STA240 Final Project: Kakuritsu Ramen Restaurant Simulation

Tamsin Connerly, Eunice Lee, Sarah Wu

May 3, 2024

Background

We are looking to open a restaurant named Kakuritsu Ramen in Downtown Durham. To create a business plan, we are making two models, one simplistic and one more complex, to analyze the average time a customer spends in line, the average amount of down-time during the working day, and the ultimate profit of the restaurant. This information will help us to determine how many chefs the restaurant should hire and how much down-time to allocate in order to maximize profit. A January 2022 survey found that 73% of people in the United States are not willing to wait more than 30 minutes for a table at a restaurant.[1] Based on this statistic, we should aim to limit waiting time to 30 minutes.

Scenario #1

Scenario and Assumptions

To build a basic model, we create a simulation with 1 dining table and 1 chef. We assume that there are no breaks between 10 am - 10 pm and that the rate of customer arrival throughout the day is constant. We assume that customers arrive according to a Poisson Process with a rate of $\lambda_A = 5$ per hour. Once a customer arrives, their total service time (ordering, cooking and eating) can be modeled by an exponential distribution with rate $\lambda_S = 6$.

Variables

In this scenario, we track the number of customers waiting, the queue time, and the down-time (defined as no customers are being served and no one is in the queue).

$N = individual\ customer$

$W_n = Wait\ time\ at\ table\ for\ customer\ n\ (to\ be\ served,\ to\ eat)$

$A_n = Arrival\ time\ of\ customer\ n$

$O_n = Total\ time\ in\ restaurant\ for\ customer\ n$

Formulas

$\{A_n\} \sim A_{n-1} + Exp(\lambda_A)$

$\{W_n\} \sim Exp(\lambda_S)$

$O_n = A_n + W_n + max(0, O_{n-1} - A_n)$

$Queue\ time\ of\ customer\ n = max(0, O_{n-1} - A_n)$

Methodology

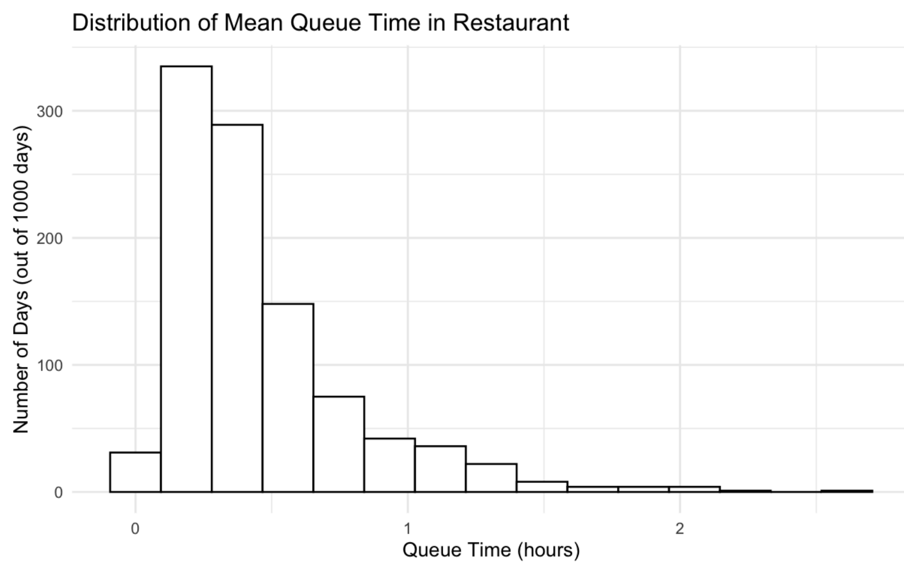
We simulate this scenario by modeling with R. Our full code is attached separately (on Sakai).

[1] https://www.statista.com/statistics/1325352/opinions-maximum-waiting-times-at-restaurants-us/

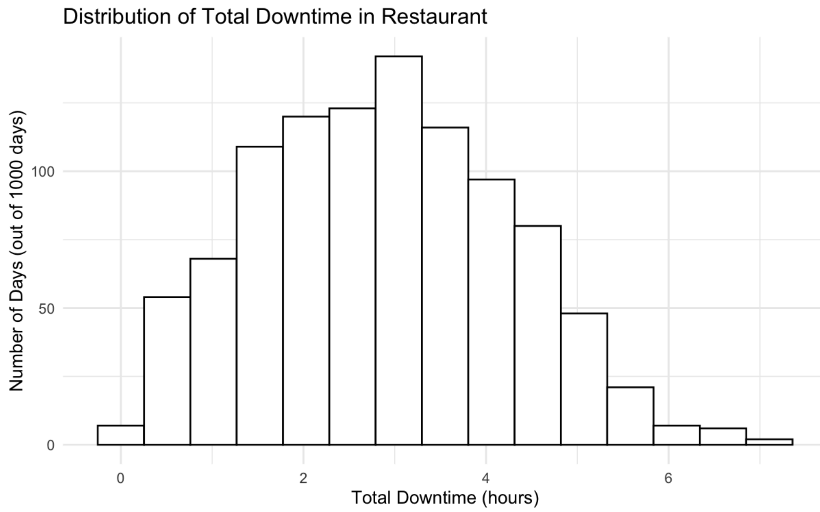
Using our given rate of customer arrival, we randomly generate from the exponential distribution using the rexp() function and keep track of the timestamps of customer arrival from 10am to 10pm (where 10am is the 0th hour and 10pm is the 12th hour). This is calculated by adding the time until the next customer to the arrival timestamp of the last customer. We also separately calculate the serving time taken once a customer is seated, randomly generated from the exponential distribution using our given rate. Then, we calculate the time in the queue (if any) by taking the max of 0 and the time obtained by subtracting the arrival time of the current customer from the leaving time of the previous customer. Our final leaving timestamp of the customer can be calculated by adding serving time and queue time to their arrival timestamp. This loop continues until we detect that the last customer left after the 12-hour mark (whom we don't serve).

