BICYCLE RENTAL SYSTEM IN A THEME PARK

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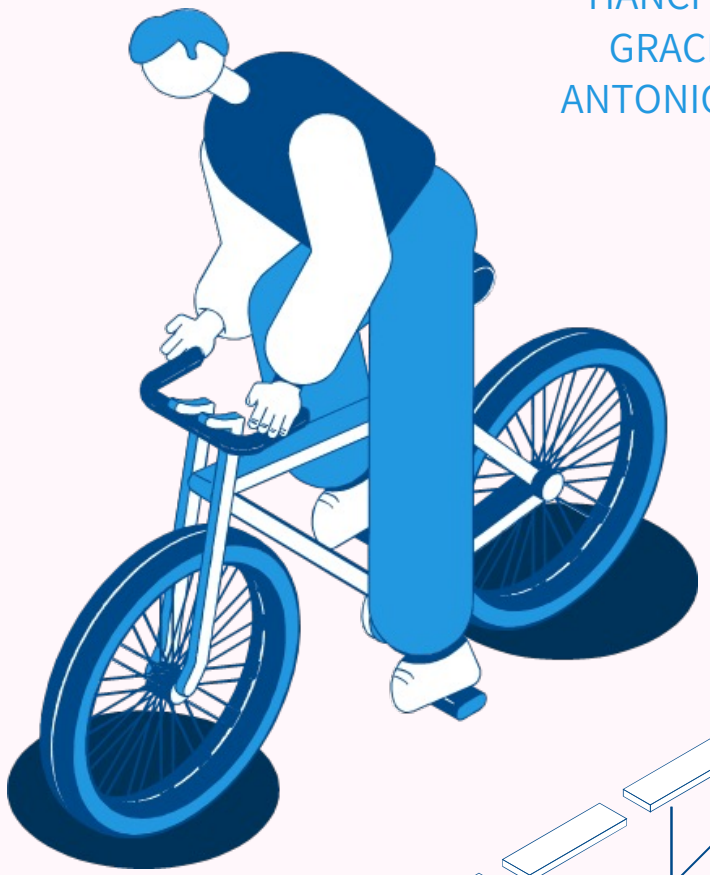
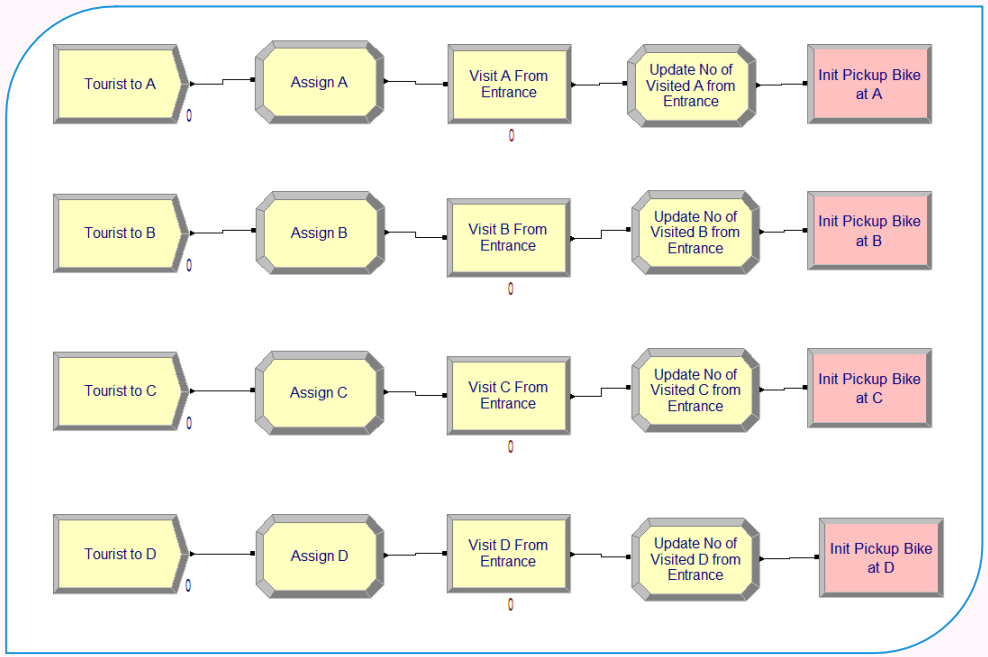


4 attractions connected by bike routes.
80 bikes, 80 docks.

