Bus Station Policy Simulation For Mogbazar- Mohakhali Road

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Abstract—*Mogbazar - Mohakhali Road is a road of around 2.5 km length between Mohakhali Bus Stand and Mogbazar Station. On this road, buses carry passengers in both directions. We considered that the buses are allowed on the road for 12 hours (from 8 am to 8 pm). The path has only two terminals, so there is no stoppage in between. Passengers arrive and get on buses from both terminals. For simplicity, let's assume that there is a FIFO queue of passengers in each terminal. For every trip, a passenger pays Tk 10. In one trip, a bus can carry at most 20 passengers. But if it finds fewer passengers, it waits until a threshold is reached. The policy followed by a bus is defined by the minimum number of passengers it needs to carry before starting a trip. Currently, most bus drivers wait for all 20 of their seats to be filled up before starting the trip, wasting a huge amount of time in the process. In this project, we try to simulate buses with different policies to find the best policy balancing the benefits of the bus drivers and the passengers.*

Index Terms—Bus, Terminal, Passenger, Trip, Policy, Profit, Arrival, Departure, Delay.

I. Introduction

Every bus on the road has a capacity of exactly 20 passengers. So, a bus can follow one of 20 policies: Policy 1, 2, 3, 4,..., 20; where a bus following Policy x will carry at least x passengers on every trip.

In every policy, the bus driver faces a trade-off between time and fuel. A high passenger threshold ensures high profit in one trip which is fuel efficient. On the other hand, a low threshold ensures less waiting time which maximizes the time utilization (ensures more number of trips in the same time). The relevant outcome for a passenger is the waiting time. Minimum waiting time maximizes customer satisfaction.

This simulation can be considered as a complex variation of the Multi-Server Queue System where each bus acts as a server. It also possesses some properties of the Inventory System. For example, the simulation can be extended for other vehicles, to compare seating service vs local service.

In the upcoming section, we will have a look at the description of the system which consists of the state variables, events, input, and output variables of the system. Then we will go through the simulation program, its classes, and their relationships. The flowcharts of some of the major functions of the system will be provided. Then, the result data will be presented and analyzed.

II. System Description

A. Problem Statement

Let's consider inter-arrival times of passengers are independent and exponentially distributed. A passenger who arrives at a terminal and finds at least one idle bus immediately enters one of the buses. Any free bus waiting at the terminal at that moment has an equal probability of picking up the passenger. If the passenger finds no free buses at that moment, he enters a FIFO queue.

When a bus arrives at a terminal, it picks up passengers from the queue. If it is following policy x, it will wait idly at the terminal until it has picked up x passengers. However, after picking up x customers, it will wait a short time δ to pick up more customers if possible. After that, it starts the trip. The duration of the trip is also exponentially distributed. The cost of a trip is normally distributed. After completing the trip, every passenger on the bus pays Tk 10 and departs.

The simulation will begin with an equal number of buses in both terminals in an 'empty-and-idle' state; i.e., no passenger is present in the bus or terminal and the bus is idle. We will start waiting for passenger arrivals from time 0 to time 720. Here, time t represents t minutes after 8 am. Here, the total number of passengers served, n is a random variable.

B. Input Variables

The average inter-arrival times of the two terminals are different. As expected, Mohakhali Bus Stand is the busier end.

TABLE I
Inter-arrival Time

Terminal	Average Passenger Inter-arrival Time
Mohakhali	1 minute and 12 seconds
Moghbazar	1 minute and 30 seconds

Total Number of buses, m = 10.

Per Passenger Fare = Tk 10.

We consider the mean cost of a trip to be Tk 6 with a standard deviation of Tk 0.25. It is also assumed that the bus could complete 50 trips with a 300 Tk refill. Also, the current rate of a Bus is 75 Tk/L and the usual mileage of a Bus is around 20 km/L. From this calculation, the fuel cost of a

2.5 km trip is Tk 9.375 which is very close to the Bus driver's input.

