Cal Poly Dining:

The Avenue Redesign

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Executive Summary

Campus Dining is planning to close VG's Cafe during the 2015-2016 school year; as a result, the remaining restaurants on campus need to accommodate the additional student demand. The student team consisting of Eric Calbonero, Derek Nollsch, and Casey Reilly met with Campus Dining's Director of Operations, Greg Yeo, about this issue—he directed the team toward a redesign of The Avenue Food Court. To redesign The Avenue, the project team focused on several key deliverables as follows:

- Study current customer trends in The Avenue
- Develop a proposed facilities layout and design
- Perform a capacity analysis of The Avenue
- Technical Report of Findings

First, the project team needed to define key stakeholders and communicate their goals. After this, the team observed the Avenue and performed the following time studies: customer inter-arrival time, register processing time, and the processing times of each of the restaurants in The Avenue. These observations were done to create a current state 2D and 3D model of the restaurant. Next, the project team created a simulation model of The Avenue to test each of four different experiments on the system. The first experiment was to test the result of the projected 10% increase in customer demand. The second experiment was to test the result of equal demand across all restaurants. The third experiment was to test the result of an equal processing time across all restaurants. Finally, the fourth experiment was to test the result of increasing the number of register queues from three to four.

After performing the experiments on the simulation model, the project team was able to create a 2D and 3D model of the proposed changes to The Avenue. The proposed changes were as follows:

- Replace the salad bar with a smaller, tiered design
- Add an additional restaurant with the necessary equipment
- Simplify menus to reduce processing time
- Add two additional POS stations with an associated queue

As a result of the projected 10% increase in sales, The Avenue is projected to earn an additional $1,663 in revenues per day. However, the proposed changes are expected to cost a total of $33,500—resulting in a payback period of 20.14 business days.

Introduction

Students at Cal Poly have many on-campus dining locations to choose from. These locations include popular locations such as VG's Cafe, Metro 19 Station, The Avenue, Sandwich Factory, Subway, Ciao, and Red Radish--a new salad restaurant on campus located adjacent to Ciao. Among these, one of the most popular locations is VG's Cafe--located adjacent to the Tenaya and Sierra Madre dorms. According to Mustang News, "Plans to renovate and rebuild the Vista Grande building will be tentatively taking place next year during fall or spring. 'We are underway right now with programming a design for a new Vista Grande building,' Cal Poly Corporation (CPC) Interim Executive Director Lorlie Leetham said. 'It would be done and ready to go by the time Student Housing South is built, so that's fall of 2018.'" Indeed, Campus Dining's Director of Operations, Greg Yeo expressed that the university plans to tear down and remodel the existing VG's Cafe during the 2015-2016 school year. The current plan for remodel includes the fact that the VG's Cafe location will no longer include a full-service restaurant like Sage. In addition, all the current dining facilities inside VG's Cafe will be replaced with new dining options. To accommodate the increased traffic as a result of the closing of VG's, existing campus dining locations will need to be renovated.

The idea for this project originated from the project team consisting of Eric Calbonero, Derek Nollsch, and Casey Reilly contacting Campus Dining to inquire about potential Senior Project opportunities through the organization. Campus Dining's Director of Operations, Greg Yeo, expressed the need for students to complete a variety of projects through Campus Dining. The available opportunities ranged from the food preparation areas, warehousing, and allergen-free areas to sustainable dining facilities--however the most compelling project from the project team's point of view was related to the closing of VG's Cafe and the changes required to expand existing campus dining locations. Indeed, Yeo noted that Campus Dining was exploring options to expand the aforementioned dining facilities. Yeo explained that the project team would have a specific focus on The Avenue location. The objective of this report is to analyze the current The Avenue dining location along with the proposed schematics from Campus Dining and propose a new facilities layout and design to accommodate the increased traffic as a result of the closing of VG's Cafe. In addition, studies of the current state of The Avenue will be required.

Proposed Methodology

- Study current customer trends in The Avenue
  - Focus on customer counts, POS queuing, time studies, and customer throughput
- Develop a proposed facilities layout and design
- Perform a capacity analysis of The Avenue
  - Facilities layout utilization and proposal of maximum capacity
- Technical Report of Findings
  - Relevant data and analysis for the client
  - Senior Project Paper with guidelines outlined in IME Senior Project Guidelines

The rest of the report is organized into several sections--each explaining a different aspect of the project--including Introduction, Background, Literature Review, Design, Methodology, Results, Conclusion, Appendix, and References.

Background

As mentioned earlier, The Avenue is one of only sixteen dining options on Cal Poly's campus. Of these sixteen (some of which are grouped together in the same building), only nine facilities serve food appropriate for meals. With a student body of approximately 19,000 students (8,000 of which live on campus) and growing, each of these facilities are stretched to their capacity every day.

According to Mustang News, two of the main meal facilities, VGs and Sage, will be shut down and remodeled over the course of the next two years. As a result, the seven other meal facilities will take on much more throughput. The facility that is expected to take on the largest increase is The Avenue due to their convenient location in the center of campus.

The university is taking certain measures to prepare for this. One is to alter meal plans to eliminate meal credits, therefore lifting the limit on students' choices in an attempt to spread the throughput of students for each facility. The university has also proposed altering the working hours and number of workers for The Avenue. Even with these changes, management still does not feel that they have the capacity to provide for the projected throughput. Because of this, the team has been asked to determine if in fact The Avenue has the necessary capacity to handle the increased load. A good capacity analysis is going to be very important to know what peak demand can be accommodated. If The Avenue does not have the necessary capacity, the team has been asked to suggest recommendations to improve upon their current designs, layout, and processes.

Literature Review

The literature relating to the Senior Project topic covers every aspect of the project including the following topics; customer trends and queuing, facilities layout and redesign, and capacity analysis. The first article relates to time studies as applied to Industrial Engineering.

Time Studies

Taking time studies can be both time consuming and expensive. However, they are a useful tool that can have lasting benefits in many fields. The Industrial Engineering Terminology Standard defines time study as "a work measurement technique consisting of careful time measurement of the task with a time measuring instrument, adjusted for any observed variance from normal effort or pace and to allow adequate time for such items as foreign elements, unavoidable or machine delays, rest to overcome fatigue, and personal needs" (IIE). Before carrying out a time study, one should determine the most efficient way of doing so while still ensuring statistical accuracy. An effective method of doing this is to use the Pareto principle before any measurements are taken (Hadad). This will help identify the relative weights of the elements or tasks being examined. Tasks that are responsible for more of the cumulative weight should be examined more closely. These tasks will require more cycles of measurements since they affect the process the most and need more accuracy. Tasks that account for smaller weights do not need to maintain the same statistical accuracy, and less measurement cycles can be taken (Hadad). This method of performing time studies helps redirect the conductor's time and effort where it is needed most.

The question then becomes the following: would a work-sampling or continuous observation be appropriate for this project? The article "A Comparison of Work-

Sampling and Time-and-Motion Techniques for Studies in Health Services Research" notes the advantages and disadvantages of both techniques. While a continuous observation approach would be more accurate, a work sampling technique requires fewer resources (Finkler et. al). The article goes on to say that the decision needs to be made on a case-by-case basis. If the precision of work-sampling can be close to the precision that continuous observation can achieve, then work-sampling would be the more attractive option. In this case, since assumptions can be made about peak hours, the team determined that work sampling would be a possibility during peak hours—however, a time study would be more accurate.

Queueing Theory

The article starts off with the advent of fast food restaurants. According to National Public Radio, the aforementioned restaurants have a long history--with the first fast food restaurant, Automat, opening in New York in 1912 (National Public Radio). The second restaurant, A&W Root Beer, was opened in 1919--soon followed by White Castle in 1921. The most popular and far-reaching fast food restaurant, McDonald's, subsequently opened in 1948 and started selling hamburgers, Coca-Cola, french fries, and coffee (National Public Radio). McDonald's is also known for their "production-line approach" to fast food. Since the 1960s, McDonald's has been a pioneer in the service industry by deploying three main IE principles: standardizing processes and reducing the variety of products, simplifying and automating processes, and monitoring and controlling process performances (Chase). Despite its popularity and success, McDonald's often faces the problem of a long and far-reaching queue. For fast food restaurants, fast queuing time and short lines are instrumental in the success of any such company. These factors, along with inexpensive price, good worker attitude, and superb food quality play an important role in the success of any fast food company. Queueing theory allows one to analyze the lines and wait times at such a restaurant--and subsequently attempt to shorten lines and wait times. However, queuing theory can be applied to many other fields--such as restaurants, computer architecture, transportation, and various other industries (Koh et. al).

At fast food restaurants, long lines often form during peak hours--specifically during promotions, lunch, and dinner time. When customers are unable to be served immediately, they often leave--depending on how much they value their time compared to money. Research on this type of quick service restaurant revealed that a long queue resulted from long preparation time in the kitchen--therefore improving food preparation time is key to reducing long queues and wait times (Koh et. al). The authors of this study observed a local McDonald's in Taman Connaught, Kuala Lumpur to monitor arriving time, waiting time, serving time, and departure time during lunch hour (12:30 PM - 2:30 PM) to provide the data for this study.

Before analyzing the data, a useful model had to be determined. A useful model should fulfill two requirements, they are as follows: represent a real-life system with sufficient accuracy and be analytically tractable. Both the Poisson model and the corresponding exponential probability distribution fulfill the requirements for a useful model. Additionally, a Poisson process models random events such as customer arrival. Put into layman's terms, the length of the time interval from the current time to the occurrence of the next event does not depend upon the time of occurrence of the last event. In contrast, in the negative exponential probability distribution, the observer records the number of events occurring in a fixed time interval.

An important theorem entitled Little's Law is the fundamental principle of queuing theory explaining the relationship between three critical parameters--the average number of customers in a queue (L), average waiting time (W), and average arrival rate (λ) (Allen). Little's theorem has become widely used due to its simple theoretical application--in addition, it has been used in fields as diverse as operation management and computer architecture as well as manufacturing and service industries. Little's law is as follows:

$$L = \lambda W$$

Equation 1: Little's Law

Customer satisfaction is key to understanding business success strategy of a restaurant--higher customer satisfaction leads to higher customer loyalty and higher revenues. Therefore service depends on how long a customer spends waiting in queue. After recording the queuing time, servicing time, and waiting time of customers on each respective server--and giving 100 McDonald's customers a quick 1-minute survey the team was able to draw conclusions about queuing at McDonald's (Koh et. al). It can also be useful to take into account the time spent walking from the front of the queue to the service window--though it would be minimal in this case (Yanagisawa et. al). The survey regarding McDonald's customer satisfaction recorded that there is overall customer satisfaction at McDonald's with no difference across genders.

This study is very applicable to the senior project at The Avenue because it also deals with queuing theory in a food-service environment. Both of these environments are fast-paced restaurants that serve food from a counter without wait-service. During

The Avenue analysis, the student-based team will be able to collect data in a similar manner--timing minutes spent in queue and actually ordering.

Facilities Design

Facilities layout design plays a huge factor when considering the productivity of a manufacturing system. When an effective facilities layout design is put into effect, time and money can be saved in huge amounts. One important system that governs much of the material movement throughout a facilities design is called the Material Handling System (MHS). This system acts as a connector between all processes in a manufacturing system to make sure that the correct amount of materials are delivered at the optimum time, place, and cost. Material handling costs usually account for 15-70 percent of the total operating cost in a manufacturing system, depending on the processes and materials involved (Raman). A good MHS can ensure that these costs are kept at a minimum by reducing any waste within the system.

Another system where facility design improvement can be made is through Systematic Layout Planning (SLP). The goal of SLP is to arrange a facility by placing areas with high usage and logical relationships near each other. A detailed study of the facility layout such as its operational processes, flow of materials and activity relationships is an integral step of SLP (Hosseini et. al). This article focuses on the combination of SLP and human factors. Conventional SLP typically ignores the human component, which is not ideal. The people involved in a manufacturing process must be considered a priority as their physical and physiological states will contribute greatly to their production (Raman). By limiting their walking distance throughout the day, a good facilities layout can reduce operators' fatigue and keep their productivity high. It also increases the throughput of the system. Additionally, proper equipment for operators can reduce skeletal stress and improve posture. Proper lighting can reduce fatigue on an operator's eyes and keep him or her more mentally focused throughout the day. All these factors lead to a happy and healthy operator which should be a priority in any manufacturing process. SLP is an important tool when designing an efficient facility, but the addition of human factors elements makes it much more effective.

Restaurant Design

The dining experience is meant to be exciting, stimulating, and comfortable. If done correctly, a restaurant will create an atmosphere that offers more than just food. Customers will become immersed in their surroundings without even noticing it, and the venue will serve as more than just a place to eat. A great example of this is the Rainforest Cafe, where customers feel as if they have found themselves in the middle of a dense rainforest. Imitation animals, vegetation, thunder, and rain help create a unique atmosphere that customers are unlikely to forget (Chen). Although the Rainforest Cafe is an extreme example of a themed restaurant, many of its principals can be translated to other restaurants as well. The Avenue at Cal Poly can utilize some of these tricks to create an ideal dining environment for college students. Since it’s based in the center of a college campus, many students will be using this area to study as well as eat. The Avenue should create an environment that supports both. Incorporating couches or other comfortable furniture could produce an enticing area where students could read or study. They could also play soft background music to block out students’ voices and create a relaxing atmosphere to help students focus (11 Ways). This can help keep students locked into their studies while screening out the sounds of food being prepared in The Avenue (Advising and Learning Assistance Center).

