33rd European Modeling & Simulation Symposium
18th International Multidisciplinary Modeling & Simulation Multiconference

ISSN 2724-0029 ISBN 978-88-85741-57-7 © 2021 The Authors.
doi: 10.46354/i3m.2021.emss.037

The Impact of the Constraints of Class Scheduling on Campus Dining: A Simulation-based Case Study

Jeremiah Ivan[1], Steven Rooney[1], Hunter Carlson[1], Spencer Bentley, Derek Fisher[1] and Anastasia Angelopoulou[2,*]

[1]Embry-Riddle Aeronautical University, 3700 Willow Creek Rd, Prescott, AZ 86301
[2]Columbus State University, 4225 University Ave, Columbus, GA, 31907, USA

[*]Corresponding author. Email address: angelopoulou_anastasia@columbusstate.edu

Abstract

Waiting in queues in service systems is an inevitable part of the customer's everyday routine. Waiting time is an important indicator of a service system's performance. This paper studies the efficiency of service operations in a college campus dining setting. The authors implemented a discrete event simulation (DES) model in Simio to study how class scheduling may affect the overall customer waiting time and satisfaction at the college campus dining location. The results provide recommendations on how classes could be scheduled to optimize students' satisfaction with their lunchtimes and the quality of service. The results also provide valuable insights for operating during the COVID-19 pandemic, as campus dining locations have a decreased maximum capacity, which may lead to more bottlenecks than usual and increase waiting times.

Keywords: Discrete Event Simulation; Campus Dining; Service Systems; Customer Satisfaction.

1. Introduction

Queues in service systems are an inevitable part of the customer's everyday routine. In the United States (US), an average American spends between two and three years in his/her lifespan waiting in physical queues (Stone, 2012). The waiting time in service systems affects the perceived service quality and customer satisfaction (Melachrinoudis & Olafsson, 1995; Law et al., 2004; Bielen and Demoulin, 2007) and ultimately the customer's return behavior. Thus, the waiting time is an essential indicator of a service system's performance.

Simulation has been extensively used to study the waiting time in various service settings, such as grocery stores (Mykoniatis et al., 2020), restaurants (Tasar, 2020), banks, healthcare facilities, movie theaters, and amusement parks.

This paper uses simulation to evaluate the flow efficiency and effectiveness of the service operations in a college campus dining setting. Campus dining presents a uniqueness compared to a typical restaurant due to the relationship between class schedules and dining choices: large groups of students visit the dining location simultaneously, usually in "waves", which can quickly lead to bottlenecks. Therefore, service efficiency is a high priority in a time-constrained college campus setting.

In this work, we present the implementation of a discrete event simulation (DES) model in Simio. The model allows us to study how class scheduling may affect the overall customer waiting time at the college campus dining location. The simulation includes the restaurant system and multiple classrooms on campus, as well as accurate path distances from the classrooms to the campus dining. Different scenarios are simulated, and the results are analyzed in terms of the average waiting time a student spends getting lunch on campus.

The study's objective is to determine if classes could be scheduled in a way that optimizes students' satisfaction with their lunchtimes and the quality of service. Student satisfaction is defined as being served as quickly as possible without worrying about missing a class. The results provide valuable insights on how the different arrival times of students to the restaurant and the intensity of the arrivals from different classes across the campus impact the customer waiting time at the campus dining location. The study is also important in relation to the COVID-19 pandemic, as all campus dining locations have a decreased maximum capacity, which may lead to more bottlenecks than usual and increase waiting times.

The remainder of the paper is organized as follows: Section 2 provides a literature review on the use of modeling and simulation for improving operations and waiting time in service systems. Section 3 describes the design and implementation of the simulation model. Section 4 presents the verification and validation of the model as well as the results of the simulation experiments. Finally, Section 5 discusses the conclusions and future work.

2. State of the art

Discrete event simulation has been extensively used to study and improve the performance of service systems.