To find the average trip duration, a sample was recorded using a personal stopwatch. The results are listed in the following table:

TABLE II
SAMPLE TRIP DURATION

Date	Trip Duration
19 Sep, 2022	1 minute and 5 seconds
19 Sep, 2022	38 seconds
20 Sep, 2022	1 minute and 17 seconds
22 Sep, 2022	1 minute and 13 seconds
28 Sep, 2022	57 seconds
03 Oct, 2022	2 minutes and 3 seconds
05 Oct, 2022	1 minute and 4 seconds
16 Oct, 2022	40 seconds
19 Oct, 2022	51 seconds
07 Nov, 2022	3 minutes and 8 seconds
10 Nov, 2022	1 minute

So, Average Trip Duration = 1 minute and 16 seconds.

C. State Variables

The state of the system is defined by the state of the terminals and the CNGs.

1) Terminal State Variables: The state of a terminal at a certain point of time t is represented by two variables:

c(t) = number of CNGs at the terminal at time t

q(t) = passenger queue length at time t

2) CNG State Variables: The state of a CNG in a certain point of time t is represented by three variables:

$$\text{CNG State, } x(t) = \begin{cases} 0, & \text{if CNG is idle at time } t \\ 1, & \text{if CNG is busy at time } t \end{cases}$$

l(t) = at time t, the terminal from where the next passenger will be picked up

s(t) = the number of passengers at time t

D.

Event Set, E = {Arrival, Start Trip, Departure}

Arrival works on a Terminal and the other two events work on a CNG.Arrival increases either the number of passengers on a Bus at that terminal or the queue length of the terminal.

Start Trip changes the Bus state from idle to busy and changes its terminal.

Departure changes the number of passengers on a Bus to 0 and changes the Bus state from busy to idle. After that, it may increase the number of passengers on the Bus and decrease from the terminal.

E. State Equations

The state equations of the system:

$$c(t+) = \begin{cases} m/2, & t = 0 \\ c(t) + 1, & \text{departure of a Bus at time } t \\ c(t) - 1, & \text{start the trip of a Bus at time } t \\ c(t), & \text{otherwise} \end{cases}$$

$$q(t+) = \begin{cases} \text{No free CNG? } q(t) + 1 : 0, & \text{arrival at } t \\ q(t) = 0 ? 0 : q(t) - 1 & \text{boards} \\ q(t) & \text{otherwise} \end{cases}$$

$$x(t^+) = \begin{cases} x(t) = 0 ? 1 : x(t); & \text{start trip at time } t \\ s(t) < \text{threshold} ? 0 : x(t), & \text{departure at time } t \\ x(t), & \text{otherwise} \end{cases}$$

$$s(t^+) = \begin{cases} s(t) + 1, & \text{passenger boards CNG at time } t \\ 0, & \text{departure at time } t \end{cases}$$

F. Statistical and Output Variables

1) **Variables associated with passenger i**:

Arrival Time ≥ 0

Boarding Time ≥ Arrival Time Trip

Start Time ≥ Boarding Time

Departure Time ≥ Trip Start Time

Queue Delay = Boarding Time − Arrival Time Halting Delay = Trip Start Time − Boarding Time Road Delay = Departure Time − Trip Start time Waiting Time = Queue Delay + Halting Delay Total Delay = Waiting Time + Road Delay

