Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 4, 2023
A Regional Conference of the Society for Industrial and Systems Engineering

Improving the Student Pickup Process at a School without Busing

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Author Note: The cadet authors are all first-class cadets at the U.S. Air Force Academy, partnering with The Classical Academy. We would like to thank our faculty advisors for their expertise in the completion of this capstone research analysis. The views expressed herein are those of the authors and do not reflect the position of the United States Air Force Academy, the Department of the Air Force, or the Department of Defense.

Abstract: The Classical Academy is the largest K-12th grade public charter school in Colorado Springs that requires students without a driver's license to be picked up from school at the end of the day as they do not maintain a busing system. Our project focuses on improving the end-of-day pick-up process at the Central Campus. The Central campus consists of 630 Kindergarten-6th grade students being picked up by their parents in about 300 vehicles from either the church parking lot across the street, the neighborhood parking lot behind the school, the school parking lot, or the pickup lines. We created a discrete event simulation and interviewed parents and school faculty to assess the current pickup process. We then tested various methods of improvement through this simulation process. Based on our analysis, the average time in the system for the Central Campus pickup process could be improved by about 20 percent, which would save over 8,000 hours of waiting per school year, and make the process safer. In addition, our group recommends various qualitative methods to further improve the process for the faculty running the process at the school.

Keywords: Student Pickup Problem, Simulation

1. Introduction

The Classical Academy Central campus is a K-6 charter school in Colorado Springs that services about 630 students daily with roughly 40 faculty members. The school does not provide student transportation to and from the school, and the result is over 300 cars arrive in the afternoon to pick up students. The faculty at the Central campus want to increase the efficiency of their student pickup procedures while maintaining the highest level of safety. Long wait times and lines that back up to the main city streets have caused complaints from parents. The current pickup line system, shown in Figure 1, consists of a singular entrance point where parents split into two lines. The idea is that parents drive through the line, pick up their students from the designated area, and then proceed to the exit. However, parents arrive up to 30 minutes early and the line quickly backs up onto Springcrest Road. This causes frustration from parents and, as a result, many of these parents choose alternative methods for pickup. Some parents choose to park in a church parking lot across the street from the school. This causes a safety issue because the parents and students are crossing the same streets that the cars from the pickup line and surrounding neighborhood are using to leave, Springcrest Road and Old Ranch Road. This also slows down the entire process as it slows down cars that are trying to leave. Additionally, some parents choose to park in the parking lot to pick up their students. This presents a problem because when these parents leave the parking lot it creates another line in addition to the two lines formed for drive-through pickup. Furthermore, increasing the time it takes each car to exit. See Figure 1 for a visual of this process. The staff at the Central TCA Campus has notified our team that there is an inability to add a crosswalk for the parents that park across the street, an inability to direct traffic on city-owned streets, and an inability to add additional infrastructure (additional parking, roundabout, etc.). TCA has asked us to evaluate their current process and provide either implementable changes to improve the system or validate that their current method is in fact the best option within their constraints.

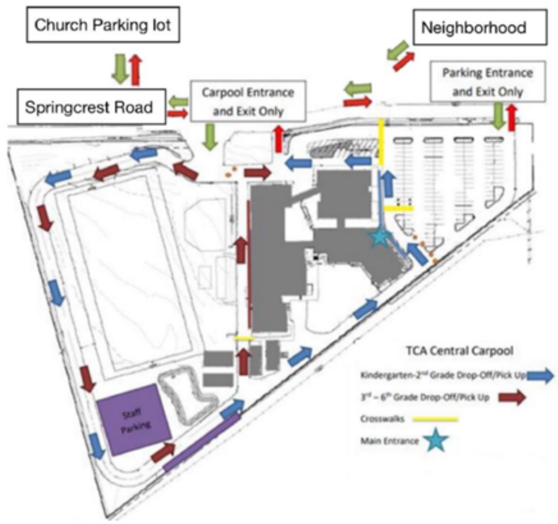

Figure 1. Diagram of TCA Carpool Process

1.1 Problem Statement

TCA is interested in finding the safest, most efficient, and most convenient dismissal operation system for the Central Classical Academy campus for pick-up. The current pickup process takes roughly 25 minutes to service students; they hope to minimize this value by changing certain constraints that currently lengthen the time of the carpool process.