Dharmawirya et al. (2012) analyzed the customers' waiting time for many fast-food restaurants. They compared the actual waiting times with the customers' perceived waiting times and discussed how the fast-food restaurants try to manage the waiting time that customers expect. The results indicated that the customers' actual time in the restaurant, including waiting time in queue and service time, was slightly lower than the customers' perceived waiting time.

Ahsan et al. (2014) developed a DES model in Arena Simulation to study the waiting time in queue in busy restaurants. They analyzed the results in terms of average service time, average idle time, and average waiting time at the cash counter and proposed changes to reduce the customers' waiting time.

Vieira et al. (2018) conducted a simulation study to assess the performance of a Portuguese self-service restaurant through DES in Simio. The model quantified specific performance indicators, such as the total time the customers spent on the system, average customer waiting time, and worker utilization rates to evaluate the level of service of the restaurant.

Tasar (2020) developed a simulation model using Arena Simulation software to investigate the consequences of restaurant capacity decisions on waiting-time standards of an actual upscale restaurant. More specifically, Tasar examined how the number of servers/chefs and tables may affect the number of customer losses and customers served.

The following section describes our implementation of a DES model in Simio to study and improve the performance of a campus dining service system.

3. Discrete Event Simulation Model

Prior to the model development, input data analysis took place, and assumptions were defined.

3.1. Input Data Analysis

One of the most critical input data for our simulation is the average student population that visits the campus dining location. According to information from our campus dining services, the average attendance at the campus dining location is between 180-200 students. For our simulation, our student body consists of 196 students. The student population was uniformly distributed into average class sizes of 7-30 students based on data collected through observation.

Another important aspect of our input data analysis is the size of the model. We intend to simulate the impact that walking speed variation and distance-to-travel have on interarrival time. To generate this data, we used Google Earth and its measurement tools to determine the distance between classrooms and the dining location. The average human walking speed was defined as the triangular distribution between 0.89 and 2 meters per second (m/s), with an average of 1.34 m/s (or 3 miles per hour).

We also calculated the distance for 10 locations, but due to limited software license capabilities, the final model used 5 of the 10 classrooms, as depicted in Figure 1. Input data for the distance of 10 locations were randomly selected and measured.

When modeling the arrival rate to the dining location, we included an additional variation to capture the students exiting the classroom at different points in time. Thus, we used a triangular distribution between 0 seconds and 1.5 minutes, with an average of 30 seconds.

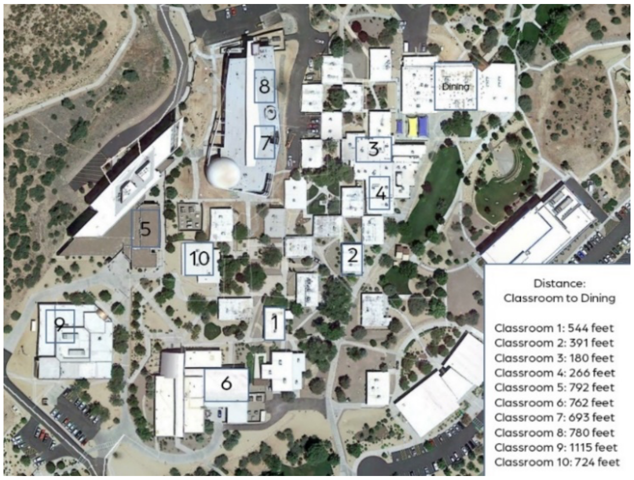

Figure 1. Classroom locations in the model

Finally, the dining location has inconsistent service times depending on how busy the restaurant is (non-busy hours usually indicate slower service). The service time was modeled between 3-15 minutes to account for peak hours, based on data gathered through observations and surveys.