We observe trends on customers' waiting experience by examining patterns in queue time. We also observe the amount of down-time in our restaurant. To assist with calculating down-time, we calculate how many people are in front of the current customer by checking how many previous customers have leaving times that are greater than the current customer's arrival time. We add up all the time frames in which a customer arrived at the restaurant and there was no one in front of them, subtracting the leaving time of the customer before from the arrival time of the current customer.

<u>Results & Analysis</u>



We run this simulation 1000 times to simulate 1000 days, then calculate the mean statistics. Based on the simulation, the mean queue time is 0.6586 hours (39.5 minutes) with a standard deviation of 0.3866 hours (23.2 minutes). Given that most people do not want to wait more than 30 minutes in line, the number of tables and chefs for this scenario is not efficient.



This simulation also has a mean down-time of 2.8860 hours with a standard deviation of 1.3712 hours. Given the large down-time, it may be reasonable for the restaurant to close down for ~2.8 hours per day to focus on prep and save costs on paying the chefs.

Scenario #2

Scenario and Assumptions

In this next, more complicated scenario, we assume that the restaurant has 5 dining tables and L chefs. We continue to assume that the restaurant is open for 12 hours, between 10 am to 10 pm. Furthermore, we assume that customers arrive according to a Poisson Process with a rate of $\lambda_A = 10$ per hour and that a customer's total service time is modeled by an exponential distribution with rate $\lambda_S = 3L$. We estimate profit using the given information that a customer spends $50 per meal, and each chef earns a wage of $40 per hour.

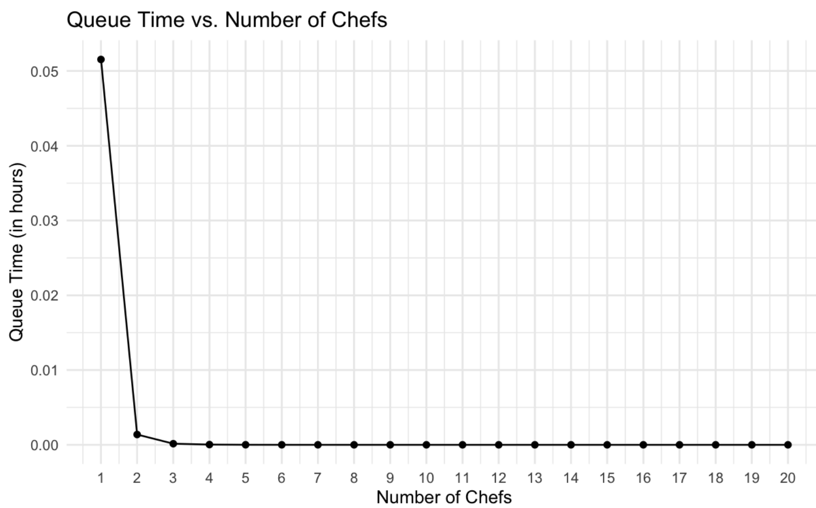
Methodology

Drawing on the principles from the first scenario, we simulate this scenario by modeling with R. Again, our full code is attached separately (on Sakai).

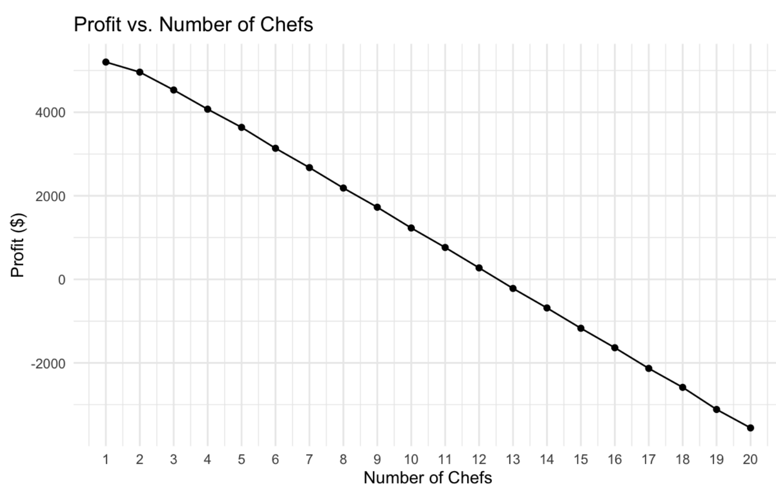
Building on our main framework from Scenario #1, we keep track of arrival times, serving times, and leaving times to find trends on queue times, which signify the customers' waiting experience. This time, however, we consider two additional variables: the number of tables and the number of chefs. The number of chefs is directly used to model the rate of serving time, as more chefs lead to a quicker rate. When calculating queue time, we check if the arriving customer has to wait or not by checking if the number of total tables is greater than the number of people in front. If all tables are full, we calculate how much longer each present customer is at the restaurant. Then, we sort the times and take the index of the minimum number of people that need to leave the restaurant in order for the current customer to be seated.

