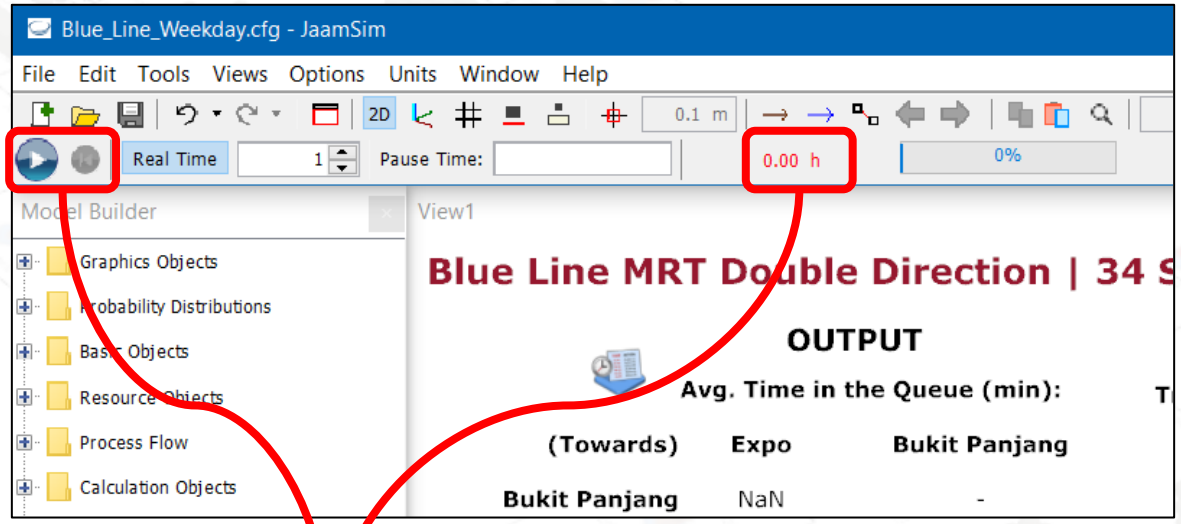
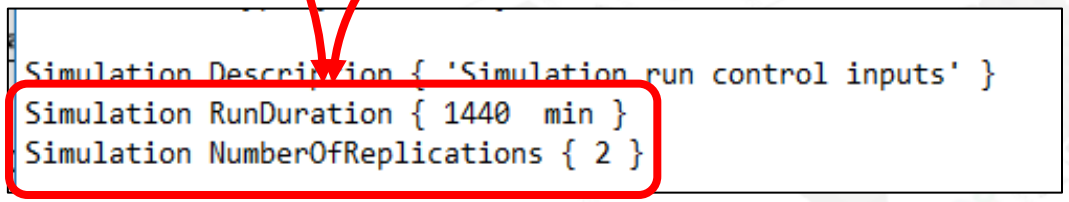
Simulation Run (RECAP)





- We declared the following attributes for the Simulation Object in the cfg file of the models.
- Each model cycle has a SimTime duration of 24 hours, while the train operations are from SimTime: 05 h to 24 h.
- In addition, the number of replications is currently set to 2. Hence after pressing the “Run” button, the simulation will run once first and then reset automatically and run again for a second time.
- For this **Output Analysis** we will be increasing the number of repetitions to 100 to provide a better overall estimate after averaging.

Common Random Number

- To reduce the variance in our results such that any observed differences between models (if any) is due to the different configurations and not random conditions.
  - JaamSim uses the same default GlobalSubstreamSeed in the Simulation Parameters since the GlobalSubstreamSeed is not specified.
  - Hence this uses the same Global Seed for the different .cfg models.

```
Simulation Description { 'Simulation run control inputs' }
Simulation RunDuration { 1440  min }
Simulation NumberOfReplications { 2 }
```

