Modeling and Simulation
SSIE 520
TERM PROJECT

Competitive store in terms of sales

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ABSTRACT

Simulation is an approach where we replicate a real-world system. The two common types of simulation often used are discrete-event simulation and continuous simulation. In this project we have used a discrete-event simulation method to simulate the store named Price chopper using the software Simio. The simulation here focuses on the optimal number of checkout lanes to be operated during weekdays and weekends. The next aspect of this project was to increase the sales of the store which is done by analysing the average time spent by customers in each of the sections of the store. Based on the results of the sensitivity analysis a better recommendation is given on how to improve the customer satisfaction by reducing the waiting times. It also suggests how to make customers spend more time in other sections.

1. Introduction

Price chopper is a high quality grocery store which is located in Johnson City, Binghamton which is modeled using discrete-event simulation. In discrete event simulation, the operation of the system is modeled as discrete events with respect to the time. In can be used to provide a good insight of the problems arising with respect to queueing. For a long time discrete-event simulation is used to improve the operations in the sectors like manufacturing, warehousing and supply chains. Nowadays its application has been expanded to the field of retail service and healthcare. The main problem addressed here are the reducing the average customer waiting time in the queue in the self-checkout and regular-checkout. For this we have created different scenarios for 5 replications for both of these checkouts. The next is increasing the sales, this is done by attracting customers revisits and tracking the path followed by the customers. This provide some insights on the sections were the customers spend more time based on these result we can change the products place to a different section were the customer has spent least time. These are implemented using a software name Simio, were the model is designed first then inputs parameters are given for each of the resource by selecting the proper type of distribution fit using Expert fit software. Then based on the output responses we get we make the system more efficient.

2. Problem Statement

We know that the first thing which comes to our mind when we say Binghamton is that it is famous for the school, State University of New York, Binghamton University. In recent years we see the number of international students joining this university is increasing. As the store is located centrally to all the student housing, there are more number of customers approaching the store.

We see an increase in the number of customers during the weekends compared to the weekdays. This increases the customer waiting time during weekends and the next problem the store is facing is the increased sales in a particular type of product. This causes reduced sales in other types of products.

So, in order to overcome these challenges and make the store more efficient and competitive in sales a simulation is done on the Price chopper.

3. Research objectives

By creating this simulation some we had to nail down a few research objectives in order to determine what we should include in the simulation and what we should collect data on. To start our main objective was to be able to make the shoppers trip to the store as efficient as possible with little to no hassle and wait time in lines at check out. Our next research object was to determine what a proper layout would be for the store based on where customers went most often and which sections they spent most of their time in. We wanted to know if the store's layout was already at its most optimized layout for the customers and the business together and if not we wanted to make suggestions to Price Chopper for changes. Another Research objective we had was to determine if they were operating their checkout lanes properly. By this we mean, did they have enough staff on hand to help the customers have little to no wait, when and how many self-checkouts were open, etc.? Our overall goal was to be able to determine if the customers and the business were satisfied. To do this we would analyse the customers time in system and other business aspects.

4. Assumptions:

- The grocery store which we modeled is not the exact, because of its complexity and the variabilities.
- The store is divided into 5 sections.
    - Section -1 – Produce/bakery/seafood
    - Section 2 – Aisle 1-4 and butcher
    - Section 3 – Aisle 5-7
    - Section 4 – Aisle 8-10
    - Section 5 – Frozen foods
- There are 4 regular check outs and 6 self-checkouts.
- The employees have different service times.
- Workers don't have breaks.
- There is never a shortage of employees.
- All the customers who have shopped should pass through "Transfer node" before selecting regular checkout or self-checkout.
- There is a probability that a customer leaving a section will return to the same section if he forgets to get a product.
- A person leaving a section has 5 possibilities. For example, that a person leaving section1, can go to any of the following sections that is section2, section 3, section 4 and section 5 or can go directly to the checkout.
- There were not a significant number of groups that were larger than 1 for us to consider batching in the simulation
    - If there was a group bigger than 1 it was usually a child with their mother who would not get separated.

5. Data Collection:

When considering data collection it is important to visualize the model and think about the specific inputs that we should have in order to get the correct outputs to complete our research objectives. From there it was our job to determine what data we should collect from the system. Based on the system some important data that we collected was the inter-arrival times of the customers. This was important to us because we needed to know how fast customers were coming into the system. The next thing we collected data on was how long each customer spent in a specific section and to which section they travelled to afterwards (sections listed above in assumptions). This piece of data was important to our team because it would help us calculate our probabilities of each path from the individual servers and it would also help us calculate our service times within those servers, which will be discussed in a later section. The next data that we collected was the amount of customers that would choose self-checkout over regular checkout. This would help us create the correct amount of entities going to each different server in our model. From there we also had to collect data on the service times of each of these separate servers, self-checkout and regular checkout. We collected all of this data by going to the Price Chopper store and watching and timing our phones and then we wrote down our observations by hand and input them into an excel file which we then used to calculate our probabilities.