3.2. Assumptions and Limitations

When conducting a simulation study, it is not always feasible to include all the possible events that will occur in reality. Therefore, during this system analysis, the following assumptions were taken into consideration:

- All students leaving the classrooms will visit the campus dining location.
- All classrooms can fit the required number of students, and there are no spatial restrictions.
- The campus dining location is open between 11am and 3pm.
- There is only one path from a given classroom to the dining location.
- Classes last approximately 50 minutes, according to the university's standard Monday, Wednesday, Friday schedule.
- Food is not served in a first-in, first-out (FIFO) order, but the queue to order is FIFO.
- Classes do not end simultaneously, but there is a plus/minus 5-10 minutes difference.
- Students do not leave at the same time. It may take an average of 30 seconds to 1.5 minutes for a student to exit the classroom.
- Ordering food in the checkout queue takes between 15 and 45 seconds.
- Service times are inconsistent and range between 3-15 minutes due to the kitchen's order fulfillment and food preparation policies.

3.3. Model Development

To build our model, we used Simio to lay out a network of sources that represent the classrooms and lead to a series of two servers that represent the dining locations. Figure 2 illustrates the simulation model's layout.

Figure 2. Simulation Model Layout

At the beginning of the simulation, students exit the classrooms and walk to the food service location to get lunch. As discussed in the input data analysis section, class distances were considered. To achieve class and path placement and accurate distances, we built the model to scale: the source image of the campus was measured edge to edge in Google Earth and scaled in Simio to 380 meters in length.

Once the basic layout was set up, the classroom system was modeled as follows: we modeled 5 classrooms with no capacity constraints, where 15 class periods would take place. This allowed for all five locations to be utilized from 11:00-3:00 while allowing for 5 empty periods to be assigned to different classrooms throughout the day.

Then, the inter-arrival schedule was modeled to represent the way a class releases the students. The schedule accounts for both the number of arrivals and time of arrivals to allow us to run multiple schedule combinations during the experimentation. Using the source's built-in arrival table reference, we created a unique table for each classroom schedule with reference properties for each class period slot, as depicted in Figure 3.

Classroom1 Schedule | Classroom2 Schedule | Classroom3 Schedule

	Class Period	Num Arrivals
1	3/24/2021 10:50:00 AM	Classroom1_10AM
2	3/24/2021 11:50:00 AM	Classroom1_11AM
3	3/24/2021 12:50:00 PM	Classroom1_12PM
4	3/24/2021 1:50:00 PM	Classroom1_1PM

Figure 3. Arrival table with reference properties for each class period

Each classroom schedule arrival table includes the following properties: number of arrivals and per classroom time slot. Each class period was also assigned a random student population, as shown in Figure 4.

Classroom1_Schedule	
Classroom1_10AM	Class_1
Classroom1_11AM	Class_10
Classroom1_12PM	Free_Period
Classroom1_1PM	Class_3
Classroom2_Schedule	
Classroom2_10AM	Free_Period
Classroom2_11AM	Class_7
Classroom2_12PM	Class_9
Classroom2_1PM	Class_4
Classroom3_Schedule	
Classroom3_10AM	Class_5
Classroom3_11AM	Class_6
Classroom3_12PM	Free_Period
Classroom3_1PM	Class_8
Classroom4_Schedule	
Classroom4_10AM	Class_11
Classroom4_11AM	Class_13
Classroom4_12PM	Class_2
Classroom4_1PM	Free_Period
Classroom5_Schedule	
Classroom5_10AM	Class_14
Classroom5_11AM	Free_Period
Classroom5_12PM	Class_15
Classroom5_1PM	Class_12

Figure 4. Classroom Scheduling System in the simulation model.

The campus dining system was modeled by splitting up the service into two components: the checkout service and the waiting-for-food service, as illustrated in Figure 5.