1.2 Related Work

While pickup processes of primary schools are not a very common problem to come across in literature, there has still been some work done in this field that our project falls into the realm of. Our problem relates to some classic queuing problems as well as traffic control problems. A specifically related study from Chiu and Pan (2021), explored how to influence parents to use strictly the carpool lane in order to increase safety and parent engagement levels. Cooner (2009) modeled the queue in a school in Texas that resembles the TCA campus and found the optimal layouts of the queue based on the existing building constraints. Isebrands and Hallwark (2007) address safety concerns and provide ways to mitigate these concerns; some mitigation techniques include encouraging carpooling, increased communication with parents, and separating the different pickup methods (biking, walking, etc.). These works address safety concerns, the queuing problem, and influencing parents, which are all things TCA faces. What makes our problem unique is our problem has more constraints and a unique pre-built system. Since TCA is a charter school, there is no public bus system to get students home, so every student must be picked up by carpool.

1.3 Organization

Section 1 introduced the reader to the capstone project. This section defined the main problem our team is trying to solve in the project. Then, section 2 describes the methodology for this capstone project. More specifically, it details the data used throughout this project and how this data was collected. The application of this data to our group's simulation is then explained in further detail after the data methods have been summarized. The final part of this section details the layout of our experimental design of simulations that are compared against each other in the following section. Section 3 presents the results that our initial baseline simulation and each of the alternate simulations provided, along with an analysis of the data. In the final section, section 4 reveals the conclusion that our team reached at the end of this project, and ultimately our recommendation to increase the efficiency of TCA's student pickup process while maintaining their current level of safety at the Central campus. Furthermore, this section also details our recommendation for further research with the other two classical academy campuses in the Colorado Springs metropolis.

ISBN: 97819384964-4-8

2. Methodology

Initially, our team sent a survey to the parents/guardians at the TCA Central campus in order to collect raw data on the current pickup process. The survey provided insight into the parents/guardians' current satisfaction with the pickup process and why parents choose their respective routes. If we can understand their decision-making, we can influence them to use the carpool lane rather than unauthorized options such as the surrounding neighborhood. The common theme among parents who chose to not use the pickup line is the concern that the pickup line is too time-consuming to wait in. We also sat down with the teachers and staff at TCA who help run the pickup process so that we could hear another perspective on the process. This group includes line monitors, crossing guards, and floaters who ensure the children get to their desired locations safely. We discussed their concerns and suggestions to improve the process. Some insight they provided was that many of the issues they encounter revolve around parents not following the provided guidance. Whether this be parking in an unauthorized location or walking to the school to pick up their children prior to the designated time, parents ultimately slow down the process and make it harder for the system to run as intended. Our raw data collection consisted of observations of the carpool line such as car counts, arrival rates, and the time it takes to get through the line. Our raw data will be processed and used in creating a simulation to model the current operation.

Our team created a discrete event simulation to model the pickup process of the TCA Central campus using the data collected from the parent/guardian survey, interviews with TCA Central Campus pickup staff, and observations from the actual pickup process. In order to create this simulation our group used a simulation interface called "SIMIO". There are several areas throughout the simulation that require the input of data collected from the Central campus. Some examples include things such as the amount of time that the simulation lasts, the number of cars that show up, the average time that an individual spends in the queue, and the average service time for each resource within "SIMIO". The goal of this original simulation was to recreate the student pickup process at the Central TCA Campus. Then using that baseline simulation to ultimately make minor changes that will increase the efficiency of the pickup process at the TCA Central campus. Our team initially created two entities to represent the types of cars that come to TCA to pick up their students. These entities were labeled "Pickup" and "Other". The Pickup entities receive their students in the K-2 and 3-6 pickup lines. While the Other entities pick up their student by either parking in the church parking lot, school parking lot, or parking in the surrounding neighborhood. According to previous data from our survey, 40 percent of the Pickup entities go to the K-2 pickup line and the other 60 percent go to the 3-6 pickup line. Conversely, 68 percent of the other entities park in the school's parking lot, 12 percent park at the church's parking lots, and 20 percent park in the surrounding neighborhood. In addition, roughly 85 percent of cars go to Springcrest Road, and 15 percent go to Old Ranch Road when they are exiting the system. Figure 3 shows a flow chart of the baseline simulation that models the current student pickup process at TCA's Central campus.