6. System Model:

6.1 The Design of the Model

Our team felt that the best way to model this system was to split the different sections/aisles of the store into separate servers, as noted in our assumptions. Within the model we split Price Chopper into 5 different sections which were modeled as 5 separate servers. To model the shopper's paths within the model we used selection weights. Selection weights are probabilities that the entity takes that path. We calculated these selection weights from our collected data. There are 25 separate paths and probabilities shown in the model. This is because once a customer has entered the system they can go from section 1 to section 2 and vice versa, so we had to account for both of these occurrences. From there once the shoppers are finished they all exit to a transfer node and from there are sent to the checkout areas. The checkout areas are modeled as two different servers in our model. The first server is used to model the self-checkout area and the second server is used to model the regular checkout area with a clerk. Below is the basic design of the model before animation is added.

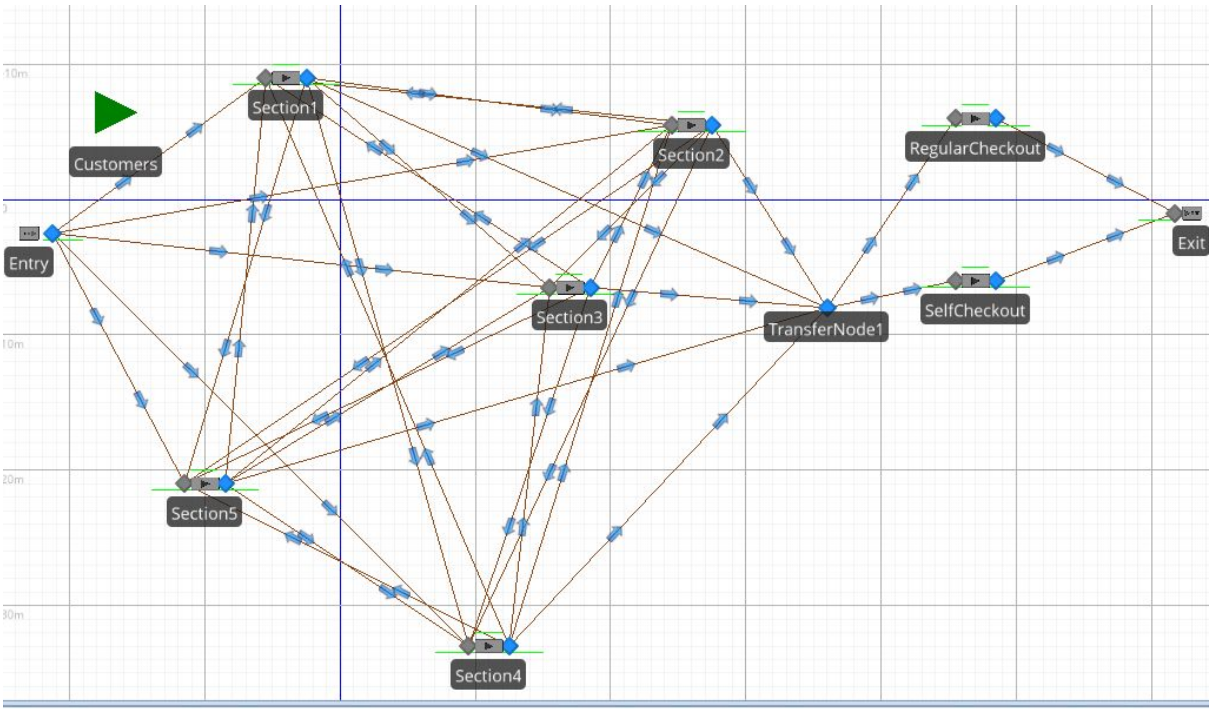


Figure 6.1.1: Basic view of model before animation

6.2 Determining the Inputs for the Model

After the team decided on the basic model to represent our system properly, we had to determine the arrival rates and service rates to input to each component in order to represent our system properly. So, to do this the team used the software, ExpertFit. When using this software the first step was to input the data for each individual source or server. Once the data for each was put in the software automatically gave our team suggestions for the best fit. Shown below is an example of the ranking of distributions the software gave us based on our interarrival times at the source.