2) **Variables associated with Bus i:**

Passenger Count

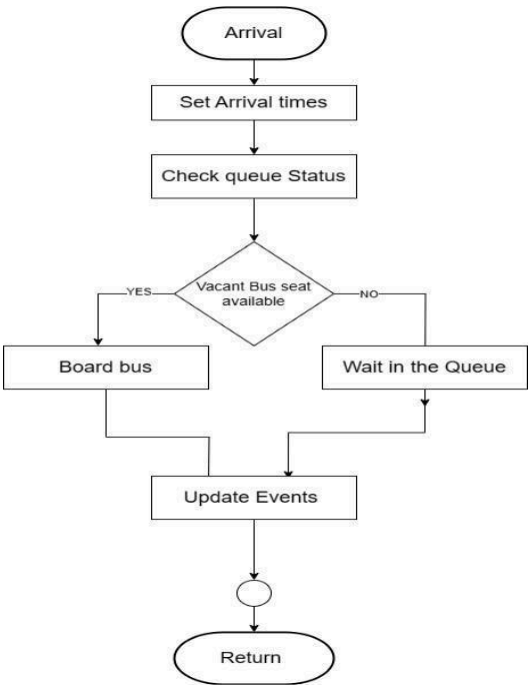
Trip Count

Profit

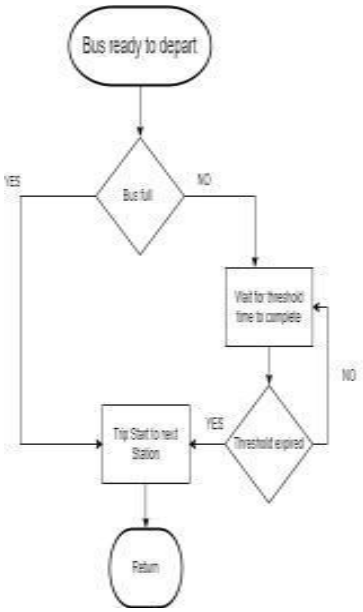
Fuel Efficiency = 20 ∗ Passenger Count/ Trip Count

G. Event Routines

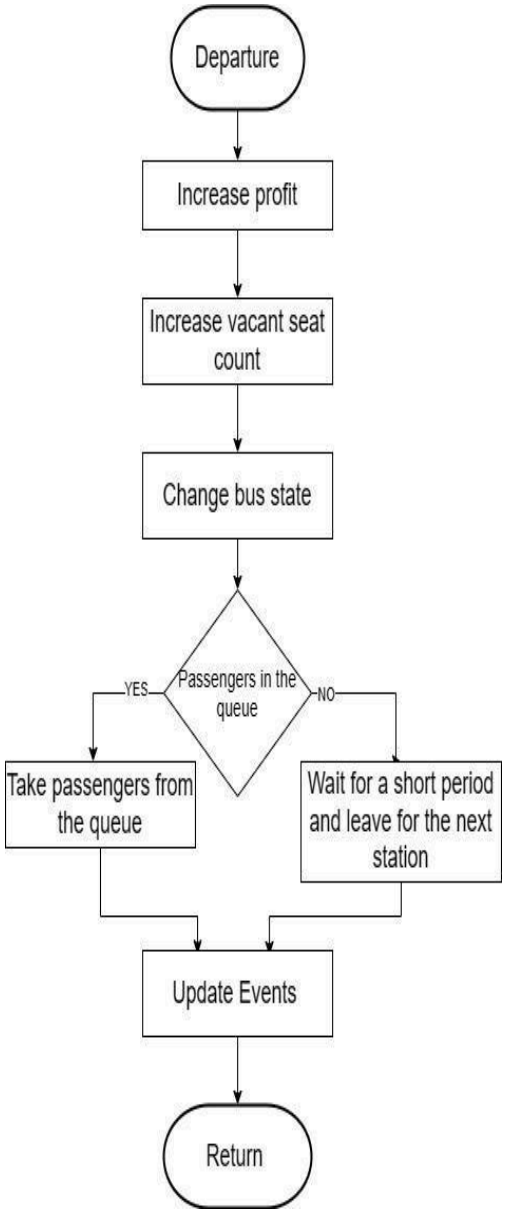
1) **Arrival Event:** Flow-chart for Arrival Event:



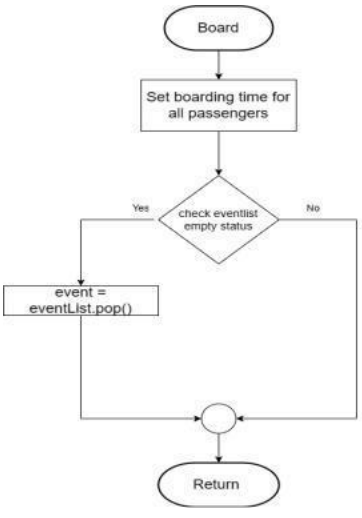
2) **Start Trip Event**: Flow-chart for Start Trip Event:



3) **Departure Event**: Flow-chart for Departure Event:



4)Utility function for adding a Passenger to a CNG:



III. Simulation Program Description

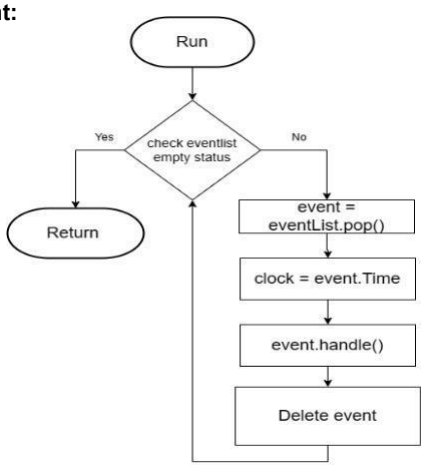
The program consists of five major classes: Simulator, Event, Terminal, Bus, and Passenger. Among these, Terminal, Bus, and Passenger can be defined as System classes. Minor classes include a FIFO Queue, a min Heap, and a static class for generating random numbers and variates.

The Event class is abstract. Its child classes represent the Arrival, Start Trip, and Departure events. Each of those classes has a handler function that manipulates the state of the three system classes.

The system classes consist of the system variables and containers, and the statistical variables. Handling an event involves updating the statistical variables and creating changes to the system variables.

Finally, we have the Simulator class which mainly comprises the event list and system clock. The event list is a min heap where the upcoming events are stored. The Simulator has a **run function** that pops an event from the event list and handles it. In every occurrence of a new event, the clock is updated.

5)**Run event:**



IV. Result

The simulation was run for 10 days and the data is stored in trace files. A Origin Pro script was used to perform statistical calculations on the raw data and get the results.

A	B	C	D	E	F
ID	Policy	Passenger Count	Trip Count	Profit	Fuel Efficiency
1	1	258	67	2175	0.192537
2	2	231	45	2044	0.256667
3	3	167	25	1518	0.334
4	4	141	19	1296	0.371053
5	5	107	16	973	0.334375
6	6	112	15	1029	0.373333
7	7	114	11	1075	0.518182
8	8	144	15	1352	0.48
9	9	110	11	1034	0.5
10	10	110	11	1033	0.5
11	11	97	8	921	0.60625
12	12	98	8	931	0.6125
13	13	52	4	495	0.65
14	14	90	6	864	0.75
15	15	90	6	864	0.75
16	16	100	6	964	0.833333
17	17	68	4	655	0.85
18	18	72	4	696	0.9
19	19	76	4	736	0.95
20	20	80	4	776	1