- Can we bring happiness to this always-open theme park?
- How many bikes? How many docks?

Contents

Tourist Generation

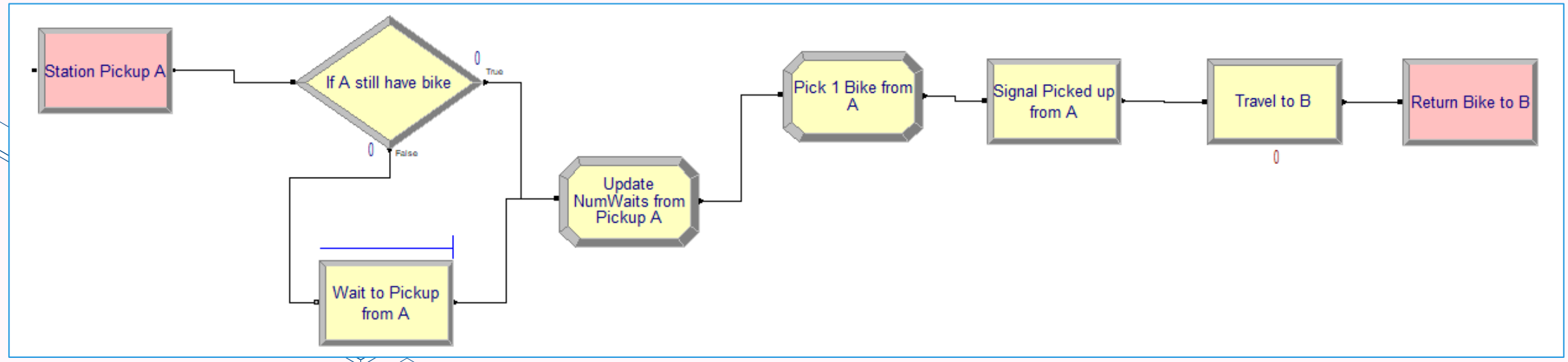


4 repetitions of:

- **Create** tourists with inter-arrival time from some distribution
- **Assign** key attributes:
  - Randomly generated Speed unchanged throughout the time at the park
  - Number of attractions to visit No2Visit
  - Number of queues entered NumWaits
- **Delay** by some time for attraction visiting
- No2Visit **decreases**
- **Transfer** to bike pick-up station

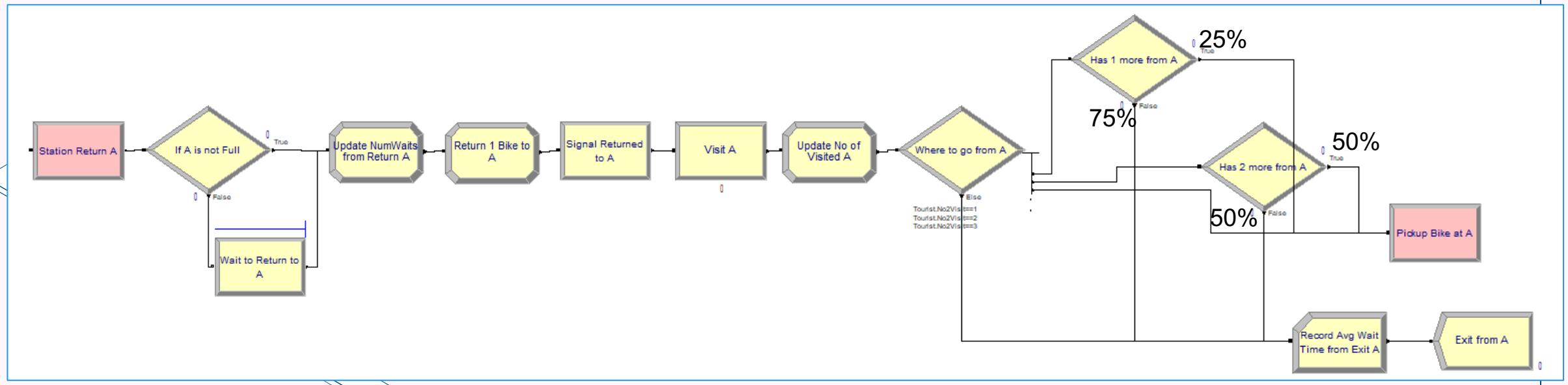
Change of Attraction:

At a bike pick-up block:
- Check for available bikes. If there are none, **Wait** in a queue until there is a **Signal**.
- NumWaits **increases** regardless.
- The number of available bikes **decreases**.
- **Send** a pick-up **Signal** to the return block.
- A **Delay** to simulate traveling to the next station.
- **Transfer** to a bike return block.



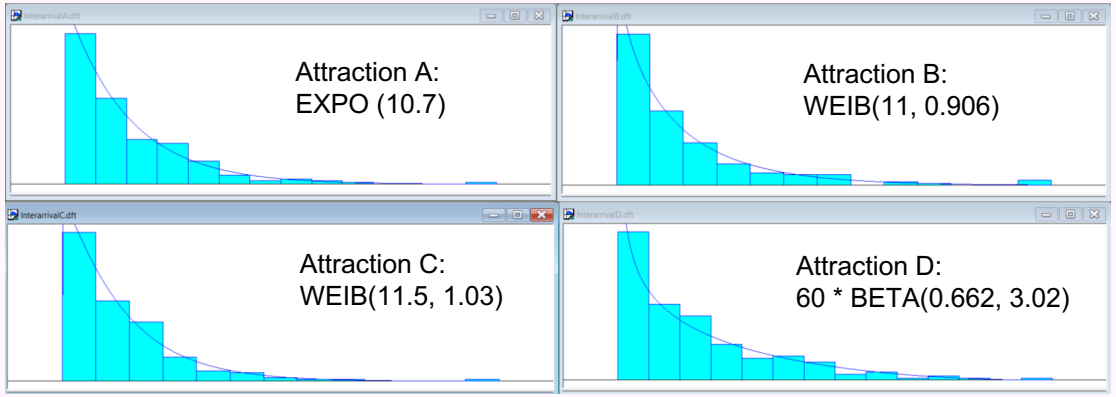
Change of Attraction:

At a bike return block:
- Check for available docks. If there are none, **Wait** in a queue until there is a **Signal**.
- **Assign** an increment to NumWaits regardless.
- The number of available docks **decreases**.
- **Send** a return **Signal** to the pick-up block.
- A **Delay** to simulate visiting the attraction.
- **Assign** decremented value to No2Visit.
- **Select** where to go based on No2Visit.
- If a tourist leaves, their necessary data is **Recorded**.

