Optimization of Community School of Davidson Afternoon Carpool System

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Abstract

Community School of Davidson (CSD) is interested in improving their afternoon carpool system to establish a more optimal process. We partnered with CSD's Director Connie Wessner, using mathematical modeling techniques in our efforts to observe the current carpool system and increase its efficiency. Queueing theory is used to model the carpool system, with each vehicle in the carpool lane representing a customer. The following data was collected: the arrival time of each vehicle in the carpool line, the time when each vehicle entered the pick-up area, the time each student entered their respective vehicles, and the departure time of each vehicle. Subsequent modeling strategies utilize Monte Carlo simulation. These techniques allow us to make an assessment of the carpool system and determine what changes, if any, should be made to optimize afternoon carpool.

Introduction

The Problem

- Community School of Davidson (CSD) is a North Carolina public Charter School.
- As a charter school, CSD does not receive capital funding. The school does not have funds for sufficient transportation (only 4 full-sized buses).
- Students commute from many different neighborhoods various distances away since any student in North Carolina can attend the school.
- Our project focuses on the afternoon carpool of CSD's High School and 8th grade, which share a building and carpool lane.
- There are 600 students in the High School and 8th grade. A majority of students participate in after-school activities and do not leave during carpool, but there are a large number of students who are picked up in afternoon carpool each day.

The Solution

- CSD is interested in improving their afternoon carpool system, which they believe is inefficient and lengthy.
- We partnered with CSD and Director Connie Wessner with the goal of establishing a more optimal carpool process.
- We utilized mathematical modeling, specifically queueing theory and Monte Carlo simulation.
- We hoped to use our models to determine which aspects of the carpool system could be altered to produce a more efficient and timely system.

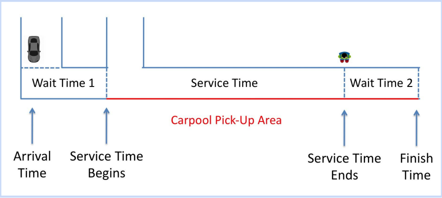

Figure 1. Diagram of CSD carpool lane used to model the queue.

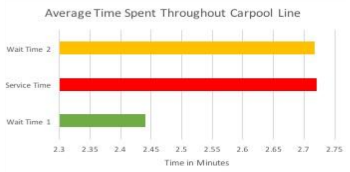

Figure 2: Graph of the average time spent by vehicles in sections of the carpool lane under the current system.

Mathematical Model

Assumptions

- Each car picks up only one student
  - If a car picks up more than one student, record the last student's arrival at vehicle
- Cars can only pick up students in the carpool pick-up area (15 cars long)
- Students wait for their cars inside the school building
- Once the car enters the pick-up area, the student knows their car has arrived

Model

- Queueing theory
  - Normal distribution
  - Arrival Time = time car enters carpool line
  - Wait Time 1 = time after car enters line until car reaches carpool pick-up area
  - Service Time = time after car enters carpool pick-up area until student enters car
  - Wait Time 2 = time after student enters car until car leaves carpool pick-up area
  - Departure Time = time car leaves carpool pick-up area
- Monte Carlo simulation
  - 100,000 iterations of 60 cars
  - Ran simulation twice with same results to conclude the model converges to the given results by the Law of Large Numbers
- Scenarios modeled:
  1. Cars cannot leave until they exit the carpool pick-up area (current system)
  2. Cars can leave as soon as the student enters the car
  3. Half of the cars follow scenario 1 and half follow scenario 2
  4. Students wait in the carpool pick-up area and cars follow scenario 1
  5. Students wait in the carpool pick-up area and cars follow scenario 2

Results

Scenario	Total Time of Carpool
1	23.52 min
2	19.75 min
3	27.02 min
4	21.9 min
5	18.2 min

Improvements

- Allow for cars to pick up more than one student in the model
- Collect data at the beginning of the school year
- Collect data over more than 1 afternoon

Conclusion

- The current system is not optimal. In the current system, cars spend approximately the same amount of time waiting on a student in the pick-up lane as they do waiting to pull out of the lane once the student is in the car.
- Scenario 5 is the most optimal. This scenario models students already waiting outside when their car pulls up to simulate that some drivers text/call students to tell them they are arriving. This scenario also allows cars to leave once the student is in the car, avoiding Wait Time 2.
- Scenario 3 is the least optimal. This scenario models a randomized mix of cars that stay in the pick-up lane until it ends and cars that leave once their student gets in. This free-for-all process lacks order and creates massive wait times as the carpool gets longer.

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