Another trending theme in today's restaurants is creating a system where customers take participation in preparing the food (Chen). Examples of this would be a coffee shop which allows the customer to grind and boil the coffee beans, or a pizza restaurant that has the customer place the toppings on their pizza and place it into the oven. The customer feels more attached to the experience and the food seems more organic. People want to see that their food is coming from healthy sources, and it is demonstrated by the organic food sales of about 42 billion U.S. dollars in 2014 (Topic: Organic Food Industry). Although customer participation would not be feasible in The Avenue, they could still incorporate ways to show the food is fresh. Greg Yeo gave a tour to the team behind the scenes of The Avenue. He showed that all the veggies used in campus dining are in fact freshly cut on a regular basis. The Avenue could showcase this by placing the veggies in a transparent enclosure that would be visible to all customers in The Avenue. Students would see their food is fresh, and would help fight the stigma against campus dining food quality.

In addition to the aforementioned trends in themed restaurants, it is becoming more popular to reduce the carbon footprint of a green restaurant. A carbon footprint is the total set of greenhouse gas (GHG) emissions caused by an organization, event or product (Zih Ping Ho). In order for food and beverage restaurants to deliver their food in the greenest manner, they have to keep carbon emissions at a minimal level. However, the restaurant industry is often not concerned with carbon footprint, indeed only "a small fraction is focused on reducing carbon footprints in a culinary room" (Zih Ping Ho).

Through the research team's careful study, they were able to develop a distributed cost model to accelerate the computing ability of a carbon footprint minimization model. Through this approach, the research team was able to develop a solution that cost 68.6% as much as the original model. According to Greg Yeo, Campus Dining is also attempting to become more environmentally conscious by implementing sustainable initiatives.

Capacity Analysis

In order to analyze the performance of The Avenue, a capacity analysis will need to be done in order to obtain the current state and identify where possible problems may exist. The online article "Strategic Capacity Planning for Products and Services" lists strategies to employ when performing this type of an analysis. When performing a capacity analysis or capacity planning, there are three main inputs that need to be considered:

- The kind of capacity that will be needed
- How much capacity will be needed
- When will it be needed

Of course along with any type of planning procedure an accurate forecast is also essential to the planning process. Capacity analysis can be performed for a number of different facilities--for example IBM developed a capacity analysis tool to quickly screen potential wafer profiles for a multi-technology, multi-part number, IBM microelectronics semiconductor fabricator (Sisler). "Strategic Capacity Planning for Products and Services" focused on a more general approach to capacity analysis.

There are a few numbers that must be considered: the design capacity, the effective capacity, and the actual output. Once these numbers are obtained, an analysis can be performed and the questions listed above can be answered.

The design capacity is the maximum designed service capacity. The effective capacity is the design capacity minus certain allowances. Some of the things that need to be considered are:

- Facility size
- Service factors
- Process factors
- Human factors
- Policy factors
- Operational factors
- Supply chain factors
- External factors

Finally the actual output is simply the average output that the facility typically sees. This can be obtained from historical data.

Finally, once these numbers have been obtained, the facility can be analyzed using two key measures: utilization and efficiency. Utilization refers to how much of the capability is actually being used (Strategic). The formula is stated below:

$$Utilization = \frac{Actual\ Output}{Design\ Capacity} \times 100\%$$

Equation 2: Utilization Equation

The efficiency refers to how well a facility is doing, considering output under realistic conditions (Strategic). The formula for efficiency is:

$$Efficiency = \frac{Actual\ Output}{Effective\ Capacity} \times 100\%$$

Equation 3: Efficiency Equation

Using these measures, a facility can be judged and alternative processes and layouts can be developed to reach the desired goals. These measures are applicable to the project because it will allow the team to quantify the current state of The Avenue and give a metric that the team can compare to in the future.

The article "A Study on the Supply Chain's Service Process Capability Index Based on Service Blueprinting" lays out how to determine the process capability for a service based business (Liu). This measure can help in determining either the design or effective capacity listed above. In a manufacturing setting, the capability of a process is clearly defined in the equation below:

$$\frac{T_U - T_L}{6\sigma}$$

Equation 4: Capability of a Process in a Manufacturing Setting

where T_u and T_L are the upper and lower standards of the process, and σ is the tolerance, or standard deviation of the process.

Using this procedure in a service type of environment such as The Avenue, however, is not appropriate. The article goes on to say that it is "hard to measure service quality with definite technical targets and assess the tolerance, σ, as in manufacturing products." The article instead suggests using the Service Process Capability Index (SPCI), first proposed by Tian Zhiyou in 2005. Calculating SPCI involves mapping out the process, describing and quantifying relationships between departments, and finally using the formula to determine the overall SPCI (Tian). The end formula, however, cannot be used in this project since it refers to an entire supply chain for a business, while the scope of this project is limited to simply The Avenue and its internal components. This article is still relevant because it lists the similarities and differences between a manufacturing and a service environment, and how those differences should be handled. In addition, some of the techniques in quantifying capacity can be used in this current project.

Part of determining the capability of the process is by determining the bottlenecks. These will dictate the rate at which a process delivers to their customers, regardless of the volume that is placed before those identified bottlenecks. The case study at the National Health Service, or NHS, shows this concept. The NHS was experiencing excessive queuing, and adding additional resources was not helping increase their service rate. This occurred because resources were randomly being added to the system without considering which operations were bottlenecks. It was only when the process was fully understood that resources were added to the appropriate bottlenecks (Silvester). The concept of identifying bottlenecks will be important to the redesign of The Avenue when quantifying the capability of current and any proposed future facility layouts.

Simulation

One way to easily compare alternatives is through simulation. Simulation has been a widely accepted tool in the service industry, including many studies that have been done in the past decade regarding fast food restaurants (Smith).

The measures listed in the Capacity Analysis section above can be difficult to define and measure since it is based on perfect circumstances that rarely occur. However, use of simulation, in combination with queuing, capacity analysis measures, and other similar tools can help give an accurate model. In fact, Burger King has used simulation in the past to help introduce their drive-thru service and new menu items. Turning what seemed to be a simple process into a much more calculated process has helped Burger King save millions in operation, design, and procurement areas (Swart). The team plans to use simulation as a main tool in this project to compare propositions without having to spend the time and capital to build prototypes and test them.

Another case study of a project that was done at the University of Michigan named “Reducing Service Time at a Busy Fast Food Restaurant on Campus”, used simulation and other techniques to solve queuing and other service issues at the Tim Horton’s restaurant on campus (Curin). The following questions were examined:

1. Server allocation under current setup
2. Adding a “runner” position
3. Changing the service setup
4. Adding an arrival queue
5. Increased arrival analysis
6. Recommending an improved system

Simulation was used as a reliable source to answer the questions above. Many if not all of these questions will need to be considered by the team for this study, and will likely be examined through simulation as well. Their methods and techniques can also be a useful reference for the team, as the service industry is unfamiliar territory for the team, but important nonetheless.

Ergonomics and Sustainability

Ergonomics and sustainability play a large part in the development and growth of any company. Indeed the new emphasis on sustainability plays a large part in the development of human factors and ergonomics. According to Merriam-Webster dictionary, sustainability is involving methods that do not completely use up or destroy natural resources (Sustainable). Some of the reasons for increasing interest in sustainability include the following: the current dramatic ecological changes, an increasingly critical discussion about the consequences of globalization, wrongly understood shareholder value concepts, which lead to the practice of short-term evaluations instead of focusing a company's long-term success, the crisis of the financial markets, a growing demand for corporate social responsibility, and other important factors (Zink et. al).

When redesigning any work environment or facility, sustainability is an important factor to keep in mind. It is important to keep the environment and society as a focus along the entire value stream. This will allow the company in question to achieve LEED certification and a reputation as a positive force in the community (Zink et. al).

Indeed, as the Earth's population becomes aware of its potentially harmful impact on the planet, corporations are adding sustainability objects to their usual business-oriented objectives (Moyer). If a corporation can simultaneously emphasize people, planet, and profits--they can gain favor with ecologically minded consumers. Sustainability initiatives run abound in the restaurant industry--everywhere from packaging to sustainable food production and preparation. These concepts will be important to keep in mind in the redesign of The Avenue. The team will need to consider the environmental effect on the planet and people when considering potentially profitable changes.

Design

Stakeholder Bill of Rights

First, the project team needed to define key stakeholders in the project process. The project stakeholders are the people who request, pay for, consume or are affected by a simulation and its results are often referred to by its stakeholders. For any project, the stakeholders should have reasonable expectations from the people actually doing the work. In addition, the final results and deliverables of the project need to satisfy all key stakeholders--and the results of the project need to deliver valuable results to project stakeholders. When undergoing any project--there are a number of criteria that need to be followed so the integrity of the project can be maintained. These criteria are outlined in *Simio and Simulation: Modeling, Analysis, Applications* by W. David Kelton, Jeffrey S. Smith, and David T. Sturrock. They are as follows:

First, comes the partnership. It is important for the project team to provide more than information upon request. The project team must assume ownership of the project and help the stakeholders determine the right problems. Next, the project team must define a functional specification at the beginning of the project to help define clear project objectives, deadlines, data, responsibilities, reporting needs, and other project aspects. After the functional specification is created, the prototype is built to help stakeholders and the modeler communicate and visualize the project scope, approach, and the outcomes. It's important for the prototype to help stakeholders and the modeler communicate the project with an appropriate level of detail.

After the level of detail is decided on, the iterative model of the project is created with a phased approach--a simple model is created at first and developed in stages. Each stage of the project needs to be delivered in a timely manner--if a decision-making date has been clearly identified, usable results will be provided by that date. Next, agility is the ability to change direction during the course of a project--a very important trait for any project team to exhibit. Once a preliminary model is created, the model needs to be validated and verified with the project stakeholders to verify that it accurately models the system. An ideal model will have an element of animation to aid in verification and communication with stakeholders.

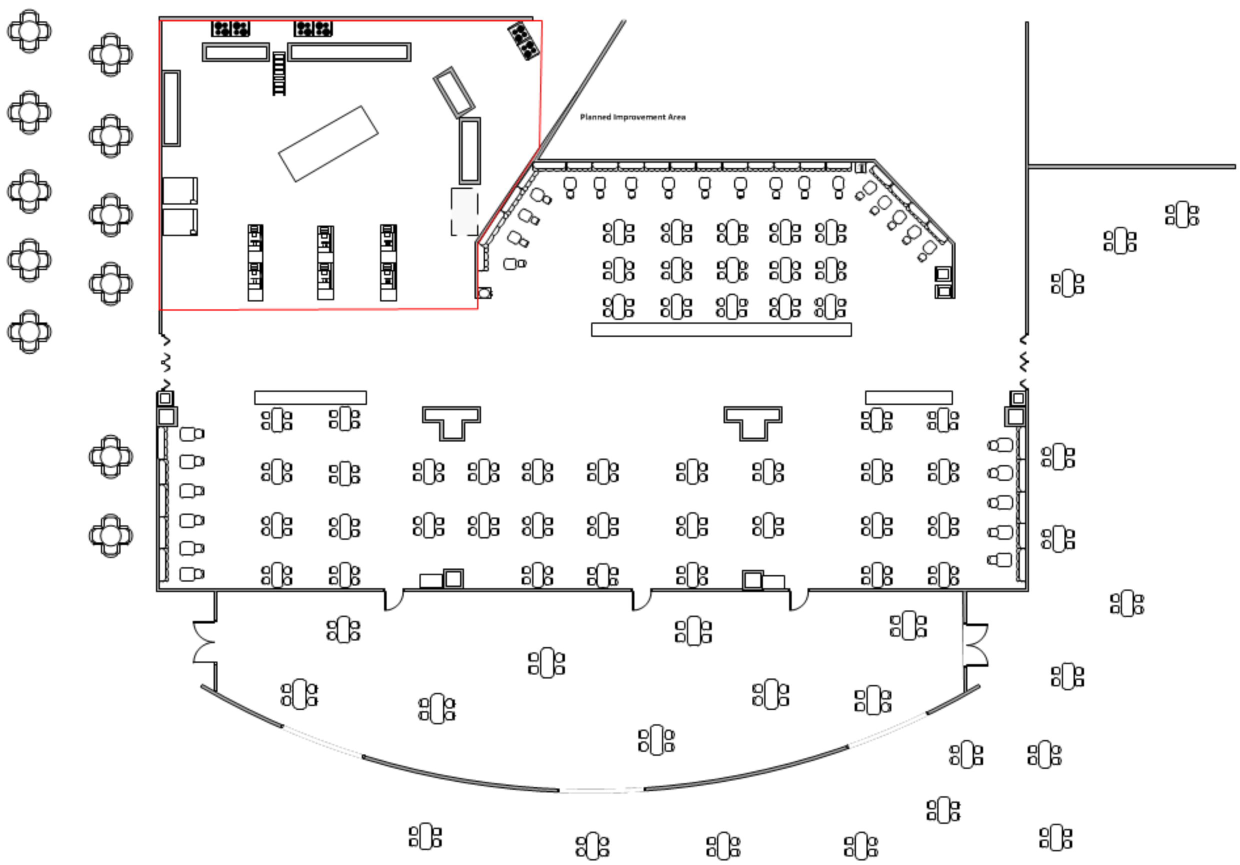
After creating the model, clear accurate results will be summarized and expressed in a form and terminology useful to stakeholders. In addition the model must be adequately documented both internally and externally to support long-term objectives and long term model viability. Last but not least, integrity must be kept as the basis of any study or project--the results and recommendations are based only on facts and analysis and are not influenced by politics, effort, or other appropriate factors.

The Avenue Overview

Now that the key stakeholder guidelines have been established, a quick overview of The Avenue food court will be established. The Avenue is an on-campus dining option at Cal Poly that features several different restaurants bordering the outside of the food-service area--with a salad bar in the center. The Avenue offers dining options ranging from American to Chinese to Mexican food. The restaurants in The Avenue are as follows: Chick-Fil-A, Tapango's, City Deli, and Fusion Bowl. In addition to the main restaurants, The Avenue also includes the aforementioned salad bar, assorted beverages, and Grab-n-Go items. Customers enter The Avenue through one of several sets of automatic doors, walk through the seating area, past the registers, and into the food-service area. Once in the food service area, customers can choose to select pre-

prepared food at Chick-Fil-A, Grab-n-Go, or the salad bar--or wait in line to be served at Fusion Bowl, Tapango's, or City Deli. After getting food from one of the restaurants, customers tend to add a beverage, go to the salad bar, or head straight to the registers. Once there, the customers wait in one of 1-3 queues--depending on how many registers are open at the time. After checking out--customers continue out of the food-service area and into the seating area. The layout of the entire facility including the seating area can be found in below Figure 1: The Avenue Seating Layout.