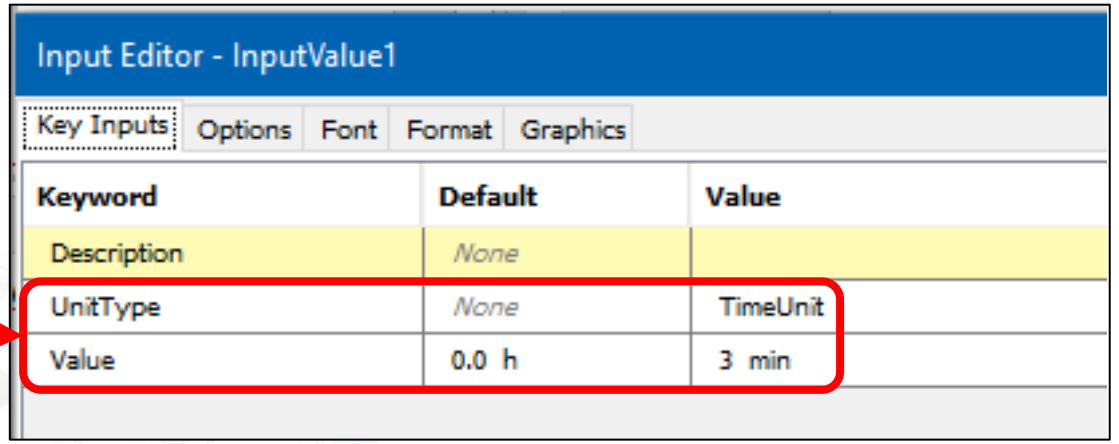
Input Parameters (RECAP)

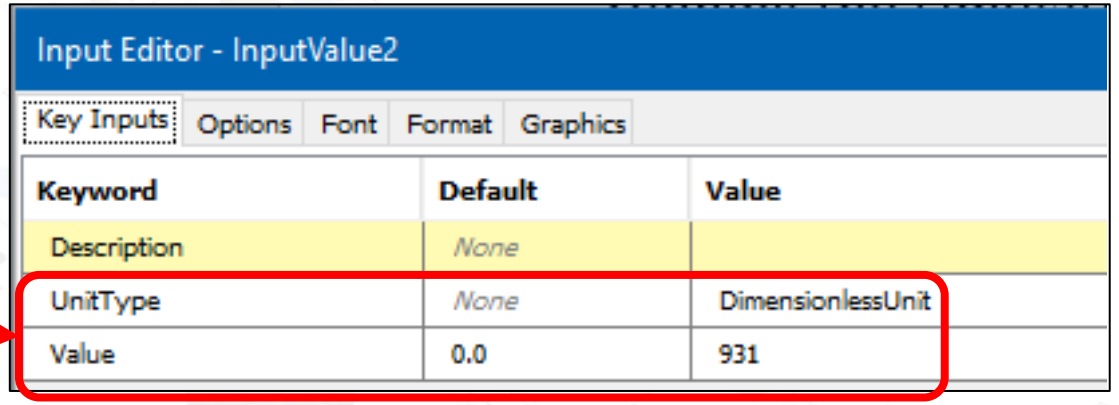
INPUT PARAMETERS

Train-InterArrival Time: 3 min

Train Capacity: 931

- The Train Interarrival time are parameters that are adjustable by the user before running the simulation using “InputValue”.
- Similar for Train Capacity which is set to the current maximum capacity of a medium-capacity MRT line.