Fig: Statistics for different threshold for 0.1 interval wait policy

ID	BUS ID	Source	Destination	Arrival Time	Boarding Time	Trip Start Time	Departure Time	Queue Delay	Halting Delay	Road Delay	Waiting Time	Total Delay
6	3	Mogbazar	Mohakhali	1.7198	1.7198	5.45402	5.76084	0	3.73422	0.306822	3.73422	4.04104
13	3	Mogbazar	Mohakhali	4.06477	4.06477	5.45402	5.76084	0	1.38924	0.306822	1.38924	1.69607
18	3	Mogbazar	Mohakhali	5.35402	5.35402	5.45402	5.76084	0	0.1	0.306822	0.1	0.406822
25	1	Mogbazar	Mohakhali	8.09958	8.09958	8.19958	8.90448	0	0.1	0.704902	0.1	0.804902
11	2	Mogbazar	Mohakhali	3.79762	3.79762	12.2674	12.8737	0	8.46977	0.606279	8.46977	9.07605
36	2	Mogbazar	Mohakhali	12.1674	12.1674	12.2674	12.8737	0	0.1	0.606279	0.1	0.706279
5	4	Mogbazar	Mohakhali	1.30417	1.30417	11.6193	13.2176	0	10.3151	1.5983	10.3151	11.9134
10	4	Mogbazar	Mohakhali	3.5379	3.5379	11.6193	13.2176	0	8.08137	1.5983	8.08137	9.67967
23	4	Mogbazar	Mohakhali	7.98556	7.98556	11.6193	13.2176	0	3.63372	1.5983	3.63372	5.23202
32	4	Mogbazar	Mohakhali	11.5193	11.5193	11.6193	13.2176	0	0.1	1.5983	0.1	1.6983
14	6	Mogbazar	Mohakhali	4.48611	4.48611	12.9817	14.7401	0	8.49558	1.75846	8.49558	10.254
26	6	Mogbazar	Mohakhali	9.33454	9.33454	12.9817	14.7401	0	3.64715	1.75846	3.64715	5.40561
31	6	Mogbazar	Mohakhali	11.0498	11.0498	12.9817	14.7401	0	1.93184	1.75846	1.93184	3.69031
35	6	Mogbazar	Mohakhali	11.8836	11.8836	12.9817	14.7401	0	1.09805	1.75846	1.09805	2.85651
37	6	Mogbazar	Mohakhali	12.6821	12.6821	12.9817	14.7401	0	0.299561	1.75846	0.299561	2.05803
38	6	Mogbazar	Mohakhali	12.8817	12.8817	12.9817	14.7401	0	0.1	1.75846	0.1	1.85846
54	1	Mohakhali	Mogbazar	17.9766	17.9766	18.0766	18.3573	0	0.1	0.280692	0.1	0.380692
28	5	Mogbazar	Mohakhali	10.1881	10.1881	18.3906	20.2086	0	8.20247	1.81803	8.20247	10.0205
47	5	Mogbazar	Mohakhali	16.4647	16.4647	18.3906	20.2086	0	1.92592	1.81803	1.92592	3.74395
50	5	Mogbazar	Mohakhali	17.0699	17.0699	18.3906	20.2086	0	1.32068	1.81803	1.32068	3.13871
53	5	Mogbazar	Mohakhali	17.7828	17.7828	18.3906	20.2086	0	0.607819	1.81803	0.607819	2.42585
55	5	Mogbazar	Mohakhali	18.2906	18.2906	18.3906	20.2086	0	0.1	1.81803	0.1	1.91803
3	7	Mogbazar	Mohakhali	0.521556	0.521556	21.1329	22.0792	0	20.6113	0.94636	20.6113	21.5577
9	7	Mogbazar	Mohakhali	2.84045	2.84045	21.1329	22.0792	0	18.2924	0.94636	18.2924	19.2388
29	7	Mogbazar	Mohakhali	10.5768	10.5768	21.1329	22.0792	0	10.5561	0.94636	10.5561	11.5025
33	7	Mogbazar	Mohakhali	11.5986	11.5986	21.1329	22.0792	0	9.53424	0.94636	9.53424	10.4806
52	7	Mogbazar	Mohakhali	17.7156	17.7156	21.1329	22.0792	0	3.41727	0.94636	3.41727	4.36363
60	7	Mogbazar	Mohakhali	19.2872	19.2872	21.1329	22.0792	0	1.84566	0.94636	1.84566	2.79202
67	7	Mogbazar	Mohakhali	21.0329	21.0329	21.1329	22.0792	0	0.1	0.94636	0.1	1.04636

Fig: Statistics of Job Average case for passengers(Wait Policy)

