ISyE 320
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Executive Summary

Starbucks on State Street is a great place of attraction for all people on campus during the weekend. From a customer's perspective, we strive to figure out the most efficient queuing system for Starbucks. Being a gold card member, we have been loyal Starbucks customers. However, we are often frustrated by the duration of waiting time. As a result, our project focuses on minimizing waiting time thus improving customer satisfaction.

The greatest challenge for our project was data collection. At first, we were overwhelmed by the amount of customers. Even though we assumed Starbucks to be somewhat busy during the weekend, we did not anticipate over 100 people within just two hours of service. Our data collecting process was simple:

When a customer enters Starbucks, she will have to wait in line until a cashier becomes available. We recorded the time arrival for each customer and the time it took for each to order. After finishing her order, the cashier would communicate with their next available server who would complete the order. When the order is completed, we recorded the service time and marked the subject as departed. It was extremely difficult to keep track of all people and orders. This was because the completion of order was random. Having three servers, the service time was never consistent. It varied depending on the order and how busy it was. We tried our best to keep things organized and accurate.

We decided to collect our data during the weekend from 1 P.M. to 3 P.M. We collected the inter-arrival time, number of customers, wait time, and service time. In addition, we also found the average number of customers that starbucks can serve at a time. These data sets followed the following distributions: an Erlang distribution for the inter-arrival time and a Gamma distribution for waiting time. We also found the probability distribution for the service time, which was also Gamma distribution. (See Part 3)

Because of limited resources and time constraints, we had to make some assumptions in order to complete the project with accuracy and precision. First, we assumed 1 P.M. to 3 P.M. to be the peak service hour. Secondly, we assumed each customer is independent of one another. This meant that when a group entered Starbucks, we counted each individual as one entity and their order was independent of their friends' orders. We also considered people who left the queue as never having arrived. Lastly, we assumed that arrival and departure times were IID.

There were some obstacles we faced during the heaviest inflow of customers. Like we mentioned above, it was extremely difficult keeping track of all orders. As the rate of the customers' arrival increased, waiting time increased while service time started to decrease. It was interesting to see that the server's performance was affected by the queue accumulation. Since our time was measured in minutes, if customers arrive within one minute of each other, they were considered to have arrived at the same time. As you can see, our data contains some sources of error. However, we tried our best to provide the most accurate data by keeping control, independent and dependent variables.

After we modeled our original model, we continued to seek for alternative solutions. By altering the number of cashiers in the system, we were able to compare the current result to a variety of alternatives. To obtain the distribution of other models, we used the collected data for the alternative model. When we replaced one cashier to a helper in the alternative model, we saw the average cashier utilization for the alternative model to be twice that of the utilization of the current cashier. The server utilization for both models are similar but the helper utilization in the alternative model is low compared to the optimal value of 0.8. To reduce the average waiting time, we tried to identify the bottleneck in the system: the serving station. The table in the index 3.3 shows a summary that assists us in choosing the best alternative. As a result, we believe alternative 10 is the best if a perfect schedule can be maintained.

In this project, we simulated the Starbuck's customer flow to find the best alternative to reduce the waiting time of the customers and without altering Starbuck's budget. The model we have designed will easily let us change the control variables to compare the different alternatives. The model resembles the real settings of the Starbucks customer line because we did not make any unrealistic assumptions of the real scenario. Since the queuing system is a simple flow we chose to focus on one objective at a time.

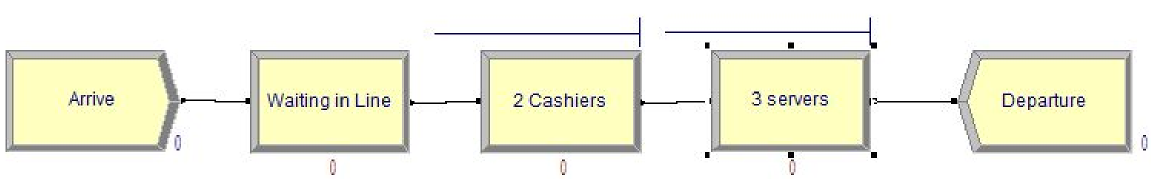
Final Report

Motivation and problem definition

Starbucks is the largest coffeehouse company in the world. It serves hot and cold drinks, whole-bean coffee, espresso, caffe latte, full-leaf teas, fresh juices, Frappuccinos, pastries, and snacks. With wide variety in drinks and snacks, Starbucks is a great place to study, socialize, and hang out. Our team was motivated to study Starbuck's queuing system because we are regular customers at Starbucks and it would be impressive if we can find a solution that minimizes waiting time for all customers. By analyzing Starbuck's current queuing system, we can identify the natural bottlenecks and employee utilization to maximize productivity as well as improve efficiency.