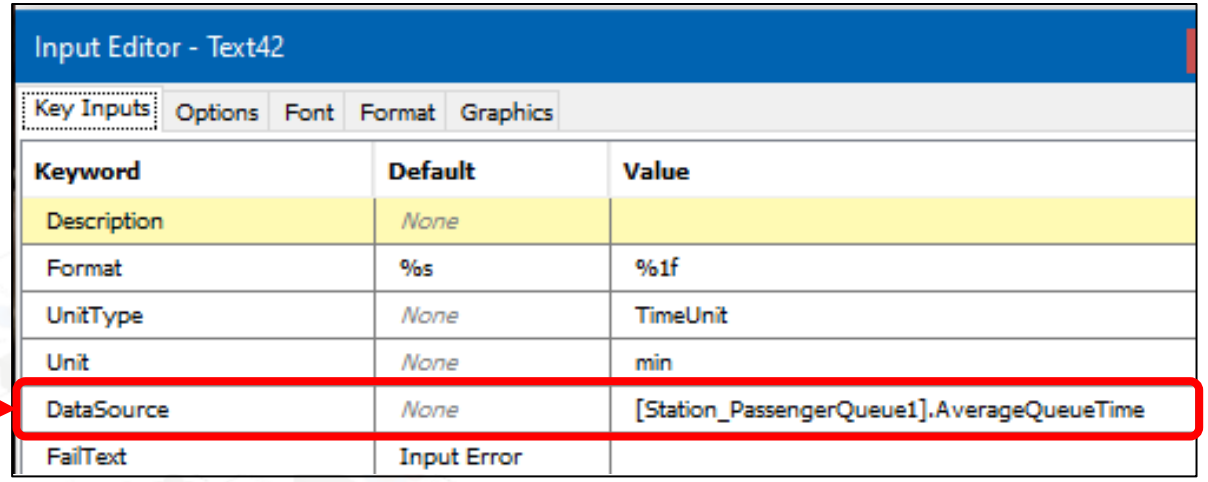




Output Table

Avg. Time in the Queue (min):

(Towards)	Expo	Bukit Panjang
Bukit Panjang	1.498612	-
Cashew	1.502106	2.167535
Hillview	1.501485	2.150831
Beauty World	1.506873	2.093071
King Albert Park	1.511002	2.054620
Sixth Avenue	1.519481	2.014089
Tan Kah Kee	1.526159	1.962044



- The average times in minutes a passenger stays in the queue for every station in the direction specified.

Output Analysis 1

Control run:

- Using parameters obtained from collected data (04 Data Collection and Manipulation).
- 2 Runs: Weekdays and Weekends (**Note** each run simulates the time for 1 actual day).
- In order to get better estimates for the results, each simulation will be repeated 100 times before averaging.

We want to simulate and visualize:

What happens to average time spent in passenger queue if safe-distancing measures are enforced in MRT trains;

- Intuitively, the average time should not change if the MRT capacity is still sufficient.
- This is done by running the simulations (also 100 repetitions and averaged) and with a lower train capacity (half), and then analyzing the average waiting time of each station against the control run.

Output Analysis 2

Control run:

Same control run results used.

We want to simulate and visualize:

How does decreasing the interarrival times of trains leaving the depot help to decrease the average waiting time in the queues?

- This is done by running the simulations (similarly 100 repetitions and averaged) with a lower train interarrival time, and then analyzing the average waiting time of each station against the control run.