Figure 1: The Avenue Seating Layout



Study of Customer Trends

Soon, the project team was able to begin their study of customer trends in The Avenue. Since The Avenue is open from 7:00AM to 7:00PM on Monday through

Thursday and 7:00AM to 5:00PM on Friday, the project team needed to decide which hours to focus on--and what times would be ideal to perform time studies. The project team met with Campus Dining's Director of Operations, Greg Yeo, to determine the peak hours of The Avenue--or the busiest hours of the day. Yeo noted that the peak hours of The Avenue tend to occur at the beginning of the hour--and during the lunch hour from 11:00AM to 12:00PM daily. According to Yeo's suggestions, the project team decided to perform initial time studies at 11:00AM. This was due to the assumption that if the system is modeled during the most impacted hours of The Avenue--it would hold true during the less impacted hours. However, before proceeding, the project team needed to determine which metrics were the most important to measure in The Avenue to create an accurate simulation. For any simulation model, one needs an inter-arrival time or distribution to represent the number of customers that enter the system in a unit of time. This regulates the number of customers that enter the system and at what rate they enter. The project team decided that the easiest way to measure this would be to record the times that each customer enters The Avenue to get food--this time study was done for about 30 minutes. This data can be found in Table 11 in the Appendix. Table 1 below shows a snapshot of the data.

Table 1: Sample of The Avenue Customer Inter-Arrival Times

Cumulative Inter-Arrival Times (min.sec)						
0.02	0.34	1.29	1.49	2.4	3.23	3.45
0.03	0.34	1.29	1.49	2.47	3.23	3.45
0.04	0.34	1.29	1.49	2.47	3.26	3.55
0.14	0.42	1.34	1.53	2.47	3.26	4.01
0.14	0.49	1.34	1.54	2.51	3.26	4.02
0.14	0.54	1.4	2.02	3.02	3.32	4.02
0.14	1.08	1.4	2.18	3.02	3.4	4.02
0.2	1.11	1.49	2.26	3.02	3.4	4.02
0.24	1.15	1.49	2.26	3.19	3.4	4.02
0.27	1.23	1.49	2.3	3.19	3.4	4.02
0.29	1.23	1.49	2.31	3.19	3.4	4.08
0.29	1.23	1.49	2.34	3.19	3.45	4.13

After recording the inter-arrival times, the project team entered the data into a statistical analysis program called Stat::Fit. A goodness of fit test was performed to see which of the following distributions best represented the inter-arrival times: exponential, lognormal, normal, triangular, or uniform. After performing the test--each of the distributions was rejected. Therefore, the project team requested daily arrival data from Campus Dining to get a more accurate distribution of the data. Arrival data from a sample day can be found by looking at the number of checks per time interval in Table 16 in the Appendix. After getting an accurate representation of the inter-arrival times of The Avenue, the project team moved onto modeling the individual restaurants in The Avenue. A sample of this data can be seen below in Table 2.

Table 2: Sample of The Avenue Sales Report--Sample Day

Service by Quarter-Hour

Business Dates 2/25/2015
Locations CPSLO
Order Types All

Avenue

Quarter-Hour	Net Sales	% Sales	Guests	Sales per Guest	Checks	Avg Check	Table Turns	Avg Minutes
Service Totals:	**16,610.84**	**100%**	**0**	**0.00**	**3,098**	**5.36**	**0**	**0**
7:00 AM	23.15	0.1%	0	0.00	7	3.31	0	0
7:15 AM	69.65	0.4%	0	0.00	13	5.36	0	0
7:30 AM	87.84	0.5%	0	0.00	23	3.82	0	0
7:45 AM	202.82	1.2%	0	0.00	43	4.72	0	0
8:00 AM	163.01	1.0%	0	0.00	44	3.70	0	0
8:15 AM	81.65	0.5%	0	0.00	18	4.54	0	0
8:30 AM	116.53	0.7%	0	0.00	27	4.32	0	0
8:45 AM	87.84	0.5%	0	0.00	24	3.66	0	0
9:00 AM	289.82	1.7%	0	0.00	71	4.08	0	0

First, a team member observed the service times at Chick-Fil-A--he observed that the restaurant constantly had long lines with an empty warming tray during peak hours. Therefore, a time-study was in order. After undergoing the time study, removing the outliers, and performing a goodness of fit test using Stat::Fit, it was determined that the processing time at Chick-Fil-A followed an exponential distribution with a mean of

16.186 seconds. The individual Chick-Fil-A processing times can be found below in Table 3.

Table 3: Chick-Fil-A Processing Times

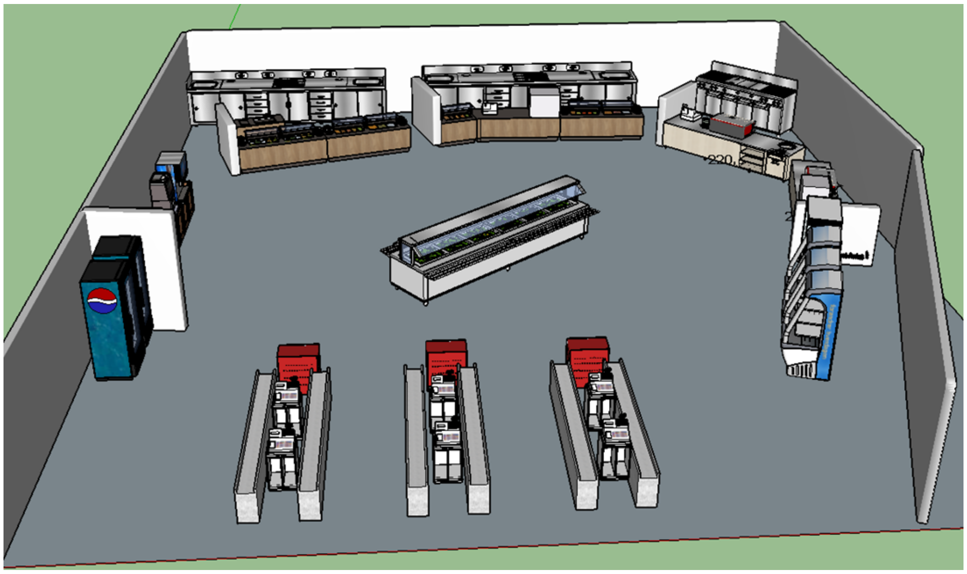
Chick-Fil-A Individual Processing Times (sec)		
5	19	13
4	4	38
4	6	13
3	41	4
10	4	2
37	37	7
4	50	95
16	65	24
17	19	5
13	4	3
32	35	4
11	11	1
19	33	16
8	26	5
7	77	17

A similar approach was taken to model Tapango's, Fusion Bowl, The City, and the salad bar. Time studies for these restaurants can be found in the Appendix in Tables 13-15. The processing time for the beverage station and Grab n' Go were modeled as a constant ten seconds after observing the areas and noticing an average of ten seconds with small variation in both of these areas.

Current State Facility Layout

After collecting processing times for each restaurant, the team was able to create a current state model of The Avenue in Microsoft Visio. This can be found in the Appendix in Figure 9. To make the model clearer, the team also created a 3D model of The Avenue in SketchUp. This model can be found on the next page in Figure 2. Like The Avenue, the model shows the four main restaurants around the perimeter of The Avenue with the salad bar in the center.

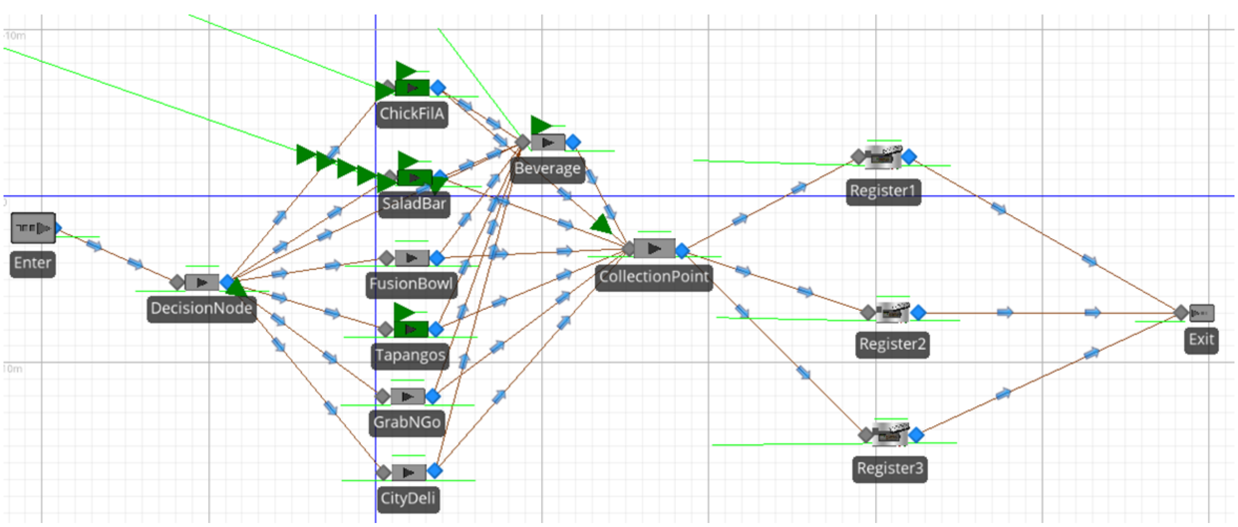
Figure 2: The Avenue Current State 3D Model



Simulation Model

With the current state of The Avenue accurately modeled, the project team moved into creating a Simio simulation model of the food court. The model was created with an iterative process--starting with a simple model, continually developing it, and adding complexity as necessary. The Simio simulation model can be found below Figure 3.

Figure 3: Snapshot of Simio Simulation Model



First, the Source was modeled using the rate table derived from Table 16 in the Appendix. This gave an accurate inter-arrival time--with demand during The Avenue operating hours from 7:00AM-7:00PM divided into 15-minute increments. After leaving the source, entities flow into a decision node where the entities are routed by link weight into one of the following servers: Chick-Fil-A, beverage, salad bar, Fusion Bowl, Tapango's, Grab n' Go, or City Deli. The respective link weights for each of the servers were derived from The Avenue sales data provided by Campus Dining--this can be found in Table 17 in the Appendix. The link weights for The City, Grab n' Go, Tapango's, Fusion Bowl, beverage, salad bar, and Chick-Fil-A are as follows: 0.03, 0.07, 0.11, 0.10, 0.13, 0.11, and 0.45, respectively. These are the probabilities of an entity going to each respective restaurant. After an entity goes to one of the restaurants--with the exception of beverage--the entity is then routed by link weight to either the beverage station or to the collection point later in the system. The system was modeled in this way from observing The Avenue and noticing the customers' tendency to get a beverage to accompany their food selection. The link weight from each restaurant to the beverage station is 0.13, while the link weight from each restaurant straight to the collection point is 0.87. After all the entities are grouped at the collection point, they move onto the registers.

In the current state simulation model of the system, there are three registers with three associated queues. From the collection point, entities are routed to the register with the shortest queue. From observing the register times, a normal distribution was assigned with a mean of 18.79 seconds and a standard deviation of 6.3 seconds for the register service times.

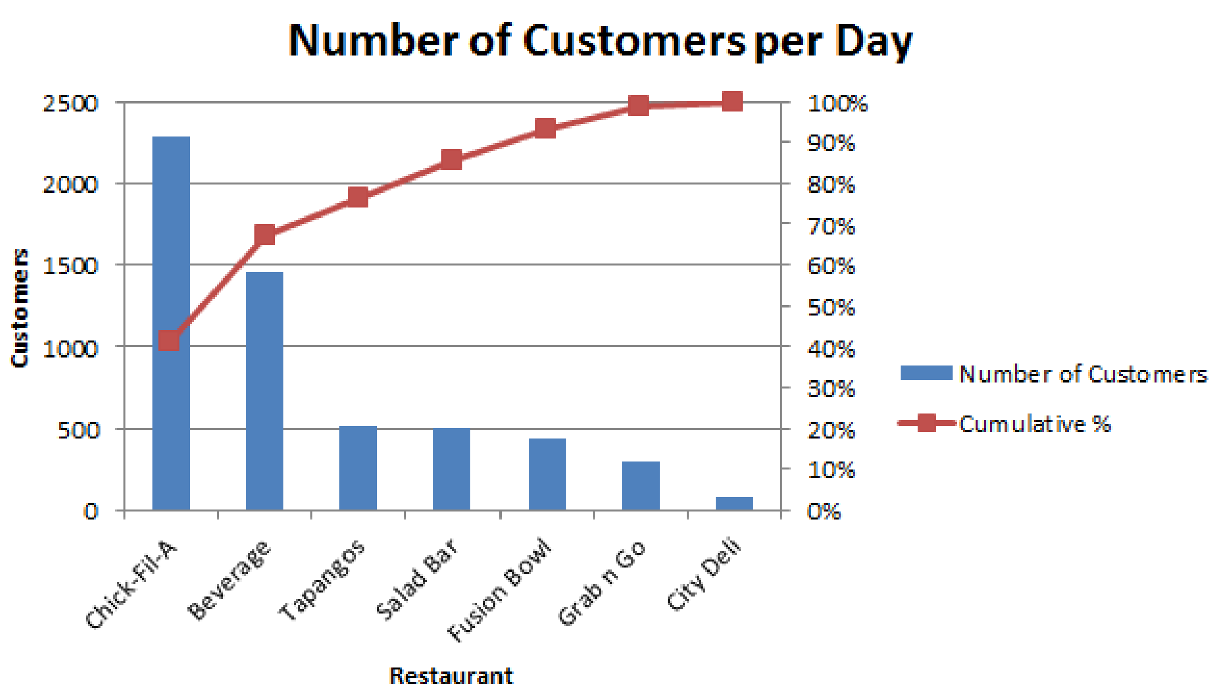
After creating the baseline model for The Avenue with all the associated processing times, the project team was able to perform experiments and compare results to the baseline model.

