OPTIMIZING THE LOCATIONS OF COCA-COLA VENDING MACHINES ACROSS KSU – MARIETTA CAMPUS

Final Design Review

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KENNESAW STATE UNIVERSITY

EXECUTIVE SUMMARY

The following project was conducted on the Kennesaw State Marietta Campus. The purpose of this project was to optimize the placement of the vending machines across campus to increase sales revenue, and to optimize the delivery route for the new locations. We conducted 100 surveys to determine which buildings with vending machines have the highest and lowest foot traffic based on students selecting which buildings they visit. We then selected the top two from the results and out of the bottom 10, we randomly selected the bottom 2 due to multiple buildings having the same number of visits. The top two buildings were the Joe Mack Wilson Student Center and the Atrium Building. The bottom two were the West Parking Deck and the Mathematics Building. We gathered data on arrival and service times of the vending machines at these four locations to help build our arena simulation to predict sales revenue and number of customers, over the course of 22 days, 15 hours per day. We were able to see what the number of customers would be, the total sales revenue, and the vending machine utilization. It was determined that West parking Deck had no service times during our recordings and therefore deemed as a location that was not generating sales revenue. It was also determined that the mathematics building had a low utilization rate of 7.2% while the Student Center had 49.4% utilization and the Atrium had 43.4% utilization. The math building also had a small amount of foot traffic and a low sales revenue of just $2250.00 which was over $10,000 lower than the top two locations. In the end, we determined four vending machines needed to be relocated and we concluded that it would be most profitable to add two into each of the top two buildings. This resulted in an estimated $7,000 increase in sales revenue across the Student Center and Atrium. The new vendor route was also determined using a program called IOR tutorial and the overall route was reduced from 4,490 meters to 4,050 for a total distanced saved of 440 meters.

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Chapter 1: General Information

1.1) Introduction

For our senior design project, we wanted to look at something that many people use daily but often overlook the complex nature behind the vending machine and where it is located. We use it often to quench our thirst for a fizzy drink, or even a cold bottle of water, sometimes we use it to satisfy our appetite. We often walk a few feet or a couple yards to get to it. For our senior design project, we are going to look at optimizing the placement of vending machines across the Kennesaw State University Marietta campus. This is something many students use daily, and depending on location, students may have to walk in the rain or a great distance to get to one. We plan to fix this problem, all while also increasing the profit the school makes from these machines. By placing them in higher foot traffic areas and areas with faster arrival times, we also will optimize the vendor route to refill the machines.

1.2) Objective

The objective of this project is to optimize the locations of vending machines across Kennesaw State University Marietta campus to higher foot traffic areas and areas with faster arrival times of the people walking past the vending machines. By improving the locations of the vending machines, it will decrease the time it takes for the delivery driver to re-stock the machines. This will allow for a quick turnaround of products, and increase the profit made from the machines.

1.3) Justification (Why?)

The reason for optimizing the location of the vending machines across Kennesaw State University is because there have been problems with the vending machines being unstocked. This causes a loss of sales and results in a profit loss for the school. A more optimized placement of vending machines across campus will increase the use of the vending machine and allow the vendor to re-stock the machines more often. The vendor delivery route will also be optimized across the campus.

1.4) Project Background

As discovered through our survey we were able to observe the dissatisfaction of students with the locations and product selections of the vending machines on campus. We also were able to determine we could develop a new more efficient delivery route for restocking the newly positioned machines. With the rearranging of the machines and a better stocking system we plan to increase the amount of uses, thus improving sales and the profit made from the machines. We plan to optimize the locations of the vending machines in the Kennesaw State Marietta campus. To increase profitability for each machine, we are going to analyze the locations. We plan to collect data on the arrival times of people walking past the vending machines at four specified locations based on survey results. We will also count how many people walk past these machines and make a transaction. By moving the machines to a higher traffic area, and areas with faster arrival times, we will be able to increase the profit for Kennesaw State.

We will also design a cost analysis and see how much the vending machine costs vs how much they made and how much they would make in each proposed location. We will also include a lifecycle cost analysis as well as analyzing if it is better to rent or outright purchase the machine. On top of improving the profitability of each machine, we will also improve the delivery route for refilling the machines. By analyzing the proposed locations, we plan to run simulations to optimize the delivery route.

Figure 1: Visual of Vending Machines

We are conducting our research on these types of vending machines. These vending machines are located across the Kennesaw State Marietta campus. They are the most popular machines on campus for students and faculty. The transparent glass allows customers to see the choices available and how much is available in the machine. The card reader allows students and staff to use their credit cards as well as their student account card to purchase items. We plan to analyze the utilization factor on these machines and will optimize profitability and usage. As shown in the pictures the vending machines are empty in the two most populated areas on campus.

1.5) Problem Statement

The vending machines across Kennesaw State University are losing out on potential profit due to them being empty and not stocked. They are also losing out on potential profit due to them being in locations where foot traffic is relatively low. Therefore, by optimizing the placement of the vending machines across the campus, it will in turn improve the utilization of the vending machines, as well as the sales made from the vending machines. We plan to increase the sales revenue of the vending machines by placing them in areas with higher foot traffic. We will be observing the 19 buildings containing a total of 32 drink machines.

Chapter 2: Literature Review

2.1) Traveling Salesman Problem

Traveling salesman problems are regarded as one of the seminal problems in computational mathematics. These problems are solved the same way as if you wanted to visit multiple cities where you arrive once and depart once but also start and finish in the same spot for the whole trip. Then you use the pairwise distances between each city to figure out the order in which you

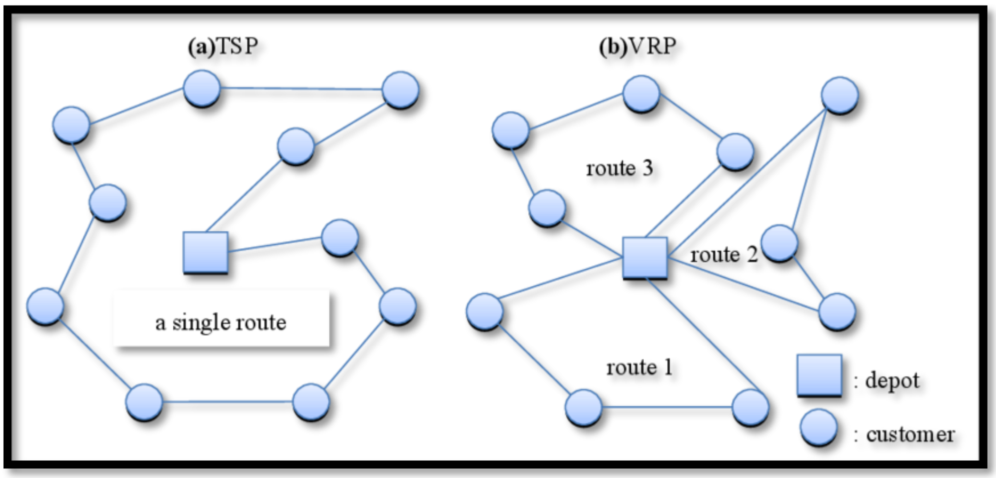


Figure 2: TSP Problem Model [1]

would visit each city in the shortest distance. There are different algorithms that can be used such as branch and cut, branch, and bound, and Opt. Each algorithm has its own advantages for solving problems. There are still advances being made on traveling salesman problems today. Delivery/stocking personnel use optimal routes when delivering to different customers, but they may not always have the best stocking route at each different location. We plan to optimize the actual stocking route of the machines themselves. Improving this route will allow all the machines to be properly filled with the desired selections. Also, it will ensure machines are not missed and that they will be filled completely more often. We will be analyzing the locations of the vending machines and all the routes to each one from each one. Traveling salesman problems can be solved using different methods such as dynamic programming, simulated annealing –

metaheuristics, or 2 opt algorithm. We will use the metaheuristics method with help of the software IOR tutorial. A traveling salesman problem is when you consider each distance between each location and optimize the route so that you make it to each location while traveling the shortest distance and not having to backtrack.

2.2) Perfect Mix

We want to make sure delivery personnel know what is missing so it can be appropriately restocked. We studied an article on the importance on the "Sweet Spot". It highlights how to increase sales and reduce waste by simply optimizing your product mix. One of the most effective ways to tackle this issue is to survey the locations by which the machines are located. In our case this could apply not only to the whole campus but based on buildings that the vending devices are located at.

The perfect Mix usually does not work the very first time you begin to implement it. It takes time to figure out what people want. This is discoverable through having more data from the customers purchasing habits. Also, what old students that graduated wanted may be different than what students want now. We can also look at what people in different buildings by more.

2.3) Pre-kitting

Is when a delivery person can fill smaller totes to take to specific machines, so the exact product is in the exact machine you want. They showed how you can use sales data and pre-kitting to get the exact things in the exact machine you want. This is done through data analysis of the vending management system.

2.4) Surveys

Surveys are crucial to figuring out the demographic for the products and locations that go into a vending machine. “It’s a great tool for growth and profitability”(Proebstle 2014). Observing and implementing survey results will directly lead to a more satisfied customer. In the future more satisfied customers means more use of the machines and a continued or raised number of restocking services. This proves Jim Proebstle’s emphasis on measuring customer satisfaction to obtain long-term profits. Surveys will allow us to gather data that we will use to make decisions before implementing any changes. The main goal of the project is to increase profit, and in order to do that we need to increase sales. One of the best approaches to increase sales transactions is by customer satisfaction.

The operators of the vending machines do not personally know the customer satisfaction levels. This is where surveys become important in figuring out the issues you do and do not have based on customer feedback. One of Dr. Knutson’s main ideas on surveys is “At-Location Survey of Customer Reactions” (Knutson 2014). This is the exact method we used to collect our data on the individuals passing and using the vending machines on campus. Satisfaction allows you to grow the whole operation.

Offering incentives will encourage people to take your surveys. In our case the students that offer to take the survey will have their opinion heard and implemented into the machines they use on a regular basis. Thus, while the incentive is not directly handed to them, but they still receive it. We did not use social media to collect any of our data, but it is an alternative way to collect survey data. In our case we wanted to collect data from people we knew would be on campus.

2.5) Contacts

Coca-Cola customer service: We contacted Coca-Cola through the phone number located on the vending machine. The representative told us that Kennesaw State University leases the machines from Coca-Cola.

Coca-Cola delivery/stocking truck driver: He stated that Coca-Cola restocks once a week on Tuesdays. He also told us the locations he visits the most are the Gym, Student Center and Engineering Technology Center. Sometimes the machines are capable of relaying what items and how many are missing from the machines. The vending machines are also incorrect sometimes and he must manually check the machines.

2.6) Seasonal Change

You must go through experimentation to get the optimal selection and quantity for consumers. This will change over time with new customers coming and going, for instance new students enrolling and older ones that have graduated leaving campus. It is encouraged to implement and control these changes. It would be ideal to review after a few months if the implementations had a positive impact on campus, and possibly consider checking on the vending machine locations once or twice a year. The population changes so changes might need to be made in order to keep these positive results.

Seasonal preparedness is also important when optimizing sales. Students during finals week are on campus a lot more leading to more consumption of both snacks and beverages. Things like canned coffees and energy drinks will spike around this time.

Using several types of promotion methods to promote the machines will boost sales. Social media is a great way to get people to notice the vending machines, but we feel it would be more effective to put up visuals around campus such as a map with the vending machine locations. These visuals will promote the use of the machines by making them more attractive.

2.7) Hivery

This is a company that implements AI technology in your existing machine to optimize product restock. This is also known as machine learning that is implemented directly from your vending data through your VMS or vending management system. They began trials in 2015 with experimentation of instillation in Australia. This technology allows you to increase sales revenue and decrease re-stock cost by assessing the current and daily/weekly supply of all products in a specific machine.

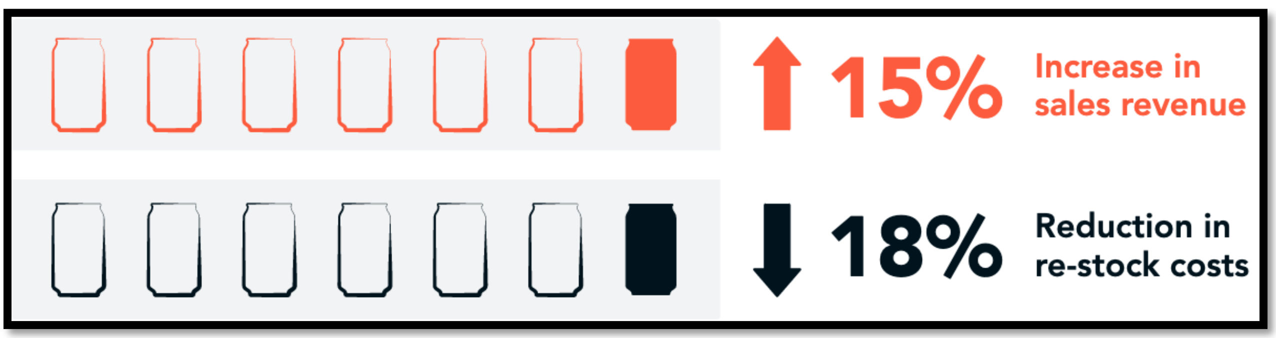


Figure 3: Shows the Benefit of using Hivery [2]

This image depicts the percentage improvement Hivery can have on your sales revenue and how much they can reduce your re-stock costs by implementing their system.

Chapter 3: Planning and Approaches

3.1) Problem Solving Approach

To determine viable locations to place vending machines across Kennesaw State University Marietta Campus. We collected data on the number of people walking past each vending machine and counting the amount of people that make a purchase. We then scoped out new locations and determine if the foot traffic is higher or less. This allowed us to determine if the new location will provide more transactions based on foot traffic. We then took this data and create a simulation in Arena software which allowed us to analyze various locations and scenarios based on foot traffic and purchases, to determine if the new location will yield a higher profit. This allowed us to see if vending machines will need to be moved to new locations or if they need to stay where they are depending on the expected revenue and machine utilization rate. Our project also will be able to optimize the delivery route and provide faster route for the vendor to restock the machines using IOR tutorial.

3.2) Requirements

Below is a list of the requirements we are expecting to meet at the end of this project.

- The vending machine shall have an available space of 72"H x 39"W x 33"D when placed outside
    - This is the standard space required for standard size vending machines.
- The vending machine shall have an available space of 80"H x 45"W x 40"D when placed inside
    - The reason for these dimensions is because it takes into consideration the space for the door opening of the vending machine, as well as room in the back of the machine for the plug-in and the need for air movement for the compressor.

- The vending machines shall be placed at locations around campus where foot traffic is at-least there is a 10% higher number of people per hour than the current location
  - If the new area does not have higher foot traffic of more than 10%, then we will not move the vending machine
- Vending Machines that are moved to a new location within a building shall not increase the customer service time by more than 10s
  - Moving a vending machine to a new location will increase that locations service time due to the customers of the old location coming to the new location as well as the new location having higher foot traffic, generating more customers for that area, increasing the overall service time.
- The new locations shall be more cost effective than previously (improve Sales Revenue)
  - This will happen if the vending machine is in an area where more customers are likely to buy
- Will relocate a vending machine if the current locations utilization of the vending machine is below 20%
  - If a vending machine is not being utilized more than 20% of the time, then it can potentially be losing out on profits from a location with higher utilization.
- The optimized delivery route for the new locations shall have a total walking distance ≤4200 meters
  - We plan to cut down the total walking distance made by the delivery driver by moving the vending machines to new locations.

Table 1: Physical and Functional Attributes

Physical	Functional
Buttons to select products	Dispense purchased products
Mechanism to dispense products	Dispense Change
Clear/opaque inventory section	Receive cash/coins/card
Theft resistant	Variety of machines (drink/food)

3.3) Minimum Success Criteria

- The new locations will have better utilization rate of the vending machines.
- We plan to create a more efficient layout of machines.
- By optimizing the locations of each vending machine, we hope to gain more customers.
- Identify areas with faster arrival times and higher foot traffic to determine the optimal locations where vending machines can be relocated.
- The new locations optimized delivery route shall have a walking distance under 4200 meters
- We plan to optimize the delivery route to save distance travelled and labor time. This will also allow us to refill vending machines more efficiently.

3.4) Data Collection Plan

For this project it is important that we collect the data in the most true and unbiased way. This will allow us to be accurate in our decision making, to decide if we should move a vending machine or not. The way we have decided to collect the data to determine if an area has high foot traffic and a fast or slow arrival time, is to observe the selected vending machine location based off the survey results discussed in the next section.

We split up as a group to record the arrival and service time data of the top two and bottom two locations from the survey results. We have decided as a group to observe the foot traffic, arrival times, and service times for the vending machines starting at noon, until we have collected 32 recordings. We decided to use 32 readings to be accurate as well as too be able to stay within schedule of this project. We selected staring at noon as this will allow us to view the peak hours of lunchtime when the vending machine uses will be at its highest point. It is important to note that we collected this data on the same day for each of the four to be determined locations.

We also collected numerical data of the people that are walking past the machine, how many of them stopped and made a purchase. This will allow us to calculate a percentage of people using a vending machine at that location. For example, if 50 people walk past during the hour, and 25 of them make a purchase from the machine, then we will be able to determine that 50% of people are using the vending machines at that location and time. We will also make note of what machine they are using I.E. Coca-Cola vending machine.

3.5) Survey Development

During this project, we developed and deploy a survey to random students. This gave us an insight and allowed us to make a better decision to determine new locations for the vending machines. It is important we conduct this survey because "It's a great tool for growth and profitability" (Proebstle 2014). It will also allow us to determine how fast we need to re-stock the machines as well as determine which items are the most popular.

We will be able to get an understanding of how people feel about where the vending machines are on campus, as well as if they use them and how often? And other things like do they buy drinks or snacks more etc. Below are the questions we developed for this survey along with reasoning behind asking these specific questions:

1. Do you currently use the vending machines on campus?

o Yes
o No

We wanted to ask question #1 to determine if the vending machines across campus are being used and if the general student population are in favor for vending machines. This would help us determine if our project would have an impact on campus.

2. Have you ever encountered the vending machine being out of stock with the item you want

o Yes
o No

Question #2 was asked to see if our problem statement of the vending machines losing out on profit due to them being empty is true or false. If students answer yes, then it would indicate that there is a problem with the vending machines being out of stock.

3. Would you be interested in a campus map of the vending machine locations?

o Yes
o No

Question #3 is on our survey, because we want to know if the student body would like to have a campus map of the vending machines. By having a campus map, it will make it easier to find the vending machines across campus, and lead to a more evenly use if vending machines across campus. Our goal is to increase sales, and we believe that this could be a great marketing idea to increase transactions.

4. Would you like to have vending machines outdoors?

o Yes
o No

The reason for asking question #4 is because we are proposing to add some outdoor locations for the vending machines. By asking this question, it can help us determine if the student population would use vending machines if places outside. This also will help us determine our budget, due to solar powered vending machines for outdoors, costing much more than a regular electric one.

5. Would you like to see more vending machine locations?

o Yes
o No

Our reason for asking question #5 is to see if the students feel the need for more vending machines across campus. This can help us determine an optimal number of vending machines across campus, as well as help us calculate our cost analysis for adding more machines if needed. Or if we can relocate, the current machines without having to expense for new ones.

6. How often do you see the vending machines low or out of stock?

- o *Always*
- o *Sometimes*
- o *Never*

For question #6, we wanted to see if students notice the machines being low or out of stock. This question can help us prove that there is a loss of profit due to the machines being unstocked with snacks or drinks and in turn misses potential customers. This can also tell us if we need to restock more often.