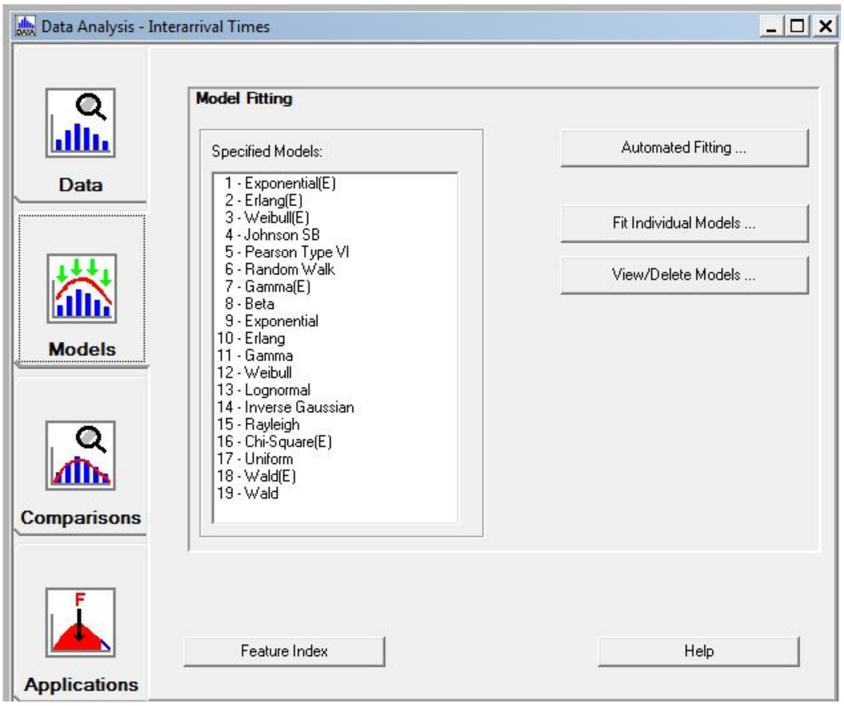
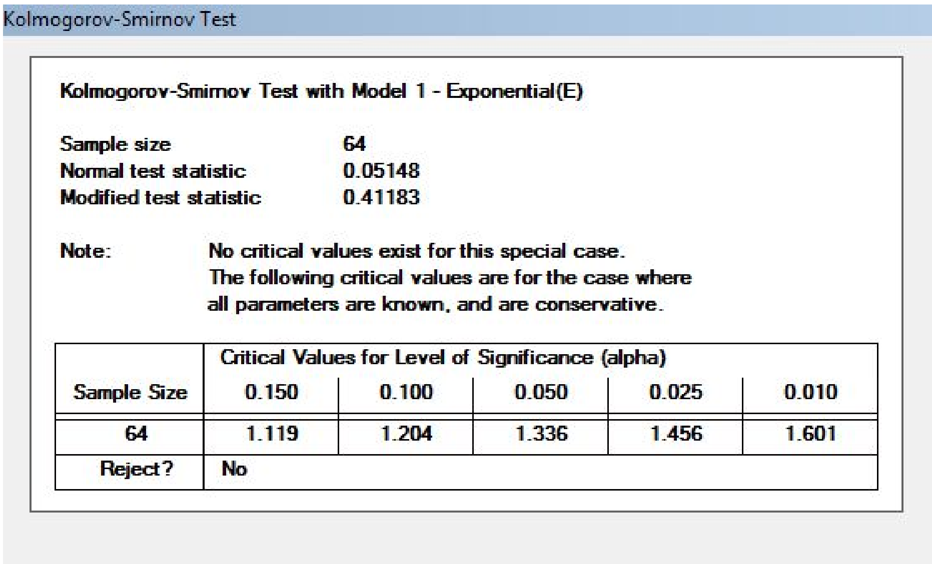


Figure 6.2.1: Fitting to a Distribution

As seen in the figure above the number one suggested distribution to represent out arrivals was the exponential. Once the distribution was suggested the next step was to conduct a Goodness-of-Fit test. This test is used to determine if the distribution actually represents the data accurately. The ExpertFit software also aided our team with the Goodness-of-Fit test. When conducting the test the software gave us three options of Goodness-of-Fit test to choose from. Those options were the Anderson-Darling test, the Kolmogorov Smirnov test (K-S Test), or the Chi-Squared test. Our group chose to utilize the K-S Test. The image below is the result of running the K-S Test in the software, also based on our inter-arrival time data and fits.


Kolmogorov-Smirnov Test

Kolmogorov-Smirnov Test with Model 1 - Exponential(E)

Sample size	64
Normal test statistic	0.05148
Modified test statistic	0.41183

Note: No critical values exist for this special case. The following critical values are for the case where all parameters are known, and are conservative.

	Critical Values for Level of Significance (alpha)				
Sample Size	0.150	0.100	0.050	0.025	0.010
64	1.119	1.204	1.336	1.456	1.601
Reject?	No				

6.2.2: Goodness-of-Fit Test

What our team was able to gather from this output of the software was that the exponential was a good fit for the inter-arrival times and it represented our data properly. We were able to gather this information because as seen in the figure, it states not to reject the original suggestion. This means the exponential was a proper fit to model the inter-arrival times. Once our fitted distributions were confirmed the next step was to input that into the model. ExpertFit also helped us to develop our expressions for the model. Under the applications tab on the software there is a section that allows you to pick which simulation software you are working with and automatically gives you an output for what your expression should be in the simulation software. For example, in the image below, again for inter-arrival times, the expression that was fed back to us after we selected that we were working with Simio is shown.

Figure 6.2.3: Simio Representation of Fitted Distribution

Similarly for the server/sections the same set of tasks were completed to determine the service rates. Another set of figures is shown below to model the steps for the Self-Checkout.

