distribution and see whether it fits with the sample data or not.

inter arrivial time		
Interval	**observed frequency**	**expected frequency**
(0-10)	23	21.66
(11-20)	13	13.11
(21-30)	7	8.55
(31-40)	4	5.13
(41-50)	5	2.85
(51-60)	2	4
(61-70)	3	1.425
P value=	0.546837887	
Error=	4.976444146	

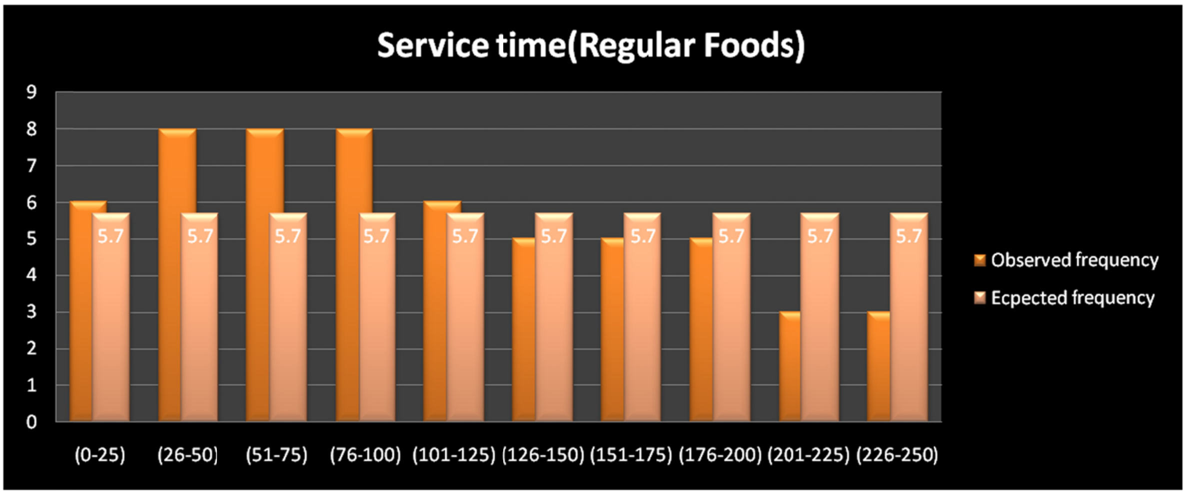


Based on the diagram and the table above, we can clearly see that the difference between the observed frequency and the expected frequency is small with the value of P = 0.546837887 and the number of customers decreased dramatically in both observed and expected frequency when the time is get longer. So, we can say that the inter arrival time of each customer in the queue of regular foods fits with exponential distribution.

Service time

For service time, we choose uniform distribution and see if it fits the sample data.

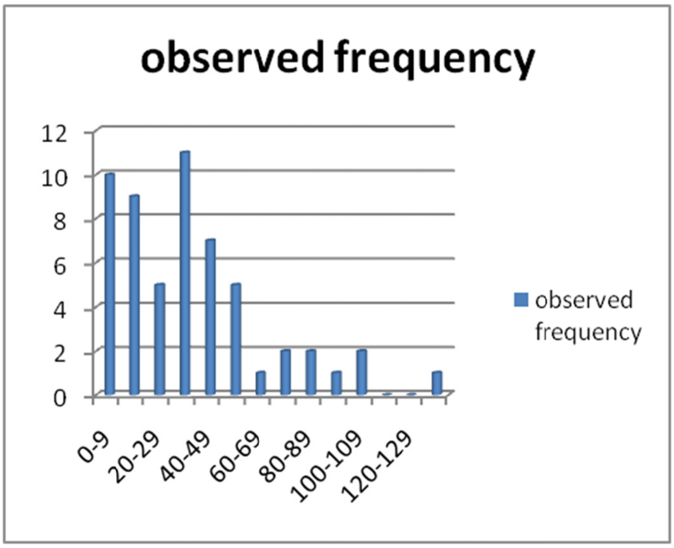
Service time		
Interval	**observed frequency**	**expected frequency**
(0-25)	23	21.66
(26-50)	13	13.11
(51-75)	7	8.55
(76-100)	4	5.13
(101-125)	5	2.85
(126-150)	2	4
(151-175)	3	1.425
(176-200)	5	5.7
(201-225)	3	5.7
(226-250)	3	5.7
	P value=	0.776149625
	Error=	5.6315788947