7. How often do you use the vending machines on campus?

- o *Daily*
- o *2 or more times a week*
- o *Once a week*
- o *Never*

The purpose for asking question #7 is to help us know how popular the vending machines are on campus. This can lead us to figure out if we need to increase the number of times the vendor comes and restocks the machines. If it results in the vendor having to come more often to restock the machines, it will be reflected on the budget for this project.

8. How happy are you with the current vending machine location?

Dissatisfied - 1 2 3 4 5 - Very satisfied

For question #8, we wanted to see the overall satisfaction of the students on the KSU Marietta campus with the current locations of the vending machines. To do this, we used a scale to rate student satisfaction. This can give us an insight into how the students would feel about new locations and if they would be happy with a proposal for new locations.

9. Which type of vending machine do you purchase from?

o Coca-Cola
o Snack Machines
o Both

Question #9 is on our survey because we wanted to see which type of machines were used more often. This can help us determine which machines may need to be restocked more often. The reason for this is because the Coca-Cola machines are stocked by a different vendor than the snack machines. We also will use the results to determine if we may need to add more vending machines. This can help us narrow down our optimal number for the two types of machines.

10. Check all that apply, which buildings do you visit?

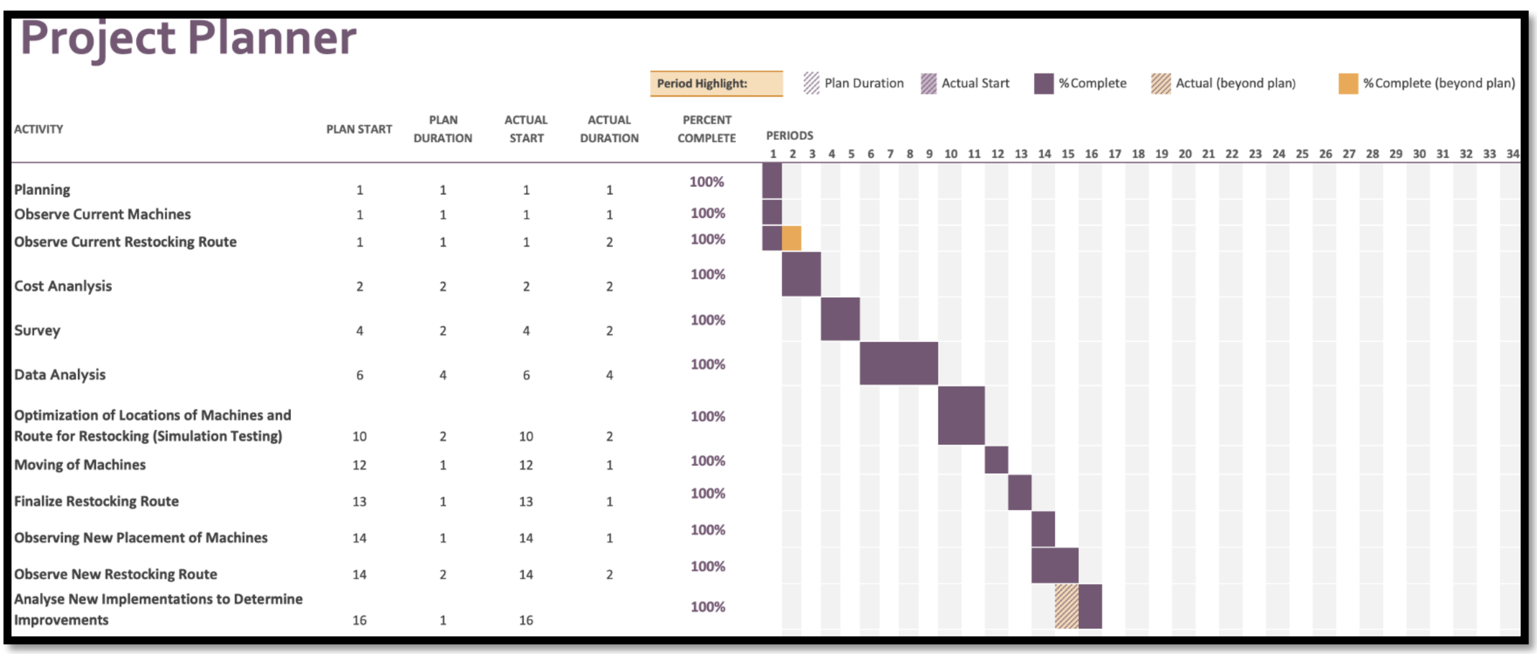
- Academic Building (H)
- Architecture Building (N)
- Atrium Building (J)
- Civil Engineering Tech Building (L)
- Crawford Lab Building (E)
- Design Building (I 1)
- Engineering Technology Center (Q)
- Facilities (F)
- Hornet Village
- Howel Hall
- Housing and Residence Life Community Center (The study)
- Howell Hall (R2)
- Joe Mack Wilson Student Center (A)
- Lawrence V. Johnson Library (C)
- Mathematics Building (D)
- Norton Hall (R2)
- Recreation and Wellness Center (S1)
- West Parking Deck
- W. Clair Harris Textile Center (M)

For question #10. We wanted to see which building had the most people visiting. The results of this question will allow us to decide which are the top two buildings with the most foot traffic, as well as the bottom five buildings with the lowest foot traffic. From those bottom five buildings, we will randomly select two. We will then go to the top two locations and bottom two locations and record foot traffic data, as well as arrival times of people walking past the vending machines to the next person walking past. This will allow us to create an Arena simulation and determine which distribution our data follows.

11. Is there a specific location or building where you would like to see a vending machine added? If yes, please specify the location and type of machine. i.e., Coca-Cola or snack vending machine?

For our last question in our survey, question #11, we wanted to leave an open-ended question and hear the thoughts of students on campus and see where they would like to see vending machines added if they answered yes. This question can lead us to brainstorm locations that we may not have thought of and allows us to make sure that we do not leave out a location that otherwise could be a good addition to one of our proposed locations in the project

3.6) Gantt Chart and Schedule



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Planning	1	1	1	1	100%
Observe Current Machines	1	1	1	1	100%
Observe Current Restocking Route	1	1	1	2	100%
Cost Ananlysis	2	2	2	2	100%
Survey	4	2	4	2	100%
Data Analysis	6	4	6	4	100%
Optimization of Locations of Machines and Route for Restocking (Simulation Testing)	10	2	10	2	100%
Moving of Machines	12	1	12	1	100%
Finalize Restocking Route	13	1	13	1	100%
Observing New Placement of Machines	14	1	14	1	100%
Observe New Restocking Route	14	2	14	2	100%
Analyse New Implementations to Determine Improvements	16	1	16		100%

Figure 4: Gnatt Chart and Schedule

In Figure 4 shown above, the Gantt Chart and schedule for this project is displayed with the milestones that were completed. The project is laid out over a 16-week period. This chart is the final updated Gantt Chart for this project. We were able to stay on track and completed everything needed in a timely manner. Each team member was a part of this project, and put forth work towards this project to ensure that the outcome was successful

3.7) Flow Chart

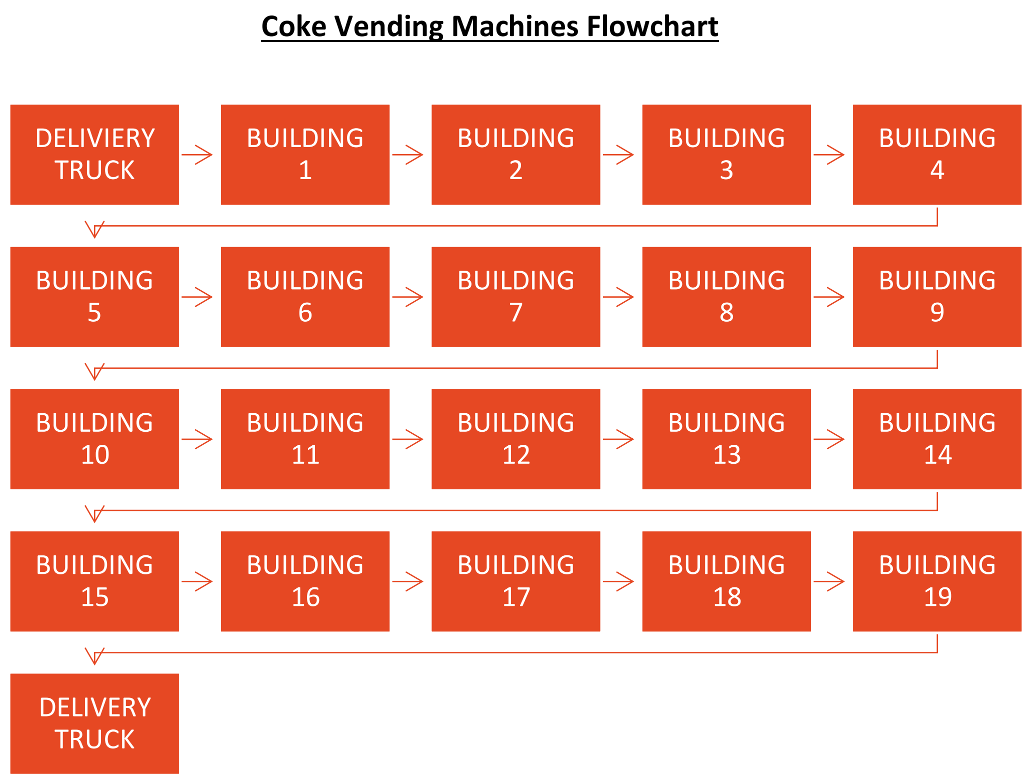


Figure 5: Flow Chart for buildings with Coca-Cola Vending Machines

There are 19 vending machine locations across campus. Some buildings have more than 1 vending machine. We will use IOR to determine the optimal solution for the route that they should follow to restock the vending machines. The number of vending machines in each building will be determined by the data collected from surveys and observations

3.8) Responsibilities

Project Manager: Chase Miller

- Makes sure each task is completed per time allotted
- Keeps the project on schedule
- Research vending machines that need improvement

Supply Chain Manager: Mario Arzate

- Research delivery route to optimize it
- Gathers data for delivery routes to each machine
- Records transaction to each vending machine

Project Director and Process Engineer: Nicholas Singh

- Inputs data into Arena Software and create a simulation model
- Records data of foot traffic and arrival times and uses to optimize and predict profit gain/loss
- Helps Organize and determine next steps in project

Budget Analyst: William Pasha

- Determines budget cost for vending machines and prices to rent vs buy and compares them
- Research cost of stocking vending machine with Coca-Cola Products
- Calculates/ Analyzes estimated profits and overall spending cost for vending machines

Continuous Improvement Engineer: Masumi Jo

- Collects data on current delivery route and calculates walking distances between each building.
- Inputs data into IOR Tutorial and analyzes the results.
- Determines optimum route for vendor to take when delivering and re-stocking vending machines.

3.9) BUDGET

Table 2 : Budget for Vending Machines (Rent vs Buy) and re-stocking cost

Vending Machine Types (If Bought)	Price	
Solar Powered (holds drinks and snacks)	$1,514-$2,199	
Drinks Only (Coke Brand)	$3,000-$4,000	
Drinks Only (Non-Coke Brand)	$3,899-$4,495	
Drinks and Snacks	$2,295-$4,295	
Snacks Only	$2,000-$3,000	
Vending Machine Types (If Rented)	**Rent per month**	**Rent per year**
Drinks Only (Non-Coke Brand)	$50-$150	$600-$1800
Snacks Only	$75-$150	$900-$1800
Drinks Only (Coke Brand)	(Free if buying products directly from coke)	(Free if buying products directly from coke)
Drinks and Snacks	$75-$150	$900-$1800
Vending Machine Types (Refill)	**Stocking Cost**	**Frequency of Restock**
Solar Powered (holds drinks and snacks)	$100	twice a week
Drinks Only (Coke Brand)	Free	once a week
Drinks Only (Non-Coke Brand)	$50-$100	once a week
Drinks and Snacks	$100	twice a week
Snacks Only	$50-$100	once a week

Table 3: Budget for Vending Machines (Rent vs Buy) and re-stocking cost (Coke Brand, Snacks Only)

Vending Machine Types (If Bought)	Price	
Drinks Only (Coke Brand)	(Free installation, no buying price)	
Snacks Only	$2,000-$3,000	
Vending Machine Types (If Rented)	**Rent per month**	**Rent per year**
Snacks Only	$75-$150	$900-$1800
Drinks Only (Coke Brand)	(Free if buying products directly from coke)	(Free if buying products directly from coke)
Vending Machine Types (Refill)	**Stocking Cost**	**Frequency of Restock**
Drinks Only (Coke Brand)	Free	once a week
Snacks Only	$50-$100	once a week

For our budget, we are highlighting what the potential expenses will be to perform a cost analysis. As you see above, in Table 2 and Table 3 there is a comparison between vending machine types if bought vs. if the vending machines were to be rented. Table 2 was made earlier on in the project to give us a better look at all vending machine types so we could make a comparison on which vending machine would be cheaper to perform a cost analysis on. Table 3 focuses on the vending machines that we believe to be the most profitable for Kennesaw State due to further analysis and data collection on these specific vending machines as the project went on. The Coca Cola drink machines, and the snack only machines are currently the only machines being utilized by Kennesaw State, and we have collected data that shows that the highest foot traffic goes to the drinks only Coca Cola vending machines. A cost analysis will be done for the Coca Cola drinks only vending machine because it has an overwhelming amount of foot traffic and greatest opportunity for increased profitability. We have also included the stocking costs for each type of vending machine. The solar powered vending machine does not have a stocking cost price since it holds drinks and snacks, which is what is estimated a few rows down on the drinks and snacks machine in Table 2. These tables also show a range of how much restocking each different vending machine may cost and the frequency at which they would have to restock the vending machine. These values are not exact but more of an estimate found through research.

Table 4: Budget for Consulting Expense

	Number of hours	**Rate per hour**	**Total**
Research and surveys	10	$30	$300
Analysis	20	$28	$560
Development	6	$20	$120
Testing	12	$20	$240
Data Collection	20	$19	$380
Total			**$1,600**

We are also including the consulting expenses based on the time that the team will spend on this project. The number of hours can vary but this is an estimate.

3.10) RESOURCES AVAILABLE

Below is a list of resources that were applied in this project.

- Microsoft PowerPoint
- Microsoft Word
- Microsoft Excel
- Rockwell Arena / Input Analyzer / Process Quest
- IOR tutorial
- Student Survey
- Faculty- Professor Keyser, Professor Khalid of Kennesaw State University

3.11) Verification approach / plan: Analysis and Simulation tests

- Plan to collect data on the number of people that walk past and use the machine.
- Plan to determine higher traffic areas.
- Run analysis on IOR tutorial to determine refill/delivery route
- Include a Lifecyle cost analysis, rent vs buy analysis.
- Create a simulation in Rockwell Arena software to simulate the delivery route.

Our verification approach and plan were successful, and we collected data on the number of foot traffic at these existing vending machines. By analyzing the foot traffic and transactions of the machines, we were able to figure out new locations to place the machine and increase sales revenue. We also ran an analysis on IOR tutorial to determine an efficient delivery/refill route. We created an analysis the lifecycle cost analysis and rent vs buy analysis. By using Rockwell Arena software, we can simulate the proposed delivery route for our new locations.

3.12) Campus Map

Figure 6: Campus Map

Above we can see the campus map as well as how many vending machines each building has. In total there are 32 Coca-Cola Vending machines. We will update this map to show the optimized route for the vendor based off the new proposed locations in chapter 6.

Table 5:Building Names with Vending Machines

Academic Building (H)
Architecture Bulding (N)
Atrium Building (J)
Civil Engineering Building (L)
Crawford Lab Building (E)
Design Building (I1)
Engineering Technology Center (Q)
Facilities (F)
Hornet Village
Howell Hall
Housing and Residence Life Community Center (The study)
Hornet Village (2)
Joe Mack Wilson Student center (A)
Lawerence V. Johnson Library (C)
Mathematics Building (D)
Norton Hall (R2)
Recreation and Wellness Center (S1)
West Parking Deck
W. Clair Harris Textile

Table 6: Bottom Half of Campus Building Number Assignments

Building	Number assigned
Atrium	1
Architecture	2
Civil and Environmental Engineering	3
Design 1	4
Facilities	5
Hornet Village 1	6
Hornet Village 2	7
West Parking Deck	8
W. Clair Harris Textile Center	9

City	1	2	3	4	5	6	7	8	9
1		280.0	210.026	150.0	600.0	240.0	140.0	400.0	120.0
2			210.0	500.0	450.0	350.0	290.0	600.0	150.0
3				450.0	600.0	270.0	230.0	550.0	230.0
4					800.0	230.0	280.0	350.0	290.0
5						750.0	700.0	950.0	600.0
6							90.0	250.0	260.0
7								300.0	190.0
8									450.0
9									

Figure 7: Bottom Half of campus Walking Distance Calculated using Google Maps

Table 7: Top Half of Campus Building Number Assignments

Building	Number assigned
Academic	1
Crawford Lab	2
Engineering Technology Center	3
Howell Hall	4
The Study	5
Joe Mack Wilson Student Center	6
Lawrence V. Johnson Library	7
Mathematics	8
Norton Hall	9
Recreation and Wellness Center	10

City	1	2	3	4	5	6	7	8	9	10
1		250.0	230.0	270.0	400.0	400.0	230.0	350.0	230.0	550.0
2			280.0	300.0	450.0	180.0	130.0	140.0	240.0	450.0
3				450.0	550.0	450.0	300.0	400.0	400.0	700.0
4					160.0	350.0	180.0	300.0	80.0	450.0
5						500.0	400.0	450.0	200.0	450.0
6							180.0	110.0	270.0	290.0
7								160.0	130.0	350.0
8									250.0	350.0
9										400.0
10										

Figure 8: Top Half of campus Walking Distance Calculated using Google Maps

Above we can see the walking distances from building to building. These distances were calculated using Google Maps, and we used meters to be more accurate in our calculations. We will input this data later into IOR tutorial to discover the best optimal route the delivery personnel should take when delivering items on campus. Our goal is to keep the final delivery route distance below 4,200 meters. We will explain how we will find this optimal route in section 5.13

Chapter 4: Data

4.1) Survey Data

For this project, we had a decent turn out for our surveys. We conducted 100 surveys that gave us an insight into what the students think about vending machines, as well as if they would like to see more, even potentially outdoor ones. It also gave us an insight as to which buildings are most visited on campus. This can help us determine which are the top two most popular buildings as well as the bottom 10 buildings. By having this data, we can determine which buildings we need to go and collect foot traffic data, as well as arrival time data. In this section of the report, we will look at the survey results for each question and discuss what the results mean and how we will move forward with our results.