Methodology

Once the initial design was established, the team was able to test the effects of changing different variables in the design. Experiments that resulted in positive results were considered in the proposed improvements.

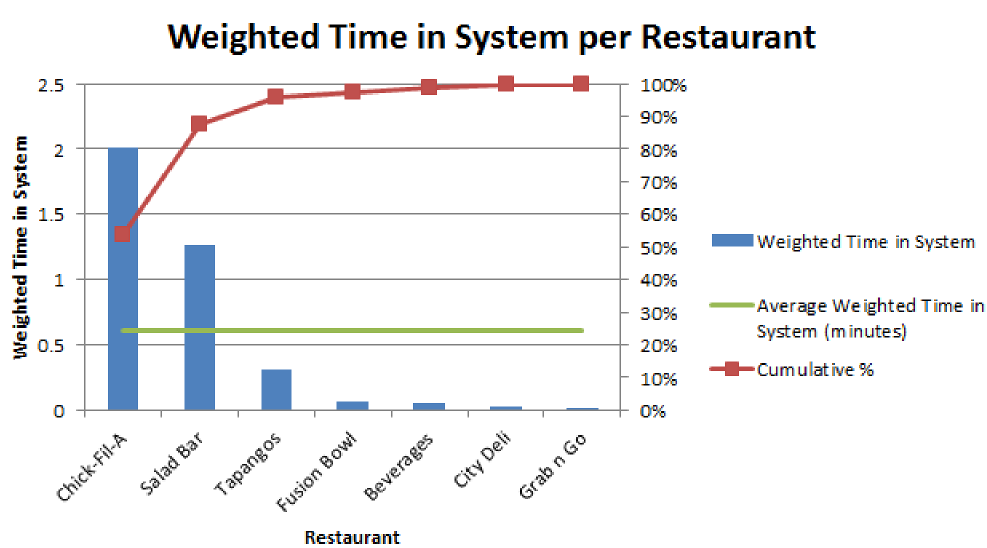
In order to identify areas where the team needed to focus their improvement efforts, a Pareto chart was created. The chart shows the average number of customers that visit each section of The Avenue every day. The team obtained this information from Greg Yeo, who provided metrics showing both the annual and daily customer count and revenue for each restaurant. As you can see in Figure 4 below, the chart shows the cumulative percentages of people that frequent each section of The Avenue. The two areas that account for a large portion of demand are Chick-Fil-A and the beverage station. These two areas alone make up nearly 70% of the total transactions.

Figure 4: Pareto of Customers per Day for each Restaurant



Although these two sections share an inflated demand compared to the rest of The Avenue, they are very different from each other in many aspects. Aside from having a larger demand than the beverage station, Chick-Fil-A also has a much longer processing time--which results in a longer time in system. Figure 5 below shows the weighted time in system, which is a metric that the team developed to determine the bottleneck of the system. Weighted time in system is measured by multiplying each restaurant's time in system with its demand percentage. In addition, weighted time in system accounts for demand as well as processing time. Below, it can be seen that Chick-Fil-A has the largest weighted time in system--this is consistent with the team's observations that it is the bottleneck restaurant. In order to improve the system, the team had two options: improve Chick-Fil-A (the bottleneck restaurant), or improve the system as a whole so that Chick-Fil-A is no longer a bottleneck. Since the team's project scope did not extend to behind to the kitchens, the team chose to focus on improving the system as a whole and use Chick-Fil-A as a baseline reference for the experiments conducted. Its unique service system will be explained in the coming sections.

Figure 5: Pareto of Weighted Time in System per Restaurant



Simulation Model

The team used a simulation model in an attempt to accurately portray The Avenue's system.

The simulation model created to test these improvements can be seen above on page 25 in Figure 3. Although the model somewhat simplifies the system of The Avenue, it effectively models The Avenue's activity, and therefore is useful for analyzing the system. The simulation model works as follows:

1. Customer enters from the left
2. Entry is connected to a decision node, where customers are assigned to one of the seven restaurants. The link weights for each restaurant, based on the average daily demand for the restaurants, can be seen in Table 5 on page 36.
3. The customer then travels to their assigned restaurant with 15 foot paths
4. The customer then waits in their assigned queue and is served at the following processing times, which can also be seen in Table 5 on page 36.
5. The customer can then go to the beverage station, or proceed to the collection point to checkout
    - 13% go to beverage
    - 87% proceed to collection point
6. Once the customer reaches the collection point, they can travel a 15 foot path to exit the system through the least loaded register
    - Register processing time of Normal(18.78889, 6.3)

The team was able to obtain numerous useful metrics from the simulation model. The metrics included:

- Number of customers served

- Average number of customers in system
- Average time in system

Metrics were also obtained for Chick-Fil-A. The team determined that it would be useful to keep track of this restaurant since it was the bottleneck restaurant, and therefore determined throughput. These metrics included:

- Average number of customers in Chick-Fil-A queue
- Average time in Chick-Fil-A queue
- Average time in Chick-Fil-A system

The key metric, as determined by the team, was average time in system. A decrease of this number would signify an improvement to the system. This also proved to be a helpful way to quantify improvements and compare results of alternatives to one another. This baseline simulation model was confirmed from the team's observations.

In order to test alternatives in a quick and efficient way, the team used experiments within the simulation model. The team conducted four experiments:

1. Increase arrival rate by 10%
2. Set demand for all restaurants equal to each other
3. Set processing time for all restaurants equal to each other
4. Increase registers from three to four

Each experiment had a purpose, and had a major influence on the eventual alternate layout that the team developed.

Experiment #1: Increase arrival rate by 10%

The purpose of this experiment was to test if the system would be constrained at the projected increase in customer arrival rate. This would be a way to confirm that the system is constrained and justify that improvements need to be made.

The 10% increase in customer arrivals is derived from the breakdown below. The team took a conservative approach to estimating these numbers, basing them from a combination of input from Greg Yeo and the team's own personal experience of eating on campus. The team's assumptions are listed below:

- (3%) Increase in student population
- (5%) VG's closure for remodel
- (2%) Elimination of meals

The hypothesis for this experiment is that if customer arrival rate is increased by 10%, then the average time in system for each customer would increase.

Experiment #2: Set demand for all restaurants equal to each other

The purpose of this experiment was to examine the effect of smoothing the demand for each restaurant. From the team's observations, it was apparent that Chick-Fil-A consistently had demand while other restaurants were not as impacted. The idea was that spreading the demand would have a similar effect to level-loading machines in a manufacturing environment. The theory is that doing so would lessen the load on Chick-Fil-A and prevent it from becoming a bottleneck.

The demand for each restaurant was set to 14.5% of the total customer arrivals. This was true for all restaurants except for the beverages station, which was kept at its 13% demand rate since other restaurants are already linked to this station--and would already alter its demand as a result.

The hypothesis for this experiment is that if the demand is spread evenly between each restaurant, the time in system would decrease.

Experiment #3: Set processing time for all restaurants equal to each other

The purpose of this experiment was to examine the effect of an equal processing time across all of the restaurants. The processing times for each restaurant were set to that of the bottleneck station, Chick-Fil-A. The individual processing times for each restaurant were set to be a random number that followed an exponential distribution with a mean of 16.186 seconds. Setting the other restaurants equal to the bottleneck station, in theory, should be the most efficient strategy to minimize unused capacity. This is similar to the Drum Buffer Rope theory in production, where the drum sets the pace for the resources, the buffer serves as safety stock for the bottleneck work center, and the rope connects the bottleneck center to the beginning of the production line.

Experiment #4: Increase number of register queues from three to four

The purpose of this last experiment was to test the necessity of one of the team's suggested improvements. Although it was not the bottleneck station, the team wanted to examine if increasing the number of register queues would have a significant effect on the time in system. The team observed that during peak hours the registers were in use consistently. The hypothesis is that with four registers the time in system would decrease.

Layout

With the current state of The Avenue (see Figure 2 on page 25 and Figure 9 in the Appendix), the team was able to analyze the use of space and the movement of customers. The team used spaghetti charts to examine the flow of customers through the system. Figures 10-14 in the Appendix show the flow charts for each restaurant.

They show the clutter of customers that the simulation model has trouble showing. This clutter, although at times may be difficult to quantify in terms of time in system, does have a significant effect on it and had to be addressed by the team.

Results

Experiment #1

The first simulation experiment was conducted to simulate the effects of a 10% increase in customer arrivals to The Avenue. For this experiment, the team expected the number of customers served to increase, the average number of customers in system to increase, and the average time in system to increase. As expected, all three of these metrics did increase, and can be seen in Table 4 below. The number of customers served did not increase by the full 10% because there was an increased number of customers still in the system once the simulation was finished. The average number of customers in system increased by 89%. This is because the current state of The Avenue is already operating at capacity. A small increase in number of customers would result in longer queues at many of the restaurants, resulting in the significant increase in average time in system. This would also create even more congestion in the already limited space of The Avenue, which is not captured in the model, but would have an effect on the system. The simulation is still a very good representation of the population increase because the number of customers is the only variable that changes in the model.

Table 4: Experiment #1 Results

	Current	Experiment #2
Total Customers served	1546.23	1679.63
Avg. customers in system	32.02	60.61
Avg. time in system (min)	4.27	7.24

Experiment #2

The second simulation experiment tested the model with an equal demand spread across the six restaurants. The beverage station demand remained unchanged as stated earlier in the methodology section. For this experiment, the team expected the number of customers served to increase, the average number of customers in system to decrease, and the average time in system to decrease. Surprisingly, all of these predictions were proved to be wrong. As seen in Table 6 on the next page, the total number of customers served decreased by 3%, the average number of customers in system increased by 137%, and the average time in system increased by 5.01 minutes. The reason for the discrepancies between the team's predictions and the results can be attributed to a couple factors. The team predicted that spreading out the demand among restaurants would evenly distribute the load of customers in The Avenue and take pressure off of Chick-Fil-A. While this is partly true, the team did not consider the fact that it would result in a larger demand to areas with much larger processing times than The Avenue. Below in Table 5 is a summary table for each restaurant including the average processing times by restaurant.

Table 5: Restaurant Selection Weights and Processing Times

Restaurant	Selection Weight	Processing Times
Chick-Fil-A	45	Exponential(16.186)
Beverages	13	10
Salad Bar	11	74.25
Tapango's	11	Exponential(50.1875)
Fusion Bowl	10	Normal(40.4828,14.1361)
Grab 'n Go	7	10
City Deli	3	Exponential(50.1875)

This is the reason that the average customers in system and average time in system increased so much. The next experiment was designed to address this problem.

Table 6: Experiment #2 Results

	Current	Experiment #3
Total Customers served	1546.23	1498.17
Avg. customers in system	32.02	75.76
Avg. time in system (min)	4.27	9.28

Experiment #3

The third Simio experiment tested the model with an equal processing time set for all restaurants. The processing times chosen were equal to the processing time of Chick-Fil-A, which was exponentially distributed with a mean of 16.186 seconds. The team expected this to reduce variability in the system while decreasing the average customers in system and the average time in system. As expected, the average number of customers in system decreased by 33%, while the average time in system also decreased by 33%. These metrics can be seen in Table 7 below. Since the original processing times of most restaurants were longer than Chick-Fil-A, decreasing them by any amount would result in faster throughput through those restaurants.

Table 7: Experiment #3 Results

	Current	Experiment
Total Customers served	1546.23	1557.10
Avg. customers in system	32.02	21.35
Avg. time in system (min)	4.27	2.87

These experiments yield very critical information needed in order to increase the capacity of The Avenue. Experiment 1 shows that the current state of The Avenue is at capacity, and a 10% increase in customer population would result in a large increase in the amount of people in The Avenue and the amount of time they spend there. Experiments 2 and 3 together yield some very interesting information. Experiment 2 shows that although demand can be evenly distributed throughout The Avenue to take pressure off the bottleneck, it will not improve the system if the processing times for those restaurants are longer. More importantly, the processing times for all restaurants must be lowered and standardized for the even distribution of customers to be utilized.

As seen in Table 5 on page 36, Chick-Fil-A has a relatively fast processing time compared to the other restaurants in The Avenue. This is because Chick-Fil-A has a very limited menu, and does not follow a typical order and pickup system like other restaurants. Instead of having customers place an order, Chick-Fil-A makes their assorted sandwiches, chicken nuggets, and french fries in bulk before placing them on a heating table where they await to get picked up by customers. When one of the items on the heating table starts to run low, they begin to make that item to replace the supply. This system works for Chick-Fil-A because of their high demand combined with their limited menu. The food is never sitting on the heating table too long since there is always a constant demand for all the items. Since they only have four main menu items, there is very little variability of ingredients and they can mass produce their food very quickly. Other restaurants in The Avenue have a greater amount of menu items, and they can only make an item once the item has been ordered, resulting in longer processing times. Chick-Fil-A is also different from the other restaurants in The Avenue because it is a popular chain restaurant, while the other restaurants are unique to The Avenue. People are familiar with Chick-Fil-A's popular menu items, and it results in increased demand relative to the other restaurants in The Avenue.

The Avenue re-design should feature more restaurants similar to Chick-Fil-A. They should be popular, feature low variety menus, and be capable of producing food quickly in large quantities. The Chick-Fil-A in The Avenue limits their menu compared to other Chick-Fil-A locations so they can meet the high demand of a college campus in the limited space of The Avenue. The new restaurants should do the same. By adding popular restaurants similar to Chick-Fil-A, the demand will be more spread out throughout The Avenue, while the processing times will be standardized and much shorter.