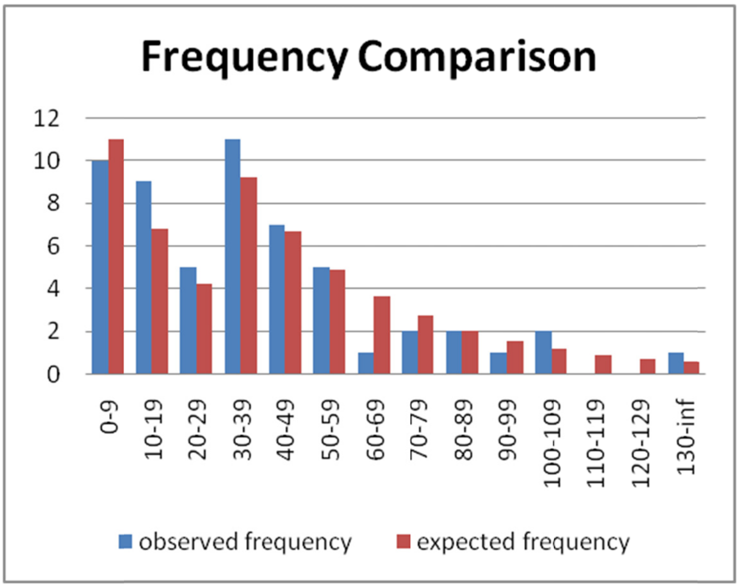
Based on the diagram and the table above, we can clearly see that the difference between the observed frequency and the expected frequency is small with the value of P = 5.6315788947 and the number of customers level off at around six customers in both observed and expected frequency at any period. So, we can say that the service time of each customer in the queue of regular foods fits with uniform distribution.

<u>Regular foods</u>

Inter-arrival time



We observed a “double peak” distribution of the inter-arrival time. We believed that normally a customer would enter the siu mei queue in every 30-50 seconds. The left peak is explained by batch arrival, in which the arrival of customers is almost simultaneous. It could be the two cashier lines eject two customers ordering siu mei at the same time. Or it could be friends staying together in the queue. Suppose batch arrival follows exponential distribution, and normal arrival follows another exponential distribution. We hypothesized the observed data to follow two super-imposed exponential distribution, with one of them shifted to the right.



We adjusted the two lambdas in the probability density function until the theoretical histogram fits the observed one. The parameters were fine tuned to minimize chi-square statistic *D*.

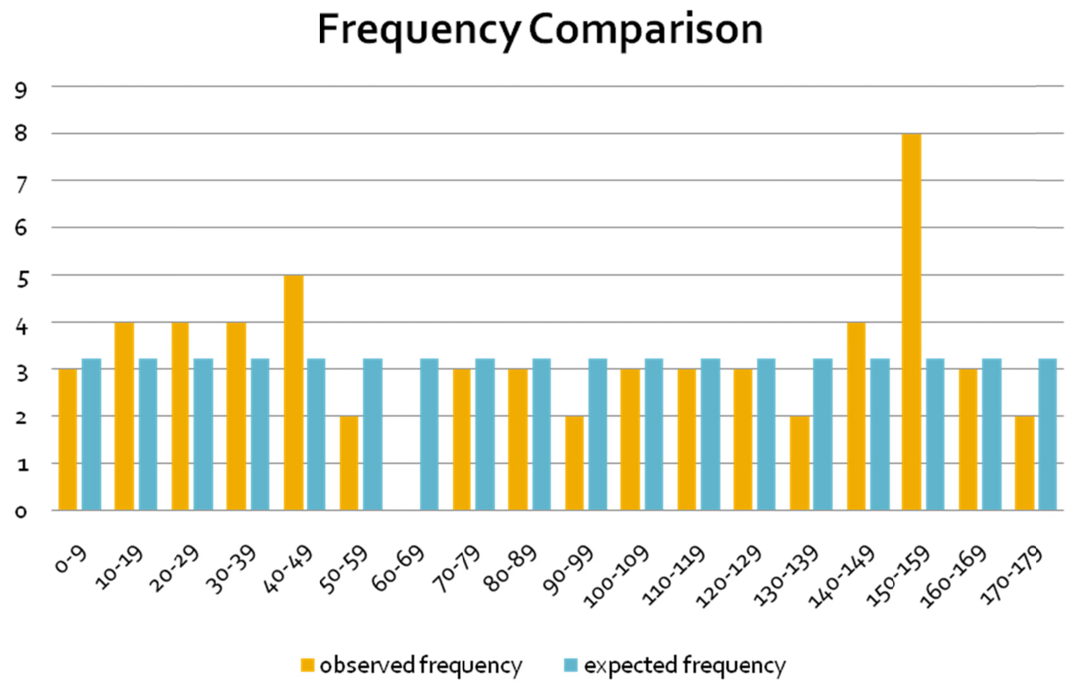
$$p(x) = c\,(0.048e^{-0.048x} + 0.026e^{-0.026(x-30)})$$

Where c = 0.51473924

The test statistic *D* is 6.1426. Null hypothesis is not rejected at significant level of 5%.