Visualization - Weekday

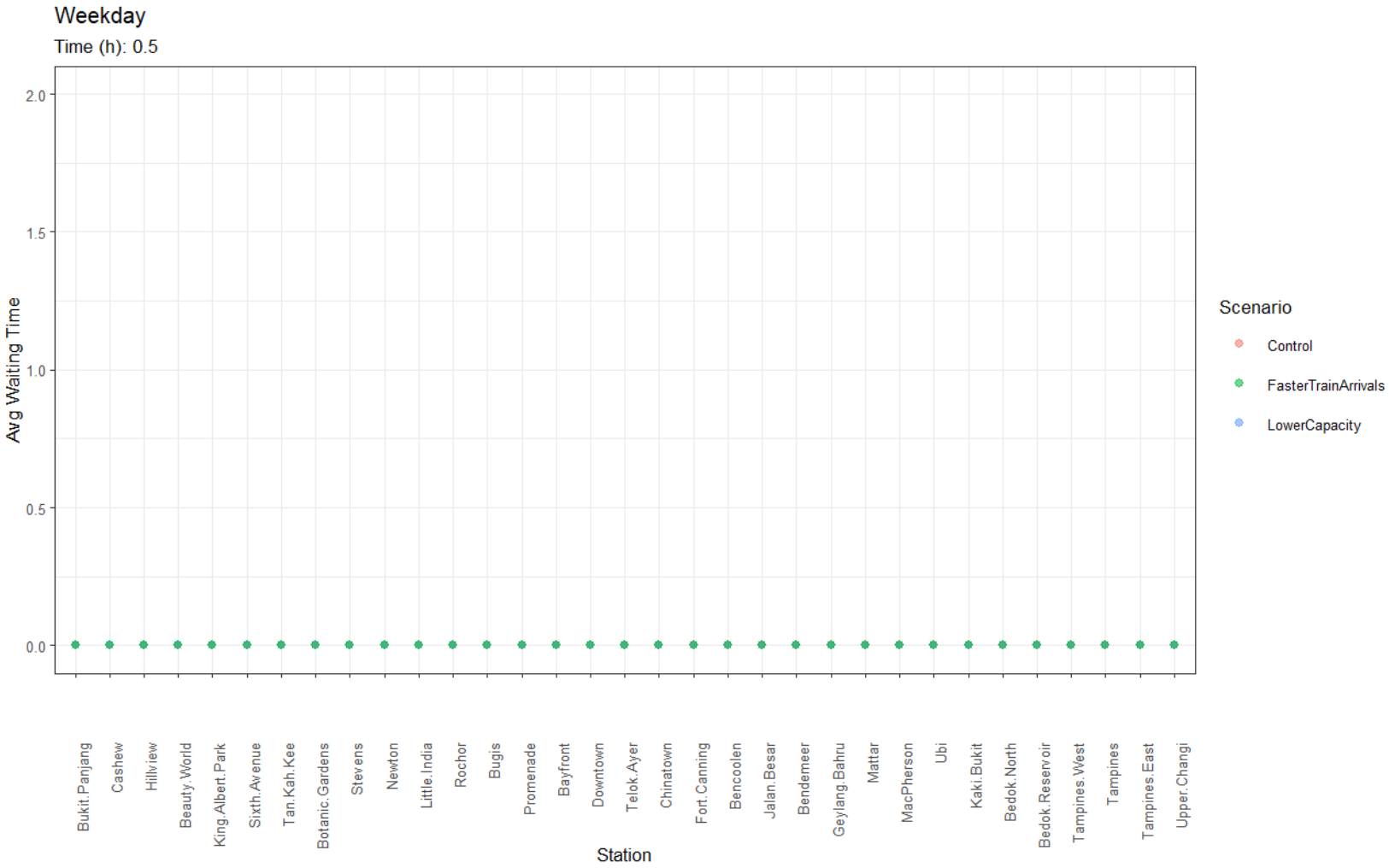
Decrease Train Capacity:

- Similar average waiting time to control.

Decrease Train Interarrival Time:

- Lower average passenger waiting times.

Note only 1 direction is being shown. To view the animation, use the link in the html page.