A simulation experiment was created to replicate this scenario, and it yielded very impressive results. In the model, the processing times for all restaurants in The Avenue were set equal to Chick-Fil-A's, while the demand was equal across all restaurants. The results can be seen in Figure 17 in the Appendix. This simulation demonstrates the improvements of the new facility of The Avenue--these numbers show The Avenue's potential under normal conditions. Since the time studies were taken under normal conditions, the model accurately models the proposed processing times of The Avenue. Though an equal demand would be ideal--adding new restaurants in The Avenue would lead to different demand for each restaurant. Additionally, the processing times used in the simulation can vary greatly depending on varying circumstances within the restaurants. If a restaurant runs out of a specific food or ingredient, there can be a large delay during the time they spend to retrieve that item. Also, the processing times will fluctuate depending on the amount of people working at each restaurant. Even though this model shows exaggerated improvement numbers, The Avenue could still see great advancements by implementing the suggestions above in an attempt to re-create the model.

Experiment #4

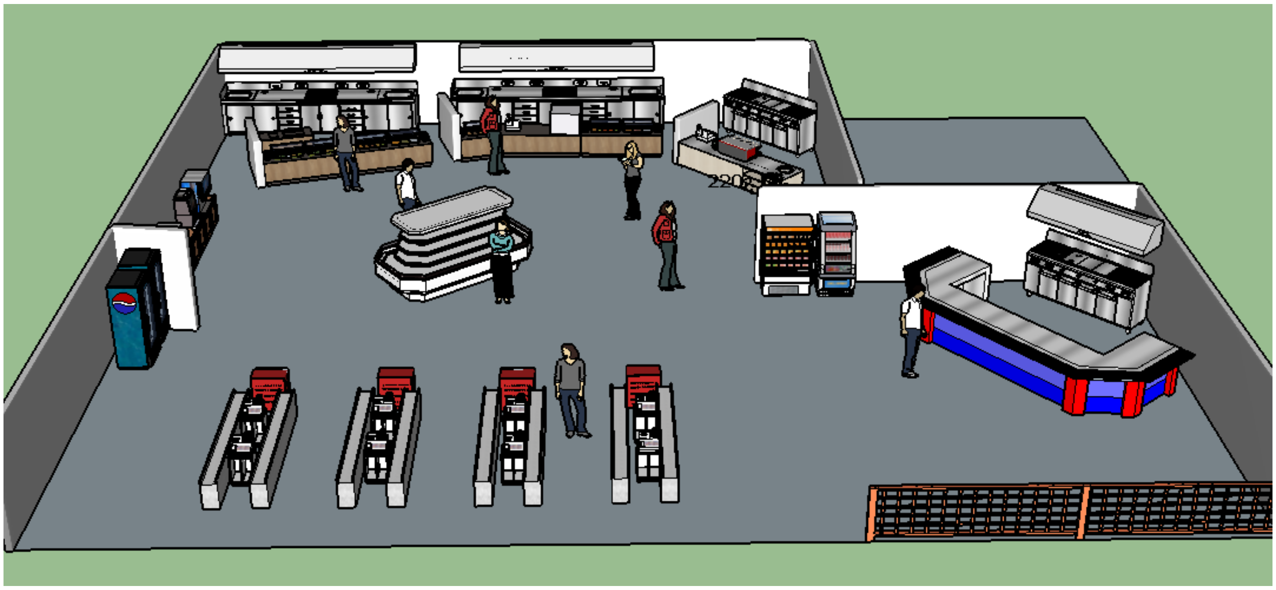
The final improvement to The Avenue involves adding an additional checkout lane. Although the checkout lanes are not currently the bottleneck in the system, they could potentially slow the system once more restaurants are added with faster processing times. The Avenue would not be required to use the additional lane, but it would add flexibility to the system if more lanes were ever needed. The team ran a simulation model with all these final changes implemented. The demand is equal across all restaurants, the processing times are standardized and equal to Chick-Fil-A's, and an additional checking lane has been added.

Table 8: Experiment #4 Results

	Current	Experiment
Avg. time in system (min)	4.27	3.67

As you can see in Table 8 above, the additional lane improved the time in system by 0.6 minutes compared to the same system without the additional checking lane. A 3D representation of the final state can be seen on the next page in Figure 6, including all the team's proposed improvements. The costs of all these layout changes were roughly calculated to justify the improvements.

Figure 6: The Avenue Re-Design 3D Model



Layout

Aside from improvements to restaurants within The Avenue, the remaining space in the facility can benefit from many other layout changes. Greg Yeo explained that the current plan is to demolish the right-side wall of The Avenue and add an additional restaurant. As seen in Figure 15 in the Appendix, the existing wall will be extended outward into the seating area. This new area will add approximately 400 square feet to the restaurant area. The expansion will add additional space in the constrained food court to help accommodate the increased customer population during peak hours. This new restaurant will include a ventilation hood to allow grilling inside The Avenue, a feature that is not currently available. Greg Yeo mentioned that one of the goals of this expansion was to expand The Avenue's menu options, and this would help accomplish that. The team ran the previous Experiment #4 in the last section with the additional restaurant included. While the time in system did decrease, its time was negligible. The new restaurants main purpose is to add variety to The Avenue, rather than to decrease time spent there by customers.

Another improvement is to replace the current salad bar with a new design featuring a tiered design with a smaller footprint. As seen in Figure 9 in the Appendix, the current salad bar takes up a considerable amount of space in the center of The Avenue. Figures 10-14 in the Appendix display spaghetti charts showing the routes of travel for all five main areas of The Avenue. As you can see, many of the routes are forced to travel around the large bar. A salad bar with a smaller footprint combined with the added space of the new restaurant would make the area feel much less confined. Since the demand for the salad bar is only 11% of The Avenue's total, the new design would still be able to satisfy the low demand. The tiered design allows the bar to efficiently utilize vertical space instead of having to extend outward like the current design.

Financial Justification

As you can see in Table 9 on the following page, the current revenue for The Avenue is $2,206,486 per year--this includes sales from each of the restaurants without accounting for cost of goods sold, overhead, and employee pay. After the projected 10% increase in sales (justified in Methodology section) projected revenues increased to $2,427,135 per year--an increase of $220,649. In addition to the yearly revenue, daily revenues of The Avenue are currently $16,634 per day. After the aforementioned increase in sales, the daily revenues are projected to increase to $18,297 per day--an increase of $1,663.

Table 9: The Avenue Financial Justification

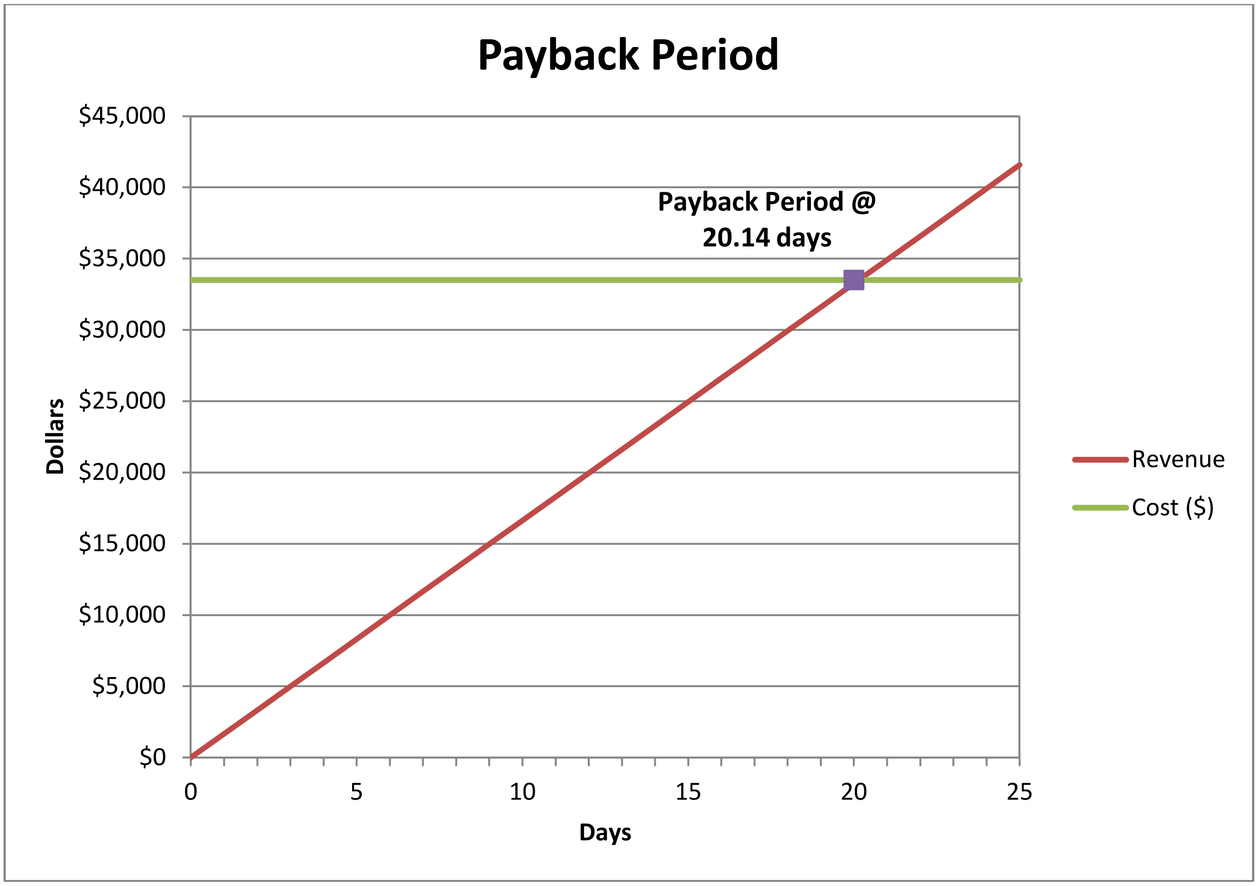
	Yearly Revenue	Daily Revenue
Current State	$2,206,486	$16,634
Re-Design State (10% Increase in Sales)	$2,427,135	$18,297
Net Revenue Increase	**$220,649**	**$1,663**

Though there is a projected increase in revenues as a result of the changes the project team suggested, the changes will require additional capital to implement. First, several walls would have to be removed to free up space for an additional restaurant. This would cost an estimated total of $2,000. After removing walls, additional walls would need to be added--costing an estimated total of $4,500. Additional restaurant equipment would also need to be added--such as a refrigerator and a hood. This would cost a total of $20,000. Finally, the addition of a checking lane and a smaller, multi-tiered salad bar would cost an additional $7,000. Implementing all of the proposed changes would cost a combined $33,500. These costs are summarized in Table 10 below. However, the increase in daily revenue would offset the increased costs--and would result in a payback period of 20.14 business days for the proposed changes, as seen on Figure 7 on the next page.

Table 10: The Avenue Implementation Cost

Improvement	Cost
Remove walls to free up interior	$2,000
Build walls for additional restaurant	$4,500
Restaurant equipment (hood, refrigerator)	$20,000
Additional checking lane	$3,000
Addition of salad bar	$4,000
Total	$33,500

Figure 7: Project Payback Period



Conclusion

In conclusion, this project's problem statement is as follows: due to the expected increase in customer traffic, The Avenue is looking to accommodate additional demand. Each of the following objectives were met through the course of this project: study current customer trends in The Avenue, develop a proposed facilities layout and design, perform a capacity analysis of The Avenue, and write a technical report of the findings. The solution was approached with a DMAIC approach which is defined as follows: define, measure, analyze, improve, and control. The report is organized similarly--with the sections ranging from introduction and background, to design, methodology, and results.

The large scope of this project combined with the relevant material to the team's major has made this project a fantastic learning experience. A large portion of the project was done using Simio software, a program that was relatively new to all the team members. After the project, all members of the team now feel comfortable with the software and can create an accurate model of most systems that exist today. The team also learned how important accurate time studies and estimates are to the accuracy of the model. Many hours were spent in The Avenue making sure the processing times and arrival weights for each restaurant were as precise as possible. Any slight differences in these values could potentially yield much different results in the experiments. Many accurate metrics such as revenue and restaurant popularity were provided to the team by Greg Yeo, which played a huge role in producing accurate results for this project. This shows the importance of constantly collecting data from a system so that the metrics can be evaluated and continuously improved.

The most important metric in this model is time in system. It is the metric that the team used in order to measure and quantify improvements. By reducing time in system, in theory, customers in system will also be reduced--which is crucial to the utilization of The Avenue's limited space.

Based on the experimental results, the team can make some general conclusions on theories that have been proven to work in manufacturing settings, but not necessarily in a food service setting. There are a number of theories that the team based the experiments on, including: drum buffer rope, resource leveling, work measurements, reducing variation between workstations/servers, and theory of constraints.

After completing this project, the team realized that many of The Avenue's weaknesses are a result of slow processing times in the restaurants. If this project were to be continued, the team would attempt to make changes behind the kitchens of each restaurant to improve each restaurant's output rate. The only challenge with this is that once the re-design takes place, there will likely be many new restaurants. Performing these changes now would only improve the current state of The Avenue.

In addition, it would be beneficial to include the number of workers at each restaurant in the model. Experiments could be run showing the different processing times of the restaurants depending on the number of workers at each one. The number of workers at The Avenue would be much different depending on the time of day--peak versus non-peak hours. It would undoubtedly be beneficial for The Avenue to know how many people need to be working at each time to maintain a low time in system and high service rate.

The social impact of this project would be minor, but it would affect certain areas of the campus. After VG's is closed, the student population--primarily first year dorm students--will be redirected to other on-campus restaurants to eat. If meal credits are eliminated, students will not be constrained to eat at certain designated locations. They will be free to eat wherever Plu$ Dollars are accepted. This will create an increased number of students to restaurants such as The Avenue that do not require meal credits. While The Avenue is taking measures to account for this increased demand, other restaurants on campus may not be as prepared for it. It will be difficult to accurately estimate the demand at each restaurant before the changes are actually implemented. The university could greatly benefit from providing surveys to students to get an estimation of what this demand will be.