4.2) Questions 1-5

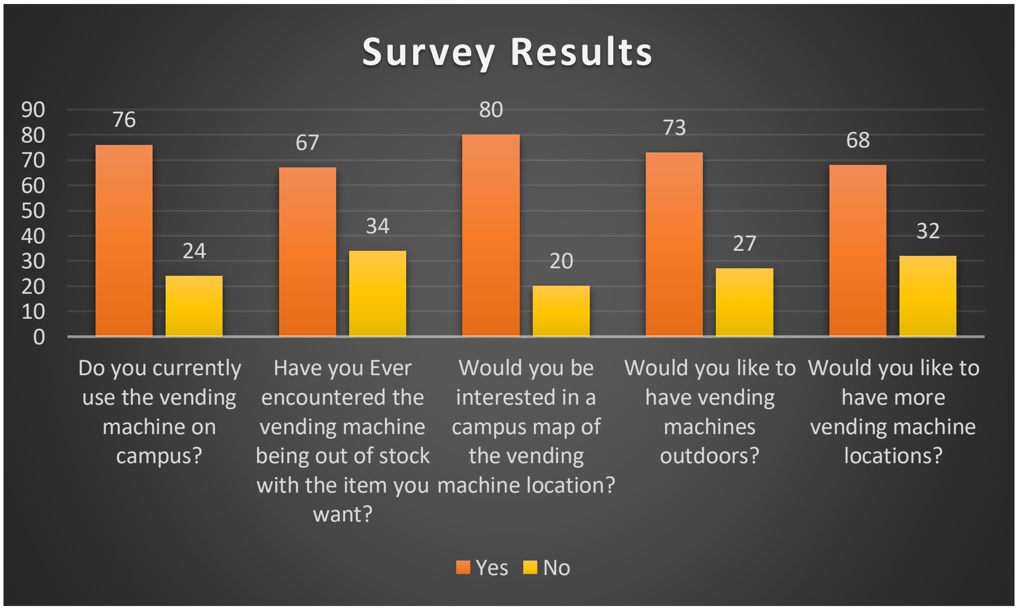


Figure 9: Survey Results for Questions 1-5

Starting out with the “Yes” or “No” questions from our surveys. We can see that every question was in favor for the answer yes as we had hoped. Starting with question one, we can see that 76 people voted for yes and 24 people voted for no. This has indicated to us that most students on campus do in fact use the vending machines on campus. Which has proven that our project has merit and a purpose.

Onto question two, we can see 67 people said yes to encountering the vending machine out of stock of the item they wanted to purchase, while 34 people said no they have not. Being that the majority said they do encounter it empty had let us know that the machines need to be stocked more often or the addition of more machines may be needed, as the budget would allow. Using Arena, we will be able to determine that.

Next is question number 3 where we ask the students, “Would they be interested in a campus map of the vending machine locations.” A whopping 80 people said yes, they would be interested while only 20 said no. This has indicated to us that we will need to create a map showing where the vending machines are located, as well as any new ones added.

Question number 4 asks would you like to have vending machines outdoors. 73 people said yes and 27 people said no. This has made us start to look at potential locations outdoors, as well as looking at the cost for the addition of these machines.

Lastly of the “yes” or “no” questions, we ask would you like to see more vending machine locations across campus. 68 people answered yes and 32 people answered no. This result lets us know that many students would like to see more locations or at the very least machines that are front and center and not hidden away or far from the entrances of buildings.

4.3) Question 6

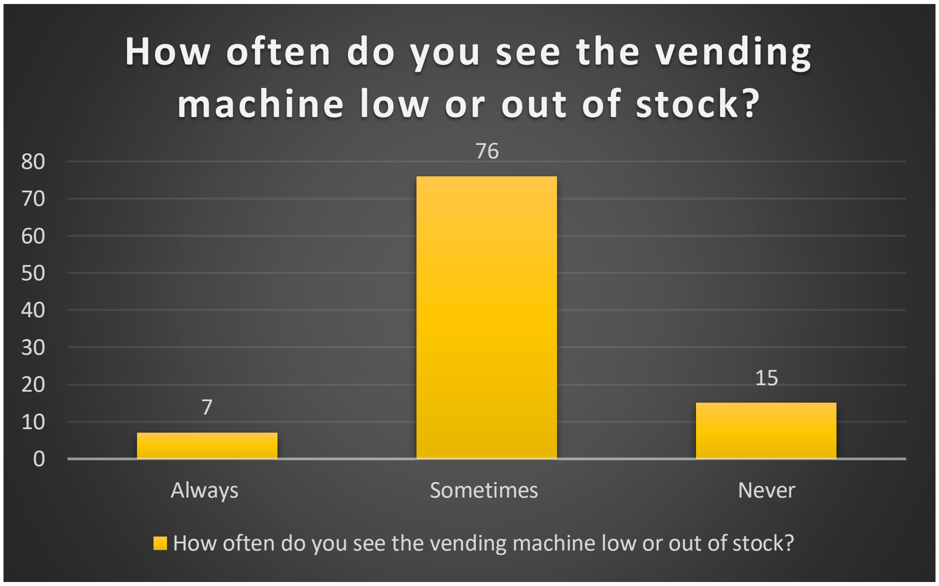


Figure 10: Survey Results for Question 6

Looking at the results for question 6, we can see that most of the students walk by the vending machines and see that they are empty. This lets us know that the delivery route that the vender takes, is not optimized. It also lets us know that the machines need to be stocked more often, which will influence the budget.

4.4) Question 7

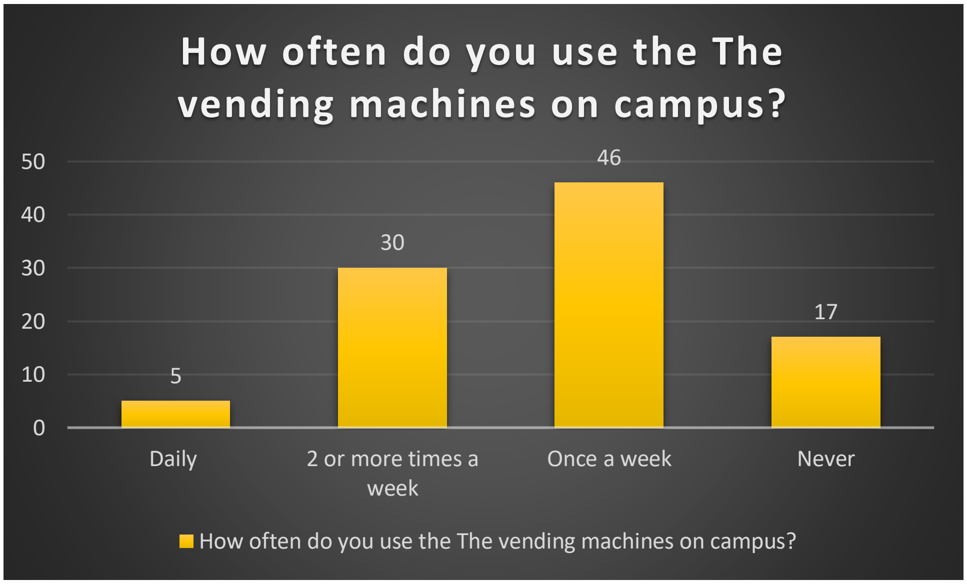


Figure 11: Survey Results for Question 7

Looking at question seven, we asked "how often do you use the vending machines on campus." Upon receiving these results, we can see most people fall in between using the vending machine 2 or more times a week with the majority being they use it at least once a week. We can also see that we had 5 people say they use it daily, and 17 people say they never use it. This can potentially be due to people bringing their own beverage to campus or ordering food from the on-campus restaurants. However, the results still show that most people do in fact use the vending machines on campus frequently

4.5) Question 8

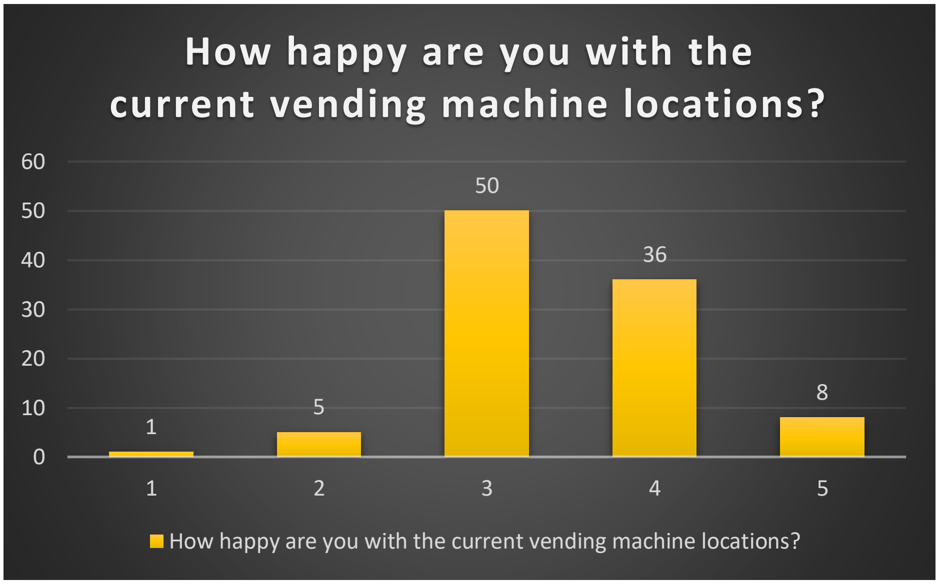


Figure 12: Survey Results for Question 8

For question 8, we asked it on a scale from 1-5, 1 being dissatisfied and 5 being satisfied. Looking at the results of the question, we can see that most people fall in between that mid to high range of being satisfied. We can see that the result is skewed left. However, this shows us that there is still room for improvement in the locations of the vending machines.

4.6) Question 9

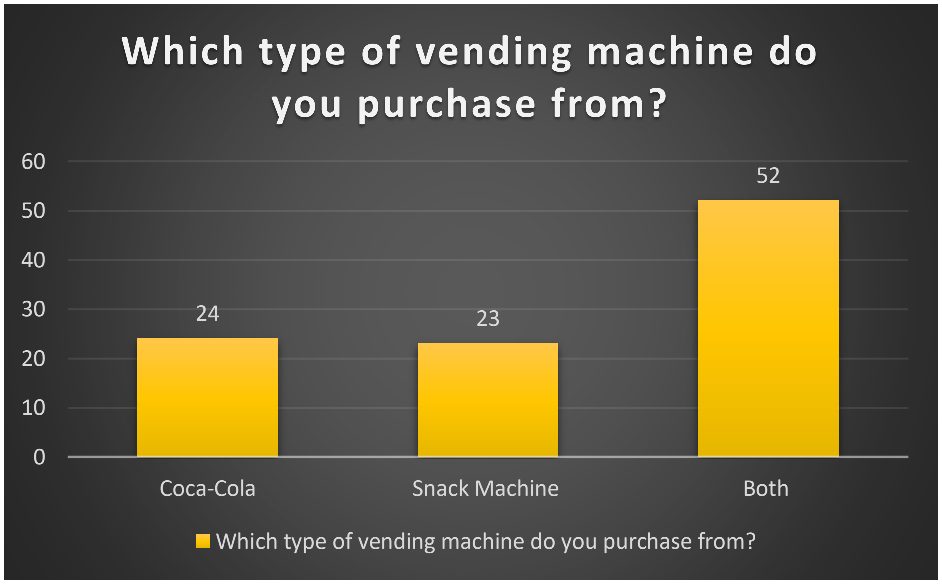


Figure 13: Survey Results for Question 9

On question 9, we asked the students what machines they purchase from. This helps us to determine which machines are being used more and if we would need to investigate adding more Coca-Cola machines or Snack machines. The result from the survey shows us that both machines are used very evenly across campus. 52 people said they buy from both, which indicates that both types of machines across campus are being used. This also ties into our budget, because the machines are stocked by two different vendors, both with different pricing. So, this will help us in our cost analysis to determine how much profit Kennesaw State University will make.

4.7) Foot Traffic Data

Table 8: Foot Traffic Data from Surveys

Academic Building (H)	35
Architecture Building (N)	3
Atrium Building (J)	62
Civil Engineering Building (L)	11
Crawford Lab Building (E)	15
Design Building (I1)	5
Engineering Technology Center (Q)	53
Facilities (F)	4
Hornet Village	8
Howell Hall	8
Housing and Residence Life Community Center (The study)	5
Howell Hall (R2)	3
Joe Mack Wilson Student center (A)	67
Lawrence V. Johnson Library (C)	49
Mathematics Building (D)	34
Norton Hall (R2)	10
Recreation and Wellness Center (S1)	16
West Parking Deck	15
W. Clair Harris Textile	19

For this project we needed to collect foot traffic data to determine which buildings had the highest number of people passing through or visiting it. The way we collected this data was through the surveys that we handed out. We needed to figure out the top two buildings that had the most visits and the bottom two that had the least number of visits.

Looking at the data, we can see that the top two buildings that have the most visitors are the Atrium Building and the Joe Mack Wilson Student Center. The way we determined the bottom two buildings was by randomly selecting two buildings out of the bottom 10 using random numbers. This allows us to not be biased on which bottom two buildings to use, due to there being buildings with the same amount of survey answers or very little amount of people visiting

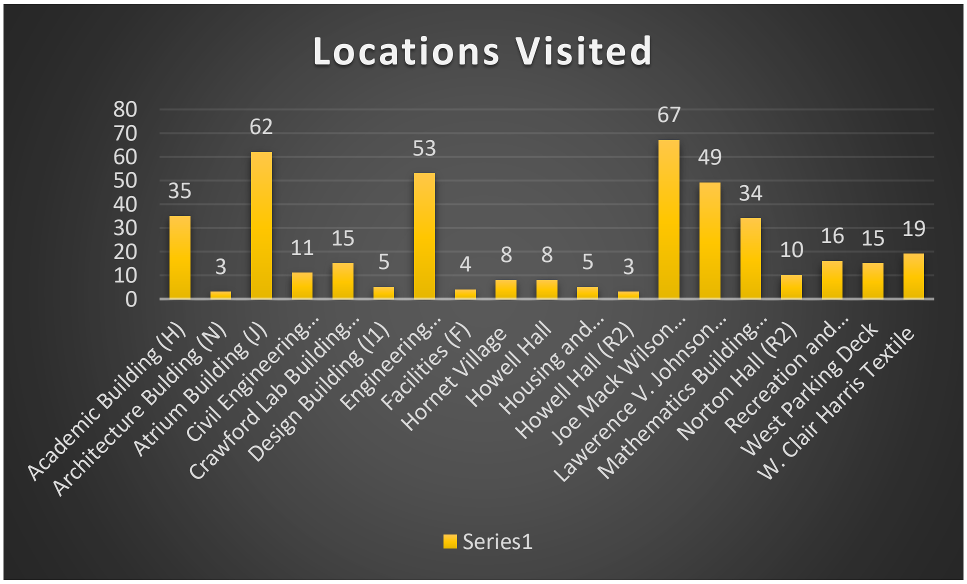


Figure 14: Foot Traffic Represented in Graphical Form

those areas. However, the bottom 5 buildings let us know that we can potentially relocate those vending machines out of those buildings and into higher foot traffic buildings.

By collecting this data on foot traffic from the surveys. We can now determine which buildings we need to visit and collect data on the arrival times of people walking past the machines. These buildings will be The Joe Mack Wilson Student Center, The Atrium Building, The Mathematics Building, and the West Parking Deck. By collecting that data next, we will be able to tell what distribution our data follows as well as the standard deviation and mean. This will also allow us to create an Arena Simulation model to predict the optimal number of Coca-Cola vending machines and Snack Machines. It will also show us the profit, considering things like the cost of the vending machines, as well as re-stocking cost from the vendor.

4.8) Challenges Faced

Several challenges were faced throughout our project. We were looking into implementing Hivery a system that allows you to remotely monitor the stock of a vending machine (Yoshimura 2021). However, Coca-Cola already has their own system installed in their machines that allow delivery personnel to know the number of products in a specific machine before they arrive. This allows them to see what sells the most out of their machines and from this information they create “The sweet spot product mix”. This mix is the best combination of drinks in a machine that satisfy most customers (Blomquist 2017)

We attempted to reach out to both the snack and drink providers with multiple calls and emails through various outlets. We were only able to have correspondence with the drink vendor, Coca-Cola. They were only able to provide minimal information over the phone. The other Coca-Cola representative we spoke with was the delivery man that we approached on campus, who stocks the machines.

We also realized that 2 snack vending machines at the Atrium were broken. People were trying to buy snacks, but the transactions would not go through. This made it hard to collect data for the snack vending machines. We tried to reach out to them again, but they never answered nor reached out back to us.

Another challenge faced by our group was some of the limitations within the IOR Tutorial program. When conducting a traveling salesman problem, you are limited to 10 locations. We have 19 locations we want to optimize. We ended up optimizing the route for the first 10 locations. The route ends where the second one starts for the last 9 locations. So, we were able to use the program it just was not as straight forward as it usually would be to conduct a traveling salesman problem.

4.9) Arrival Times

For this project, we recorded data on the arrival times of students walking past a vending machine from each of the four selected locations from the survey. The way we collected this data was to record the exact time of day in military time and write it down into our excel file. We then would record the exact time of day when another person walks past the vending machine and so on. The excel file calculated the difference between the two times all the way down to 32 readings. We chose to do 32 readings so that we can be accurate in our predictions. We also made note of out of the 32 people we recorded how many of them made a purchase from the vending machine. This allowed us to also decide how profitable the machines are in that area, and if people are just walking buy, or is there a sizable number of people stopping and making a purchase

Table 9:STUDENT CENTER ARRIVAL TIMES

Readings	Arrival Time	Diff Hr	Diff Min	Diff Sec	Decimal Min
1	12:00:00				
2	12:01:10	0.00	1.00	10.00	1.17
3	12:01:38	0.00	0.00	28.00	0.47
4	12:01:55	0.00	0.00	17.00	0.28
5	12:02:21	0.00	0.00	26.00	0.43
6	12:02:50	0.00	0.00	29.00	0.48
7	12:03:53	0.00	1.00	3.00	1.05
8	12:04:24	0.00	0.00	31.00	0.52
9	12:04:58	0.00	0.00	34.00	0.57
10	12:05:34	0.00	0.00	36.00	0.60
11	12:07:00	0.00	1.00	26.00	1.43
12	12:07:48	0.00	0.00	48.00	0.80
13	12:08:25	0.00	0.00	37.00	0.62
14	12:08:56	0.00	0.00	31.00	0.52
15	12:09:39	0.00	0.00	43.00	0.72
16	12:10:26	0.00	0.00	47.00	0.78
17	12:11:01	0.00	0.00	35.00	0.58
18	12:12:36	0.00	1.00	35.00	1.58
19	12:13:11	0.00	0.00	35.00	0.58
20	12:13:36	0.00	0.00	25.00	0.42
21	12:14:05	0.00	0.00	29.00	0.48
22	12:15:20	0.00	1.00	15.00	1.25
23	12:15:45	0.00	0.00	25.00	0.42
24	12:16:00	0.00	0.00	15.00	0.25
25	12:16:41	0.00	0.00	41.00	0.68
26	12:17:16	0.00	0.00	35.00	0.58
27	12:18:51	0.00	1.00	35.00	1.58
28	12:19:26	0.00	0.00	35.00	0.58
29	12:20:05	0.00	0.00	39.00	0.65
30	12:21:34	0.00	1.00	29.00	1.48
31	12:22:23	0.00	0.00	49.00	0.82
32	12:22:57	0.00	0.00	34.00	0.57

This is our arrival times for the student center. Here we can see that most of the times are below one minute. This indicates to us, that the foot traffic was high in this area as according to our surveys. This means that the vending machine is seeing a decent amount of traffic. We also recorded that out of the 32 people, 12 of them stopped and made a purchase. This lets us know that the vending machines in this area are profitable and will not need to relocate. However, this location can be used as an area for further addition of vending machines. To determine that, we calculate the service times and see what would happen if we doubled our arrival rate.