Visualization - Weekend

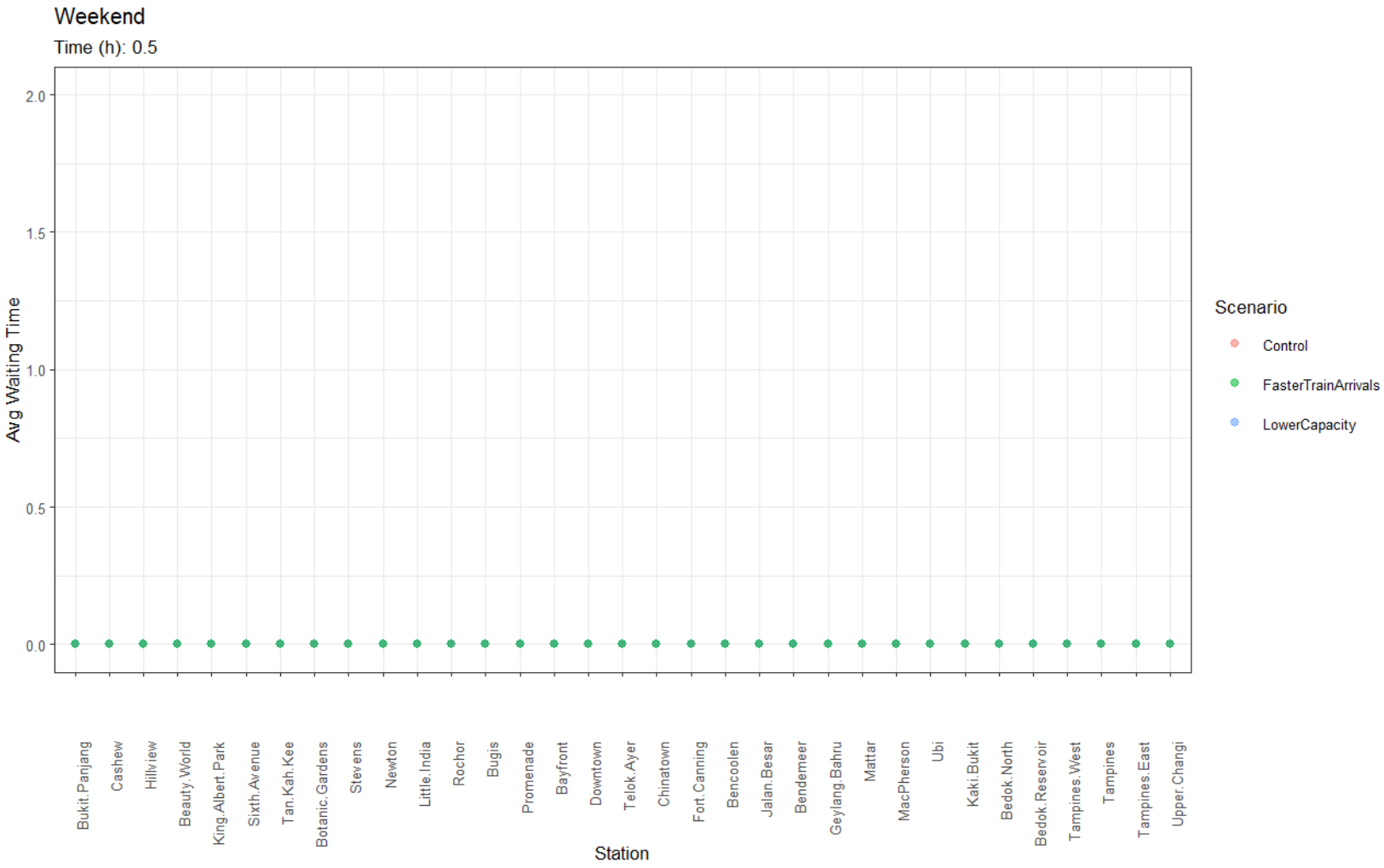
Decrease Train Capacity:

- Similar average waiting time to control.

Decrease Train Interarrival Time:

- Lower average passenger waiting times.

Note approximately similar results were observed for both weekend and weekday.



Performances of Systems

Pairwise t-tests (Control vs Alternative):

1. Control vs Lower Train Capacity (Covid Period) for Weekday;
2. Control vs Lower Train Capacity (Covid Period) for Weekend;
3. Control vs Lower Train Interarrival Timing for Weekday;
4. Control vs Lower Train Interarrival Timing for Weekend.

- Compared the expected performance measure (daily average waiting time) across 100 simulations (100 days) between the two systems for the 4 cases above.
- Identified the 95% level confidence interval of the difference **(Control Mean – Alternative Mean)**, between the expected performance of the 2 systems.