The increased demand through The Avenue will also result in greater traffic in surrounding areas such as the University Union. With the estimated 10% increased population through The Avenue, it appears that the capacity of the University Union will be able to accommodate these extra students. There is plenty of available outside seating during The Avenue's peak hours to help seat students if the inside of The Avenue becomes full.

Appendix

Figure 8: Original Project Timeline

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Senior Project**	**106 days**	**Mon 1/5/15**	**Mon 6/1/15**
2			**Project Selection**	**11 days**	**Mon 1/5/15**	**Mon 1/19/15**
3			Contacting Companies	5 days	Mon 1/5/15	Fri 1/9/15
4			Visiting Companies	5 days	Mon 1/12/15	Fri 1/16/15
5			Selecting Project	1 day	Mon 1/19/15	Mon 1/19/15
6			Project Proposal	5 days	Tue 1/20/15	Mon 1/26/15
7			Inroduction	1 day	Tue 1/20/15	Tue 1/20/15
8			Background	1 day	Tue 1/20/15	Tue 1/20/15
9			Literature Review	5 days	Tue 1/20/15	Mon 1/26/15
10			Video of Project	5 days	Tue 1/20/15	Mon 1/26/15
11			Facilities Layout and Proposed Schematic	20 days	Tue 1/27/15	Mon 2/23/15
12			Data Report or Customer Trends	15 days	Tue 2/24/15	Mon 3/16/15
13			Capacity Analysis	15 days	Tue 3/17/15	Mon 4/6/15
14			First Draft of Technical Report	20 days	Tue 4/7/15	Mon 5/4/15
15			Revisions of Technical Report	10 days	Tue 5/5/15	Mon 5/18/15
16			Finalize Technical Report	5 days	Tue 5/19/15	Mon 5/25/15
17			Create Presentation	5 days	Tue 5/26/15	Mon 6/1/15