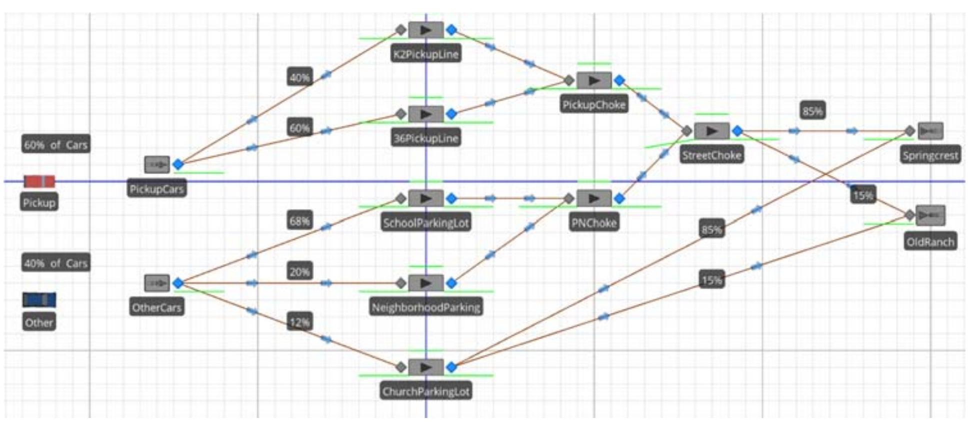

Figure 2. Flow Chart of Student Pickup Process at TCA's Central campus

The simulation starts to generate both entities at 3 PM. However, the entities that arrive early, before 3:30 PM, are not served until the students leave the classrooms at 3:30 PM. The simulation has all the servers start processing entities immediately after 3:30 PM when the final bell has rung. It takes roughly just under 30 seconds for a car to receive their child at the pickup lines. In order to accurately represent this in the simulation, our team modeled the pickup line service time with a triangular distribution that has a minimum service time of 15 seconds, a mean service time of 25 seconds, and a maximum service time of 45 seconds. There are four workers in each line following this distribution as well. The other service stations

ISBN: 97819384964-4-8

like the "Park", "Church", and "Neighborhood" nodes were modeled with a similar triangular distribution. However, they were centered at a slightly larger service time in comparison with the pickup line. Therefore, the bulk of the time in this system is spent waiting in line. Once an individual car has received their student, they will head to a chokepoint. A chokepoint is an instance in the student pickup process where cars must use courtesy to direct traffic. For example, the K-2 pickup line meets up with the 3-6 pickup line at their first chokepoint, named "PickupChoke". At this choke point, ideally, one car from the K-2 line will exit, then a car from the 3-6 line will exit, but that is not always the case. The Pickup and Other entities each go through two chokepoints, except for the Other entities that park at the church. Those specific cars will pick up their child, walk back to their car at the church, and exit the system. After exiting the final choke point, "StreetChoke", the entities will exit the system through Springcrest Road or Old Ranch Road. The specific path of each type of pickup method is shown above in Figure 2 as well.

Our team implemented three different factors into additional simulations that aimed to decrease the StreetChoke chokepoint traffic and inefficiencies. The first solution was to allow multiple cars from one pickup line to pass through a chokepoint, instead of one at a time. A crossing guard could be used on campus grounds to direct the traffic between pickup lines. The crossing guard randomly assigns four vehicles to be serviced in the PickupChoke server according to a random exponential distribution. The exponential distribution has a mean of 0.25 minutes for each batch of cars that are serviced. Therefore, from 3:30 PM to the end of the pickup process, the crossing guard will send four cars from the pickup lines to the StreetChoke bottleneck roughly every 15 seconds. Another implementation involved opening an alternative exit route that allowed entities to bypass the StreetChoke bottleneck. This exit route is currently owned and operated by the Colorado Springs Fire Department. The fire exit is used to provide help quicker in case of emergencies. If the fire exit were to be opened during the car pickup, there is an inherent risk that an emergency could occur in the Colorado Springs area. This process may slow down the firefighters if they needed to use the exit during the pickup process. The risk of an emergency happening during the student pickup process is low, but still a concern for the neighborhood and fire department. However, this poses no additional safety risk to the TCA students and guardians because they are already in their vehicles. Lastly, if we could reduce the number of cars going through the pickup process by introducing a carpooling system on a larger scale that would allow for a quicker overall process. With the current process, there is an average of two children per car. If this was increased to three children per car that would mean approximately 90 fewer cars would be coming through the system. Our team hypothesized that the implementation of these solutions would produce a student pickup process with increased efficiency, leading to less time spent in the system.

Our team created a 2^k full factorial-designed experiment with three factors in order to implement these three different solutions. The original baseline simulation is included in the designed experiment. As a result, we had to change our baseline model seven different times to create the eight different experiments that would be compared in our experiment. The other seven simulations either change the number of cars that come to pick up their student, the use of a crossing guard on campus grounds or if the fire department has opened the additional exit. In the simulations where the Fire Department's exit is open, the simulation sends roughly 40 percent of the cars to that exit. These eight simulations provided insightful information that changed our initial perspective on the significance of our solutions.