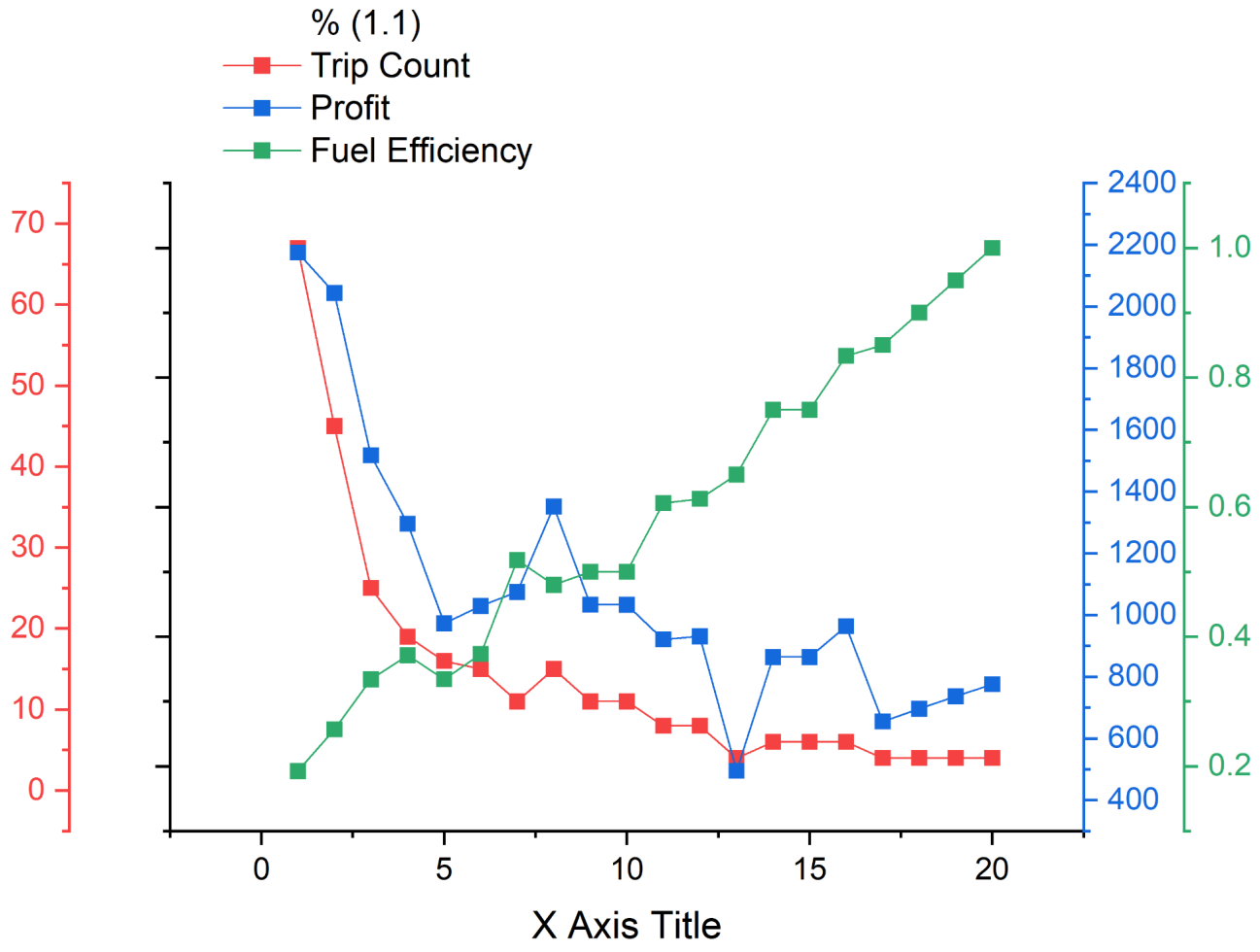


Fig: Graph for wait policy

A	B	C	D	E	F
ID	Policy	Passenger Count	Trip Count	Profit	Fuel Efficiency
1	1	333	81	2846	0.205556
2	2	236	45	2090	0.262222
3	3	148	31	1292	0.23871
4	4	154	25	1387	0.308
5	5	154	23	1399	0.334783
6	6	72	12	647	0.3
7	7	103	11	962	0.468182
8	8	96	9	907	0.533333
9	9	81	9	754	0.45
10	10	90	9	846	0.5
11	11	66	6	624	0.55
12	12	96	8	911	0.6
13	13	92	6	882	0.766667
14	14	56	4	536	0.7
15	15	60	4	575	0.75
16	16	68	4	656	0.85
17	17	68	4	656	0.85
18	18	36	2	348	0.9
19	19	76	4	736	0.95
20	20	80	4	776	1

Fig: Stats for bus (no wait policy)