Service rate

In the siu mei counter, service rates depends on food ordered, take-away, allocated staff, etc. The longest service duration recorded is 176 seconds. By frequency comparison we hypothesized it following a uniform distribution U (0, 180).



The test statistic is 14. Null hypothesis is not rejected at significant level of 5%.

CSIM Implementation

We implemented a CSIM program to model food queues. New customers are generated according to input distributions selected. The queues are modeled as single-buffer multi-server system. A server represents a food tray on the bench. In reality the number of food trays fluctuates. In the model we assumed it to be fixed.

We simulate the operation of each system for two hours. We repeated the whole simulation for 31 times. Each time we used a different random number sequence. After we collected 31 means for each performance measure, we can construct their confidence intervals using normal distribution.

Output Data Analysis

Mean response time measures the duration from entering the siu mei queue until the customer has fetched his meal. Completed count measures the number of customer siu mei section has served in two hours of simulation. Time-average queue length indicates the typical length of siu mei queue; maximum number in system refers to the maximum sum of customers waiting in siu mei queue and in front of his food tray.

At 90% confidence level:

number of server	response time	completed count	queue length	max. no. in system
2	(888.1, 2154.7)	(145.9, 172.0)	(20.5, 46.1)	(44.3, 87.2)
3	(78.0, 378.8)	(193.6, 230.0)	(1.9, 11.5)	(8.6, 26.7)
4	(90.6, 129,1)	(198.4, 239.0)	(2.5, 4.1)	(6.8, 14.4)

When number of food tray is controlled to be 2, system performance is obviously worse in every aspect.

System Comparison

The Tai Po branch of Café de Coral we observed were using 3 servers in the siu mei section. We may presuppose that adding one more server could improve the performance of siu mei section. We compared such configuration with current 3-server practice. Using paired-t comparison with standard, we set the overall level of significance to be 10%.

compared against	response time	completed count	max. no. in system
2	(648.2, 1937.7)	(-76.3, -29.4)	(28.2, 68.0)
4	(-285.4, 48.2)	(-3.8, 17.7)	(-15.0, 0.9)

Highlighted intervals include 0. It indicates that transforming from 3-server to 4-server system does not improve completed count and maximum number in system. The mean response time recorded in all replications has a high variance. Therefore it is arguable that 3-server is statistically different from 4-server system, and that 4 food tray system could reduce the mean waiting time of customers. Although this could improve customer experience, Café de Coral has strictly controlled siu mei queue to have 3 trays only. As seen, the gesture does not increase the customer flow during lunch hour. It does not reduce maximum queue length very much either. By purely business consideration, the restaurant has no incentive to make such change. It seems that Café de Coral knows the optimal queue system configuration in prior.

Discussion

There are other reasons for Tai Po Café de Coral to keep siu mei queue to stay in 3-server system. If siu mei section expand, regular food queue will have less resource to use. This is because siu mei and regular food sections are sharing the same bench and same staff, which is limited.

At lunch time, regular food queue is always accumulating. Yet there are times when siu mei section is serving no customers but still holding a space of 3 food trays on the bench. By simulation result, allocating one more tray space to regular food section runs a big risk for system performance of siu mei queue. Therefore it is forced to be under-utilized sometimes. We expect a similar scenario at breakfast and dinner time.

The situation is reversed from 2pm to 3pm when in tea time siu mei food is more popular. The regular food section is empty. Siu mei queue is long enough to cram the already limited space inside the restaurant.

Café de Coral could have used price mechanism to balance the demand for siu mei and regular food. Since this is not so feasible, we suggest abolishing the siu mei queue. Staff will schedule the delivery of siu mei food as one of the regular foods. Extra space can be freed up in peak hours. Mean response time for siu mei and regular food customers will converge. But mean response time as a whole is expected to fall, hence customer flow improves altogether.