3. Results and Analysis

In addition to the three factors already manipulated in the subsequent simulations, our team changed the allocation of cars that were either Pickup or Other entities in duplications of the original model. Our team hypothesized there was another allocation of entities that were optimal for the current system. As an initial test, we influenced the simulation to send 100 percent of the cars to the K-2 and 3-6 pickup lines. This allocation resulted in a simulation that lasted roughly 15 minutes longer than the baseline simulation. Due to this result, we created two additional simulations that changed the allocation of cars in slightly different variations. The first simulation sent 70 percent of cars to the pickup lines and the remaining 30 percent to the other pickup options. The second simulation sent 50 percent of cars to the pickup lines and 50 percent to the other pickup options. We hoped that sending 10 percent more entities to one of the lines would speed up the pickup process. However, both simulations, under the same conditions as our baseline simulation, had an average time in the system that was longer than our baseline simulation. Therefore, after trying to implement this solution, we concluded that the current allocation of cars in the TCA pickup system is a factor that should be held constant because the current allocation was more efficient than other allocations that were implemented.

The results from our survey showed that currently, 84.3% of parents rate the current system as a three or higher on a five-point scale with five representing extremely satisfied and one being extremely dissatisfied. Additionally, we asked parents where they park, and a follow-up short response question where parents had the chance to explain their reasoning for why they choose to use (or not use) the school's recommended pickup line. The satisfaction rating and location breakdown can be seen in the results and analysis section in Figure 3. Another important data point that we found through the survey results was that half of those that filled out the survey are willing to carpool. Currently, only about 15% of people report that they carpool, so increasing this number would help limit the number of cars going through pickup ultimately making it faster.

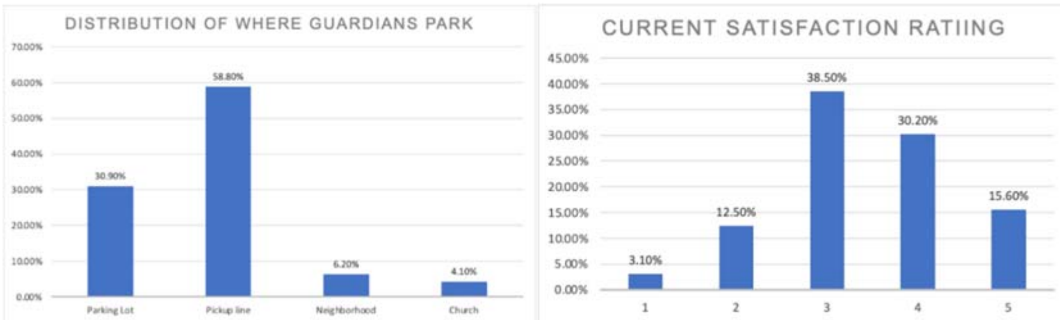

Figure 3. Distribution of Parking and Current Satisfaction Rating

The first simulation we created reflected the current TCA pickup process. The important statistics from this simulation can be found in the second observation of Table 1. The results from this simulation closely reflect what we observed in our data collection process. This simulation had 60% of the cars going through the pickup lines and the remaining 40% split up between the church, neighborhood, and parking lot. The statistic that we primarily focused on was the time spent in the queue at the "StreetChoke" server, as we wanted this to be as short as possible. Allowing parents to get through the process as quickly and safely as possible. Additionally, sending fewer entities to this server would also alleviate the stress put on the other choke points in the system. Ultimately leading to a smaller average time spent in the system for all the entities. For the real-world baseline simulation, the average time in queue was 21.23 minutes for parents in the K-2 pickup line, 21.04 minutes for parents in the 3-6 pickup line, 14.38 minutes for parents who parked at the churches, 13.34 minutes for the parents who parked in the neighborhood, and 14.48 minutes for parents who parked in the parking lot. The average time in the system will be greatly reduced by decreasing the number of cars in the StreetChoke server and decreasing those cars' times in the server.

This model currently creates a simulation that lasts about 23-25 minutes in total. The student pickup process usually lasts a similar amount of time, and other statistics in our simulation that match the real-world student pickup process at TCA's Central campus. These examples include the minimum and average time spent in pickup lines, the number of cars in the system, and the average number of cars served at each station (K-2, 3-6, church, parking lot, neighborhood). Another statistic that we can use to verify this model is the average time spent in the queue of the choke point servers. Additionally, these bottlenecks are extremely critical parts of the simulation because the entities spend most of their time stuck in the queue of the chokepoint servers. As a result, the goal of any implementation to our baseline simulation is to decrease the time spent in the queue and the number in the queue for the choke point servers in the simulations.