	ID	BUS ID	Source	Destination	Arrival Time	Boarding Time	Trip Start Time	Departure Time	Queue Delay	Halting Delay	Road Delay	Waiting Time	Total Delay
2	7	1	Mogbazar	Mohakhali	2.17044	2.17044	2.17044	2.739	0	0	0.568552	0	0.568552
3	2	2	Mogbazar	Mohakhali	0.246442	0.246442	5.86719	7.25651	0	5.62075	1.38932	5.62075	7.01007
4	20	2	Mogbazar	Mohakhali	5.86719	5.86719	5.86719	7.25651	0	0	1.38932	0	1.38932
5	5	4	Mogbazar	Mohakhali	1.45844	1.45844	10.0557	12.6089	0	8.59725	2.55318	8.59725	11.1504
6	21	4	Mogbazar	Mohakhali	6.054	6.054	10.0557	12.6089	0	4.0017	2.55318	4.0017	6.55488
7	23	4	Mogbazar	Mohakhali	6.79084	6.79084	10.0557	12.6089	0	3.26485	2.55318	3.26485	5.81803
8	41	4	Mogbazar	Mohakhali	10.0557	10.0557	10.0557	12.6089	0	0	2.55318	0	2.55318
9	12	8	Mogbazar	Mohakhali	3.24115	3.24115	14.784	15.1345	0	11.5429	0.350445	11.5429	11.8933
10	22	8	Mogbazar	Mohakhali	6.76385	6.76385	14.784	15.1345	0	8.02019	0.350445	8.02019	8.37064
11	28	8	Mogbazar	Mohakhali	7.98104	7.98104	14.784	15.1345	0	6.803	0.350445	6.803	7.15345
12	30	8	Mogbazar	Mohakhali	8.18841	8.18841	14.784	15.1345	0	6.59563	0.350445	6.59563	6.94607
13	36	8	Mogbazar	Mohakhali	8.98062	8.98062	14.784	15.1345	0	5.80343	0.350445	5.80343	6.15387
14	44	8	Mogbazar	Mohakhali	11.5806	11.5806	14.784	15.1345	0	3.20342	0.350445	3.20342	3.55387
15	51	8	Mogbazar	Mohakhali	13.022	13.022	14.784	15.1345	0	1.762	0.350445	1.762	2.11245
16	56	8	Mogbazar	Mohakhali	14.784	14.784	14.784	15.1345	0	0	0.350445	0	0.350445
17	60	1	Mohakhali	Mogbazar	16.5002	16.5002	16.5002	16.5804	0	0	0.080185	0	0.080185
18	15	7	Mogbazar	Mohakhali	4.42701	4.42701	17.5153	17.9911	0	13.0883	0.47573	13.0883	13.564
19	18	7	Mogbazar	Mohakhali	5.62071	5.62071	17.5153	17.9911	0	11.8946	0.47573	11.8946	12.3703
20	29	7	Mogbazar	Mohakhali	8.10662	8.10662	17.5153	17.9911	0	9.4087	0.47573	9.4087	9.88443
21	35	7	Mogbazar	Mohakhali	8.79305	8.79305	17.5153	17.9911	0	8.72227	0.47573	8.72227	9.198
22	52	7	Mogbazar	Mohakhali	13.1427	13.1427	17.5153	17.9911	0	4.3726	0.47573	4.3726	4.84833
23	58	7	Mogbazar	Mohakhali	15.7759	15.7759	17.5153	17.9911	0	1.73947	0.47573	1.73947	2.2152
24	66	7	Mogbazar	Mohakhali	17.5153	17.5153	17.5153	17.9911	0	0	0.47573	0	0.47573
25	64	1	Mogbazar	Mohakhali	16.9944	16.9944	16.9944	18.1534	0	0	1.15891	0	1.15891