Table 10: ATRIUM BUILDING ARRIVAL TIMES

Readings	Arrival Time	Diff Hr	Diff Min	Diff Sec	Decimal Min
1	12:00:00				
2	12:01:10	0.00	1.00	10.00	1.17
3	12:01:38	0.00	0.00	28.00	0.47
4	12:01:55	0.00	0.00	17.00	0.28
5	12:02:11	0.00	0.00	16.00	0.27
6	12:02:20	0.00	0.00	9.00	0.15
7	12:02:27	0.00	0.00	7.00	0.12
8	12:02:42	0.00	0.00	15.00	0.25
9	12:03:58	0.00	1.00	16.00	1.27
10	12:05:10	0.00	1.00	12.00	1.20
11	12:06:00	0.00	0.00	50.00	0.83
12	12:06:23	0.00	0.00	23.00	0.38
13	12:06:28	0.00	0.00	5.00	0.08
14	12:07:00	0.00	0.00	32.00	0.53
15	12:08:18	0.00	1.00	18.00	1.30
16	12:08:41	0.00	0.00	23.00	0.38
17	12:09:12	0.00	0.00	31.00	0.52
18	12:10:36	0.00	1.00	24.00	1.40
19	12:12:05	0.00	1.00	29.00	1.48
20	12:13:36	0.00	1.00	31.00	1.52
21	12:14:05	0.00	0.00	29.00	0.48
22	12:15:20	0.00	1.00	15.00	1.25
23	12:15:45	0.00	0.00	25.00	0.42
24	12:16:00	0.00	0.00	15.00	0.25
25	12:16:13	0.00	0.00	13.00	0.22
26	12:17:16	0.00	1.00	3.00	1.05
27	12:17:51	0.00	0.00	35.00	0.58
28	12:18:00	0.00	0.00	9.00	0.15
29	12:18:05	0.00	0.00	5.00	0.08
30	12:18:42	0.00	0.00	37.00	0.62
31	12:19:22	0.00	0.00	40.00	0.67
32	12:19:57	0.00	0.00	35.00	0.58

This is our arrival times for the Atrium building. Here we can see that the arrival rate is like the arrival rates of the student center. This is due to it being one of the top 2 areas that our survey indicated would have high foot traffic. During our data collection, we recorded that out of the 32 people, 10 of them stopped and made a purchase from the vending machine. This indicates to us, that the vending machines at this location is profitable and will not need to be relocated. We will record the service times of those 10 individuals and use arena to determine if this area can use a second or third machine if the arrival rates were doubled.

Table 11: WEST PARKING DECK ARRIVAL TIMES

Readings	Arrival Time	Diff Hr	Diff Min	Diff Sec	Decimal Min
1	12:00:00				
2	12:01:10	0.00	1.00	10.00	1.17
3	12:01:55	0.00	0.00	45.00	0.75
4	12:02:55	0.00	1.00	0.00	1.00
5	12:03:37	0.00	0.00	42.00	0.70
6	12:04:20	0.00	0.00	43.00	0.72
7	12:05:27	0.00	1.00	7.00	1.12
8	12:07:42	0.00	2.00	15.00	2.25
9	12:08:58	0.00	1.00	16.00	1.27
10	12:11:55	0.00	2.00	57.00	2.95
11	12:12:54	0.00	0.00	59.00	0.98
12	12:13:23	0.00	0.00	29.00	0.48
13	12:14:22	0.00	0.00	59.00	0.98
14	12:15:39	0.00	1.00	17.00	1.28
15	12:17:18	0.00	1.00	39.00	1.65
16	12:17:41	0.00	0.00	23.00	0.38
17	12:19:12	0.00	1.00	31.00	1.52
18	12:20:44	0.00	1.00	32.00	1.53
19	12:22:05	0.00	1.00	21.00	1.35
20	12:23:33	0.00	1.00	28.00	1.47
21	12:24:05	0.00	0.00	32.00	0.53
22	12:25:58	0.00	1.00	53.00	1.88
23	12:26:45	0.00	0.00	47.00	0.78
24	12:28:00	0.00	1.00	15.00	1.25
25	12:29:13	0.00	1.00	13.00	1.22
26	12:30:10	0.00	0.00	57.00	0.95
27	12:32:51	0.00	2.00	41.00	2.68
28	12:33:33	0.00	0.00	42.00	0.70
29	12:34:45	0.00	1.00	12.00	1.20
30	12:35:42	0.00	0.00	57.00	0.95
31	12:37:32	0.00	1.00	50.00	1.83
32	12:40:24	0.00	2.00	52.00	2.87

This is our arrival times for the West Parking Deck. Here we can see that most of the times are in the 1 - 2-minute range with some of the times reaching almost 3 minutes. This indicates to us that the foot traffic is relatively low which matches our survey data. Out of the 32 people we recorded 0 people stopping and making a purchase from the vending machines. This tells us that this location is not profitable and will need to be relocated to an area with faster arrival times and higher foot traffic. The location to relocate the vending machine is unknown right now, but it will be in one of the top 2 locations.

Table 12: MATHEMATICS BUILDING ARRIVAL TIMES

Readings	Arrival Time	Diff Hr	Diff Min	Diff Sec	Decimal Min
1	12:00:00				
2	12:01:10	0.00	1.00	10.00	1.17
3	12:02:24	0.00	1.00	14.00	1.23
4	12:04:45	0.00	2.00	21.00	2.35
5	12:05:43	0.00	0.00	58.00	0.97
6	12:07:20	0.00	1.00	37.00	1.62
7	12:09:38	0.00	2.00	18.00	2.30
8	12:13:10	0.00	3.00	32.00	3.53
9	12:15:02	0.00	1.00	52.00	1.87
10	12:18:13	0.00	3.00	11.00	3.18
11	12:20:34	0.00	2.00	21.00	2.35
12	12:23:23	0.00	2.00	49.00	2.82
13	12:25:28	0.00	2.00	5.00	2.08
14	12:25:59	0.00	0.00	31.00	0.52
15	12:26:32	0.00	0.00	33.00	0.55
16	12:28:21	0.00	1.00	49.00	1.82
17	12:29:58	0.00	1.00	37.00	1.62
18	12:32:12	0.00	2.00	14.00	2.23
19	12:34:29	0.00	2.00	17.00	2.28
20	12:37:08	0.00	2.00	39.00	2.65
21	12:39:05	0.00	1.00	57.00	1.95
22	12:41:41	0.00	2.00	36.00	2.60
23	12:42:34	0.00	0.00	53.00	0.88
24	12:44:33	0.00	1.00	59.00	1.98
25	12:45:19	0.00	0.00	46.00	0.77
26	12:47:58	0.00	2.00	39.00	2.65
27	12:49:37	0.00	1.00	39.00	1.65
28	12:50:33	0.00	0.00	56.00	0.93
29	12:54:01	0.00	3.00	28.00	3.47
30	12:56:20	0.00	2.00	19.00	2.32
31	12:58:00	0.00	1.00	40.00	1.67
32	13:00:24	0.00	2.00	24.00	2.40

This is our data for the mathematics arrival times. Looking at the data we can see that the difference between the times is much longer with times going past the three-minute mark. This indicates to us that the foot traffic at this location is very slow and will need to be consider as a vending machine that needs to be relocated. Out of the 32 people that walked past the machine, 4 people stopped and made a purchase. This means that the profit from this location is low over a fast period of time.

4.10) Service Times

The service time data will be from the people that stopped at the vending machine and made a purchase during our observation of the arrival times. This was recorded as the time when someone stopped in front of the machine, purchased a product, and collected the item and began walking away from the vending machine. We did not record service time for the West Parking Deck location because there were 0 people that stopped and made a purchase from these vending machines. However, we did record service times for the other three buildings:

- Joe Mack Wilson Student Center out of 32 there were 12 service times = 37.5%
- Atrium Building out of 32 there were 10 service times = 31.3%
- Mathematics Building out of 32 there were 4 service times = 12.5%

The service time data will help us to create our arena simulation model, that will allow us to predict what will happen if we have a faster arrival rate. We also will be able to see what would happen if we increased the number or increased the vending machines at a location and be able to view the service times decreasing with the addition of more machines.

Table 13: STUDENT CENTER SERVICE TIMES

Diff Min	Diff Sec	Decimal Min
0.00	56.00	0.93
0.00	42.00	0.70
1.00	17.00	1.28
0.00	35.00	0.58
0.00	59.00	0.98
0.00	58.00	0.97
0.00	56.00	0.93
1.00	36.00	1.60
0.00	51.00	0.85
0.00	47.00	0.78
1.00	1.00	1.02
1.00	5.00	1.08

Here we have listed the service times for the people who stopped and made a purchase from the vending machine during our data collection of the 32 arrival times. We have three tables for the three different location that had service times. The West Parking Deck location is not listed due to there not being any service times available. We have listed the time of how long it took them to decide what they want, insert cash, or tap their card and press the numbers of the item they wanted. Starting the student center. We can see that we have 12 readings ranging from different services times. Next, we can see that the atrium building has 10 readings and the math building only has 4 readings. We will take this data and input them into the input analyzer mentioned in the next chapter to see the distribution of this data. By doing this we will be able to construct our arena simulation and predict future arrival times and service times if our foot traffic were to double.

Table 14: ATRIUM BUILDING SERVICE TIMES

Diff Min	Diff Sec	Decimal Min
0.00	38.00	0.63
1.00	0.00	1.00
0.00	52.00	0.87
1.00	4.00	1.07
1.00	27.00	1.45
0.00	51.00	0.85
0.00	36.00	0.60
0.00	53.00	0.88
0.00	48.00	0.80
1.00	11.00	1.18

Table 15: MATHEMATICS BUILDING SERVICE TIMES

Diff Min	Diff Sec	Decimal Min
1.00	2.00	1.03
0.00	56.00	0.93
0.00	47.00	0.78
1.00	13.00	1.22

Chapter 5: Analyzing the Data

5.1) Input Analyzer

For this project, we will be using input analyzer from the arena software. This software allows us to see the distribution of our arrival times above and allows us to develop a simulation model in the arena software. It will show us the name of the distribution, as well as the sample standard deviation and sample mean. It will also show us the chi-square test and compare each distribution squared error and select the one with the lowest squared error. This will indicate that the distribution with the lowest squared error is in fact the best fitted distribution for the data inputted.

5.2) Student Center Arrival Times Distribution

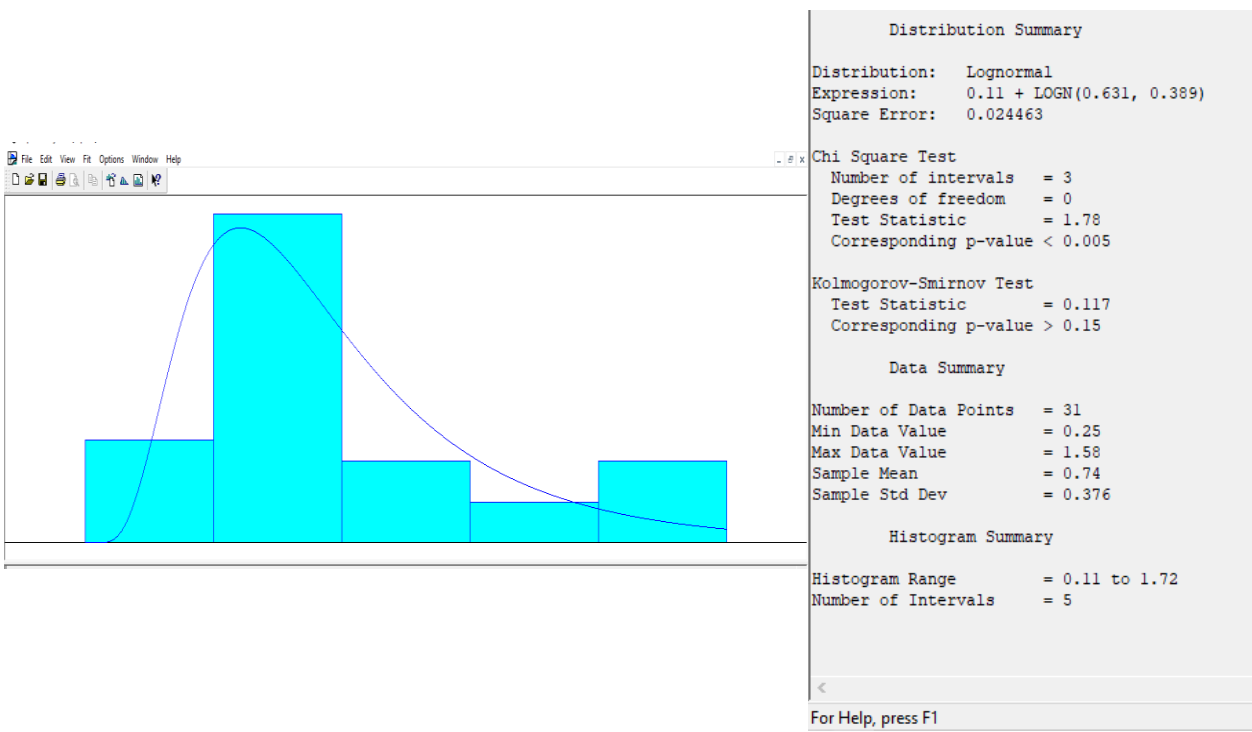


Figure 15: Student Center Arrival Times Input Analyzer

Table 16: Student Center Arrival Times Sq-Error Results

Function	Sq Error
Lognormal	**0.0245**
Gamma	**0.0393**
Erlang	**0.0405**
Weibull	**0.0567**
Triangular	**0.0613**
Beta	**0.0844**
Normal	**0.872**
Uniform	**0.13**
Exponential	**0.14**

Above we can see the distribution of the student center raw data of arrival times as well as the sq-error of the different distributions inputted into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.0245. This indicates that the distribution is the "tightest" or "best Fit". We can see that the distribution of the data for the student center is Lognormal. This indicated that we will not have any negative variables. The expression for this data is 0.11 + LOGN (0.631, 0.389). This expression will be used to represent our arrival time data in our arena simulation that we will construct in order to predict what would happen if we increased the number of people going through the system which is our Y variable, or if we manipulate the arrival times to be slower or faster with a certain number of available machines, our X variable.

5.3) Atrium Building Arrival Times Distribution

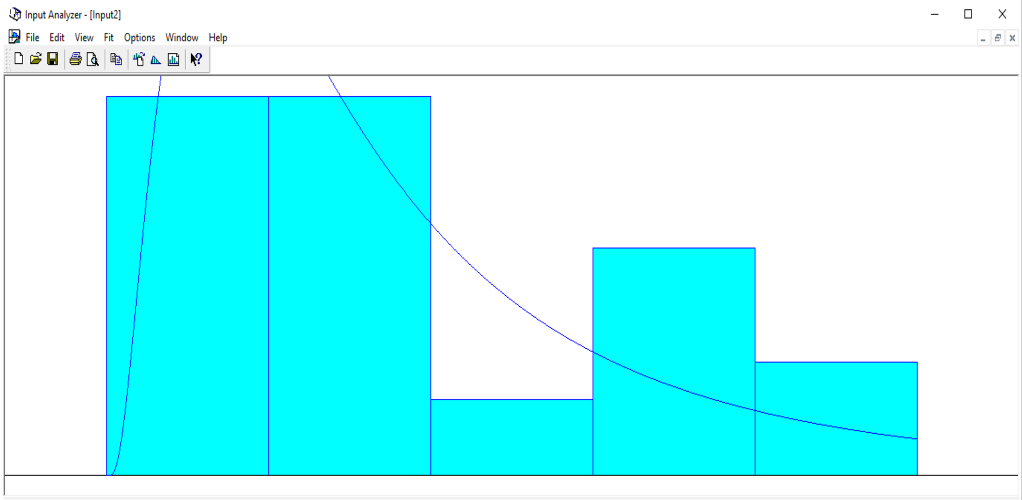


Figure 16: Atrium Building Arrival Times Input Analyzer

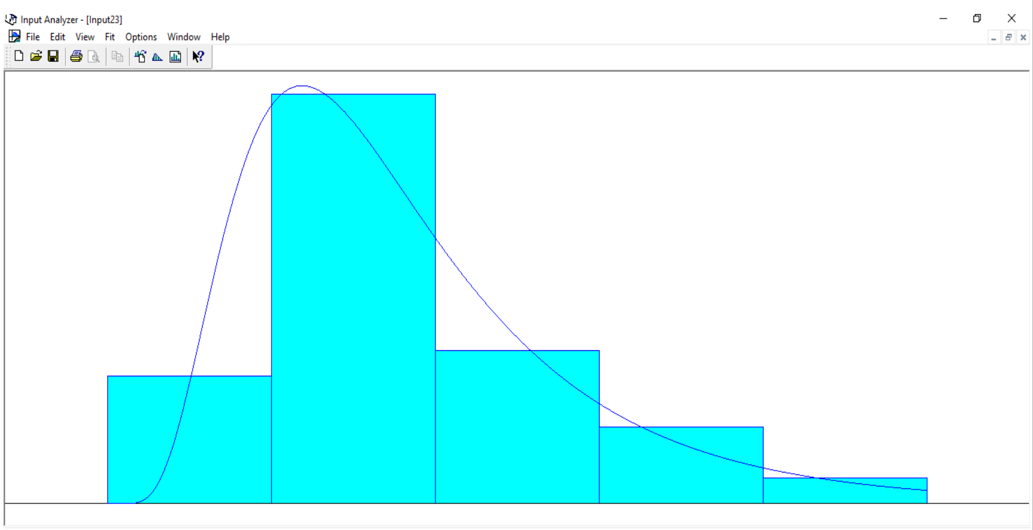
```
         Distribution Summary

Distribution:   Lognormal
Expression:     LOGN(0.679, 0.705)
Square Error:   0.024791

Chi Square Test
  Number of intervals    = 3
  Degrees of freedom     = 0
  Test Statistic         = 0.925
  Corresponding p-value  < 0.005

Kolmogorov-Smirnov Test
  Test Statistic         = 0.116
  Corresponding p-value  > 0.15

        Data Summary

Number of Data Points    = 31
Min Data Value           = 0.08
Max Data Value           = 1.52
Sample Mean              = 0.644
Sample Std Dev           = 0.464

        Histogram Summary

Histogram Range          = 0 to 1.67
Number of Intervals      = 5
```

Table 17: Atrium Building Arrival Times Sq-Error Results

Function	Sq Error
Lognormal	**0.0248**
Beta	**0.0261**
Gamma	**0.0276**
Weibull	**0.0296**
Erlang	**0.0323**
Triangular	**0.0325**
Exponential	**0.335**
Uniform	**0.0591**
Normal	**0.0689**

Above we can see the distribution of the Atrium Building raw data of arrival times as well as the sq-error of the different distributions input into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.0248. This indicates that the distribution is the "tightest" or "best Fit". We can see that the distribution of the data for the student center is Lognormal. This indicated that we will not have any negative variables. The expression for this data is LOGN (0.679, 0.705). This expression will be used to represent our arrival time data in our arena simulation that we will construct to predict what would happen if we increased the number of people going through the system which is our Y variable, or if we manipulate the arrival times to be slower or faster with a certain number of available machines, our X variable at this location

5.4) West Parking Deck Arrival Times Distribution



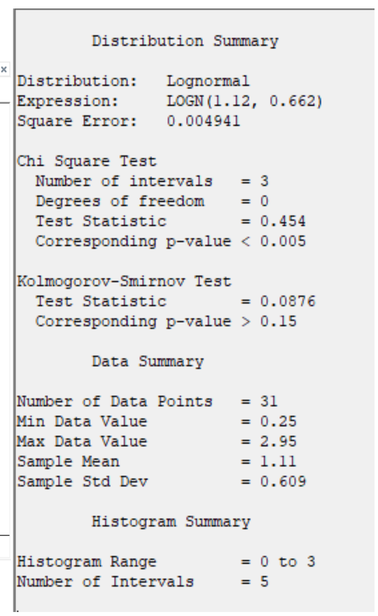


Figure 17: West Parking Deck Arrival Times Input Analyzer

Table 18: West Parking Deck Arrival Times Sq-Error Results

Function	Sq Error
Lognormal	**0.00494**
Erlang	**0.00863**
Gamma	**0.0998**
Weibull	**0.0237**
Normal	**0.0389**
Beta	**0.0398**
Triangular	**0.0423**
Uniform	**0.14**
Exponential	**0.143**

Above we can see the distribution of the West Parking Deck raw data of arrival times as well as the sq-error of the different distributions inputted into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.00494. This indicates that the distribution is the "tightest" or "best Fit". We can see that the distribution of the data for the student center is Lognormal. This indicated that we will not have any negative variables. The expression for this data is LOGN (1.12, 0.662). This data will not be used to construct an arena simulation due to there not being any service time data.