Assumptions and simulation model

When we started gathering information for our input data we needed to control some variables to make our data accurate and precise. For example, we made sure to keep the number of workers, location, and time constant. This is because we wanted to measure data accurately in a realistic scenario. We assumed there will always be five workers (two cashiers and three servers). We also assumed that the busiest time for the coffee shop is 11 A.M. – 3 P.M. This assumption was needed to make sure there was an accumulation of customers during the rush hour. Because our objective is to minimize waiting time, it would be plausible to collect data during the busiest hour. In order to make our study as real as possible, we decided to assume there will be a long line formed during the rush hour of Starbucks (1 P.M. – 3 P.M.) on State Street when there are five employees working.



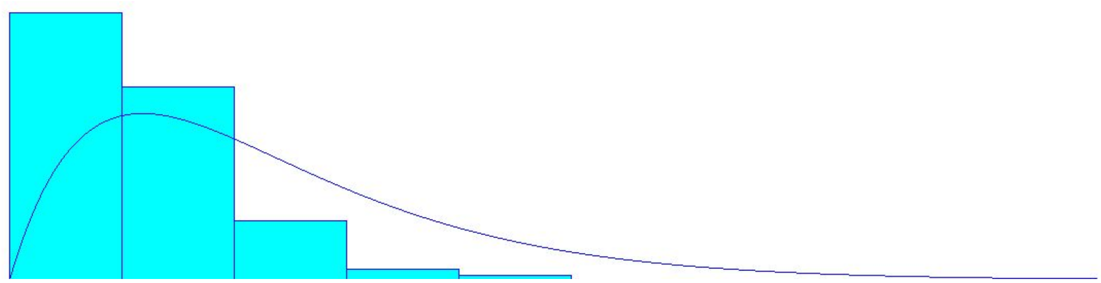
Above, you can see the simulation model for the current queuing system at Starbucks. After they enter Starbucks (*Arrive)*, customers need to wait in line to order (*Waiting in Line)*. When one of two cashier becomes available, the customer can order drink/food (*2 Cashiers)* then wait until the server completes the order (*3 servers)*. We also assumed that each server completes the entire order before continuing on to the next order. Next, we will describe the process of data collection and our input modeling.

Data collection and input modeling

Our team decided to split into two groups of two and gather data on two different weekends (Saturday and Sunday) at 1:00 P.M. – 3:00 P.M. We met at Starbucks on 661 State St, Madison, WI and as soon as the clocked turned 1:00 P.M. we recorded the time of each arrival. As a group, we thought it would be best if one person focused on the front half of the process and the second person focused on the latter. For example, one member recorded the arrival time for each customer who entered the store. When the customer reached the cashier, that same member recorded the time and let the partner know that the customer is waiting for the order. The second member recorded the time when customer received the food while the other member kept recording the arrival time and waiting time for each customer. This study will require three different inputs: inter-arrival time, waiting time, and service time. Inter-arrival time is the time between each entry. Waiting time is the time it took for the customer to enter the store and order at the cashier. Service time is the time it took for the server to complete the order and give it to the customer.

After completing the data collection, we were able to use excel to find the distribution for each inputs. Here is our following result:

3-1) Interarrival time



```
       Distribution Summary

Distribution:   Erlang
Expression:     -0.5 + ERLA(0.592, 2)
Square Error:   0.000289

Chi Square Test
  Number of intervals   = 4
  Degrees of freedom    = 1
  Test Statistic        = 2.08
  Corresponding p-value = 0.168
```