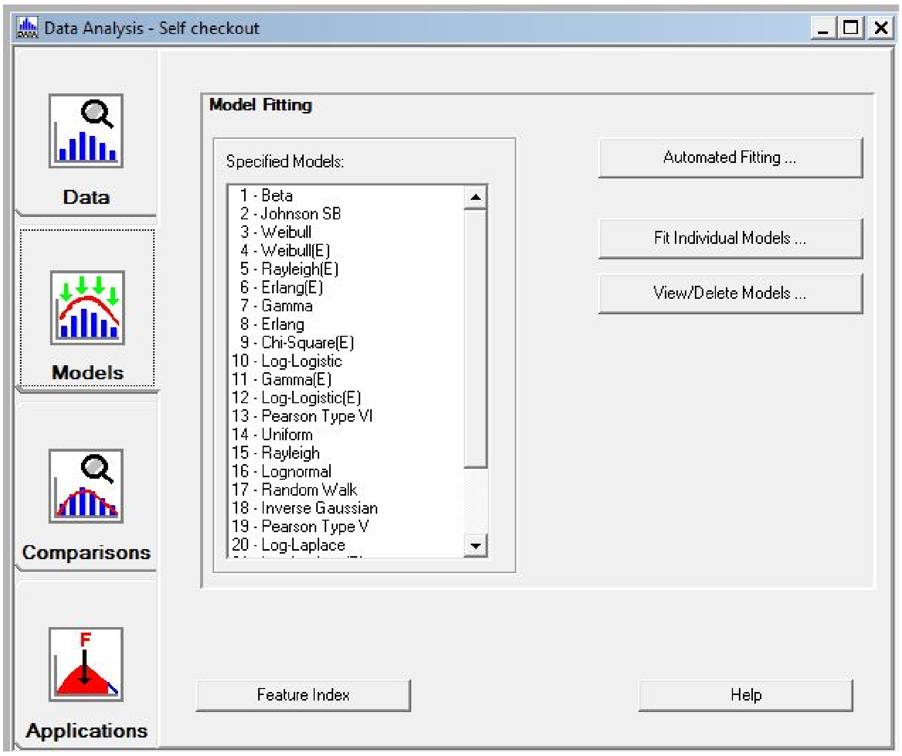
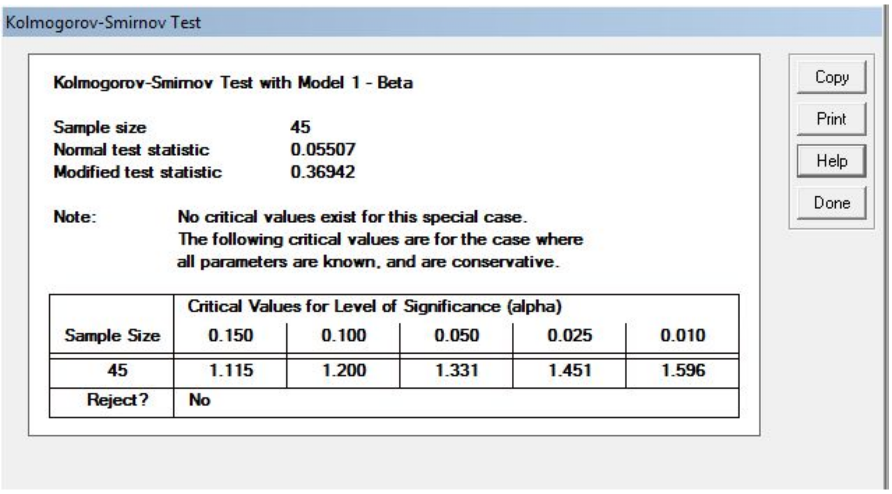


Figure 6.2.4: Fitted Distributions for Self-Checkout



	Critical Values for Level of Significance (alpha)				
Sample Size	0.150	0.100	0.050	0.025	0.010
45	1.115	1.200	1.331	1.451	1.596
Reject?	No				

Figure 6.2.5: Goodness-of-Fit Test for Self-Checkout

Figure 6.2.6: Simio Representation for Self-Checkout

6.3 Logic of the Model

In order to understand how the model works it is important to understand the logic behind each aspect. For example it is important to note that once the shoppers are all done shopping they come together at the transfer node. The transfer node is used to transfer entities from one set of servers to the next. Once they reach the transfer node they are again sent on paths based on selection weight, also calculated from our collected data. At price chopper there were 6 self-checkout lanes that operated at the same time and so to model this the capacity of the self-checkout server is 6. Similarly, with the regular check out, Price Chopper only ever had 4 lanes open at once, so to model this we set the capacity at 4. Once the entity has chosen its path our team then uses the list function. We created a list representing the two separate stations capacities. So once the entity was on its path it would then link to either self-checkout or regular checkout or the shortest line within those capacities. The list function would essentially allow the customer to choose the shortest line in a real life situation.

Another important part of the logic was the understanding that the shoppers were free entities and could go from one section to the other without restrictions. That is why to and from each "section", modeled as servers, there is a selection weight and at the end they all exit towards the checkout areas.

7. OUTPUT PERFORMANCE METRICS

Case 1:
Response results for two types of checkouts for weekdays and weekends.