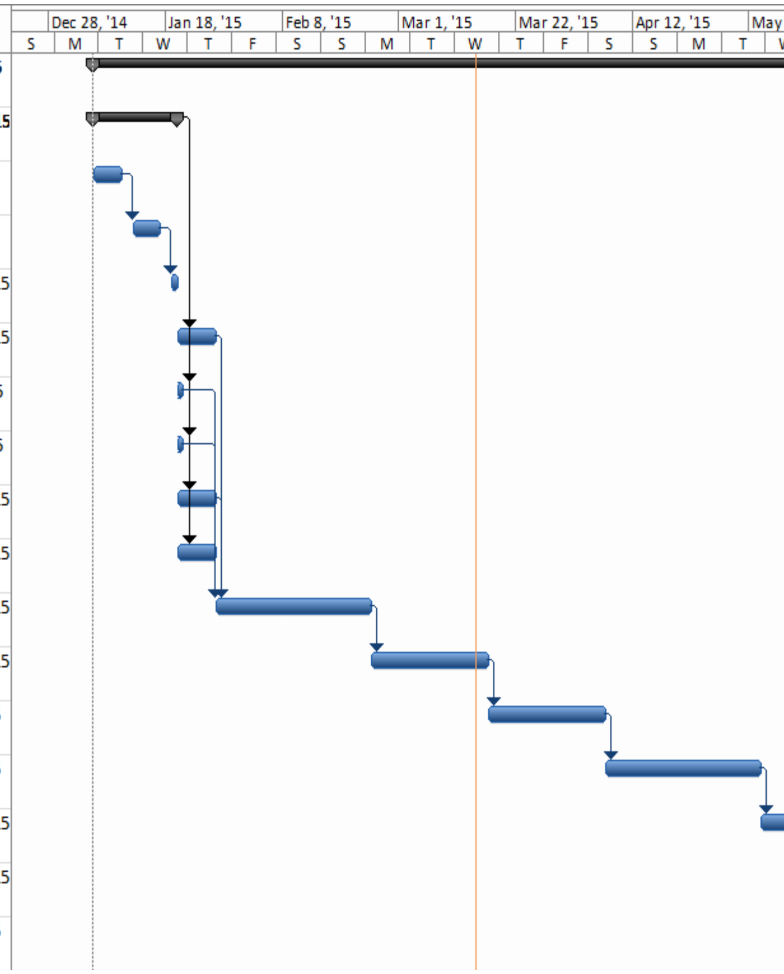


Figure 9: The Avenue Current State 2D Model

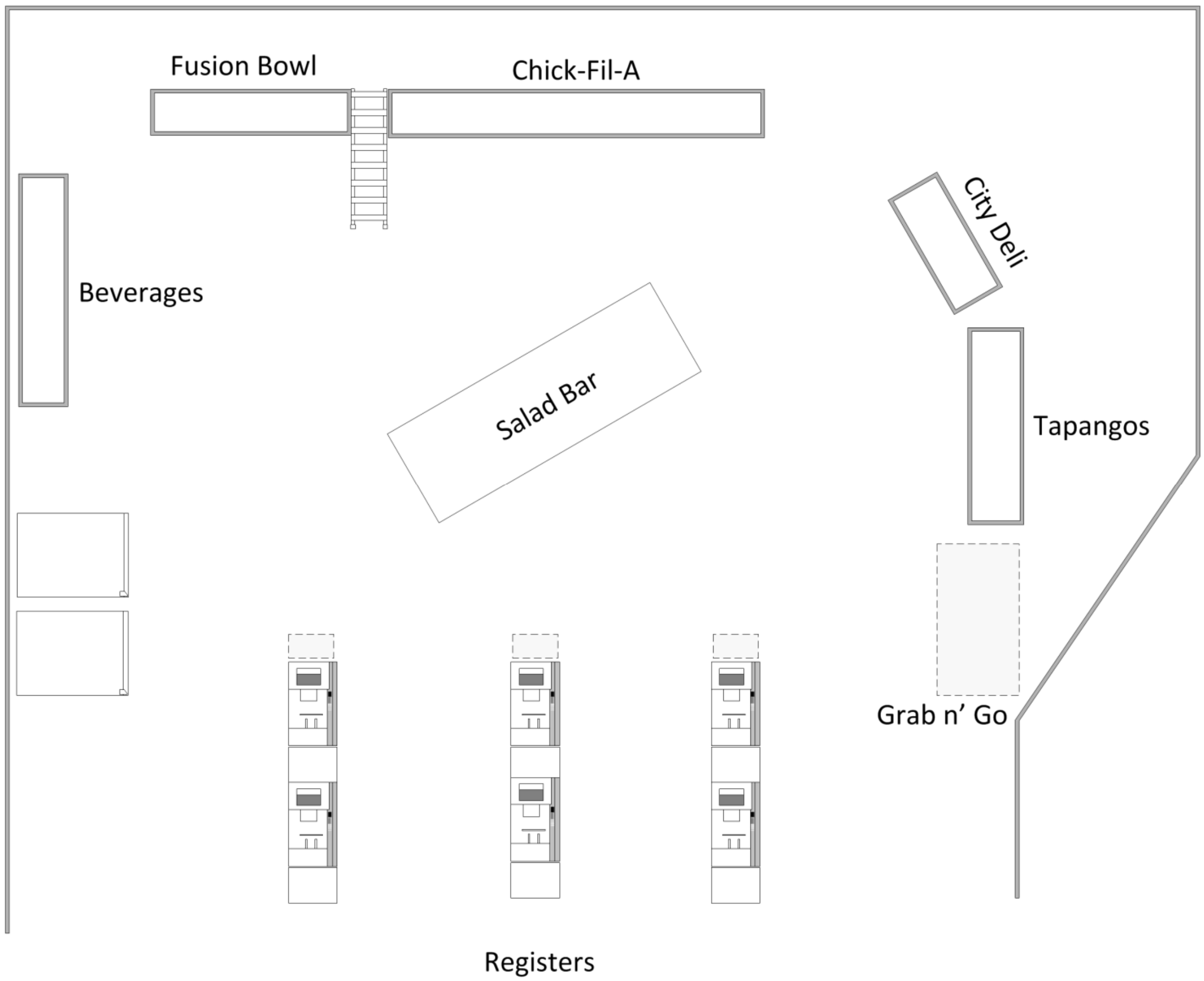


Figure 10: Chick-Fil-A Spaghetti Diagram

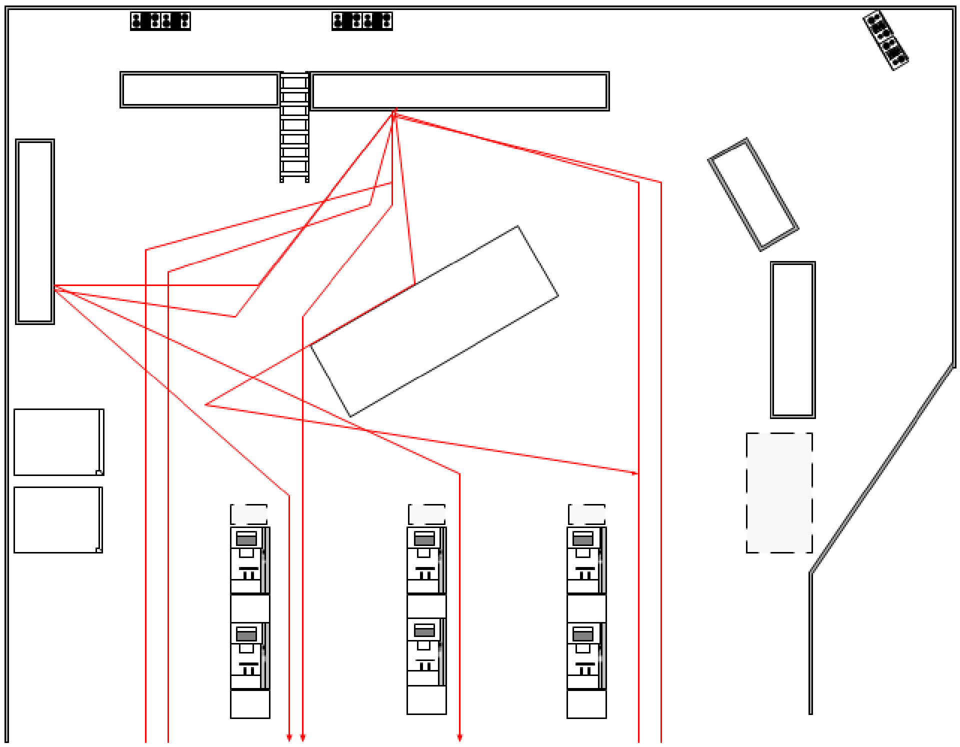


Figure 11: Tapango's/The City Spaghetti Diagram

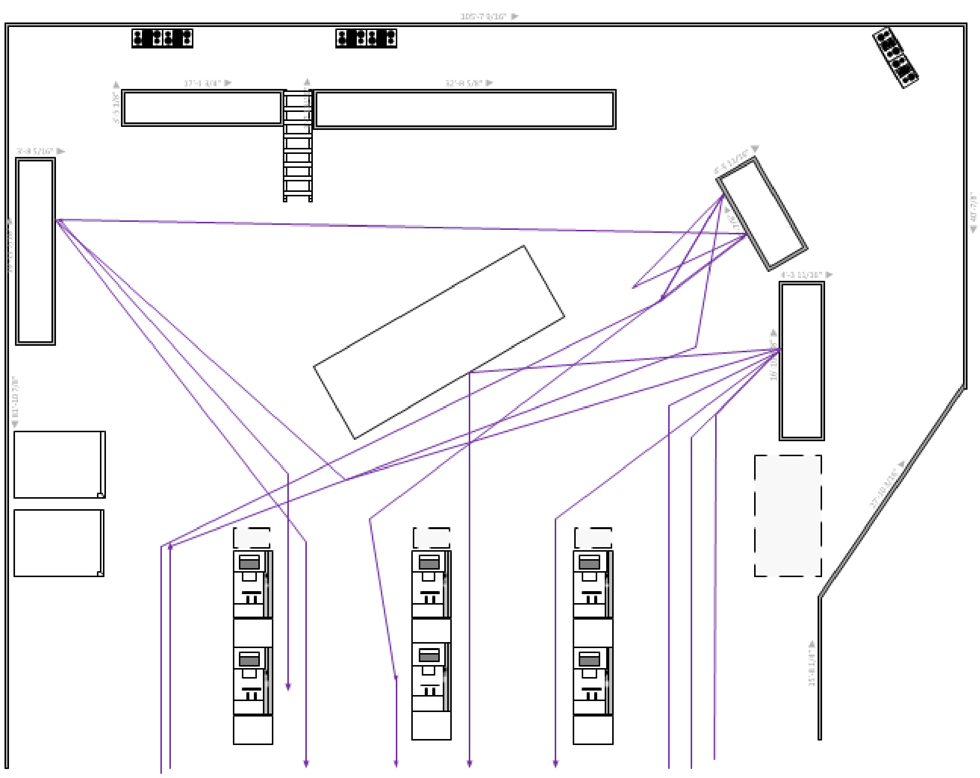


Figure 12: Fusion Bowl Spaghetti Diagram

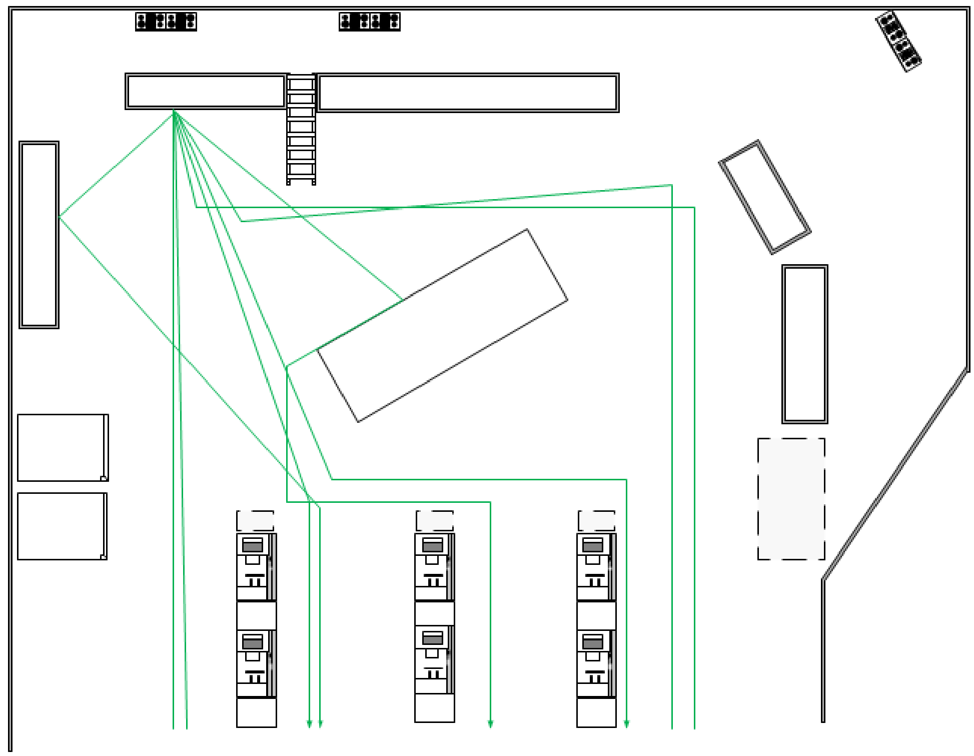


Figure 13: Beverages/Salad Bar Spaghetti Diagram

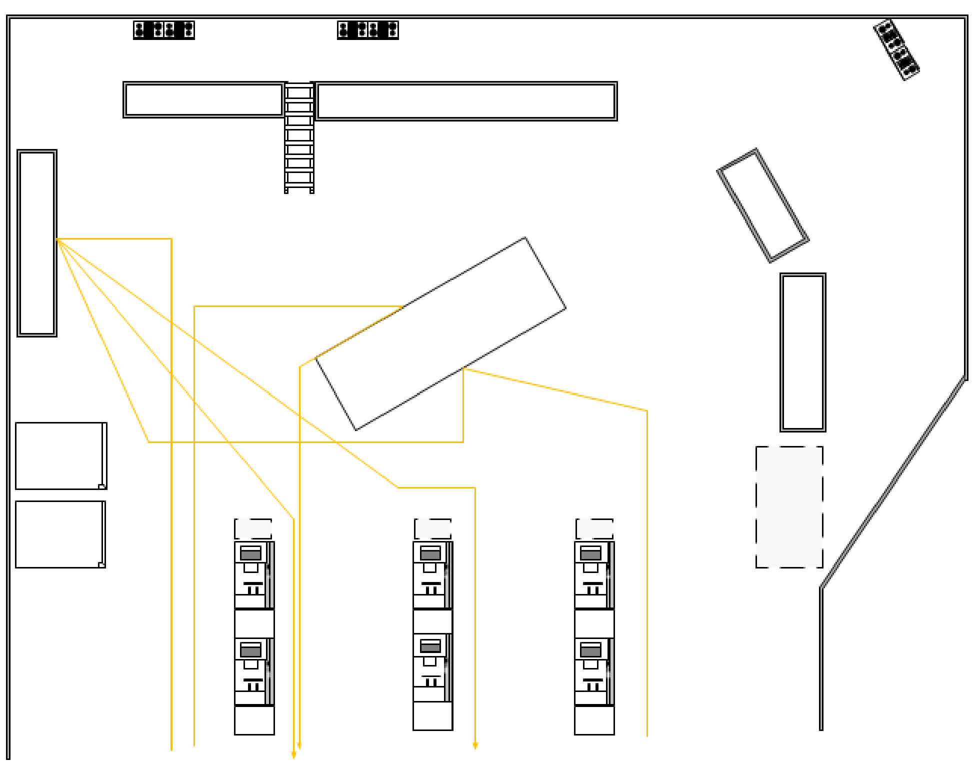


Figure 14: Grab n' Go Spaghetti Diagram

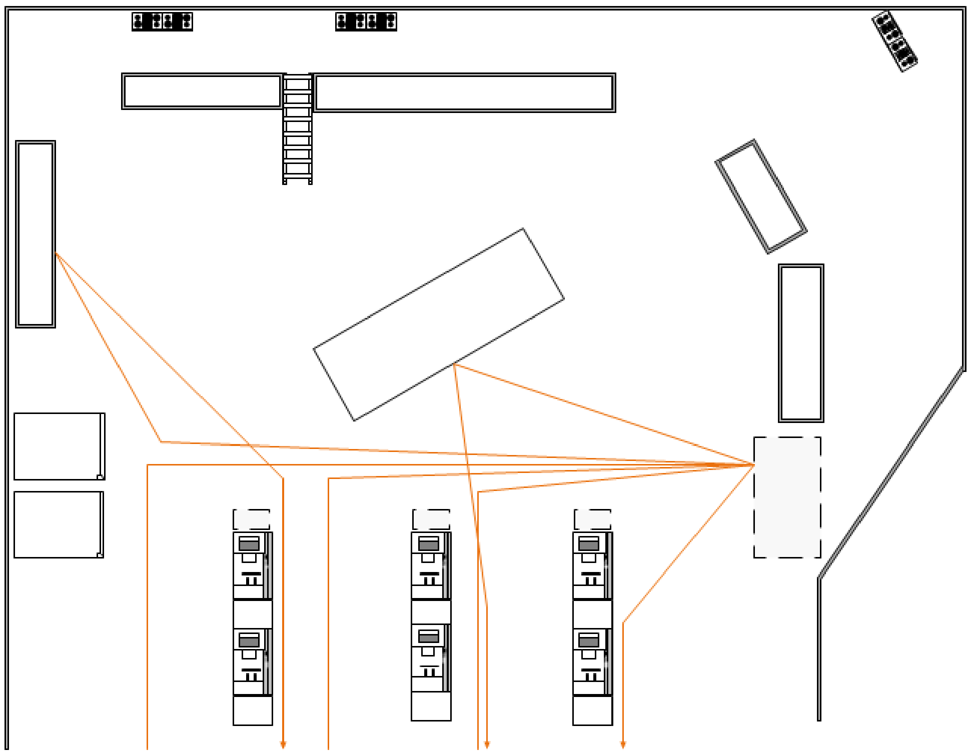


Figure 15: The Avenue Re-Design 2D Model

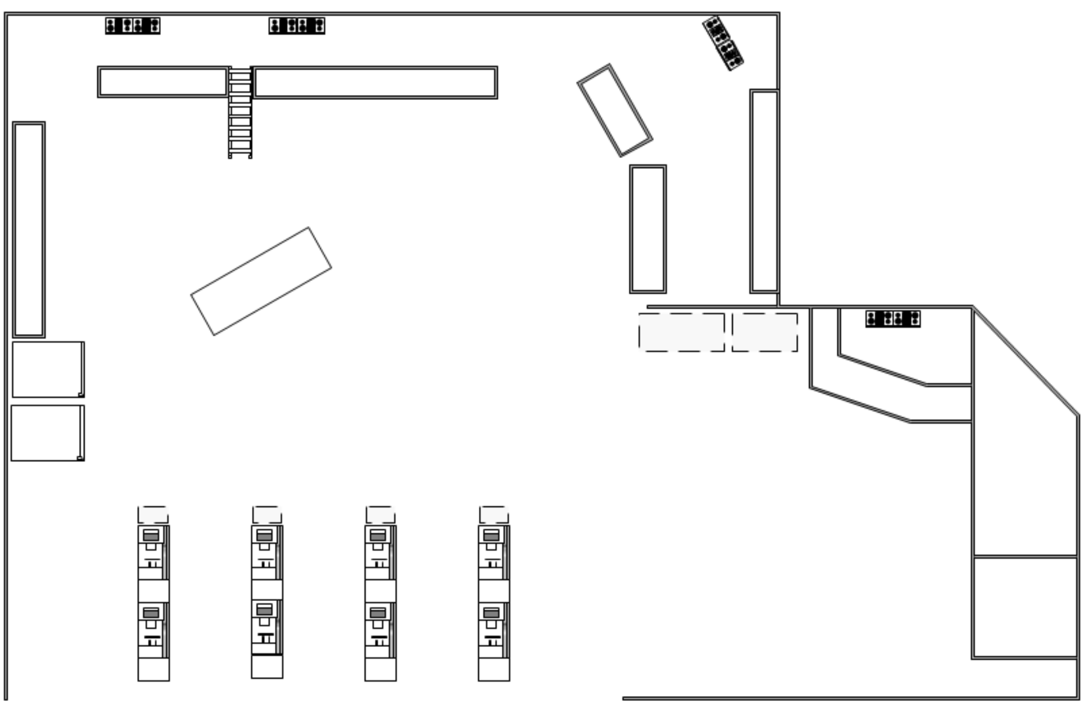


Figure 16: The Avenue Re-Design 3D Model

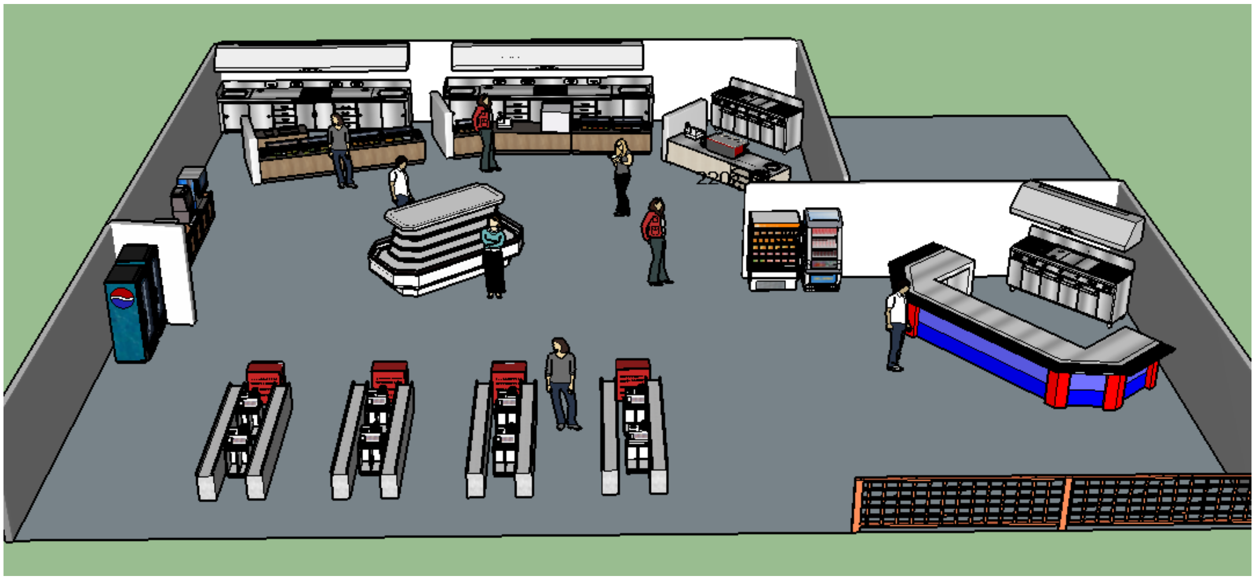


Figure 17: Simio Results

Name	ChickFilAProcessingTime (Seconds)	SaladProcessingTime (Seconds)	FusionBowlProcessingTime (Seconds)	TapangosProcessingTime (Seconds)	GrabnGoProcessingTime (Seconds)	CityDeliProcessingTime (Seconds)	BeverageProcessing
Current	Random.Exponential(16.186)	74.25	Random.Normal(40.4828 , 14.1361) > 0	Random.Exponential(50.1875)	10	Random.Exponential(50.1875)	10
Equal Processing Time	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	10
Equal Demand	Random.Exponential(16.186)	74.25	Random.Normal(40.4828 , 14.1361) > 0	Random.Exponential(50.1875)	10	Random.Exponential(50.1875)	10
Equal Chick-Fil-A	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	Random.Exponential(16.186)	10
Current with increased demand	Random.Exponential(16.186)	74.25	Random.Normal(40.4828 , 14.1361) > 0	Random.Exponential(50.1875)	10	Random.Exponential(50.1875)	10

Name	SelectionWeight	GrabnGoSelectionWeight	TapangosSelectionWeight	FusionBowlSelectionWeight	BeverageSelectionWeight	SaladSelectionWeight	ChickFilASelectionWeight	RateScaleFactor
Current	3	7	11	10	13	11	45	1.0
Equal Processing Time	3	7	11	10	13	11	45	1.0
Equal Demand	14.5	14.5	14.5	14.5	13	14.5	14.5	1.0
Equal Chick-Fil-A	14.5	14.5	14.5	14.5	13	14.5	14.5	1.0
Current with increased demand	3	7	11	10	13	11	45	1.1

Name	Status	TimeinSystem (Minutes)	CustomersInChickFilAQueue	TimeInChickFilAQueue (Minutes)	TimeInChickFilASystem (Minutes)
Current	Compl…	3.67346	12.2113	3.62707	3.89683
Equal Processing Time	Compl…	2.35468	12.4758	3.70946	3.97923
Equal Demand	Compl…	6.85068	0.137861	0.124916	0.394683
Equal Chick-Fil-A	Compl…	0.706576	0.117791	0.107701	0.377467
Current with increased d…	Compl…	6.53781	30.7021	8.43036	8.70013

Name	Status	NumberofCustomersServed	NumberofCustomersInSystem	TimeinBeverageSystem (M…	TimeinFusionBowlSystem…
Current	Compl…	1543.2	27.7096	0.204303	0.674804
Equal Processing Time	Compl…	1548.53	17.4343	0.204005	0.740356
Equal Demand	Compl…	1493.37	59.2145	0.20504	0.674868
Equal Chick-Fil-A	Compl…	1559.17	5.25562	0.207245	0.793441
Current with increased d…	Compl…	1667.53	54.1327	0.208456	0.674832