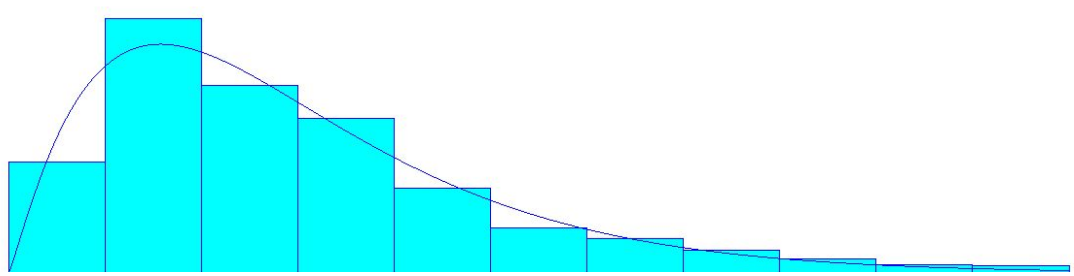
```
       Data Summary

Number of Data Points   = 530
Min Data Value          = 0
Max Data Value          = 4
Sample Mean             = 0.683
Sample Std Dev          = 0.824

       Histogram Summary

Histogram Range         = -0.5 to 4.5
Number of Intervals     = 10
```

3-2) Waiting in line time



```
        Distribution Summary

Distribution:   Gamma
Expression:     -0.5 + GAMM(1.4, 2.13)
Square Error:   0.001833

Chi Square Test
  Number of intervals   = 9
  Degrees of freedom    = 6
  Test Statistic        = 8.54
  Corresponding p-value = 0.213
```

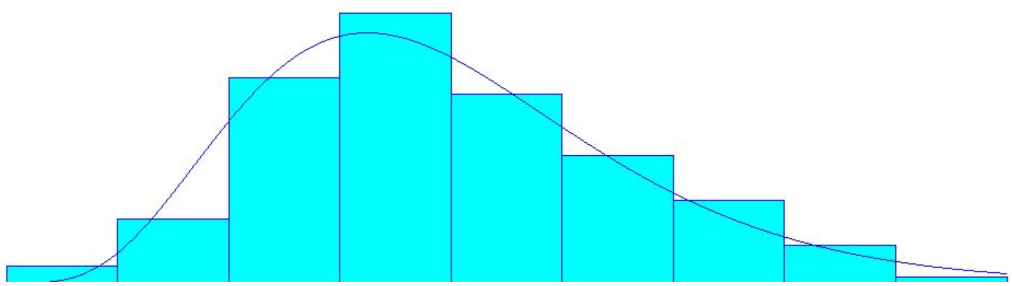
```
        Data Summary

Number of Data Points   = 532
Min Data Value          = 0
Max Data Value          = 10
Sample Mean             = 2.47
Sample Std Dev          = 2.05

        Histogram Summary

Histogram Range         = -0.5 to 10.5
Number of Intervals     = 11
```

3-3) Waiting for drink time (Service time)



```
        Distribution Summary

Distribution:   Gamma
Expression:     -0.5 + GAMM(0.745, 5.35)
Square Error:   0.002108

Chi Square Test
  Number of intervals   = 7
  Degrees of freedom    = 4
  Test Statistic        = 6.59
  Corresponding p-value = 0.174
```

```
        Data Summary

Number of Data Points   = 533
Min Data Value          = 0
Max Data Value          = 8
Sample Mean             = 3.49
Sample Std Dev          = 1.6

        Histogram Summary

Histogram Range         = -0.5 to 8.5
Number of Intervals     = 9
```

<u>Output Analysis</u>

system #	current	average alt_model	run 1	run 2	run 3	run 4	run 5	run 6	run 7	run 8	run 9	run 10
util_cashier	0.1733	0.344	0.3233	0.3228	0.3535	0.3489	0.3826	0.3459	0.3438	0.3417	0.3521	0.3257
util_server	0.7934	0.7495	0.7069	0.7255	0.7576	0.7448	0.8244	0.76	0.7331	0.7718	0.7445	0.7257
util_helper	N/A	0.1287	0.0598	0.0354	0.1265	0.1416	0.2069	0.092	0.212	0.1448	0.1333	0.1352
Total time	9.1656	8.929	8.4537	8.1022	8.7503	8.726	9.8161	8.5794	9.7173	9.2644	8.8832	8.9971
avg wait	2.7576	2.0292	1.6214	1.2658	1.9455	1.9269	2.9059	1.8557	2.5661	2.1475	2.0061	2.0511
wait_cashier	0.0134	0.1945	0.1908	0.1451	0.185	0.2039	0.2901	0.13	0.1764	0.187	0.2476	0.1887
wait_server	2.7401	1.6446	1.7407	1.1134	1.4337	1.6137	2.183	1.692	1.8778	1.885	1.5664	1.6618
wait_helper	N/A	4.6391	1.419	1.4229	7.7559	3.3707	7.2957	2.3636	8.4892	3.0234	5.3349	5.5945
# customer	490	492	460	463	508	500	548	496	493	490	499	467