We began to alter the simulation to see the effect that different adjustments had on the time and number in the queue of the StreetChoke server. We created a simulation for each of the K-factor-designed experiments mentioned in the methodology. The results from each of these experiments are summarized below in Table 1; each column represents the average over all simulations run. In each simulation, we ran 100 replications in order to grab precise measurements of the responses that are being compared between the eight different simulations. Surprisingly, including a crossing guard does not improve the pickup process. That solution slows the process down according to our simulations. This is reflected when comparing all other experiments with a crossing guard to the same simulation without a crossing guard. In contrast, the most successful experiment was the fifth simulation. We see that having fewer cars and opening the fire exit both improve the time in the queue and number in queue for the StreetChoke variable. While having both fewer cars and the fire exit open provides us with the best overall results, we can see that just having the fire exit open provides us only marginally worse results (comparing experiment 5 to experiment 6). This means that opening the fire exit would have the greatest positive impact.

ISBN: 97819384964-4-8

Table 1. Simulation Results

Simulation	# of Cars	Crossing Guard	Emergency Fire Exit	Time in Queue - StreetChoke Ave	Time in Queue - StreetChoke Max	Number in Queue - StreetChoke Ave	Number in Queue - StreetChoke Max
1	210 (-)	No crossing guard (-)	Fire exit closed (-)	0.86 Minutes	1.96 Minutes	2.87 Cars	23.7 Cars
2	300 (+)	No crossing guard (-)	Fire exit closed (-)	1.18 Minutes	2.66 Minutes	5.61 Cars	31.6 Cars
3	210 (-)	Crossing guard (+)	Fire exit closed (-)	2.56 Minutes	4.92 Minutes	8.46 Cars	57.7 Cars
4	300 (+)	Crossing guard (+)	Fire exit closed (-)	5.44 Minutes	9.80 Minutes	25.7 Cars	103.1 Cars
5	210 (-)	No crossing guard (-)	Fire exit open (+)	0.13 Minutes	0.68 Minutes	0.25 Cars	6.62 Cars
6	300 (+)	No crossing guard (-)	Fire exit open (+)	0.12 Minutes	0.74 Minutes	0.35 Cars	7.83 Cars
7	210 (-)	Crossing guard (+)	Fire exit open (+)	1.04 Minutes	2.38 Minutes	2.41 Cars	28.2 Cars
8	300 (+)	Crossing guard (+)	Fire exit open (+)	0.97 Minutes	2.98 Minutes	3.07 Cars	33.0 Cars

4. Conclusions, Recommendations, and Future Research

There are two important steps in minimizing the time it takes for students at the TCA Central campus to be picked up. First, our team would recommend minimizing the number of cars coming through the system by using a carpool system. More importantly, we also are proposing that the TCA campus should ask the Colorado Springs Fire Department about opening the emergency fire exit from 3:30-4 PM during the workweek for the TCA campus's school year. While not the best scenario, opening the emergency fire exit alone would accomplish a major improvement on its own. We found that by just opening the fire department exit there was roughly a 94 percent decrease in the average number of cars waiting in the StreetChoke server in comparison with the baseline model. Additionally, the average time in the queue at the StreetChoke server also decreased by about 90 percent between these two models. As a result, the average time in the system for all entities decreased by 5 percent from roughly 22 minutes to 20.8 minutes. Moreover, if TCA had roughly 90 fewer cars in the system as well, it would further decrease the average time in the system to about 17.3 minutes, which is roughly a 20 percent decrease. For these reasons, we recommend focusing efforts on opening the fire exit because that option is not dependent upon the collaboration of groups of parents. It rather depends on if the Colorado Fire Department is willing to open the exit for 30 minutes a day during the workweek. This alone would reduce the average time a person spends in the line of the choke point from over 1 minute and 10 seconds to less than 8 seconds. Over a school year, these savings accumulate to over 8,000 man-hours of time saved.

It is our hope that future capstone classes will be able to use the work we did for the Central TCA campus and use it to analyze the East TCA campus. Additionally, a future group could focus more on how to improve carpooling. Specifically, targeting what factors currently prevent guardians from doing it and how to motivate them to start. They could encourage parents to carpool and show them the amount of time that could be saved from carpooling annually. They could use the past survey that we conducted as a starting point for data collection. Furthermore, they could use our past attempt as a stepping stone to creating other surveys to be used at the East TCA campus. Hopefully, our past efforts will allow another capstone group to provide sound research on the East TCA campus.

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