5.5) Mathematics Building Arrival Times Distribution

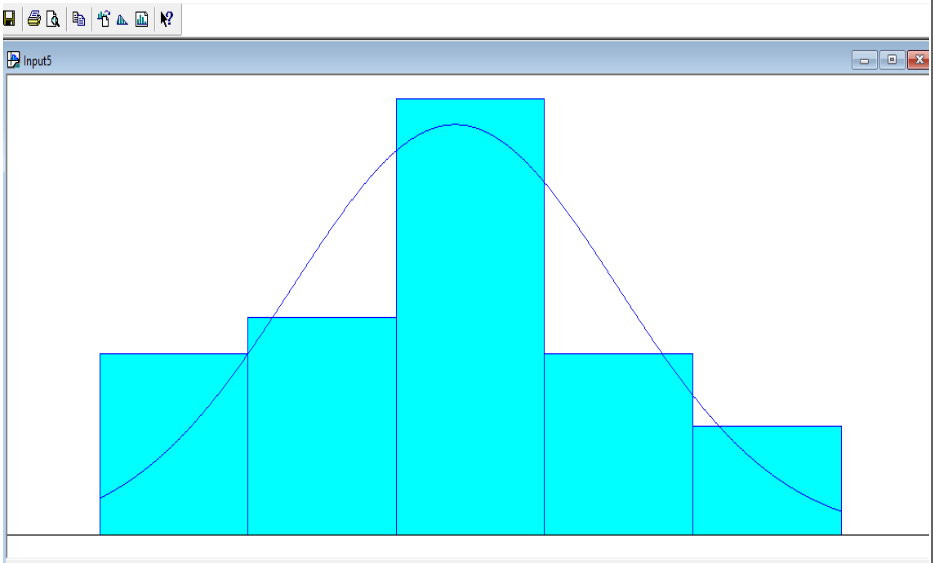
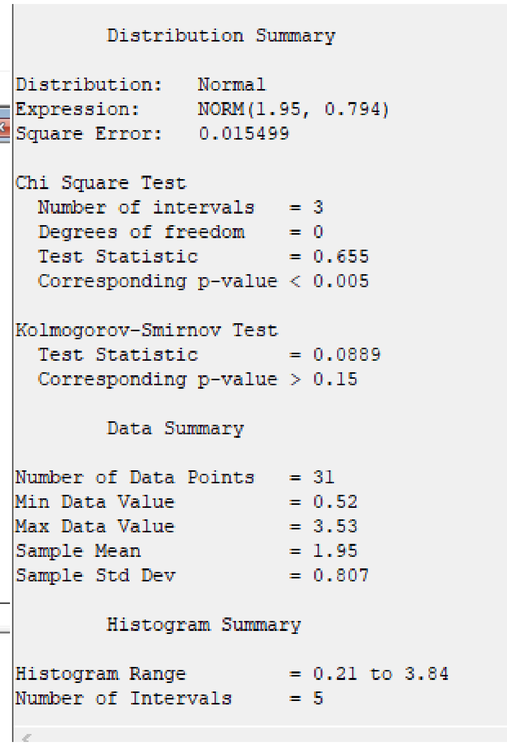


Figure 18: Mathematics Building Arrival Times Input Analyzer



```
        Distribution Summary

Distribution:   Normal
Expression:     NORM(1.95, 0.794)
Square Error:   0.015499

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 0.655
  Corresponding p-value < 0.005

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0889
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 31
Min Data Value          = 0.52
Max Data Value          = 3.53
Sample Mean             = 1.95
Sample Std Dev          = 0.807

        Histogram Summary

Histogram Range         = 0.21 to 3.84
Number of Intervals     = 5
```

Table 19: Mathematics Building Arrival Times Sq-Error Results

Function	Sq Error
Normal	**0.0155**
Triangular	**0.0162**
Beta	**0.0199**
Weibull	**0.0207**
Gamma	**0.0333**
Erlang	**0.0338**
Uniform	**0.0487**
Lognormal	**0.0508**
Exponential	**0.0956**

Above we can see the distribution of the Mathematics Building raw data of arrival times as well as the sq-error of the different distributions inputted into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.0155. This indicates that the distribution is the “tightest” or “best Fit”. We can see that the distribution of the data for the student center is normal. This indicated that most of the arrival times are center in the middle and closer to the mean. The expression for this data is NORM (1.95, 0.794). This expression will be used to represent our arrival time data in our arena simulation that we will construct to predict what would happen if we increased the number of people going through the system which is our Y variable, or if we manipulate the arrival times to be slower or faster with a certain number of available machines, our X variable at this location

5.6) Student Center Service Times Distribution

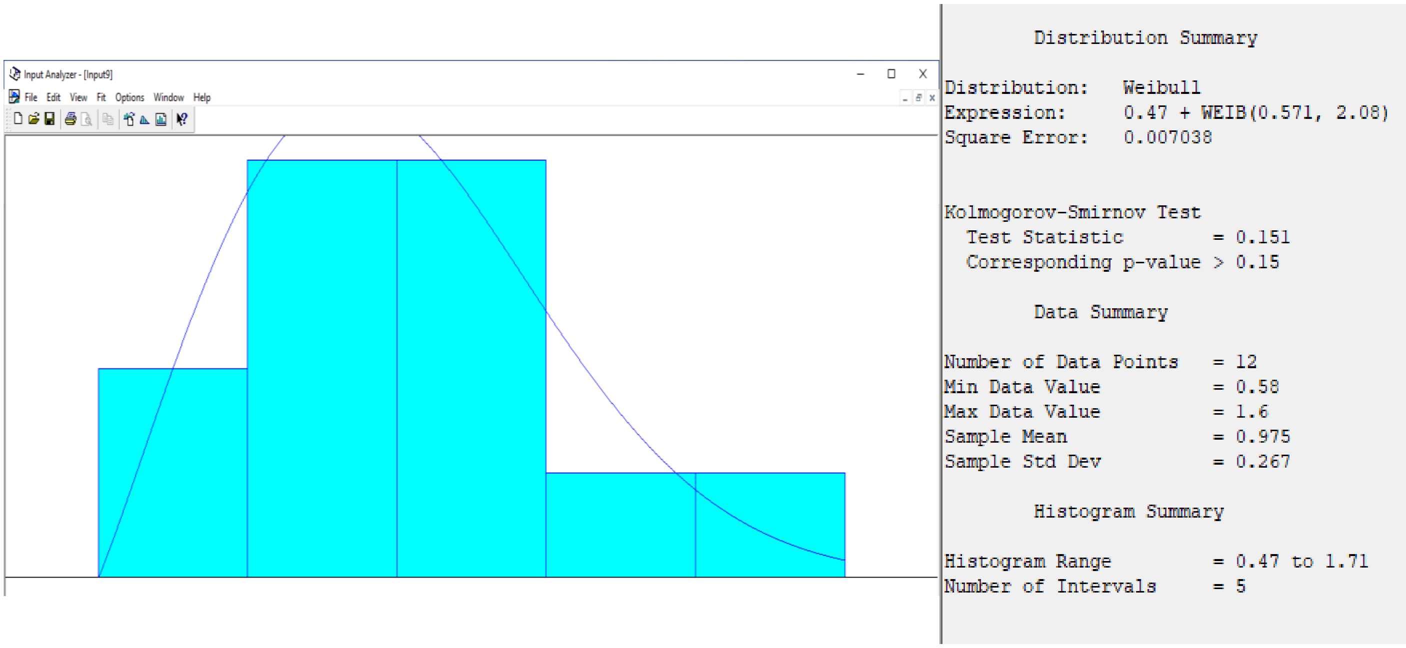


Figure 19: Student Center Service Times Input Analyzer

Table 20: Student Center Service Times Sq-Error Results

Function	Sq Error
Weibull	0.00704
Normal	0.0084
Gamma	0.0119
Triangular	0.0122
Beta	0.0122
Erlang	0.0132
Lognormal	0.0199
Uniform	0.0639
Exponential	0.0944

Above we can see the distribution of the Student Center raw data of Service times as well as the sq-error of the different distributions inputted into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.00704. This indicates that the distribution is the "tightest" or "best Fit." We can see that the distribution of the data for the student center is the Weibull distribution. This may be because the Weibull distribution is able to model a wide range of several types of data. The expression for this data is 0.47 + WEIB (0.571, 2.08). This expression will be used to represent our service time data in our arena simulation process module. It will allow us to manipulate the que line and see how many people are in the lone waiting to be served and how much the service time will increase if we increase the amount of foot traffic or decrease with the addition of more vending machines at this location

5.7) Atrium Building Service Times Distribution

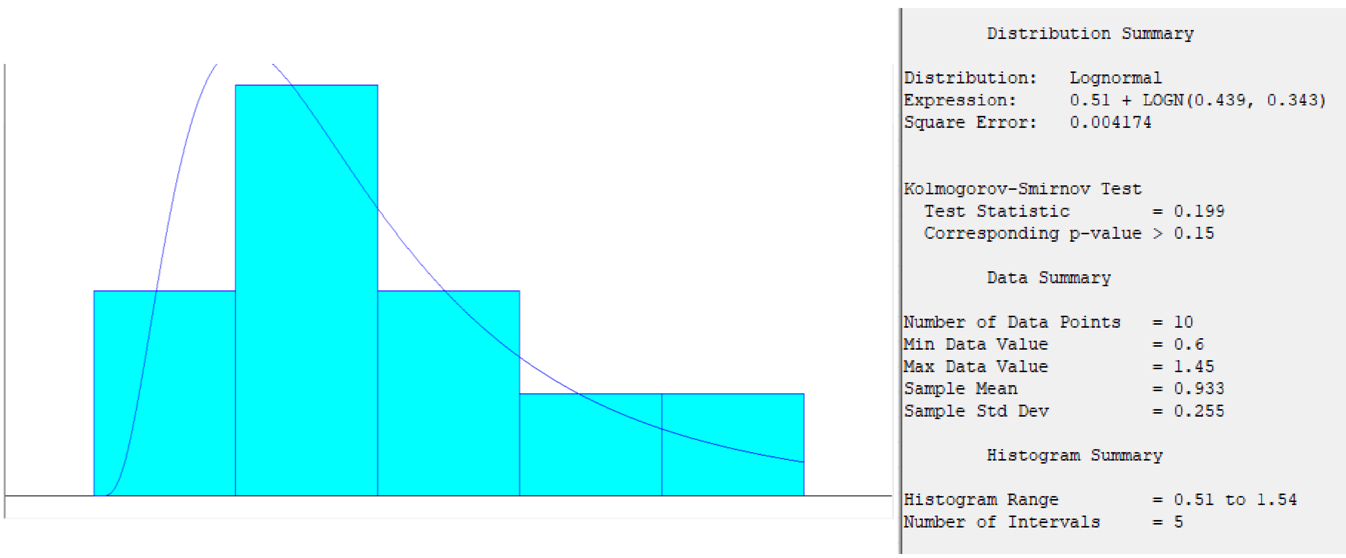


Figure 20: Atrium Building Service Times Input Analyzer

Table 21: Atrium Building Service Time Sq-Error Results

Function	Sq Error
Lognormal	**0.00417**
Gamma	**0.00589**
Erlang	**0.00699**
Weibull	**0.0112**
Triangular	**0.0116**
Beta	**0.0247**
Normal	**0.0324**
Uniform	**0.06**
Exponential	**0.0661**

Above we can see the distribution of the Atrium Building raw data of Service times as well as the sq-error of the different distributions inputted into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.00417. This indicates that the distribution is the “tightest” or “best Fit.” We can see that the distribution of the data for the Atrium Building the Lognormal distribution. The expression for this data is 0.51 + LOGN (0.439, 0.343). This expression will be used to represent our service time data in our arena simulation process module. It will allow us to manipulate the que line and see how many people are in the lone waiting to be served and how much the service time will increase if we increase the amount of foot traffic or decrease with the addition of more vending machines at this location

5.8) Mathematics Building Service Times Distribution

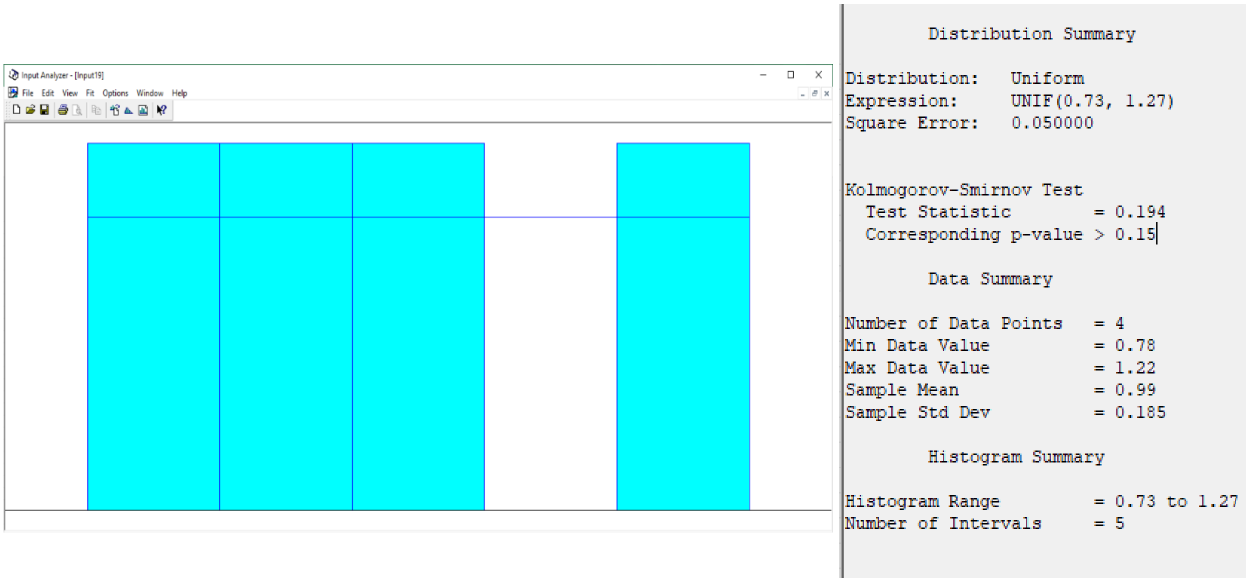


Figure 21: Mathematics Building Service Times Distribution

Table 22: Mathematics Building Service Times Sq-Error Results

Function	Sq Error
Uniform	**0.05**
Gamma	**0.0524**
Beta	**0.0527**
Erlang	**0.0536**
Lognormal	**0.0547**
Weibull	**0.0557**
Exponential	**0.0631**
Triangular	**0.066**
Normal	**0.0818**

Above we can see the distribution of the mathematics building raw data of Service times as well as the sq-error of the different distributions input into the arena input analyzer. The input analyzer ran this data through all the different distributions available and selected the one with the lowest sq-error. In this case, the lowest Sq-error was 0.05. This indicates that the distribution is the “tightest” or “best Fit” and in this case the perfect fit. We can see that the distribution of the data for the mathematics building is a uniform distribution, this is due to their only being four service times recorded and each in a different frequency on the histogram. The expression for this data is UNIF (0.73, 1.27). This expression will be used to represent our service time data in our arena simulation process module. It will allow us to manipulate the que line and see how many people are in the lone waiting to be served and how much the service time will increase if we increase the amount of foot traffic or decrease with the addition of more vending machines at this location.

5.9) Arena Simulation

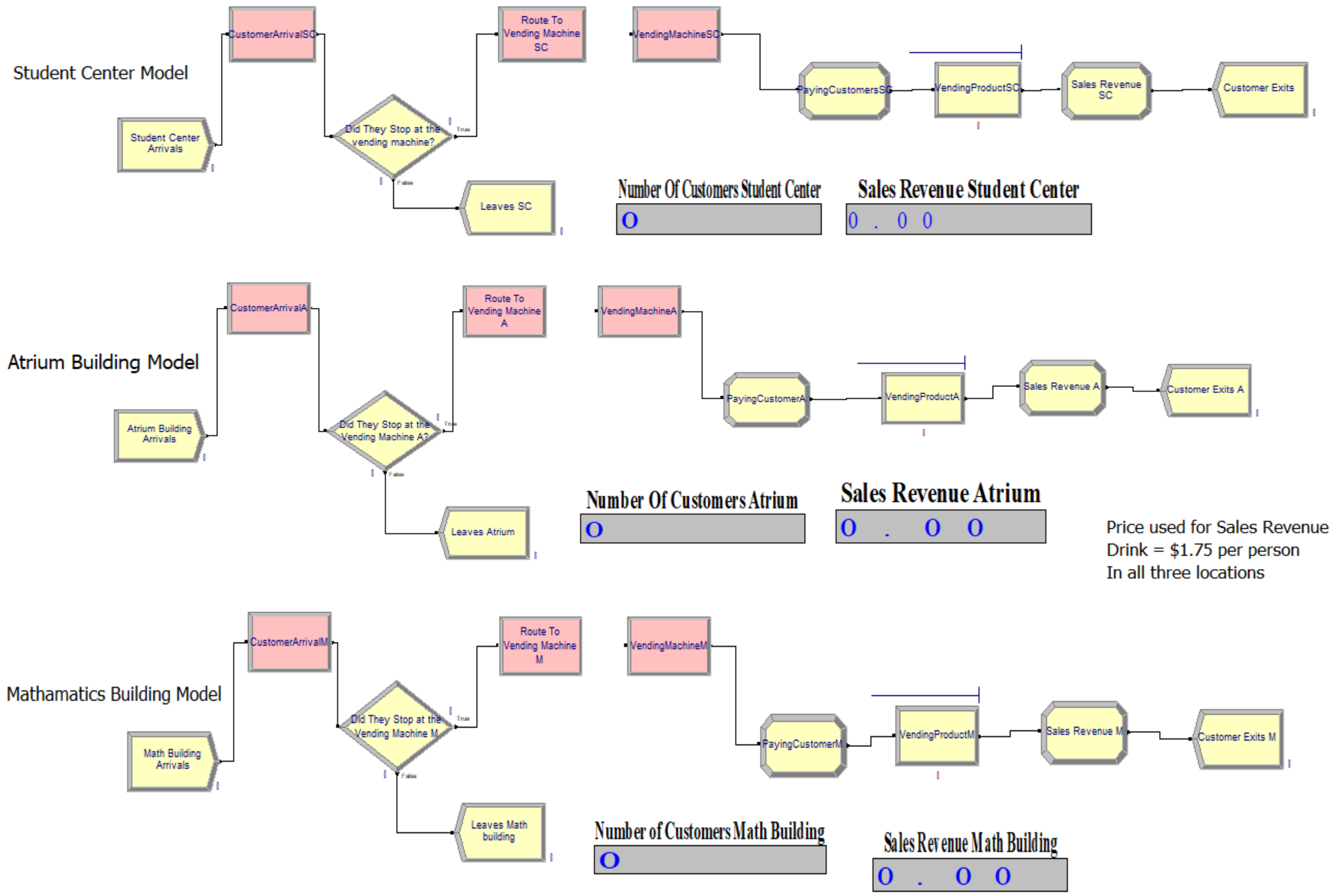


Figure 22: Screenshot of Arena Simulation

Above in figure 22 we can see our Arena Simulation model. This model is separated into three different paths, each path representing one of the three buildings. This model will simulate the number of customers and the sales revenue over the course of 22 days, 15 hours per day. This period of time was specified as campus buildings are open from 7:00am-10:00pm and we did not include weekends. The model had variable displays which can be seen in the figure below, that will change as the simulation is running in real time. This Arena model will also generate a report that will show us the average time it takes a customer to decide what they want to purchase and the average wait time. It will also show us the number of people entering and leaving the system as well as show us the vending machine utilization. This will let us know if a locations vending machines are being used frequently or not. These results will be presented in the next following pages of this report.