Above, is the output analysis for our simulation model . The second column, “current”, contains the real current system and the third column, “average alt_model” contains the average alternative model.The current system consists of two cashiers with three servers whereas the alternative model replaced one cashier with a helper. We can see the average cashier utilization value for alternative model is twice as that of current cashier utilization. The server utilization is similar but with the helper the utilization of server decreases slightly. We can see that the the alternative model’s average wait time is less than that of the current system. We can see that by replacing an underutilized server with a cross trained server will improve productivity of workers as well as improve efficiency of the queuing system.

system #	current - average
Total time	0.2366
avg wait	0.7284
wait_cashier	-0.18113
wait_server	1.0955
wait_helper	N/A
# customer	-2

For waiting time statistics, we concluded a summary with the difference between our current model and the average value of the alternative model. We found that the average waiting time dropped from 2.7 seconds to 2.0 seconds (26% decrease). This shows that even though there might be some blockage with one cashier, overall, the system improved when a cashier is changed to a helper due to the natural bottleneck in service time in the original model.

Comparison of alternative models

To compare the original model and the alternative model, we estimate the variance of the difference of two systems. Each system uses independent input data with the same variance. (Each system's inter-arrival time follows same expression: ERLA(0.592, 2)) The confidence interval level is 95% and the degree of freedom is 18. (10 replications each.) In this case, t value is 2.101. This is our result.

system #	Ave_diff	Var_ori	Var_alt	Var	Conf_int	Min	Max
util_cashier	-0.17077	7.022E-05	0.0003213	0.0001958	0.013146	-0.183916	-0.157624
util_server	0.04398	0.0005996	0.0010618	0.0008307	0.0270811	0.0168989	0.0710611
Total time	0.73655	1.0010598	0.2924959	0.6467778	0.7556464	-0.019096	1.4921964
avg wait	1.21488	2.878261	0.207614	1.5429375	1.1671192	0.0477608	2.3819992
wait_cashier	-0.1810935	7.364E-06	0.0021299	0.0010686	0.0307155	-0.211809	-0.150378
wait_server	1.06331	0.9530808	0.0819125	0.5174967	0.6759193	0.3873907	1.7392293
# customer	-0.8	992.04444	668.26667	830.15556	27.072028	-27.87203	26.272028

According to this table, the difference between the original model and the alternative model's confidence interval is min ≤ original - alternative ≤ max. If both min and max are negative, it is strongly evident that the result of the original is bigger than result of the alternative and vice versa. So we can figure out following result.

system #	Comparison
util_cashier	Strongly Increase
util_server	Strongly Decrease
Total time	Decrease
avg wait	Strongly Decrease
wait_cashier	Strongly Increase
wait_server	Strongly Decrease
# customer	No difference

In our alternative model, utilization of cashier and waiting time for server increased. In the original model, the bottleneck of the queue system occurred in the serving phase. So increasing the server's utilization can solve the problem. After improving our model, we notice a decrease in server's utilization and average waiting time. More importantly we see the total time decreased compared to that of the original model. Decreasing the average waiting time and total time spent by customer in Starbucks is our objective. We were very proud to find a solution that Starbucks can use to improve productivity and efficiency. In conclusion, our alternative model is better than the original model designed by Starbucks Corporation.

Recommendations

According to our data and analysis, we have our following conclusion. Our service time data has some variance between two different days. We think one cause was because some staff was not very familiar with the process and it would take more time to adjust than others. So our first recommendation is that in order to reduce the service time, the starbucks could improve the training process thus reduce service time and increase the utilization of each employee. Secondly, we also have the concern of some customer order something need longer time to prepare, which refers to process like heating up bakery and specialty drinks. Starbucks should identify these natural bottlenecks and the way to improve this situation is to assign a helper who is cross trained. The helper can work as a server when there is a queue for the serving process. Thirdly, for the data collection file, we use minutes as our units, but as we apply the data to the input analysis, we find the waiting time is almost 1 min to 3 min. It is not accurate enough for the model. So next time we should use seconds as our units and the real system model could depict a more accurate model with precise data.