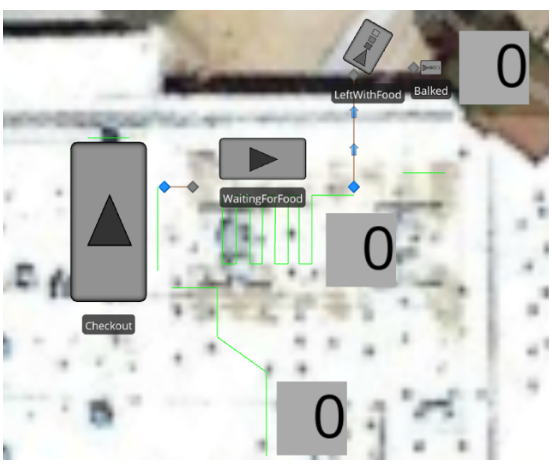

Figure 5. Campus dining system configuration

The checkout service is modeled using a server with a capacity of 1 and service time between 15 and 45 seconds. The waiting-for-food service is modeled using a server with infinite capacity and a service time of Math.Max(Random. Normal(8,5) + Random. Exponential(.1),3). This formula produces a service time that ranges between 3 and 13 minutes, with an average of 8 minutes. The exponential time also includes the minimal probability that some people will have longer (20+ minute) service times.

The separation between the checkout and the waiting-for-food service times allows us to deviate from the FIFO order and replicate the behavior of the real system. The real-world location uses pagers to inform customers that food is ready to be served when their order is ready. This implementation's impact is vital as customers more often decide to leave the service system (renege or balk) based on the number of people waiting to check out. The pager-style system makes the service time for a customer independent of any other customer who may have a faster or slower service time. Our simulation also includes a balking decision: a student decides not to enter the queue if it has more than 25 people.

Finally, student satisfaction was modeled as a parameter that takes into consideration the time they get lunch, the walking time from the classroom to the dining location, and the total time spent waiting in the dining location.

4. Results and Discussion

Once the model's input parameters were set up, we simulated the model to verify and validate it. Once we had a valid model, we could run different experiments to observe the changes in the system and provide suggestions for improvement.

4.1. Verification and Validation

The verification and validation process involved the following components and metrics: walking distance, scheduling system, and restaurant system. After running our experiment, with multiple scenarios, we found the average walking distance to be 2.29 minutes. Based on the average distance of 190 meters among the classroom areas across campus and the average walking speed, the expected average is 2.37 minutes, close to the simulated average.

The verification of the classroom scheduling system was based on the throughput (average number of students that exit the classroom). The number of people that exit the classrooms and arrive at the dining locations matches the total population of 196 students. In addition, we verified the class schedule based on the average rush size over the course of the day by taking into consideration the number of students from each classroom.

The verification and validation of the dining system involved comparing the time-to-get-food with the average total service time, which considers time in queue and checkout time. The simulated and actual times were close to each other, so we considered the dining service system valid.

Finally, the student satisfaction portion of the model was verified and validated. The average satisfaction in the simulation was close to the expected real-world average for our campus dining location. Thus, we concluded that the model can provide valid results and proceeded with the implementation of alternative scenarios.

4.2. Experimental design and analysis of results

We set up an initial classroom schedule and then randomized the arrangement of classes across a series of 54 rows, each running 10 replications for a four-hour simulation period (11am-3pm). The metrics that were recorded include: average student satisfaction, average time in system, number of balked students, and the number of students served per hour (throughput). We analyzed these metrics for the 54 scenarios in terms of satisfaction to capture the "service quality."

The level of student satisfaction stayed relatively consistent, with a minimum of 9.3 and a maximum of 11.2. The service time was on average 16.6 minutes and presented a slight downward trend as satisfaction improved. We also noticed a trend between the number of students who balked and the overall satisfaction: as more students balk, the average satisfaction decreases.

Regarding the class distance and the number of students coming from each classroom, there is no trend between the overall satisfaction and the number of students arriving to the dining location from a given class. We noticed that satisfaction increased during the 12pm "wave" of students arriving at the dining location.

