Queueing Project: Dunkin' Donut Drive-through

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OR 6620: Probability Models for Decision Making

Executive Summary:

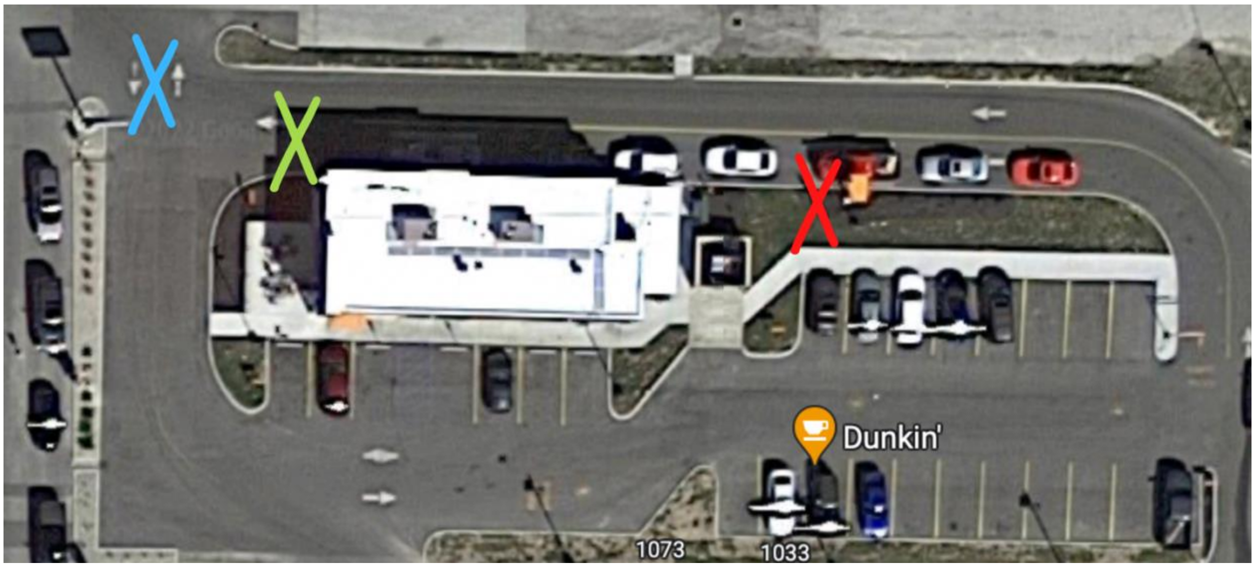
Our group studied the Dunkin' Donuts drive-through service at S Main St., Bowling Green. During the data collection process, we recorded the arrival time of each car, the time it entered service (started speaking at the ordering screen) and the time it left service. We did this for 54 cars during a 90-minute period on Thursday 14th April 2022. To analyze the data, we calculated the inter-arrival times, queueing time, service time and waiting time for all customers.

The arrival pattern appeared like a Poisson process with mean 1.57 minutes between arrivals. The service and waiting times, didn't follow any commonly known distribution. Upon analysis of the data, we noticed the system was best described as a 4-node tandem queue network as opposed to the M/M/1 model we had assumed when collecting the data. This made our data modeling section to be quite difficult as we didn't record the service and queueing times at each node.

For further exploration of this system, we would need to observe the service time at the second node when the baristas are making the food and drinks. This would better enable us to fit the model appropriate to the Dunkin Donuts drive-through system.

Introduction

The queueing setting was the drive-through of Dunkin' Donuts located at 1049 S Main St, Bowling Green, OH 43402. We Observed the drive-through on Thursday 14th April 2022 from 11:07am till 12:37pm which is a peak period. We got the data of 54 cars which we used in our analysis. The picture below is the Satellite picture of the Dunkin' Donuts we visited.