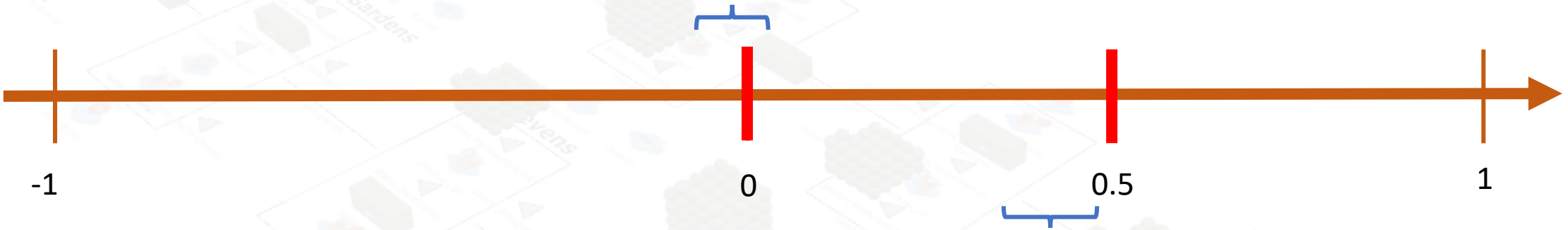
Pairwise t-test Results

Control vs Lower Train Capacity (Covid Period) for Weekday:

- 95% CI = [0,0]

Control vs Lower Train Capacity (Covid Period) for Weekend:

- 95% CI = [-0.000122246, -0.000111014]



Control vs Lower Train Interarrival Timing for Weekday:

- 95% CI = [0.4818314, 0.4821723]

Control vs Lower Train Interarrival Timing for Weekend:

- 95% CI = [0.4844047, 0.4845710]

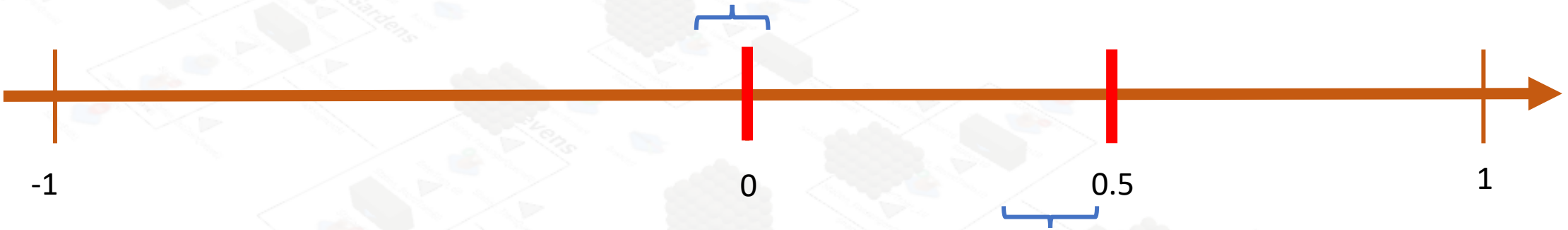
Pairwise t-test Results

Control vs Lower Train Capacity (Covid Period) for Weekday:

- No significance difference in performance

Control vs Lower Train Capacity (Covid Period) for Weekend:

- No significance difference in performance



Control vs Lower Train Interarrival Timing for Weekday:

- Alternative has better performance (lower waiting time)

Control vs Lower Train Interarrival Timing for Weekend:

- Alternative has better performance (lower waiting time)

Reflection

- In all our simulation runs, there were no occasions where passengers were unable to board the train due to full capacity. Perhaps we could reduce the proportion of passengers exiting.

- With that said, this simulation model would be useful for countries planning to build a subway system as having to test these different trains capacity and arrival frequencies in real life would be costly and unpractical.

- They could build their own system with our model and simulate what train capacity and arrival frequencies are necessary to obtain a target average passenger waiting time, given some estimate for passenger arrivals.

Model Extensions

Possible Extensions and Improvements to the Model:

- Distinct passenger interarrival rates for each station and direction given more detailed data.
- Passenger departures to follow a certain distribution instead of constant proportion.
- More complex models extending from basic model:
  - Split tracks
  - Consider passenger arrivals from other lines at connecting station.
  - Consider downtime entities in JaamSim (breakdown disruptions or signaling faults).
- All stated improvements require more data to determine the parameter values and distributions.