Weekdays

Fig: Regular-checkout utilization

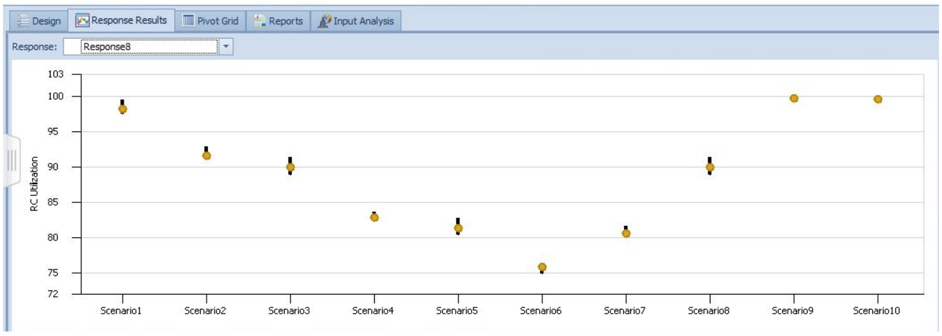


Fig: Self-checkout utilization

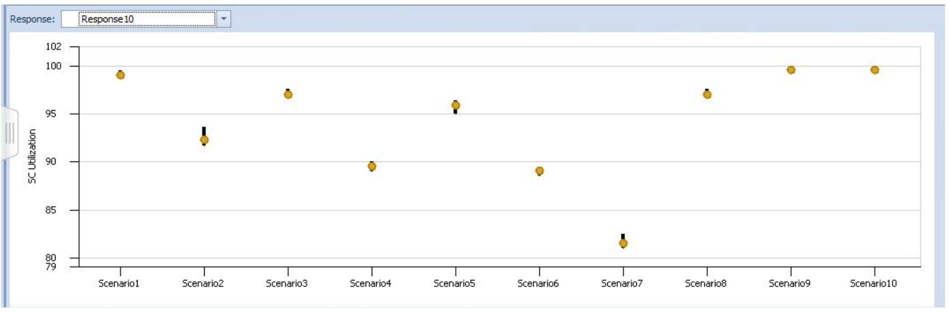


Fig: Waiting time in regular-checkout

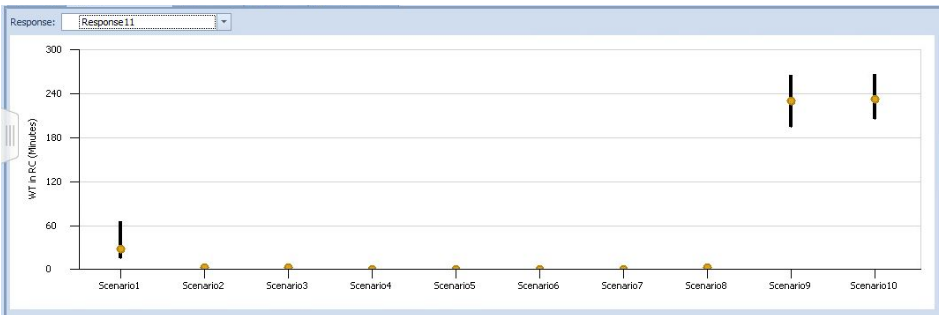
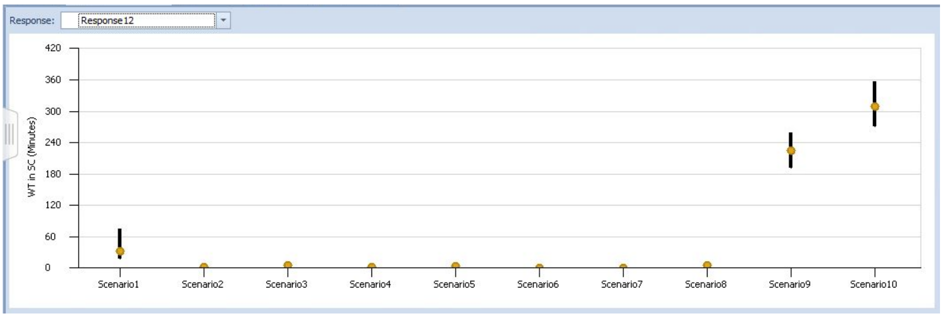


Fig: Waiting time in self-checkout



Weekends:

Fig: Regular-checkout utilization

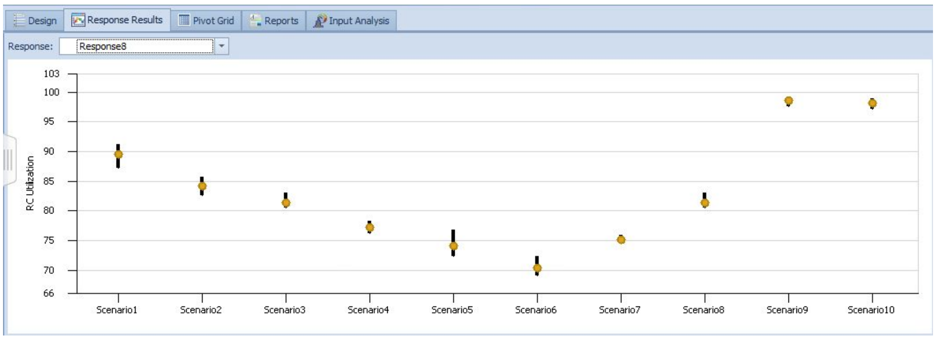


Fig: Self-checkout utilization

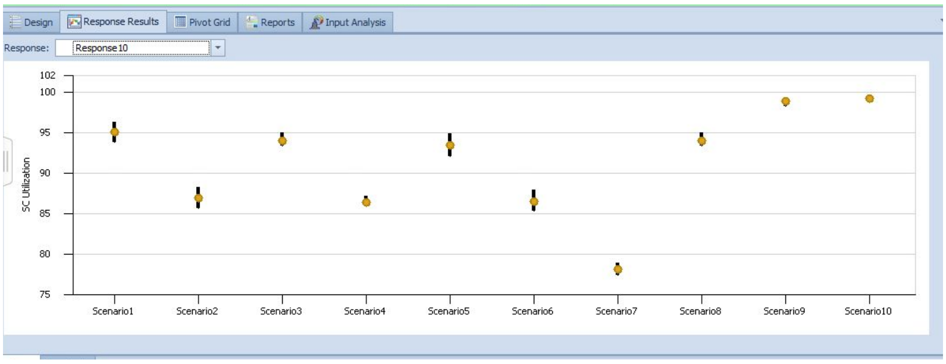


Fig: Waiting time in regular-checkout

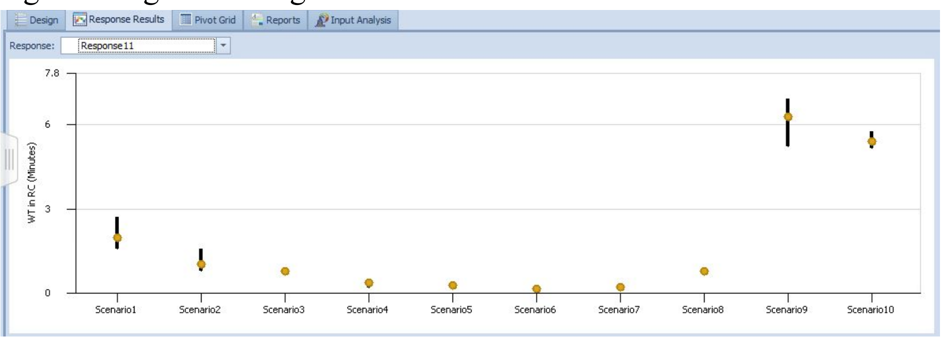
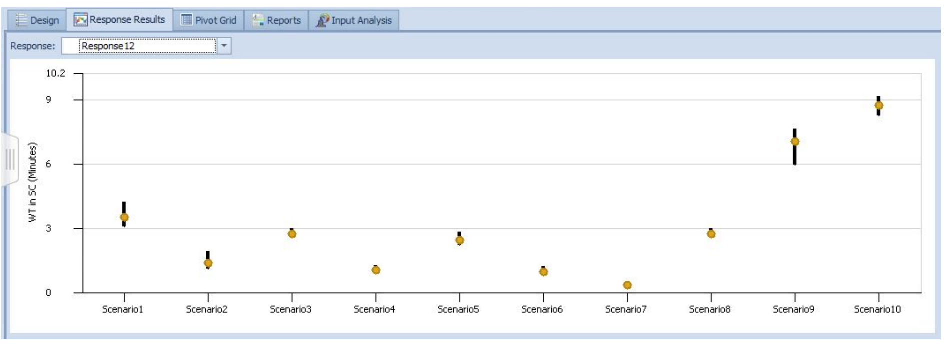


Fig: Waiting time in self-checkout



The below table shows the results for the two types of checkouts for weekends and weekdays.

Weekdays

Scenario	Avg Time in system	RC	SC	RC_uti	SC_uti	Waiting time in RC	Waiting time in SC	WN_RC	WN_SC
1	39.7857	8	6	97.6941	98.8991	4.61201	6.59392	3.86194	5.00034
2	28.0766	8	7	91.6997	93.0127	2.35465	2.81694	1.83757	2.33153
3	28.5414	9	6	89.5183	97.2101	1.82077	4.20666	1.5784	3.12064
4	25.7463	9	7	83.2953	90.6062	0.8312	1.72132	0.66586	1.38599

The simulation is run for 5 days
Scenario1 – This depicts the actual model of the system with 8 regular checkouts and 6 self checkouts. Though the resource utilization is high for both the checkouts, the waiting time is higher in this case compared to others.
Scenario2 – Here we have 8 regular checkouts and 7 self-checkouts. Though the utilization of these servers has only reduced slightly compared to scenario 1, there is significant difference in the waiting time. This is the best as there would be a cost of only one self check out which will be incurred.
Scenario3- Here there are 9 regular checkouts and 6 self-checkouts. The resource utilization is higher in this case and the waiting time is higher in the case of self-checkout compared to scenario 2.
Scenario 4- Here there are 9 regular check out and 7 self-checkouts. Though they have slightly less utilization rate compared to all the other scenarios. They have the least waiting time in both types of self checkout lanes.

So, our recommendation for the price chopper is to add one more self-checkout counter and keep the regular checkout number the same. The waiting time in the regular checkout decreased by 49.13%. The waiting time at the self-checkout decreased by 57.35%.

Weekends

Scenario	Avg Time in system	RC	SC	RC_ut	SC_ut	Waiting time in RC	Waiting time in SC	WN_RC	WN_SC
1	31.1973	8	6	89.5161	95.1351	1.97715	3.54926	1.69568	1.09012
2	28.8236	8	7	84.1542	86.952	1.04046	1.39811	0.83932	1.98447
3	29.5113	9	6	81.4221	94.0369	0.80698	2.75834	0.70776	0.85609
4	28.4069	9	7	77.2222	86.487	0.37793	1.10383	0.31536	1.76377

Scenario 1 – In this case there are 8 regular checkouts and 6 self checkouts. This is the initial condition replicating the price chopper. It can be seen that the utilization values are lower compared to that of the weekdays. The waiting time is higher here compared to the other scenarios.
Scenario 2- The number of regular checkouts is 8 and the self checkouts are 7. Here the waiting time at the self-checkout is less compared to the scenario 1.
Scenario 3- The number of regular-checkouts is 9 and the number of self-checkouts is 6. Here we see that the utilization is similar to the previous scenarios and also the time taken in the regular checkout is lower compared to the previous cases but the waiting time at self-checkout is higher compared to the scenario2.
Scenario 4 – The number of regular check out is 9 and the number of self checkouts is 7. The utilization of the two checkouts are the least compared to all the previous scenarios. But, it has the least waiting time at the two self-checkouts.