5.10) Number of Customers Current

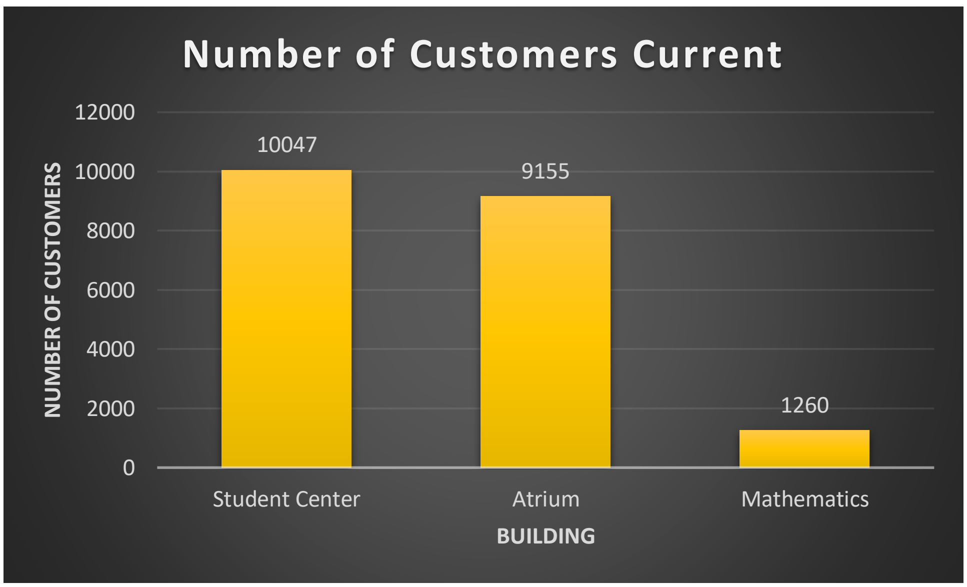


Figure 23: Number of Customers During Simulation

In the figure above we can see the number of customers to pass through our simulation over the course of 22 days. We can see that currently both the Student Center and the Atrium have a decent number of people, with the student center having just over 10000 people and the Atrium just over 9100. The math building is significantly lower than the other two with just 1260 people using the machine in that location. Based off these finding, the math building is under consideration for relocation into one of the other two buildings, due to it having significantly lower traffic than the other two locations. However, we have conducted further analysis into the sales revenue of each location which we will discuss in the next section.

5.11) Sales Revenue Current

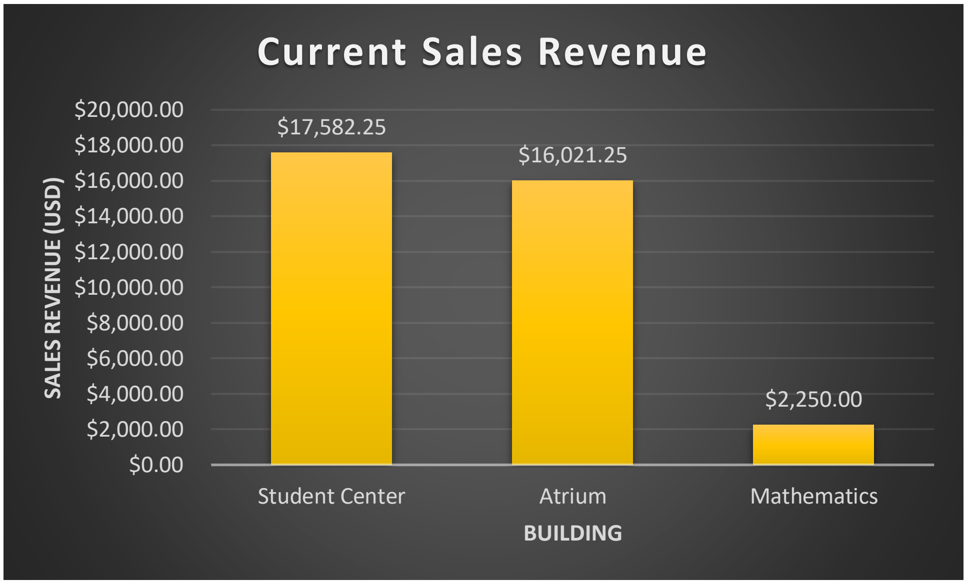


Figure 24: Current Sales Revenue Graph

Looking at the figure above we can see the sales revenue of the current situation. We can see that over the course of 22 days that both the Student Center and the Atrium Building vending machines are making a good amount of sales revenue. The Student Center estimated to bring in around $17,582.25 and the Atrium $16,021.25. Looking at the Mathematics Building we can see that it was estimated to bring in only $2,250.00, this is over $15,000 difference from the student center. The reason the mathematics building is significantly lower is due to the foot traffic being incredibly low as we saw in the previous section, only 1260 people used the machine. Whereas over 10000 people used the student center. This sales revenue result has led us to determine that the math building is not profitable as the other two buildings. In the next section we will look at the utilization of the vending machines.

5.12) Vending Machine Utilization

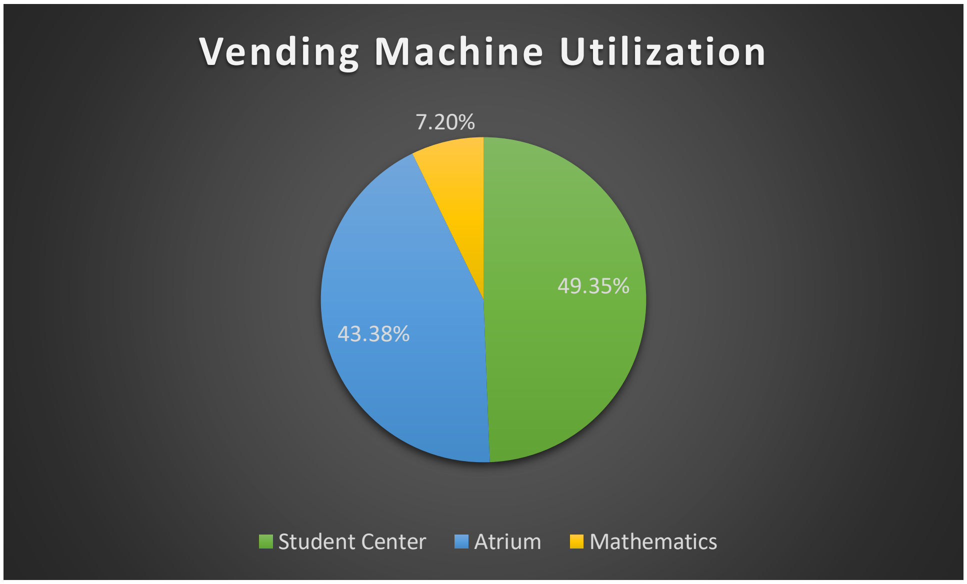


Figure 25: Vending Machine Utilization

The figure above shows us the vending machine utilization as determined from the Arena Simulation. The utilization is what the percentage of time the vending machines were being used during our simulation run of 22 days. We can see that the Student Center vending machines were being utilized 50% of the time, while the Atrium is a close second with the vending machines in that building being used 43.38% of the time. This indicates that the vending machines in those locations are being used and are in a good area. However, the Mathematics building is not, we can see that during our simulation the mathematics building was only being utilized 7.2% of the time. This is low and with these findings we have solidified our decision that the mathematics building vending machines need to be relocated to either the Student Center or the Atrium. This is due to the mathematics building vending machines having low foot traffic, low sales revenue, and low utilization. In chapter 6, we will see which building the machine will go in to best reduce the total service time, while also increasing the sales revenue

5.13) IOR Tutorial Current Route

In this section we will use IOR Tutorial to find the optimal route to re-stock the vending machines and use the Metaheuristics – Traveling Salesman Problem approach. To do that, we will find the distance between buildings, and then use IOR to find the shortest path. This would allow us to maximize profit and minimize the distance travelled.

There are 19 buildings with vending machines on campus, which means there are 19 stops that we must make to re-stock the vending machines. Since IOR tutorial software is only able to find the optimal path for a maximum of 10 stops, we decided to split the campus in half. We selected 10 buildings from the top half of campus and used IOR Tutorial to find the shortest path to restock these buildings. Then we followed the same process for the remaining 9 buildings from the bottom half of campus. The first route would end where the second one starts so we will be able to put both routes together and find the final optimal delivery route for the entire campus.

Below in table 24 we can see the list of the ten buildings located in the top half of campus. We assigned them numbers from 1 to 10. These assigned numbers are the numbers that we will input into IOR Tutorial. Then we calculated the walking distance between each building. We used Google Maps to calculate these distances, and we used meters to make the results more accurate and simpler.

Table 23: Top Half Building Number Assignment

Building	Number assigned
Academic	1
Crawford Lab	2
Engineering Technology Center	3
Howell Hall	4
The Study	5
Joe Mack Wilson Student Center	6
Lawrence V. Johnson Library	7
Mathematics	8
Norton Hall	9
Recreation and Wellness Center	10

The image below shows us the solution we got from IOR Tutorial. We can see that there are 10 cities which are the 10 buildings from the previous table. We input the distances we calculated, and then we ran the program. The trial solutions are all the possible paths that he can take, and the highlighted one is the optimal solution, the one with the shortest distance. We can see below that the optimal route for the current locations is 3-2-8-6-10-5-4-9-7-1 with a distance of 2100 meters. This means that the person who restocks should start at building number 3, which is the Engineering Technology Center, then go to building number 2, then to building number 8, then to building number 6, etc. The flowchart below in figure 27 shows us the optimal path for the current locations to follow from the results obtained from IOR Tutorial.

City	1	2	3	4	5	6	7	8	9	10
1		250.0	230.0	270.0	400.0	400.0	230.0	350.0	230.0	550.0
2			280.0	300.0	450.0	180.0	130.0	140.0	240.0	450.0
3				450.0	550.0	450.0	300.0	400.0	400.0	700.0
4					160.0	350.0	180.0	300.0	80.0	450.0
5						500.0	400.0	450.0	200.0	450.0
6							180.0	110.0	270.0	290.0
7								160.0	130.0	350.0
8									250.0	350.0
9										400.0
10										

Best Distance = 2100.0 Best Solution = 1-3-2-8-6-10-5-4-9-7-1

Iteration	Trial Solution	Distance	Tabu List
0	1-2-3-4-5-6-7-8-9-10-1	3180.0	
1	1-2-3-4-5-9-8-7-6-10-1	2770.0	5-9,6-10
2	1-2-3-4-5-9-7-8-6-10-1	2580.0	5-9,6-10,9-7,8-6
3	1-3-2-4-5-9-7-8-6-10-1	2410.0	9-7,8-6,1-3,2-4
4	1-3-2-10-6-8-7-9-5-4-1	2280.0	1-3,2-4,2-10,4-1
5	1-3-2-8-6-10-7-9-5-4-1	2160.0	2-10,4-1,2-8,10-7
6	1-3-2-8-6-10-7-4-5-9-1	2170.0	2-8,10-7,7-4,9-1
7	1-3-2-8-6-10-5-4-7-9-1	2200.0	7-4,9-1,10-5,7-9
8	1-3-2-8-6-10-5-4-9-7-1	2100.0	10-5,7-9,4-9,7-1
9	1-3-7-9-4-5-10-6-8-2-1	2140.0	4-9,7-1,3-7,2-1
10	1-3-7-2-8-6-10-5-4-9-1	2120.0	3-7,2-1,7-2,9-1

Figure 26: Top Half of Campus Current Route IOR Tutorial Solution

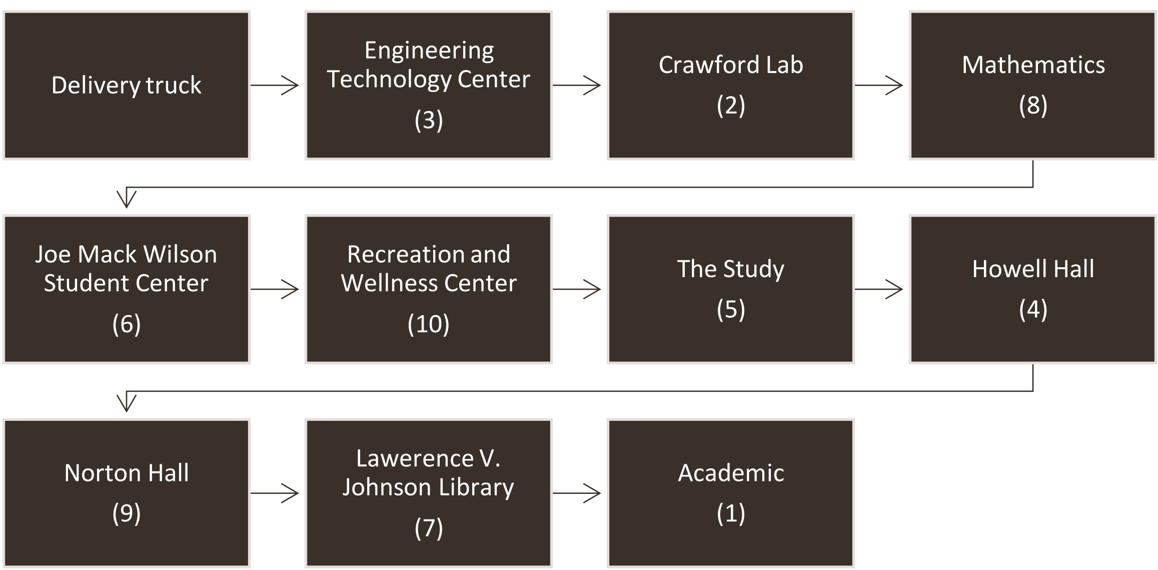


Figure 27: Top Half Current Route Flow Chart

We followed the same process for the remaining 9 buildings from the bottom half of campus. The following table 25 shows us the name of the buildings and the numbers assigned to each building. These numbers will help us identify the name of the buildings when we input this data into IOR Tutorial. We also calculated the walking distances between each building using Google Maps.

Table 24: Bottom Half Building Number Assignment

Building	**Number assigned**
Atrium	1
Architecture	2
Civil and Environmental Engineering	3
Design 1	4
Facilities	5
Hornet Village 1	6
Hornet Village 2	7
West Parking Deck	8
W. Clair Harris Textile Center	9

Once we had the distances between every building, we input that information into IOR Tutorial. The top table from figure 28 shows us the distances calculated. The “cities” 1 to 9 are the 9 buildings explained in the previous table. After we have all the data in IOR, we run the program until we find the optimal solution for the current locations. Once we have the optimal solution, we still run the program 3 more times to make sure there is not a better solution than the one initially found. In the second table from figure 28 we can see the results after running the program. The trial solutions column shows us all the possible routes we can use to re-stock the vending machines. The one highlighted in blue is the optimal route we will choose.

We found that the optimal route of the current locations for the bottom half of the map would be: 1-4-8-6-7-3-5-2-9. The flowchart from figure 29 shows us what these numbers mean and what that route would look like.

City	1	2	3	4	5	6	7	8	9
1		280.0	210.026	150.0	600.0	240.0	140.0	400.0	120.0
2			210.0	500.0	450.0	350.0	290.0	600.0	150.0
3				450.0	600.0	270.0	230.0	550.0	230.0
4					800.0	230.0	280.0	350.0	290.0
5						750.0	700.0	950.0	600.0
6							90.0	250.0	260.0
7								300.0	190.0
8									450.0
9									

Best Distance = 2390.0 Best Solution = 1-4-8-6-7-3-5-2-9-1

Iteration	Trial Solution	Distance	Tabu List
0	1-2-3-4-5-6-7-8-9-1	3450.0	
1	1-4-3-2-5-6-7-8-9-1	2970.0	1-4,2-5
2	1-4-8-7-6-5-2-3-9-1	2650.0	1-4,2-5,4-8,3-9
3	1-4-8-7-6-3-2-5-9-1	2540.0	4-8,3-9,6-3,5-9
4	1-4-8-6-7-3-2-5-9-1	2450.0	6-3,5-9,8-6,7-3
5	1-4-8-6-7-3-5-2-9-1	2390.0	8-6,7-3,3-5,2-9
6	1-4-8-6-7-9-2-5-3-1	2440.026	3-5,2-9,7-9,3-1
7	1-7-6-8-4-9-2-5-3-1	2530.026	7-9,3-1,1-7,4-9
8	1-7-6-8-4-9-5-2-3-1	2590.026	1-7,4-9,9-5,2-3

Figure 28: Bottom Half of Campus Current Route IOR Tutorial Solution

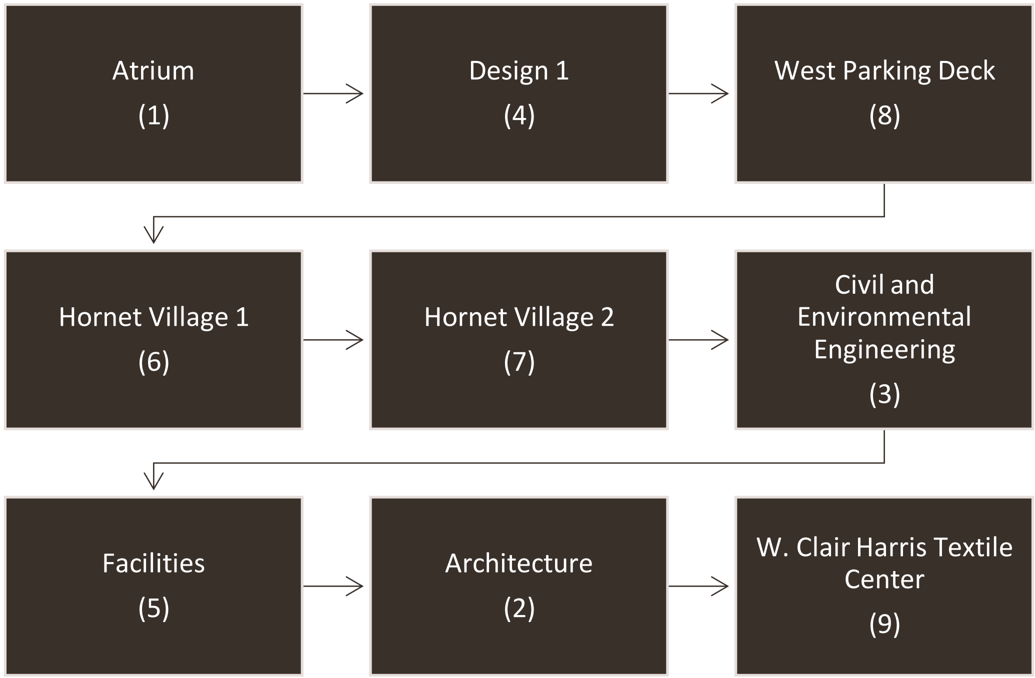


Figure 29: Bottom Half Current Route Flow Chart

After finding the optimal routes for the current locations for both sides of campus, we put them together and came up with the final route to restock all the vending machines throughout the entire campus. The following flowchart in figure 30 shows us this final route. This route is the optimal one for the current locations of the vending machines