Fig: Stats for the passengers in no wait policy

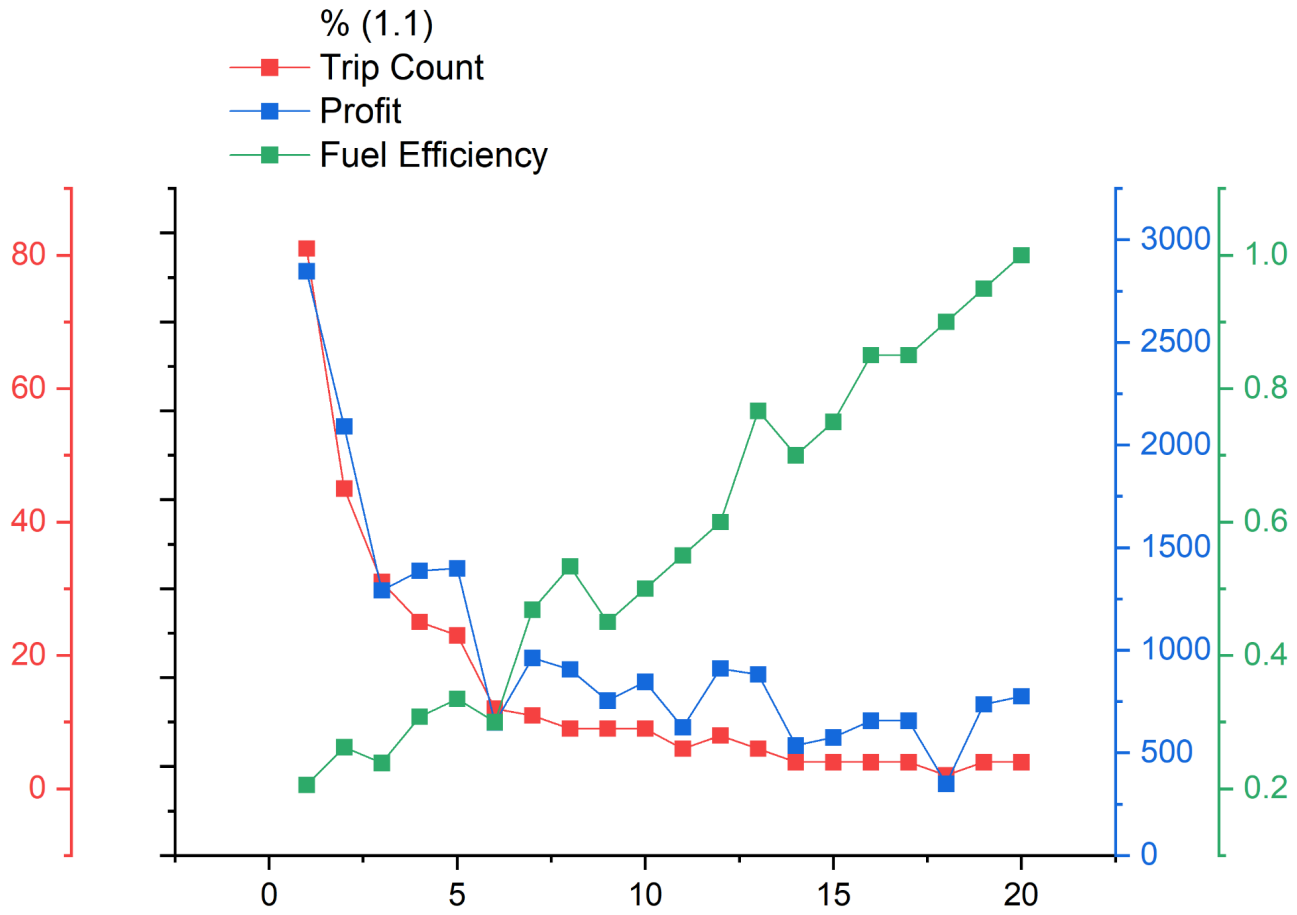


Fig: Wait less policy graph

Inference: We can see in these two graphs the comparison almost variantly differs as there is no wait.

Waitless : Higher Passenger and Trip count and Higher Profit

Waiting : Lower Passenger and Trip count and Lower Profit

Waitless : Due to less threshold low efficiency of fuel

Waiting : Due to higher threshold the efficiency is much higher this case as chance of passenger boarding is higher

V. Analysis

A. Delay

As expected, the total delay has a direct positive correlation with the threshold. From the observation, we can see that the total delay is mostly determined by the halting delay. The more passengers a Bus needs, the more it has to wait in the terminal before starting a trip. So, in terms of delay, the best policy is Policy 1.

B. Profit

As stated before, in every policy, the Bus driver faces a trade-off between time and fuel. From the observation, we can see that as the threshold value increases, the number of trips per day increases but the passenger count also increases. The difference between the mean number of trips for Policy 1 (67 trips) is huge compared to that for Policy 5 (16 trips). The difference in average passenger count is not that high (129 vs. 107) because the Buses following Policy 5 carry more passengers in a single trip. Because of this, as the threshold value increases, the fuel efficiency increases almost linearly. However, it is not completely linear because even after a CNG gets its threshold number of passengers, it waits a few more seconds to pick more passengers.

The optimal policy for the highest profit turns out to be Policy 3. However, the high variances in the data and low differences in the mean values indicate a small confidence level.

VI. Conclusion

By running the simulation, we can conclude that the policy of 'minimum 20 passengers per trip' which the Bus drivers follow at the moment not only wastes the passengers' valuable time but also is not optimal for gaining profit. The 'minimum 3 passengers per trip' is an optimal policy for both passengers and Bus drivers.