***PROJECT 4 REPORT***

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Honors

The bus simulation creates an unfortunate conundrum — the more express buses you have, the higher the average capacity of buses, but the higher the wait time for the passengers at the stops. The more regular buses you have, the lower the wait time but the lower the capacity. Thus, it is difficult to maximize PMPG while keeping customers satisfied, so the best solution is to find a compromise — maximize costs while refusing to sacrifice customer satisfaction. After endless testing, I found what seems to be a happy medium. Testing for 2 hour (7200 second) and 4 hour (1440 second) intervals — peak testing times — with 12 buses, 3 of them being express, all launched at even numbered stops, the bus simulation results in an average bus capacity of a bit over 60% (roughly 30-35 riders on each bus) with an average passenger wait time of around 12 minutes. This is under the assumption that all stops will have a steady influx of passengers, which is purportedly not true — though we accounted for the more populous downtown stops, it wouldn't be amiss to assume that more suburban stops may have at most 5 riders at one stop per day.

Having extensive experience with the Metro Transit system, being that I commute home every day, I'd say this is an optimal outcome. Not only are profits being made with an above average PMPG, but the riders are left to wait skewing at a lower than average wait time. With a properly implemented scheduling system and a way for riders to track their bus's arrival time, riders can prepare accordingly for their buses and not be left waiting by the bus time for extended stretches of time, especially come the winter months. In fact, according to a 2014 Metro Magazine study, US commuters wait approximately 40 minutes a day for public transit, which assuming that riders wait 2 times a day to get to and from work, with this bus system would be roughly half the natural average. In comparison to the University of Minnesota's Campus Connectors, these results cleave similarly close — the Campus Connectors arrive every 10-15 minutes and service over 30,000 students in total on just a college campus. To have this bus simulation replicate this success on a larger scale while servicing a city of over 500,000 is what I consider a success.

Some miscellaneous results after testing include running 11 regular buses with an average bus occupancy of roughly 20 and an 8 minute average waiting time with a 30 minute max wait time. Though the wait time is optimal, the PMPG is subpar (higher than necessary) and thus costly for the bus company. Other miscellaneous results are extensive and can be found at the end of this document.

However, I cannot purport these results to be definitive. After hours of testing, I am only more certain that there are an infinite number of combinations I have yet to test — be it varying the number of buses (express or otherwise), which stops should generate riders, or the arrival rate. For the purposes of this experiment, I used the arrival rate of one passenger every 2 minutes. Ultimately, an AI could do what I've attempted far faster, but I am proud of my results.

WORKS CITED

"U.S. Commuters Wait Approximately 40 Mins. a Day for Public Transit." *Metro Magazine*, Metro Magazine, 11 Dec. 2014, www.metro-magazine.com/accessibility/news/292870/u-s-commuters-wait-approximately-40-mins-a-day-for-public-transit.

MISC OBSERVATIONS

some observations

- with 2 buses — one regular & one express — avg wait time was around 17-18 min, max waiting time was 45-48 min
- with each new bus added, waiting time goes down 1 min
- express buses especially effective in reducing wait time
- evenly distribute buses to launch — 1 at every 4 stops

over the span of 100 minutes arrival rate of 120 seconds (the norm)

- ran simulation with 2 buses (1 regular, 1 express), launch from stop 0. 4 stops (regular influx of passengers)
    - average wait time around 17-18 min, max wait time 45-48 min
- 2 buses (still), 10 stops
    - average wait time soared to 30 min, max wait time 90-95 min
    - queue lengths — avg 10-15, max length — 31
- 4 buses (3 regular, 1 express) at 4 and 8
    - average wait time dipped to 21-22 min, max wait time 1.5 hours
    - queue lengths — 8-9, max length — 20
- 6 buses (4 express, 2 regular) at 8, 12, 16, 20
    - average wait time dropped to 11, max wait time — 30
    - max queue — 13, avg 5-7
- 10 buses (4 express), 20 stops
    - average wait time 11 min, max — 35
    - max queue length — 15

When running the simulation with 2 buses, one regular and one express, with an arrival rate of 120 seconds (the norm) and both launching from stop 0, the average wait time was around 17-18 minutes, the max waiting time being 45-48 minutes. At this simulation, only 4 bus stops were regularly seeing an influx of passengers. Having taken the Metro Transit countless times myself, I can personally attest to this wait time being close to the norm, so the fact that only two buses managed to achieve this level of average wait time was quite astounding. Upon adding 10 stops with a regular rider influx, the average wait time soared to 30 minutes, the max being 93 minutes. The queue lengths at each stop ranged from an average of 10-15 to a max length of 31. Upon adding two regular buses at stops 4 and 8 respectively and running several simulations, the average wait time dipped to around 21-22 minutes, the max time still being around 1.5 hours. The queues also grew shorter, the max dropping to around 20 passengers and the average being around 8-9 passengers. After adding 2 more buses, 2 express and the other 2 regular, at stops 8, 12, 16, and 20 respectively, the average wait time dropped to 11 minutes, the max wait time being around 30 minutes. The max queue length at any of the bus stops looked to be around 13, the queue length averaging around 5-7 people.

When having 20 stops get a regular influx of passengers and running 10 buses, 4 of them being express and the rest otherwise, the average wait time persisted at around 11 minutes, the max wait time being around 35 minutes. The max queue length was around 15 people for all buses.