Based on these results the scenario 3 would be recommended for the weekends. The waiting time in the regular check out decreased by 59.39 % and the waiting time in the self- checkout decreased by 22.31%.

7. Cost Benefit Analysis:
We assume that for the setup of the self check out approximately costs $ 14,000 and to set up the regular checkout it takes $5000 plus a dedicated employee to operate it.
So, by observing all the scenarios above including the average waiting time, waiting time and the costs involved, one can easily infer that one self-checkout will be beneficial. Also, if extra regular checkout is set up the utilization is not that great (scenario 3 and 4). But if extra self-checkout is set up both the server utilization is good with a little bit trade-off with the waiting times.

Case 2:
It deals with looking up for the sections where the customer spends more time by tracing their flow path and the inputs are applied to see the results.

Unplanned Buying:

Fig: Waiting time of customer in each section during the weekdays.

Scenario												
☑	Name	Status	CustomersInSection5...	CustomersInSection2...	CustomersInSection3...	CustomersInSection4...	RC Size	RC Utilization	SC Size	SC Utilization	WT in RC (M...	WT in
☑	Scenario1	Compl...	6.44278	5.10647	5.51909	5.56648	8	98.2643	6	99.0948	27.7393	
☑	Scenario2	Compl...	6.43931	5.0935	5.49716	5.55881	8	91.6077	7	92.3456	3.1267	
☑	Scenario3	Compl...	6.42474	5.11296	5.51522	5.5591	9	89.9993	6	97.0965	2.91145	
☑	Scenario4	Compl...	6.4666	5.10743	5.50489	5.60102	9	82.9072	7	89.5303	0.880416	
☑	Scenario5	Compl...	6.38981	5.09127	5.51584	5.59925	10	81.3596	6	95.9139	0.672066	
☑	Scenario6	Compl...	6.45586	5.10722	5.49276	5.58841	10	75.9406	7	89.1254	0.328176	
☑	Scenario7	Compl...	6.48559	5.10235	5.54198	5.60177	9	80.6916	8	81.5199	0.534286	
☑	Scenario8	Compl...	6.42474	5.11296	5.51522	5.5591	9	89.9993	6	97.0965	2.91145	
☑	Scenario9	Compl...	6.44209	5.10806	5.51722	5.57323	7	99.6748	6	99.6719	230.201	
☑	Scenario10	Compl...	6.441	5.11209	5.50666	5.58104	8	99.5489	5	99.6888	233.201	

Fig: Waiting time of the customers in each section during the weekends.

	Name	Status	CustomersInSection1...	CustomersInSection5...	CustomersInSection2...	CustomersInSection3...	CustomersInSection4...	RC Size	RC Utilization	SC Size	SC Utilization
☑	Scenario1	Idle	8.43457	6.44589	7.13416	5.51655	7.43524	8	89.5161	6	95.13
☑	Scenario2	Idle	8.41147	6.39208	7.06659	5.50119	7.35268	8	84.1542	7	86.9
☑	Scenario3	Idle	8.42436	6.39144	7.1104	5.52042	7.3485	9	81.4221	6	94.03
☑	Scenario4	Idle	8.39321	6.4426	7.10942	5.50674	7.4008	9	77.2222	7	86.4
☑	Scenario5	Idle	8.389	6.45334	7.0913	5.46979	7.41557	10	74.0379	6	93.47
☑	Scenario6	Idle	8.38566	6.35431	7.11618	5.48491	7.37702	10	70.3221	7	86.4
☑	Scenario7	Idle	8.42015	6.43789	7.07021	5.54374	7.37171	9	75.1417	8	78.19
☑	Scenario8	Idle	8.42436	6.39144	7.1104	5.52042	7.3485	9	81.4221	6	94.03

The tables show you how much time the average customer is spending in each section. So, from the observations above, customers spent higher times in section 1 and lesser times in section 3. Also, from the data we collected there is a 0.4 (40%) probability of unplanned buying. 40% of the customers come to the store to buy the things they need and with those they buy some products that they didn't plan for. These are called unplanned products. So, the right product mix between section 3 and section 1 could increase the sales by unplanned buyings.