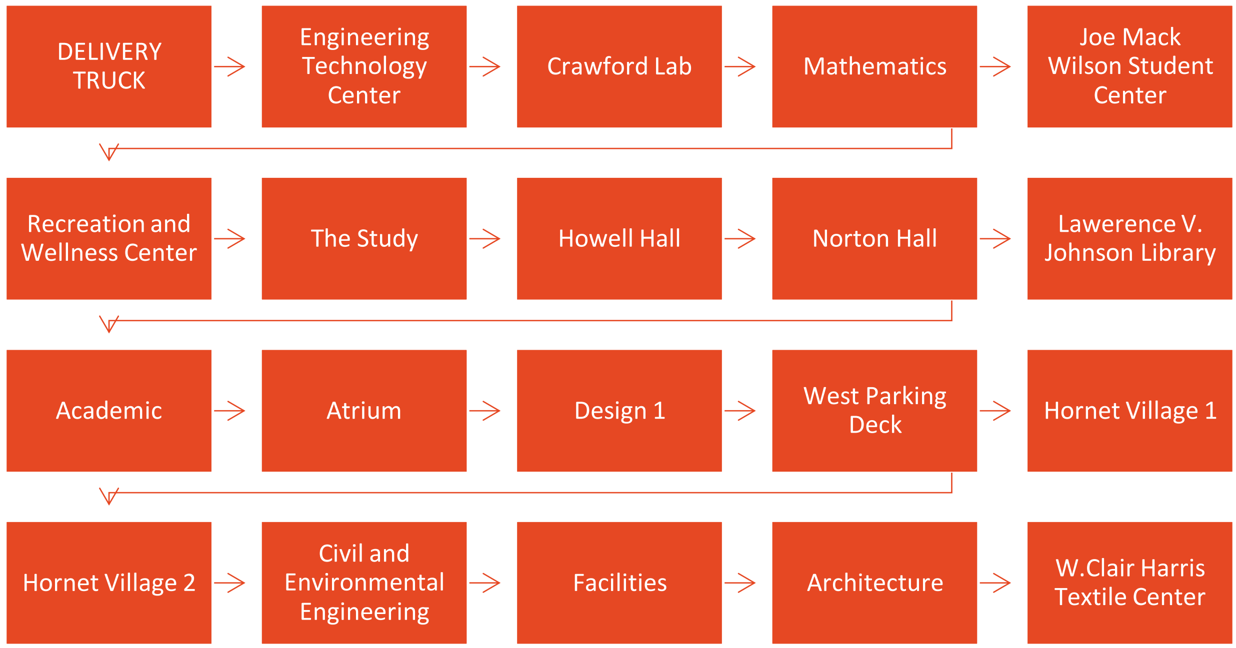


Figure 30: Top and Bottom Half of current route Flow Chart Combined

Figure 31: Campus map of Current Route taken for Current Locations

The map of campus in figure 31, shows us the optimal route for the current locations, with the shortest walking distance we calculated from IOR Tutorial. This map is just a visual representation of the route that we will use. The arrows are just symbols to indicate the order of the buildings where the delivery personnel are stopping at. The arrows do not represent the walking distance. The walking distance are not straight lines, and those were calculated with Google Maps. The green star represents the start point and the red star represents the end point.

Chapter 6: Recommendations and Solution

6.1) Locations to be moved

The locations that need to be moved based off our analysis are the West parking deck and the mathematics building. The west parking deck needs to be moved because out of the 32 people we recorded, we did not get a single person to purchase anything at the vending machine. During our data collection, we noticed many students were in a rush to get to class. Students were not willing to stop at the machine to make a purchase. This has indicated to us that due to no service times available then the vending machine in this location is not profitable.

The Mathematics Building vending machines need to be relocated because of the small number of foot traffic, low sales revenue, and a significantly low utilization rate of just 7.2%. Over the course of an hour during our recordings for this location which started at 12:00pm and ended at 1:00pm. There were only 4 purchases made from our 32 recordings which amassed to just 12.5% of people using the vending machines in this area. For these reasons, it has been concluded that these locations are not generating significant sales revenue.

There is one vending machine in the west parking deck and three vending machines in the mathematics building. That is a total of four vending machines that need to be relocated in one of the top two buildings from our surveys and our Arena simulation, which are the student center and the Atrium Building. To determine how many vending machines will be placed, we will use the process analyzer from arena in the next section.

6.2) Process Analyzer Solution

At current, there are 4 vending machines in the student center and 2 vending machines in the Atrium building, we have a total of four vending machines that need to be relocated for a total of 10 vending machines across both buildings. Using the Process analyzer from arena we will be able to determine the optimal number of vending machines per building to maximize our profit and still be within our requirement of not increasing the avg. total service time by more than 10s Being that there is a total of four vending machines that need relocating, we have every possible option of where the vending machines can go in the process analyzer. For Example, scenario 1 has 5 in each building, which means 1 vending machine would be added to the SC and 3 to the Atrium.

	Scenario Properties				Controls		Responses					
	S	Name	Program File	Reps	Vending Machine SC	Vending Machine Atrium	Number of Customers Atrium	Number of Customers Student Center	Sales Revenue Atrium	Sales Revenue Student Center	Student Center AVG.Total Service Time	Atrium AVG.Total Service Time
1		Current	43 : Vending	1	4	2	9155	10047	16021.25	17582.25	44.36	36.30
2		Scenario 1	48 : Vending	1	5	5	11348	12118	19859.00	21206.50	53.08	45.05
3		Scenario 2	48 : Vending	1	6	4	11442	12146	20023.50	21255.50	53.51	44.75
4		Scenario 3	48 : Vending	1	7	3	11271	12163	19724.25	21285.25	53.40	44.61
5		Scenario 4	48 : Vending	1	8	2	11282	12042	19743.50	21073.50	53.10	45.21
6		Scenario 5	48 : Vending	1	4	6	11352	12101	19866.00	21176.75	53.08	44.93

Figure 32: Process Analyzer Results

Now we can see that scenario 2, outlined in red is the best way to distribute the vending machines, by adding 2 in each building. This leads to a total of 6 in the SC and 4 in the Atrium building. It is the optimal number to distribute the vending machines because it produces the maximum sales revenue. We can also see that it stays within our requirements of not increasing the avg. total service time by more than 10s. The SC moves from 44.36s to 53.51s for an increase of 9.15s. We can see that the Atrium building service times increases from 36.30s to 44.75s for an increase of 8.45s.

Looking at the figure 33 below, we can see the impact this has on the sales revenue for the two buildings based on the Process analyzer results.

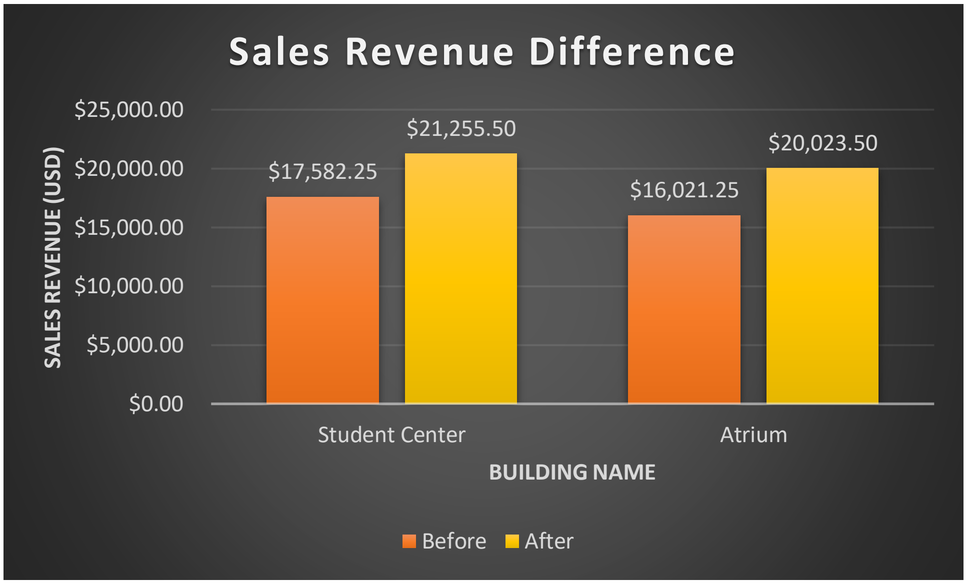


Figure 33: Sales Revenue Increase based off New Locations

We can see that by moving placing two more vending machines into these buildings will increase the sales revenue. The Student Centers sales revenue increased to $21,255.50 over a period of 22 days, 15 hours per day. The sales revenue for this location increased by $3,673.25. For the Atrium building. The sales revenue increased to $20,023.50 over the same length of time. This is an increase of $4,002.25. The grand total of sales revenue increased for both buildings is $7,675.50.

6.3) Cost Analysis

So, the question we asked ourselves is how much profit Kennesaw State would make if selling the vending machine products and how much would the overall cost be to run these said vending machines in the desired locations that we have recommended. The machines are installed, stocked with products, and serviced/maintained all at no cost when using the Coca Cola manufacturer. However, Kennesaw State will have to buy the products directly from Coca Cola. So, how much money will Kennesaw State spend on Coca Cola vending machines and how much will they profit? That question is answered below:

On average most bottles sold from Coca Cola vending machines cost around $1.75. There are 24 bottles per case. The case price is $21, which means each bottle costs around $0.88 per bottle. Each vending machine holds around 300 bottles, which will be around 12.5 cases. If we multiply 12.5 cases by the case price of $21 you will get $262.50 per vending machine. We collected data from 10 vending machines in total so, 10 x $262.50 will be $2,625 that KSU will spend for the 10 vending machines we collected data for.

So, how much profit will KSU make after their initial cost? Here is a breakdown of what we estimated for Kennesaw State to make yearly and monthly with the data we collected from the 10 Coca Cola vending machines. The average sales price that we observed on the KSU Marietta campus is $1.75. There are 24 bottles per case. If we multiply $1.75 x 24 bottles the vending machines will make $42 per case.

Table 25: Monthly and Annual Case Sales Per Machine

Monthly and Annual Case Sales Per Machine	
Sales Price Per Bottle	$1.75
Bottles Per Case	24
Case Sales (Per Month)	98
Case Sales (Per Year)	1,176
Estimated Sales Revenue (Per Month)	98 cases x $42 per case = $4,116
Estimated Sales Revenue (Per Year)	1,176 cases x $42 per case = $49,392
Sales tax paid (4% in GA)	-$164.64
Commissions Paid (15%)	-$617.40
Drink Costs	-$262.50
Estimated Net Profit (Per Month)	$3,071.46
Estimated Net Profit (Per Year)	$36,857.52
Total (Per Month x 10)	*$30,714.60*
Total (Per Year x 10)	*$368,575.20*

In total Kennesaw State University will be estimated to profit ($36,857.52 x 10 vending machines) $368,575.20 annually on the 10 Coca Cola vending machines that we collected data for, and ($3071.46 x 10 vending machines) $30,714.60 monthly on the Coca Cola vending machines.

6.4) Optimized Route

Since we came up with the conclusion that the vending machines are going to be moved from the West Parking Deck and from the mathematics building, then we would not have to make any stops at those buildings when we are re-stocking the vending machines. We worked on a new optimal restock route without those two buildings. We followed the same steps that we did for the current route, but this time we are not including the west parking deck nor the mathematics building in our analysis. Therefore, we only have 17 buildings now. Similarly, as we did before, we are splitting these 17 buildings in two lists of 9 buildings for the top half of campus and 7 buildings for the bottom half of campus.

The following table 26 shows us the 9 buildings for the top half of campus. We assigned them numbers and calculated the walking distances between each building using Google Maps. Then we input this data into IOR Tutorial. We can see the distances in the top table from figure 34. After running the program, we found the optimal solution for this side of campus. The optimal solution obtained was 3-2-6-9-5-4-8-7-1. This shows that the new optimal route is of 2030 meters now compared to the old route that was 2100 meters. This means that new route is 70 meters shorter than the initial one. We are saving labor time and reducing the distance walked.

Table 26: Top Half New Location Number Assignment

Building	**Number assigned**
Academic	1
Crawford Lab	2
Engineering Technology Center	3
Howell Hall	4
The Study	5
Joe Mack Wilson Student Center	6
Lawrence V. Johnson Library	7
Norton Hall	8
Recreation and Wellness Center	9

City	1	2	3	4	5	6	7	8	9
1		250.0	230.0	270.0	400.0	400.0	230.0	230.0	550.0
2			280.0	300.0	450.0	180.0	130.0	240.0	450.0
3				450.0	550.0	450.0	300.0	400.0	700.0
4					160.0	350.0	180.0	80.0	450.0
5						500.0	400.0	200.0	450.0
6							180.0	270.0	290.0
7								130.0	350.0
8									400.0
9									

Best Distance = 2030.0 Best Solution = 1-3-2-6-9-5-4-8-7-1

Iteration	Trial Solution	Distance	Tabu List
0	1-2-3-4-5-6-7-8-9-1	2900.0	
1	1-2-3-4-5-8-7-6-9-1	2490.0	5-8,6-9
2	1-3-2-4-5-8-7-6-9-1	2320.0	5-8,6-9,1-3,2-4
3	1-3-2-9-6-7-8-5-4-1	2190.0	1-3,2-4,2-9,4-1
4	1-3-2-6-9-7-8-5-4-1	2090.0	2-9,4-1,2-6,9-7
5	1-3-2-6-9-7-4-5-8-1	2100.0	2-6,9-7,7-4,8-1
6	1-3-2-6-9-5-4-7-8-1	2130.0	7-4,8-1,9-5,7-8
7	1-3-2-6-9-5-4-8-7-1	2030.0	9-5,7-8,4-8,7-1
8	1-3-7-8-4-5-9-6-2-1	2070.0	4-8,7-1,3-7,2-1
9	1-3-7-2-6-9-5-4-8-1	2050.0	3-7,2-1,7-2,8-1
10	1-3-2-7-6-9-5-4-8-1	2030.0	7-2,8-1,3-2,7-6

Figure 34: Top Half of Campus IOR Tutorial Optimized Route New Locations

This flowchart in figure 35 shows us the new optimal route for the top half of campus. We can see that there are 9 buildings now, instead of 10. The mathematics building was removed from this route.

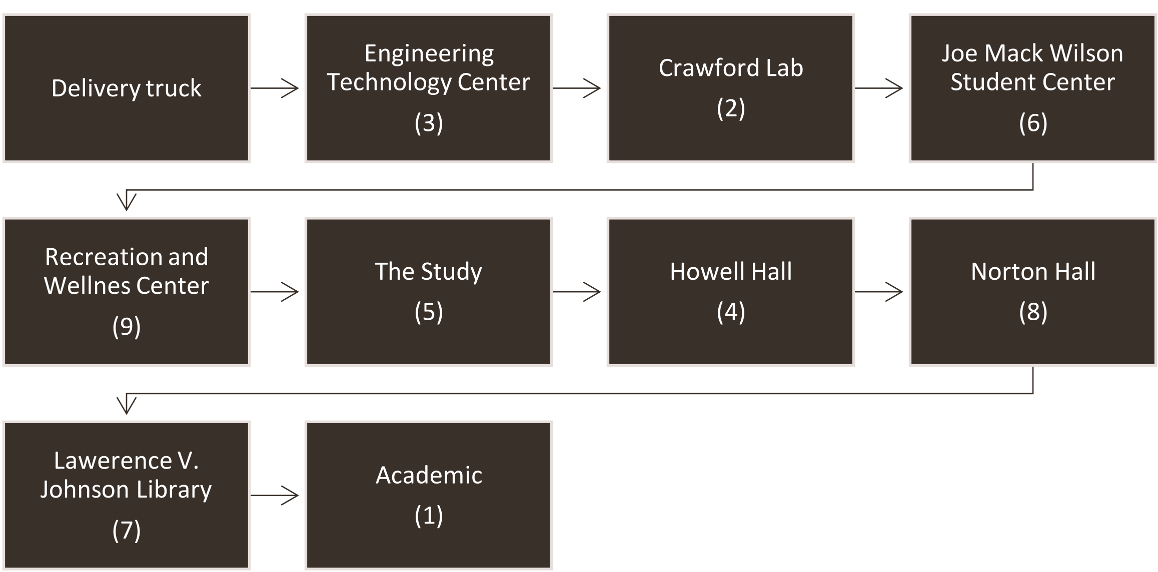


Figure 35: Top Half of Campus New Locations Optimized Route Flow Chart

Similarly, we created a new table with the buildings for the bottom half of campus. We had to remove the West Parking Deck from the list, and re-assign numbers to the buildings. After calculating the walking distances for this new list of buildings, we inputted this data into IOR, and then we ran the program until we found the optimal solution. The optimal solution for this side of campus was 1-4-6-7-3-5-2-8 with a walking distance of 2020 meters. This new route saved us 370 meters if we compare it with the initial route.

Table 27: Bottom Half New Locations Number Assignment

Building	**Number assigned**
Atrium	1
Architecture	2
Civil and Environmental Engineering	3
Design 1	4
Facilities	5
Hornet Village 1	6
Hornet Village 2	7
W. Clair Harris Textile Center	8

City	1	2	3	4	5	6	7	8
1		280.0	210.0	150.0	600.0	240.0	140.0	120.0
2			210.0	500.0	450.0	350.0	290.0	150.0
3				450.0	600.0	270.0	230.0	230.0
4					800.0	230.0	280.0	290.0
5						750.0	700.0	600.0

Best Distance = 2020.0 Best Solution = 1-4-6-7-3-5-2-8-1

Iteration	Trial Solution	Distance	Tabu List
0	1-2-3-4-5-6-7-8-1	2890.0	
1	1-4-3-2-5-6-7-8-1	2410.0	1-4,2-5
2	1-4-5-2-3-6-7-8-1	2280.0	1-4,2-5,4-5,3-6
3	1-4-7-6-3-2-5-8-1	2170.0	4-5,3-6,4-7,5-8
4	1-4-6-7-3-2-5-8-1	2080.0	4-7,5-8,4-6,7-3
5	1-4-6-7-3-5-2-8-1	2020.0	4-6,7-3,3-5,2-8
6	1-4-6-7-8-2-5-3-1	2070.0	3-5,2-8,7-8,3-1

Figure 36: Bottom Half of Campus New Locations IOR Tutorial Optimized Route

This flowchart in figure 37 shows us the new optimal route that we will follow for this side of campus. We can see that the flowchart is very similar to the initial one, but the total distance is shorter because we removed the west parking deck, and IOR found a more optimal solution.