We also analyzed the number of students that arrive to the dining location per hour. Looking at the best scenario in terms of waiting times and satisfaction, we observed that the 57 students had lunch at 11am, 56 students at 12pm, 53 students at 1pm, and 30 students at 2pm. The worst scenario included a distribution of 57 people having lunch at 11am, 17 students at 12pm, 64 students at 1pm, and 58 students at 2pm.

Based on the analysis, an ideal class schedule that would reduce the waiting time at the dining location and improve the perceived service and customer satisfaction should involve an even spread around the busy hours.

We also investigated adding a second person full-time at the register. Based on observation at the campus dining location, two people are working near the register. With the given responsibilities of both workers, only one of the two can check people out at a given time. This optimizes their workflow when the line is not particularly busy but sacrifices speed.

With two full-time servers at checkout, there is an immediate increase in overall satisfaction by an average of 3.5 and an overall reduction in service time by an average of 4.68 minutes. Additionally, balking was heavily reduced with a maximum of 18 and a minimum of 3 people balking compared to a maximum of 38 and 20 people balking with one server.

Thus, another recommendation is having a second register always open between peak lunch hours to increase the total number of people who get lunch in a timely manner.

5. Conclusions

This work presented the development of a DES simulation model. The model was used to study the efficiency of service operations in a college campus dining setting. More specifically, we investigated how class scheduling affects the overall customer waiting time and satisfaction at the college campus dining location.

The results provide recommendations on scheduling classes evenly around the average expected lunchtime to optimize the students' satisfaction and the perceived quality of service at the dining location. The simulation results also indicated that adding a second register during peak times will increase the throughput. The results can also be useful during the COVID-19 pandemic, as campus dining locations have a decreased maximum capacity, which may lead to more bottlenecks than usual and increase waiting times.

Future work will further investigate a scheduling system that can optimize overall customer satisfaction at a service system. Experimentation with a more significant portion of the population will also take place to observe changes in the overall opinion and performance of the foodservice location.

References

Ahsan, M. M., Islam, M. R., & Alam, M. A. (2014). Study of queuing system of a busy restaurant and a proposed facilitate queuing system. *IOSR Journal of Mechanical and Civil Engineering*, *11*(6), 31-35.

Bielen, F. & Demoulin, N. (2007). Waiting time influence on the satisfaction-loyalty relationship in services, Managing Service Quality: An International Journal, Vol. 17 No. 2, pp. 174-193.

Dharmawirya, M., Oktadiana, H., & Adi, E. (2012). Analysis of expected and actual waiting time in fast-food restaurants. *Industrial Engineering Letters*, 2(5).

Law, A. K., Hui, Y. V., & Zhao, X. (2004). Modeling repurchase frequency and customer satisfaction for fast food outlets. *International journal of quality & reliability management*, Vol. 21 No. 5, pp. 545-63 34-50.

Melachrinoudis, E., & Olafsson, M. (1995). A microcomputer cashier scheduling system for supermarket stores. International Journal of Physical Distribution & Logistics Management, 25(1).

Mykoniatis, K., Shirzaei, S., Katsigiannis, M., Panagopoulos, A. A., Deb, S., Potter, T., & Angelopoulou, A. (2020). Society 5.0: A Simulation Study of Self Checkout Operations in a Grocery Store. 32nd European Modeling & Simulation Symposium.

Stone, A., (2012). Why Waiting Is Torture. The New York Times. Retrieved on May 2, 2021 from:

https://www.nytimes.com/2012/08/19/opinion/sunday/why-waiting-in-line-is-torture.html

Tasar, B., Ventura, K., & Cicekli, U. G. (2020). A simulation model for managing customer waiting time in restaurants: scenarios and beyond. *British Food Journal*.

Vieira, A. A. C., Dias, L. S., Pereira, G., & Oliveira, J. A. (2018). Assessing the performance of a restaurant through discrete simulation in Simio. Available at: http://hdl.handle.net/1822/66689