During the data collection, we collected 3 times:

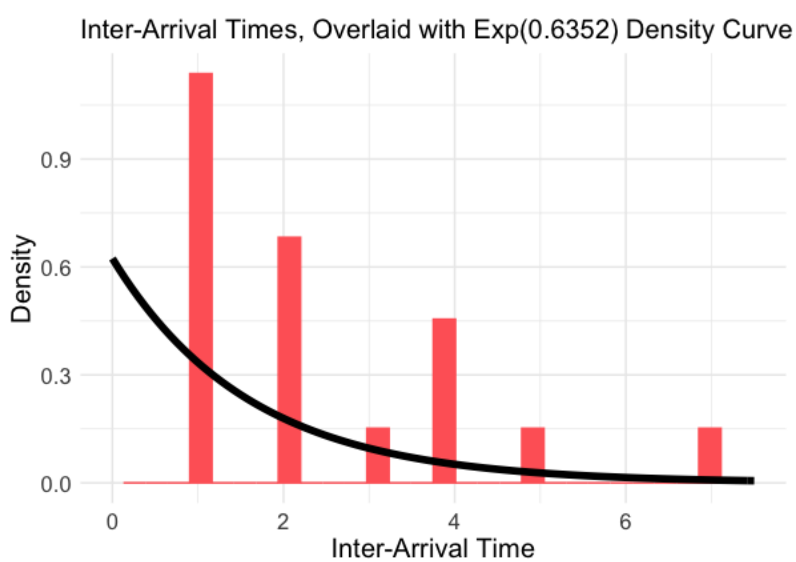
1. The Arrival time of each car which was collected at the blue colored point X in the picture above. This was recorded by Segun.
2. The time of entrance into service which we collected at the red colored point X in the picture above. This was the point they placed their order. This was recorded by Nzube.
3. The departure time which was the time they left the service area. This was collected at the green colored point X above. This was recorded by Virtus.

We collected the data through paper and pen, and later collated it into an Excel sheet. We all recorded the color and make of the car to help in the final data collation process.

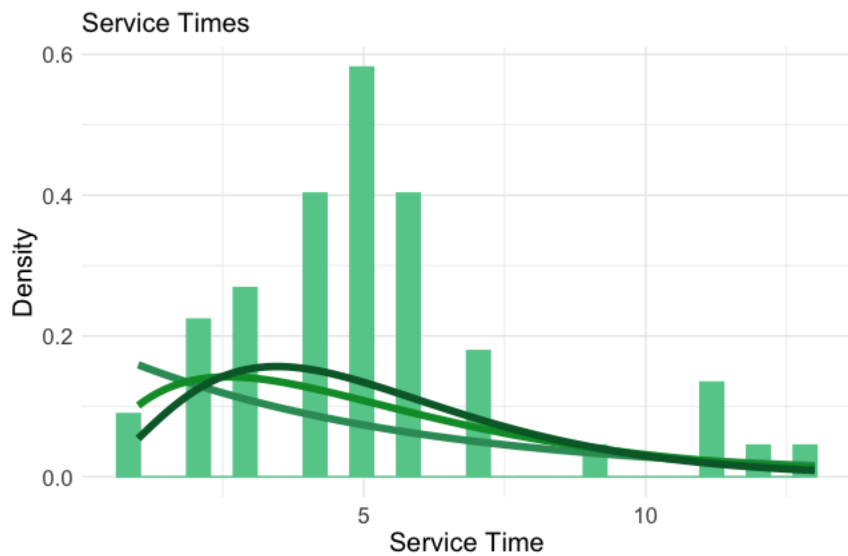
Data Analysis

We began our analysis by recording the written data into Excel as time stamps first which we later converted into minutes to help with our calculations. To get our interarrival time, we subtracted the lag of the arrival times from the arrival times. We calculated our queueing time from subtracting the arrival time from the time of entrance into service. We calculated the service time from subtracting the time of entrance into service from the departure time. We calculated the waiting time from subtracting the arrival time from the departure time. Their means and rates are shown in the table below.