TimeinTapangosSystem…	TimeinSaladBarSystem…	GrabnGoTimeInSystem…	CityDeliTimeInSystem (Minutes)
2.53543	11.1315	0.175462	1.04992
0.913288	1.31549	0.207208	0.857417
8.08241	35.6638	0.185132	8.02582
0.950741	1.36253	0.294444	0.953572
3.89309	17.4678	0.176776	1.07307

Table 11: The Avenue Customer Inter-Arrival Times

Cumulative Inter-Arrival Times (min.sec)							
0.02	1.54	4.02	7.32	11.05	15.5	21.16	26.56
0.03	2.02	4.02	7.36	11.05	15.5	21.16	26.56
0.04	2.18	4.08	7.36	11.07	15.59	21.2	26.56
0.14	2.26	4.13	7.36	11.07	16.13	21.3	26.56
0.14	2.26	4.23	7.36	11.17	16.13	21.35	27.03
0.14	2.3	4.27	7.4	11.37	16.13	21.35	27.03
0.14	2.31	4.27	7.4	11.59	16.17	21.43	27.03
0.2	2.34	4.27	7.4	12.02	16.23	21.58	27.09
0.24	2.4	4.27	7.47	12.18	17.04	22.05	27.09
0.27	2.47	4.31	7.5	12.28	17.09	22.1	27.09
0.29	2.47	4.38	8.04	12.37	17.09	22.25	27.12
0.29	2.47	4.42	8.11	12.4	17.09	22.33	27.24
0.34	2.51	4.42	8.11	12.4	17.24	22.5	27.24
0.34	3.02	4.58	8.11	12.4	17.3	23.2	27.24
0.34	3.02	5.02	8.11	12.45	17.49	24.17	27.24
0.42	3.02	5.08	8.29	12.45	18.33	24.17	27.24
0.49	3.19	5.08	8.29	12.45	18.33	24.17	27.24
0.54	3.19	5.12	8.37	13.07	18.39	24.17	27.24
1.08	3.19	5.16	8.37	13.07	18.42	24.38	27.33
1.11	3.19	5.16	8.47	13.07	18.54	24.52	27.37
1.15	3.23	5.26	8.55	13.23	18.54	24.52	27.55
1.23	3.23	5.3	9.01	13.23	18.57	24.56	27.55
1.23	3.26	5.36	9.01	13.23	18.57	25.07	28.05
1.23	3.26	5.51	9.04	13.41	19.06	25.15	28.2
1.29	3.26	6.14	9.04	13.5	19.15	25.21	28.33
1.29	3.32	6.28	9.19	14.02	19.22	25.23	28.5
1.29	3.4	6.28	9.23	14.23	19.35	25.41	28.5
1.34	3.4	6.34	9.34	14.23	19.35	25.41	28.55
1.34	3.4	6.34	10.12	14.23	19.35	25.41	28.55
1.4	3.4	6.34	10.12	14.41	19.43	25.43	28.55
1.4	3.4	6.37	10.15	14.41	19.46	25.49	29.01
1.49	3.45	6.43	10.19	14.41	19.58	25.49	29.01
1.49	3.45	6.45	10.23	14.5	20.04	26.14	29.06
1.49	3.45	6.52	10.23	14.55	20.04	26.47	29.26
1.49	3.55	7.03	10.27	15.17	20.04	26.47	29.42
1.49	4.01	7.23	10.27	15.17	20.08	26.47	29.45
1.49	4.02	7.24	10.34	15.17	20.32	26.47	29.5
1.49	4.02	7.24	10.49	15.17	20.38	26.47	30.01
1.49	4.02	7.24	10.49	15.41	20.52	26.47	30.01
1.53	4.02	7.24	10.49	15.44	21	26.56	30.01

Table 12: Register Processing Times

Register Individual Processing Times (sec)					
16	21	9	19	65	18
20	9	35	15	36	13
12	11	14	15	11	28
20	16	9	9	29	22
17	12	25	15	16	20
15	15	13	9	23	16
10	11	26	16	19	7
14	14	23	10	10	8
24	11	25	25	6	10
17	16	19	19	24	9
11	14	24	62	25	11
20	12	45	19	11	14
10	16	21	26	17	22
28	30	14	31	27	41
12	22	11	25	14	15

Table 13: Tapango's Processing Times

Tapango’s Individual Processing Times (sec)			
82	12	11	41
24	129	77	53
31	13	63	16
203	9	19	119
15	68	37	19
74	87	22	59
19	97	42	44
7	4	61	49

Table 14: Fusion Bowl Processing Times

Fusion Bowl Individual Processing Times (sec)	
31	24
30	18
38	69
59	38
42	61
45	34
42	26
39	28
32	35
35	38
70	26
59	65
44	40
36	22
48	

Table 15: Salad Bar Processing Times

Salad Bar Individual Processing Times (sec)		
31	89	77
102	20	106
47	90	7
31	90	98
99	65	105
80	38	111
104	81	22
23	71	56
82	78	72
81	103	82

Table 16: The Avenue Sales Report--Sample Day

Service by Quarter-Hour

Business Dates 2/25/2015
Locations CPSLO
Order Types All

Avenue

Quarter-Hour	Net Sales	% Sales	Guests	Sales per Guest	Checks	Avg Check	Table Turns	Avg Minutes
Service Totals:	**16,610.84**	**100%**	**0**	**0.00**	**3,098**	**5.36**	**0**	**0**
7:00 AM	23.15	0.1%	0	0.00	7	3.31	0	0
7:15 AM	69.65	0.4%	0	0.00	13	5.36	0	0
7:30 AM	87.84	0.5%	0	0.00	23	3.82	0	0
7:45 AM	202.82	1.2%	0	0.00	43	4.72	0	0
8:00 AM	163.01	1.0%	0	0.00	44	3.70	0	0
8:15 AM	81.65	0.5%	0	0.00	18	4.54	0	0
8:30 AM	116.53	0.7%	0	0.00	27	4.32	0	0
8:45 AM	87.84	0.5%	0	0.00	24	3.66	0	0
9:00 AM	289.82	1.7%	0	0.00	71	4.08	0	0
9:15 AM	189.32	1.1%	0	0.00	45	4.21	0	0
9:30 AM	126.84	0.8%	0	0.00	30	4.23	0	0
9:45 AM	275.92	1.7%	0	0.00	62	4.45	0	0
10:00 AM	568.26	3.4%	0	0.00	105	5.41	0	0
10:15 AM	294.07	1.8%	0	0.00	57	5.16	0	0
10:30 AM	181.48	1.1%	0	0.00	37	4.90	0	0
10:45 AM	420.86	2.5%	0	0.00	82	5.13	0	0
11:00 AM	906.41	5.5%	0	0.00	156	5.81	0	0
11:15 AM	587.81	3.5%	0	0.00	102	5.76	0	0
11:30 AM	604.38	3.6%	0	0.00	104	5.81	0	0
11:45 AM	600.45	3.6%	0	0.00	111	5.41	0	0
12:00 PM	865.11	5.2%	0	0.00	152	5.69	0	0
12:15 PM	687.55	4.1%	0	0.00	103	6.68	0	0
12:30 PM	922.49	5.6%	0	0.00	155	5.95	0	0
12:45 PM	504.55	3.0%	0	0.00	89	5.67	0	0
1:00 PM	577.94	3.5%	0	0.00	105	5.50	0	0
1:15 PM	557.26	3.4%	0	0.00	97	5.74	0	0
1:30 PM	508.56	3.1%	0	0.00	88	5.78	0	0
1:45 PM	452.99	2.7%	0	0.00	92	4.92	0	0
2:00 PM	636.63	3.8%	0	0.00	116	5.49	0	0
2:15 PM	584.99	3.5%	0	0.00	100	5.85	0	0
2:30 PM	232.97	1.4%	0	0.00	53	4.40	0	0
2:45 PM	391.30	2.4%	0	0.00	73	5.36	0	0
3:00 PM	473.31	2.8%	0	0.00	91	5.20	0	0
3:15 PM	364.98	2.2%	0	0.00	64	5.70	0	0
3:30 PM	252.66	1.5%	0	0.00	51	4.95	0	0
3:45 PM	278.89	1.7%	0	0.00	55	5.07	0	0
4:00 PM	374.56	2.3%	0	0.00	76	4.93	0	0
4:15 PM	212.06	1.3%	0	0.00	40	5.30	0	0
4:30 PM	130.97	0.8%	0	0.00	26	5.04	0	0
4:45 PM	111.66	0.7%	0	0.00	23	4.85	0	0
5:00 PM	167.87	1.0%	0	0.00	33	5.09	0	0
5:15 PM	161.37	1.0%	0	0.00	31	5.21	0	0
5:30 PM	255.73	1.5%	0	0.00	41	6.24	0	0
5:45 PM	329.66	2.0%	0	0.00	63	5.23	0	0
6:00 PM	260.57	1.6%	0	0.00	44	5.92	0	0
6:15 PM	186.53	1.1%	0	0.00	33	5.65	0	0
6:30 PM	122.38	0.7%	0	0.00	23	5.32	0	0
6:45 PM	112.61	0.7%	0	0.00	18	6.26	0	0
7:00 PM	14.58	0.1%	0	0.00	2	7.29	0	0

Table 17: The Avenue Sales Mix Summary -- Sample Day

Sales Mix Summary

Business Dates 2/25/2015
Locations CPSLO
Revenue Centers Avenue

Group	Gross Sales	Item Discounts	Sales Less Item Disc	% Sales	Qty Sold	% Qty Sold	Average Price
Total Item Sales:	**16,612.92**	**(2.08)**	**16,610.84**	**100%**	**6,171**	**100%**	**2.69**
Food Sales	**16,343.52**	**(2.08)**	**16,341.44**	**98.4%**	**6,063**	**98.2%**	**2.70**
Chick Fil A	6,864.57	0.00	6,864.57	41.3%	2,286	37.0%	3.00
Beverage	2,843.98	(1.34)	2,842.64	17.1%	1,453	23.5%	1.96
Salad Bar	1,749.67	0.00	1,749.67	10.5%	499	8.1%	3.51
Fusion Bowl	1,509.05	0.00	1,509.05	9.1%	442	7.2%	3.41
Tapangos Super	1,095.41	0.00	1,095.41	6.6%	515	8.3%	2.13
Grab n Go	1,034.69	0.00	1,034.69	6.2%	293	4.7%	3.53
City Deli	473.21	(0.60)	472.61	2.8%	79	1.3%	5.98
Baked Goods	377.38	(0.14)	377.24	2.3%	205	3.3%	1.84
Etcetera	344.61	0.00	344.61	2.1%	255	4.1%	1.35
Groceries	50.95	0.00	50.95	0.3%	36	0.6%	1.42
Retail	**269.40**	**0.00**	**269.40**	**1.6%**	**108**	**1.8%**	**2.49**
Groceries	147.95	0.00	147.95	0.9%	76	1.2%	1.95
Beverage	121.45	0.00	121.45	0.7%	32	0.5%	3.80

Table 18: The Avenue 13-14 Sales Summary

Daily Operations Summary

Business Dates 7/1/2013 - 7/31/2013, 8/1/2013 - 8/31/2013, 9/1/2013 - 9/30/2013, 10/1/2013 - 10/31/2013, 11/1/2013 - 11/30/2013, 12/1/2013 - 12/31/2013, 1/1/2014 - 1/31/2014, 2/1/2014 - 2/28/2014, 3/1/2014 - 3/31/2014, 4/1/2014 - 4/30...
Locations CPSLO
Revenue Centers Avenue

Total Revenue	2,206,485.50	
Net Sales	2,201,600.57	99.8%
Gross Sales	2,204,760.33	
Discounts	(3,159.76)	-0.1%
Service Charges	0.00	0.0%
Taxes	4,884.93	0.2%
Cost of Goods Sold	11,174.18	0.5%

Receipts	2,206,485.50
Paid In	2,205.13
Paid Out	5.21

Operating Metrics		
Service	Total	Average
Guests / Avg Spend	0	0.00
Checks / Avg Spend	411,090	5.36
Table Turns / Avg Spend	0	0.00
Avg Table Turns / Minutes	0.00	0
Adjustments	Total	Count
Returns	(610.33)	209
Voids	(3.74)	2
Error Corrects	67,737.50	24,138
Cancels	15,070.38	2,628

Revenue Center	Net Sales	Checks	Avg Check	Guests	Avg Guest
Total	**2,201,600.57**	**411,090**	**5.36**	**0**	**0.00**
Avenue	2,201,600.57	411,090	5.36		

Table 19: The Avenue Daily Operations Summary -- Sample Day

Daily Operations Summary

Business Dates	2/25/2015
Locations	CPSLO
Revenue Centers	Avenue

Total Revenue	**16,634.08**	
Net Sales	**16,610.84**	**99.9%**
Gross Sales	16,612.92	
Discounts	(2.08)	-0.0%
Service Charges	**0.00**	**0.0%**
Taxes	**23.24**	**0.1%**
Cost of Goods Sold	**123.85**	**0.7%**
Receipts	**16,634.08**	
Paid In	0.00	
Paid Out	0.00	

Operating Metrics		
Service	**Total**	**Average**
Guests / Avg Spend	0	0.00
Checks / Avg Spend	3,098	5.36
Table Turns / Avg Spend	0	0.00
Avg Table Turns / Minutes	0.00	0
Adjustments	**Total**	**Count**
Returns	(1.67)	1
Voids	0.00	0
Error Corrects	394.33	141
Cancels	68.70	17

Revenue Center	Net Sales	Checks	Avg Check	Guests	Avg Guest
Total	**16,610.84**	**3,098**	**5.36**	**0**	**0.00**
Avenue	16,610.84	3,098	5.36		

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