Leaving times can be calculated in the same manner as Scenario #1. After modeling this, we additionally calculate the profit that our restaurant will make by subtracting the amount we have to pay the chefs (assuming we hold constant the number of chefs throughout the day) from the total revenue made by serving the simulated number of total customers. In order to maximize profit, we would have to find an optimal spot that gives the largest return when we balance revenue (number of customers) to payments (number of chefs). We also need to balance this with the mean queue time to ensure that customers are not waiting for an over extended period of time for a satisfactory dining experience.

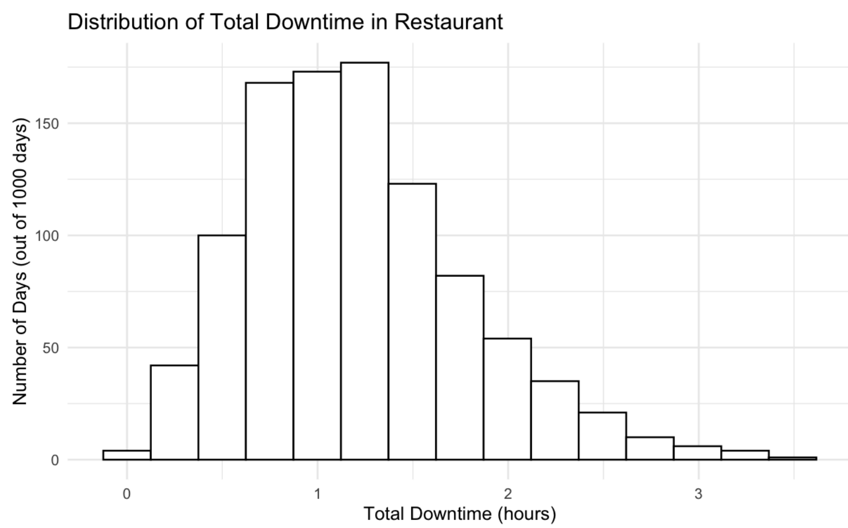
Results & Analysis



We run this simulation 1000 times to simulate 1000 days, then calculate the mean statistics. According to the model, the mean queue time is significantly higher at 1 chef (0.0515 hours or 3.09 minutes), and the mean queue times are lower and more consistent for 2 or more chefs (0.00138 hours or 4.968 seconds for 2 chefs).



The simulation shows that the profit is the greatest, however, with 1 chef ($5200.60) and then starts decreasing. 2 chefs yields a profit of $4959.70, and each additional chef continues to decrease profit. Despite lower mean queue times with 2 chefs, we believe that the $240.90 profit trade-off is not worth it because the average queue time only decreases by 3.007 minutes, a wait time customers would likely still be satisfied by. Thus, we recommend that the restaurant hire only 1 chef to maximize profit (from a business perspective). Though we recognize that having one chef would increase the serving time, we believe that customers will be more lenient to wait when seated at a table. Therefore, we are not too concerned by the increased service time, which, in this scenario, still remains at a reasonable duration.



Based on the simulation using 1 chef, the mean down-time during one day is 1.21 hours (72.6 minutes) with a standard deviation of 0.5827 hours (34.962 minutes). To maximize profits, it may be reasonable for the restaurant to temporarily close down during the day for ~72 minutes so that it does not lose money through paying the chefs when no one is at the restaurant.

Final Recommendation

For the restaurant to provide reasonable queueing experiences for customers while maximizing profit, we recommend hiring 1 chef when having 5 tables. Furthermore, to take advantage of the down-time during the day, we recommend closing the restaurant for ~72 minutes each day in between lunch and dinner service. This down-time will also allow staff to take a break and relax.

Future Extension

In future simulations, we could explore varying the rate of customer arrival throughout the day to account for lunch or dinner rush hours. We could also simulate more fine-tuned variations in the long term, such as seasonal-dependent customer flow or varying costs dependent on the market (e.g. food prices, real estate, cost of labor). It would be interesting to branch out our model into more sub-scenarios by accounting for different prices for different menus, or customer party sizes when being tabled. With the addition of each variable, we should be mindful of what type of distribution would be the most appropriate in calculating the rate of each. This project overall highlights how tuning probability models into real-life scenarios can be extremely insightful, when carefully applied with reasonable assumptions and clear variable definitions.