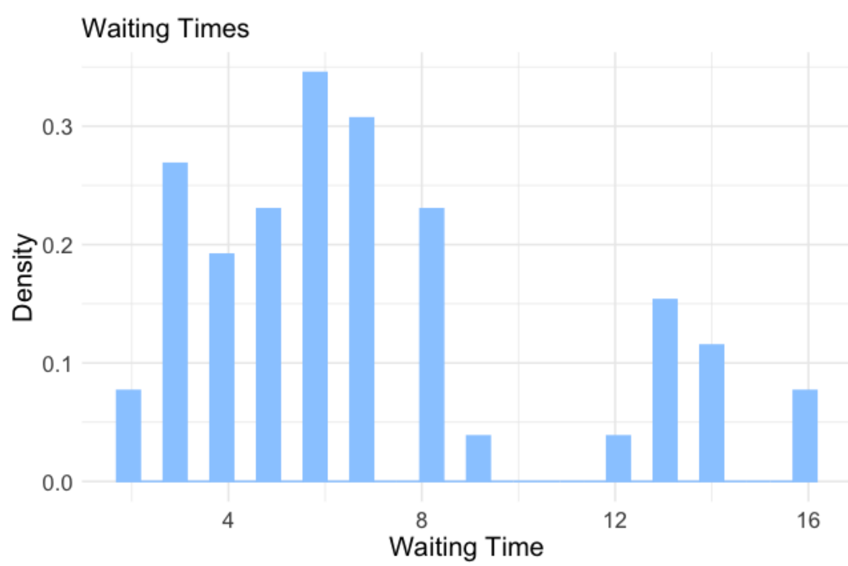
	Mean (minutes)	**Rate (per minute)**
Inter-arrival time	1.574074	0.6352941
Queueing Time	1.851852	0.5400000
Service Time	5.185185	0.1928571
Waiting Time	7.037037	0.1421053



The plot above shows us that the inter-arrival times appears to be somewhat exponential, with a rate of 0.6353 cars/minute. The Exp(0.6353) density curve which over lays the plot further confirms this claim. To model the service time, we plotted it alongside the density curves for exponential, Erlang type 2 and Erlang type 3. We see that none of them fits the data very well.



The plot of waiting times which is the total amount of time a customer spent at Dunkin' Donuts appears to be left skewed. It doesn't appear to follow any known distribution.



Modeling

After performing data analysis, we realized that the Dunkin' Donuts drive-through queueing setting is best described by the tandem queueing model with 4 nodes. The first node would be placing the order at the screen while the second node would be the baristas preparing the orders (food and drinks), the third would be where the customers pay for the order and the fourth would be where they receive the delivered food. Our data collection process was limited as we couldn't find out how many baristas were making the food and drinks in the kitchen for the customers.

Explaining the Kendall notation, the arrival pattern as we said in the data analysis part strongly follows a Poisson process. Since we don't have data for the number of baristas making fulfilling orders, we would assume the number of parallel servers is one. The system capacity for the ordering screen is un-capacitated since it is a drive-through and cars can join the queue without restriction. While the system capacity for the other nodes has capacities as only about 5 cars can be parked between the ordering screen and the collection window. We can see that the calling population is infinite since there is no limit to the number of people that can use the drive-through ranging from residents of Bowling Green and people in transit that want to get a snack for their journey.

At the point of data collection, we didn't know this was a tandem queue, so we only collected the arrival time of each car, the time it entered service and the departure time. We didn't get the time they spent at each node, so we were unable to perform an analysis of the service time at each node of the network.

Dividing 4 (the number of nodes in the network) by the mean service time, and using the overall arrival rate we observed, the waiting time at each node is 7.346 minutes and the total time in the entire system is 29.38 minutes which doesn't match our mean waiting time 7.037 minutes. This calculation doesn't seem appropriate since the service time we recorded includes queueing time, but it is the best we could do given the data we collected.

Conclusions

The queue at the other nodes is highly dependent on the queue at the first node (the ordering screen), this is a huge weakness of this model. So, the routing of a customer amongst the nodes is highly dependent on the customers before them. As a recommendation for a better queueing model, we would observe the indoor orders placed in Dunkin' Donuts. This should be an M/M/s queue based on the number of servers there.

Appendices

The R code and excel file has been attached to the Canvas assignments area.