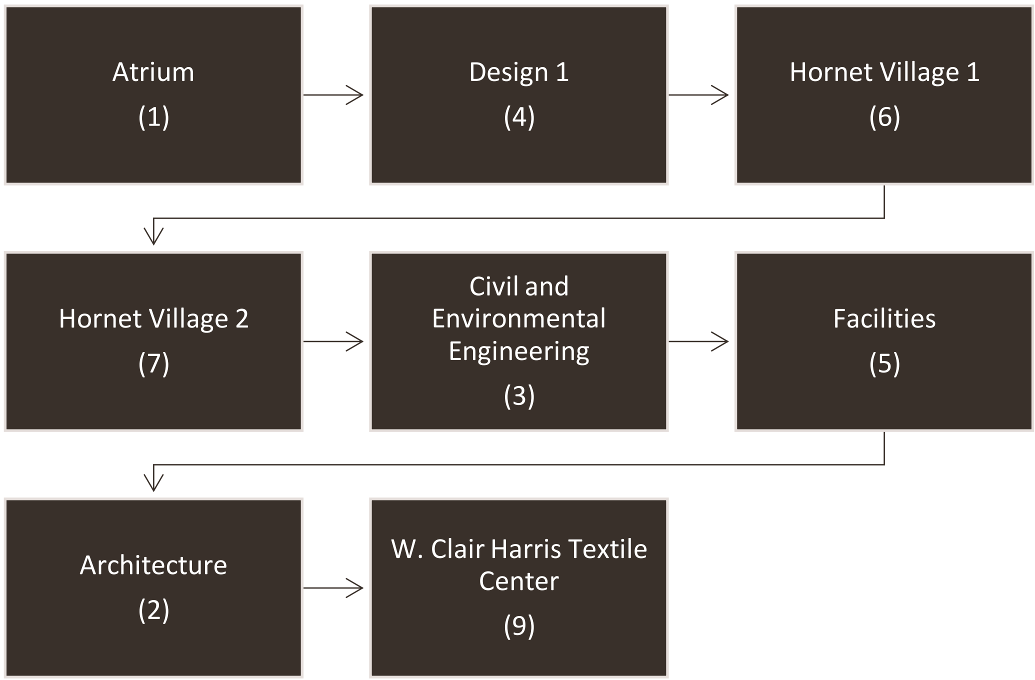


Figure 37: Bottom Half of Campus New Locations Optimized Route Flow Chart

Once we have the 2 optimal routes for both sides of campus, we worked on putting them together, and we came up with the final optimized route that the delivery person will follow to restock all the vending machines throughout the entire campus. The following flowchart shows this final route with all the vending machines and their new locations.

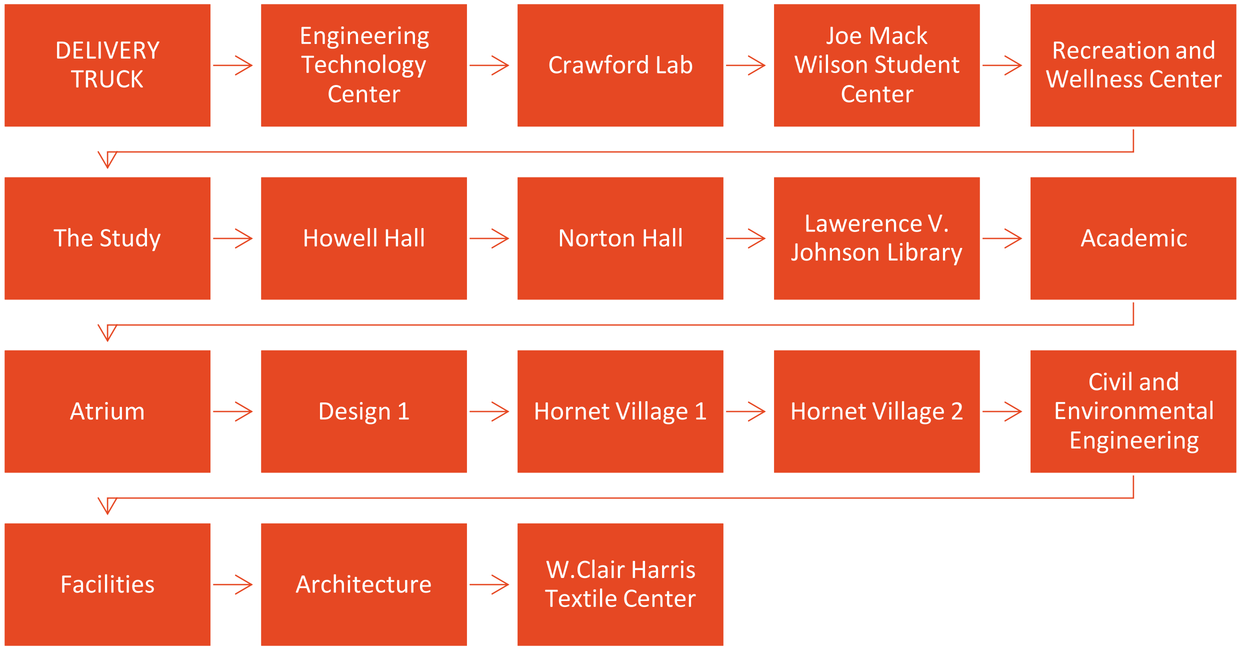


Figure 38: Final Optimized Flow Chart

Figure 39: Final Optimized Route Campus Map

In figure 39 we can see the final optimized route to restock all the vending machines on campus. The purpose of this map is to show the order of the buildings where the delivery personnel stop. The arrows do not represent the path that he/she will walk because these are just straight lines. The walking distances were calculated from Google Maps. The green star represents the start of the route, and the red star represents the final stop. This final optimized route is a total walking distance of 4,050 while the initial optimal route is 4,490 meters. We saved a total of 440 meters in walking distance.

6.5) Conclusion

In conclusion, we have successfully determined viable locations to relocate vending machines that we are providing little to no sales revenue. Using surveys, we were able to pinpoint and focus on the top two buildings on campus that have the highest foot traffic, and the bottom 2 with the lowest. We were also able to determine that using maps with the locations of the vending machines will be a good marketing idea that can increase sales by an approximate of 8%. We were able to determine that the west parking deck and the mathematics building were not generating significant sales revenue compared to locations with higher foot traffic using arena simulation software. Using process analyzer, we were able to see what would happen if we moved these low performing vending machines into these top two buildings and were able to discover, that relocating them would increase the sales revenue over $7,000. We were also able to stay within our requirement of not increasing to total average service time by more than 10s We were also able to determine the optimal path the vendor should take, when delivering to the campus, now that two locations would be removed. This amounted to the total distance traveled decrease from 4,490 meters to 4,050 meters for a difference of 440 meters saved in walking distance. Overall, we have successfully proved that with the relocation of these vending machines, that sales revenue should be expected to increase, as well as the distance traveled by the vendor decrease, overall saving time and money.

REFERENCES

"Frequently Asked Questions." Vending Solutions. JFD Designs, 2013. https://www.vendingsolutions.com/faq#:~:text=The%20most%20standard%20soda%20vending,%22W%20x%2040%2.

"Coca-Cola Vending Machine Locations." Vending Services. Kennesaw State University, 2021. https://vending.kennesaw.edu/drink-vending-locations.php.

[1] Liu, Wan-Yu, et al. "Figure 1. Illustration of the Traveling Salesman Problem (TSP) and..." *ResearchGate*, Research Gate, 6 Oct. 2020, www.researchgate.net/figure/Illustration-of-the-traveling-salesman-problem-TSP-and-vehicle-route-problem-VRP_fig1_277673931.

Blomquist, Chris. "The Sweet Spot in Vending: Product Optimization." Parlevel Systems, July 21, 2017. http://www.parlevelsystems.com/2015/03/03/the-sweet-spot-how-to-increase-sales-reduce-waste-by-simply-optimizing-your-product-mix/.

[2] Yoshimura, Hideaki. "Vending Machine AI Merchandise Optimization." Hivery, 2021. https://www.hivery.com/products/enhance.

Vending Machine Price Guide. Accessed November 1, 2021. https://blog.vendinggroup.com/how-much-do-vending-machines-cost.

"Home." Solar Powered Solar Powered Hot Dog Apple Juice Vending Machine - Buy Diy Vending Machine, Petite Vending Machine, Laundry Machine Vending Product on Alibaba.com. Accessed November 1, 2021. https://www.alibaba.com/product-detail/solar-powered-solar-powered-hot-dog_1600172162780.html?spm=a2700.7724857.normal_offer.d_image.23c22127GhZCig.

"Seaga Prosper Drink Machine." Gumball.com. Accessed November 1, 2021. https://www.gumball.com/products/seaga-prosper-drink-machine?gclid=CjwKCAjw7rWKBhAtEiwAJ3CWLNhGYk-NSHxS08DRtqZ7S1-KZ39xuK-YUKacVzplhANsqCRUla9lmhoCyGcQAvD_BwE.

Myers, Josh. "Seaga SM23 Snack and Soda Combo Machine." CandyMachines.com. Accessed November 3, 2021. https://www.candymachines.com/Seaga-Snack-and-Soda-Combo-Machine-

P2635.aspx?gclid=CjwKCAjw7rWKBhAtEiwAJ3CWLARIgKKy1VR3ZCHqAlq50hdc_a78Oz7ulamh5Eo4O_kNb8H4fJKV4xoCna4QAvD_BwE.

"Seaga Infinity INF5C Snack and Soda Vending Machine." CandyMachines.com. Accessed November 3, 2021. https://www.candymachines.com/Seaga-Infinity-INF5C-Snack-and-Soda-Vending-Machine-P2643.aspx?gclid=CjwKCAjw7rWKBhAtEiwAJ3CWLCGqFm5R5trVvZ42MPLtVB73g72Vtqym1rdSr3ZuQA6Ltj30k77LRBoCBxYQAvD_BwE.

"Grow Your Vending Machine Business with Powerful Software." VendSoft. Accessed November 3, 2021. https://www.vendsoft.com/.

Vend Purchase Group. "Best Software to Help You Manage Your Vending Machine Business." Vend Purchase Group, August 6, 2019. http://www.vendpurchasegroup.com/2019/03/19/best-software-to-help-you-manage-your-vending-machine-business.

Vendnet USA Blog, December 16, 2013. https://blog.vendnetusa.com/how-often-should-you-restock-your-vending-machines.

Lisse, Jamie. "How to Rent a Coca-Cola Vending Machine." Bizfluent, February 11, 2019. https://bizfluent.com/how-7684799-rent-cocacola-vending-machine.html.

"Costowl.com." 2021 Average Vending Machine Service Prices: How Much Does a Vending Machine Service Cost? Accessed November 3, 2021. https://www.costowl.com/b2b/office-vending-machine-service-cost.html.

"Why Do Vending Machine Products Cost so Much?" Why Do Vending Machine Products Cost So Much? Accessed November 14, 2021. https://blog.vendinggroup.com/the-pricing-of-sodas-in-a-vending-machine.

"Coca Cola Vending Machines & Products." Express Vending, September 15, 2021. https://www.expressvending.co.uk/our-services/premium-brands/coca-cola/.

"Georgia Sales Tax Exemptions." Agile Consulting Group. Accessed November 14, 2021. https://www.salesandusetax.com/sales-tax-by-state/georgia-sales-tax-exemptions#:~:text=The%20state%20of%20Georgia%20levies,4%25%20to%208%25%20range.

Appendix A: Contributions

Name	Chapter/Section Contribution(s)
Nicholas Singh	**Chapters:** 1, 3, 4, 5, 6 **Sections:** Executive Summary, 1.1, 1.2, 1.3, 1.4, 1.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.7, 3.8, 3.10, 3.11, 3.12, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.9, 4.10, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 6.1, 6.2, 6.5, Appendix
Chase Miller	**Chapters:** 1, 2, 3, 4 **Sections:** Executive Summary, 1.4, 1.5, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 3.1, 3.2, 3.3, 3.5, 3.6, 3.8, 3.12, 4.7, 4.8, Appendix C, Appendix D
William Pasha	**Chapters:** 3,6 **Sections:** 3.9, 6.3, 6.5, Appendix C

Mario Arzate	**Chapters:** 1, 3, 4, 6 **Sections:** Executive Summary, 1.2, 1.3, 1.4, 1.5, 3.1, 3.2, 3.3, 3.8, 3.11, 4.7, 6.1, 6.5, Appendix B, Appendix C
Masumi Jo	**Chapters**: 2,3,5,6 **Sections:** Executive Summary, 2.1, 2.4, 2.6, 3.2, 3.3, 3.6, 3.7, 3.8, 3.9, 3.10, 3.12, 4.8, 5.13, 6.4, 6.5

Name	Contribution(s)
Nicholas Singh	• Defined Project Problem, Scope, and Objective • Assisted in Developing Problem-Solving Approach • Assisted in Creation of Requirements • Assisted in Creation of Executive Summary • Developed Data Collection Plan • Led Creation of Survey • Led final decision of locations to be moved • Led results of Sales Revenue differences • Assisted in Flow-Chart Creation • Assisted in Cost Analysis • Created Verification Approach/Plan • Led Survey Data Collecting • Led Arrival and Service time Data Collection • Created Arena Simulation, • Created Input Analyzer Results • Created Process Analyzer Results • Created Figures for Report and Presentation • Led Revising & Editing of report and presentations • Assisted in coordinating group meetings • Assisted in creating project poster • Led conduction of Sensitivity analysis
Chase Miller	• Created and led literature review • Defined Project Problem, Scope, and Objective • Assisted in Developing Problem-Solving Approach • Created and led references • Assisted in traveling salesman problem and IOR tutorial • Created Gantt chart • Assisted in Creation of Requirements • Assisted in Flow-Chart Creation • Assisted in Survey Data Collecting • Created Figures for Report and Presentation • Assisted in grammatical and visual editing of report • Assisted in creation of project poster • Assisted in coordinating group meetings • Assisted in creating PowerPoint presentations

William Pasha	• Assisted in Survey Data collection • Assisted in creating design requirements and Specifications • Led the creation of project budget • Assisted in collection of report references • Led creation of report appendices • Created Appendix C • Assisted in creating PowerPoint presentations • Created Cost Analysis on Coke brand vending machines • Calculated estimated Profit for Coke Brand Vending Machines • Researched the Buying Price for Vending Machines • Researched the Stocking Cost for Vending machines • Researched the Frequency of restock for Vending Machines • Created YouTube Video
Mario Arzate	• Led creation of executive summary • Defined project problem statement • Assisted in creation of project scope • Led creation of project background • Assisted with justification (Why?) • Created the requirements for each group member • Assisted in creating PowerPoint presentations • Assisted in creating project poster • Assisted in recommendations and solutions • Assisted in survey data collection • Created contact information in appendix • Assisted in revising and editing report • Assisted in the creation of survey • Assisted and created part of Appendix C • Created Appendix B

Masumi Jo	• Led Optimization of Delivery Route • Assisted in developing the project budget. • Researched general costs for the creation of the budget. • Assisted in creation of requirements. • Developed solution for the Traveling Salesman Problem. • Created IOR results. • Created maps with optimal delivery routes. • Calculated walking distances from each building. • Assisted in creating Power Point presentations. • Assisted in creation of Gantt Chart. • Led creation of flowcharts. • Assisted in collection of data. • Assisted in creation of surveys. • Assisted in creation of project poster. • Assisted in making final decisions of new locations. • Assisted in coordinating group meetings. • Assisted in grammatical and visual editing of report and presentations.

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Appendix C: Acknowledgements

The Distinctive Optimizers would like to thank the Coca-Cola Customer Service and the Coca-Cola delivery truck driver for helping us gain insight into when the vending machines are stocked and refilled. Coca-Cola Customer Service gave us valuable information on who leases the vending machines, and the truck driver gave us insight on what locations were most visited, machine relay of items, and any manual checks that were necessary for the vending machines.

We would also like to thank Professor Keyser for allowing us to have a meeting with him regarding our data. He was extremely helpful and insightful with guiding us to the right path with our data collection. The courses we took with him in the past also helped us with this project. We used several methods that we learned from his courses to find our solution using the data we collected. His guidance allowed us to move forward with our project and find a solution.

Professor Khalid was also very helpful with our project. He answered many questions that we had regarding our project and our data collection. He gave many insightful answers and helped guide us with our project. His feedback really helped steer us in the right direction. Professor Khalid was a great senior project advisor. He was available to meet and responded to emails in good time. We are very appreciative of our professors on allowing us to meet with them and answer our questions regarding our senior project.

Appendix D: Reflections

Nicholas Singh- Working on this project was an enjoyable experience and one that has shown me that everything can be improved. Throughout this project, I was able to utilize many techniques and software programs learned throughout my college career, to complete and determine a solution for our problem. I was able to see what it's like working on a team of engineers together, and see that by working together, greatness can be accomplished. This project gave me an insight into the reality that everything around us can be improved in some way, such as in our case, the vending machines. Before this project, I would have just bought a Coca-Cola and been on my way. However, this project has changed my perspective and was rewarding seeing the results our findings can have on the real-world, by improving the sales revenue earned from the vending machines. I, like many others who read this report in its fullness, will never look at a vending machine the same way again, but rather, start to ponder the idea that there may be a better location for it. And so, with this, I am delighted to begin my next chapter of life, being a graduate in Industrial and Systems Engineering from Kennesaw State University. I would like to say thank you, to my family for their support through my college journey, as well as the professors that helped and guided me along the way. It has been a true pleasure and I will always remember my days here at Kennesaw State University.

Chase Miller- This project has been a true learning experience for me. While our group had several obstacles to hurdle throughout the process, we used our knowledge and experience to overcome them. I was able to use a lot of what we have learned in our time at Kennesaw State in our project. By completing this project, I got a glimpse into what the real world of engineering is like and how it really benefits your results to work with a team of engineers. It was very rewarding being able to use our skills to improve a process in the real world and be able to see the benefits it had. This expanded my view on how everyday processes you see can almost always be improved, hence why we learn about continuous improvement.

Masumi Jo- Working on this project has been a challenging and rewarding experience for me. It taught me that in real life, problems will not be given to you as easy and straight forward as they are in class. We had a few setbacks, but I am glad that I had a great team that worked hard to overcome these obstacles. I was able to see that effective communication and teamwork skills are essential for the success of any project. It was very exciting to see how we got to use several software programs, techniques, and skills learned throughout the past four years as an industrial engineering student. This project was also a great example of how industrial engineers can improve real world processes, and how we can positively contribute to the success of a company with our work. I am excited to take on new challenges and to see what the real world has out there for me.

William Pasha- Working on this project has been challenging but eye opening. A lot of the problems we faced had to be tackled through rational thinking and problem solving. None of the answers popped up on their own, we had to go out and take the initiative to find the solutions ourselves. Sometimes our answers took multiple days/attempts to find but through perseverance we prevailed. One of the biggest take a way that I observed throughout the project is the use of strategic and effective communication. This project was a good example of what I will see in the future as I go on to continue my career. Overall, I would like to thank my family for being there through thick and thin and my professors for helping me prepare for the real world. I am excited for the future challenges that I will have to face and happy to turn the page and close the chapter of being a student at Kennesaw State University.

Mario Arzate- Overall, I enjoyed working on this project. Throughout the project, I was able to use many concepts and techniques that I learned in my many courses. It was a wonderful experience learning and working on this project with my group members. This project gave me an insight as to what it would be like to work in an engineering team. I now understand why many engineering workplaces require most of their engineers to work together. Remarkable things can happen when we all put our minds together to tackle a problem and find a solution. I enjoyed tackling a real-world problem and figuring out a solution. The project was a great learning experience as well. It showed me that there are many careers within Industrial Engineering. I am now excited to start the next chapter of my career as an engineer and finally end my chapter as a student at Kennesaw State University.