Fig: Animated 2D view of Model of the Price chopper

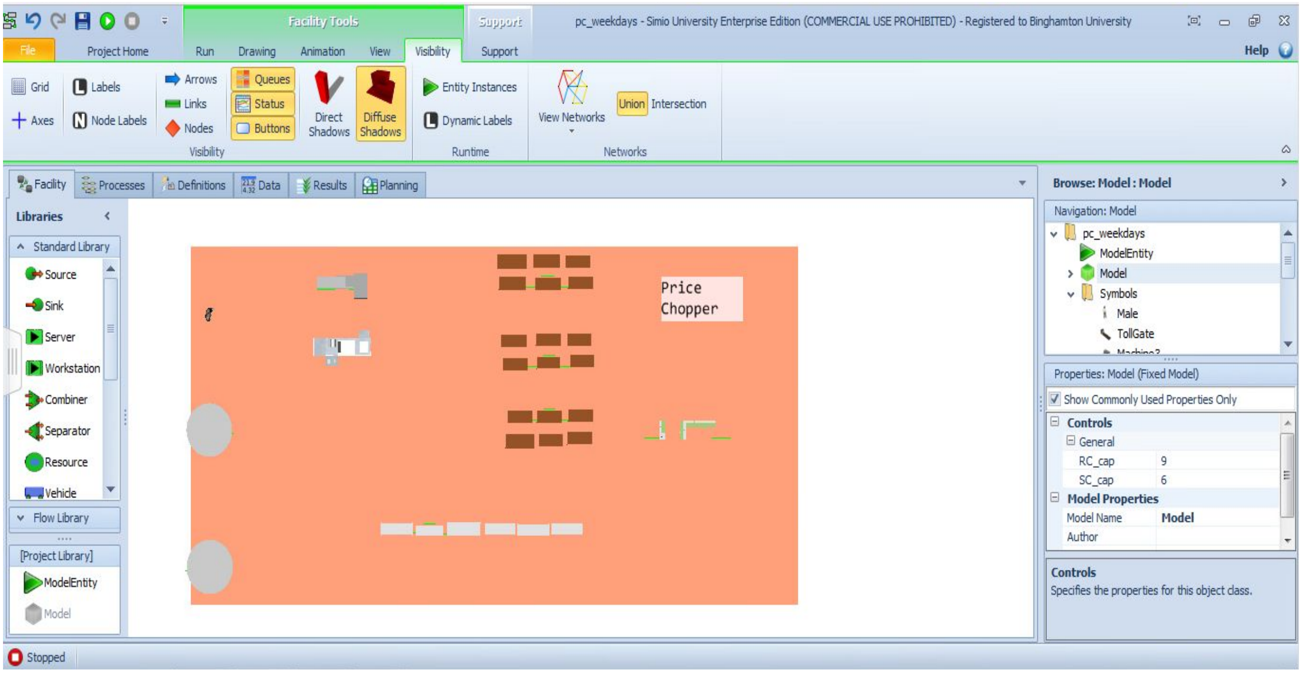
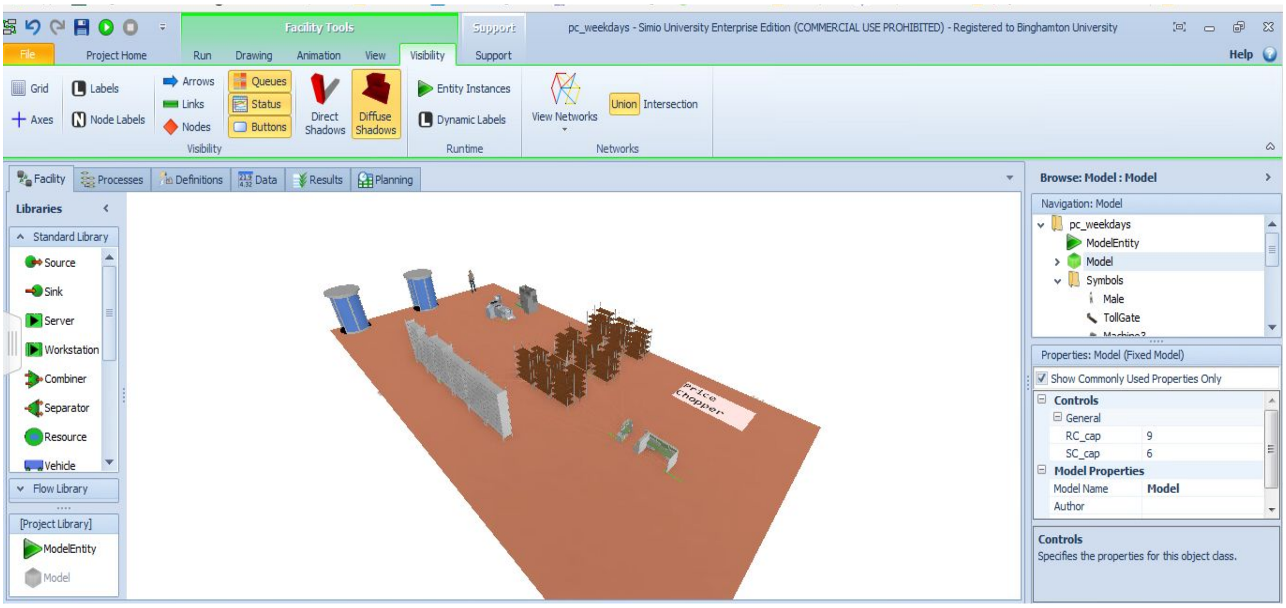


Fig: Animated 3D view of Model of the Price chopper



8. Conclusion

We have compared the results from the different scenarios for both the self-checkout and the regular-checkout. We finally have suggested our results not only based on the average waiting time for the checkouts but also based on the cost incurred while implementing which is suggested based on the cost benefit analysis. Then the product sales is improved by seeing the output analysis results of the average time spent by each customer in these sections and based on the sections were we see the average time spent is higher and lower we make the product mix on these two areas so that the customers will be allowed to go through most of the products in the store thereby increasing the sales.

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