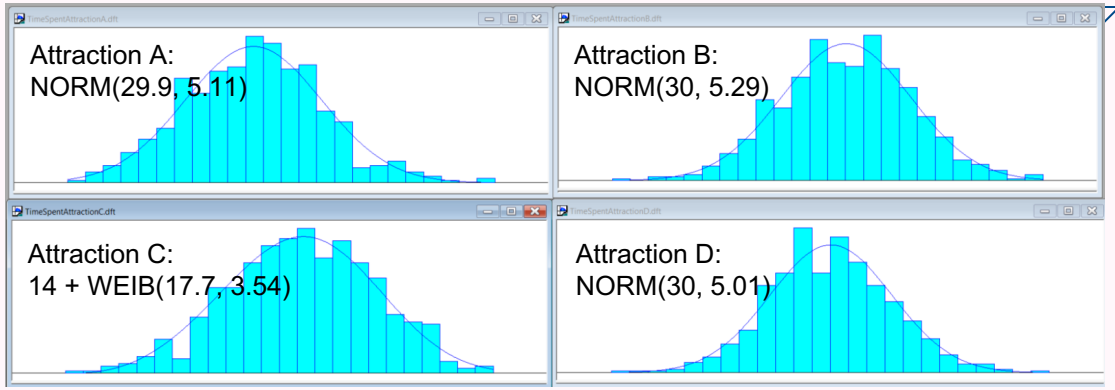


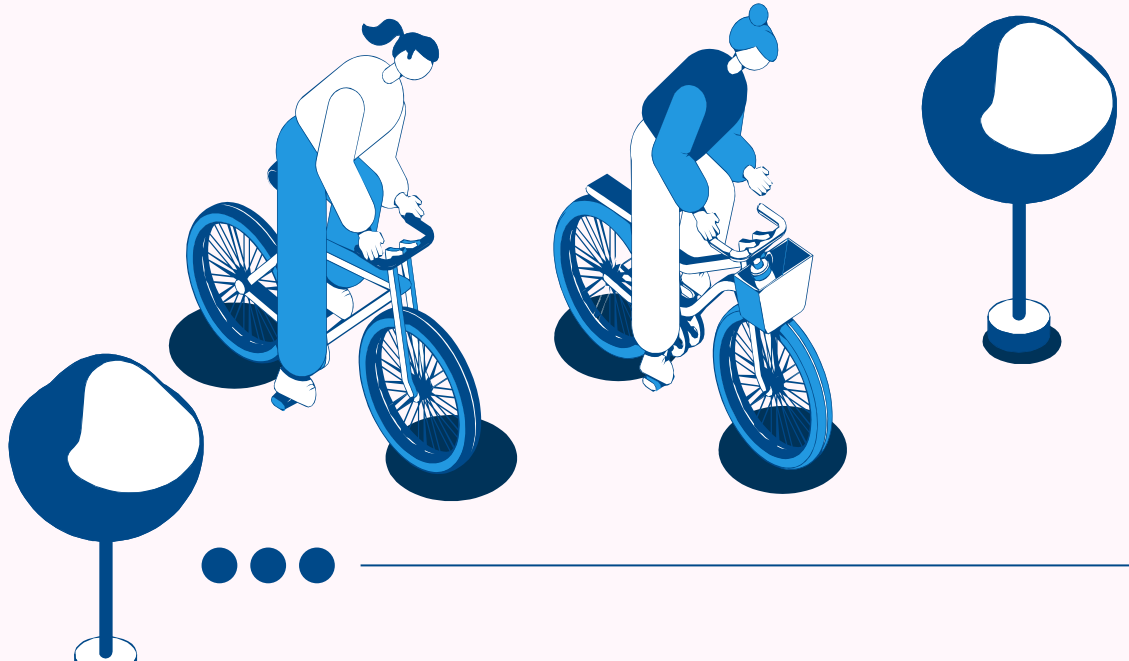
Input Analysis

Interarrival Times

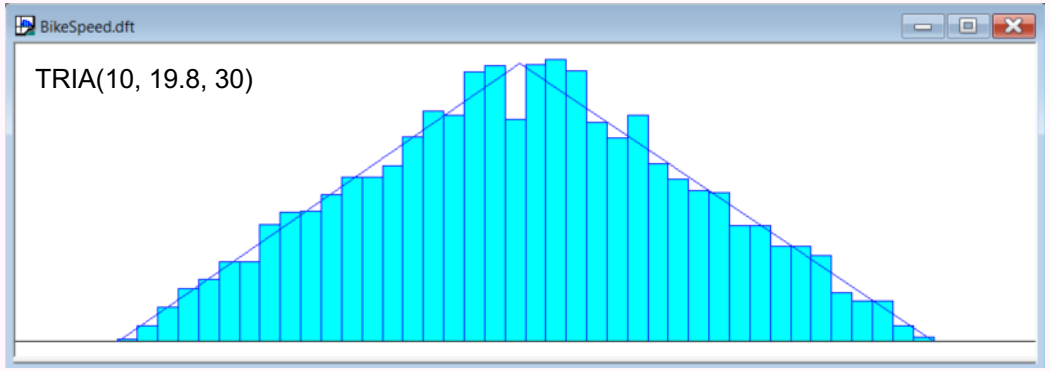


Time Spent in Attractions





Bikes Speed



Verification and Validation

Verification:

- Visual inspection and code review
- Varying inputs can affect outputs as expected

Configurations (Right)	Baseline	Reduce Interarrival Times
Performance Metrics (Bottom)	Interarrival Time @ Attraction A **EXPO(10.7)**	Interarrival Time @ Attraction A **EXPO(8.2)**
Average Total WaitTime	190.57 mins	569.57 mins
Average Avg WaitTime	58.73 mins	181.45 mins

Validation:

- Run tests to ensure it produced expected outputs.
  Example: {constant times, 2 attractions} -- outcomes can be calculated manually
- Compare the model's data (arrivals, speeds, etc.) to historical data

Output Analysis
Warm-up period estimation

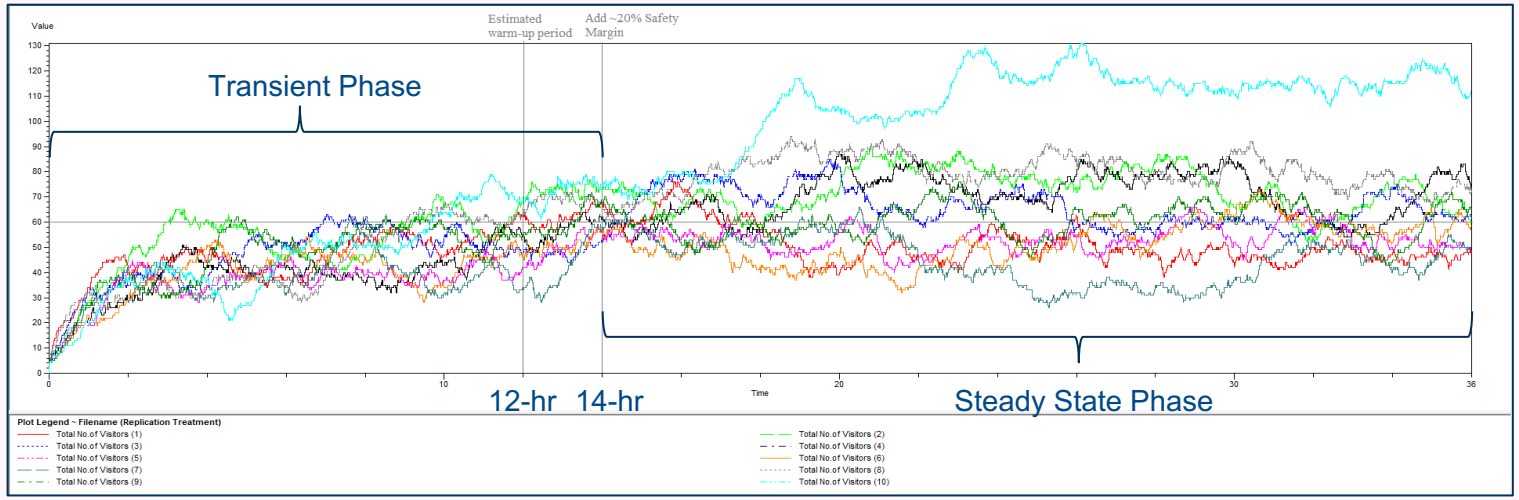
- To estimate warm-up period, the run setup parameters is initialized as follows:

No. of Replications	Replication Length	Warm-up Period	Hours per Day
10	36 hours	0 hours	24

- The total no. of tourists output is generated using the 'Statistics' module, with the following expression:

$$Total\ No.of\ Visitors = EntitiesWIP(Tourist)$$

- Using output analyzer, the no. of visitors vs. time plot is analysed:



Note: 10th replication: larger no. of tourists beyond the 16 hour mark -> excluded from the replication number estimation

Conclusion

Warm-up period = 14 hour + 20% safety margin to account for point estimator bias = **16 hour**

Output Analysis
Replication Number Estimation

Initial Estimation

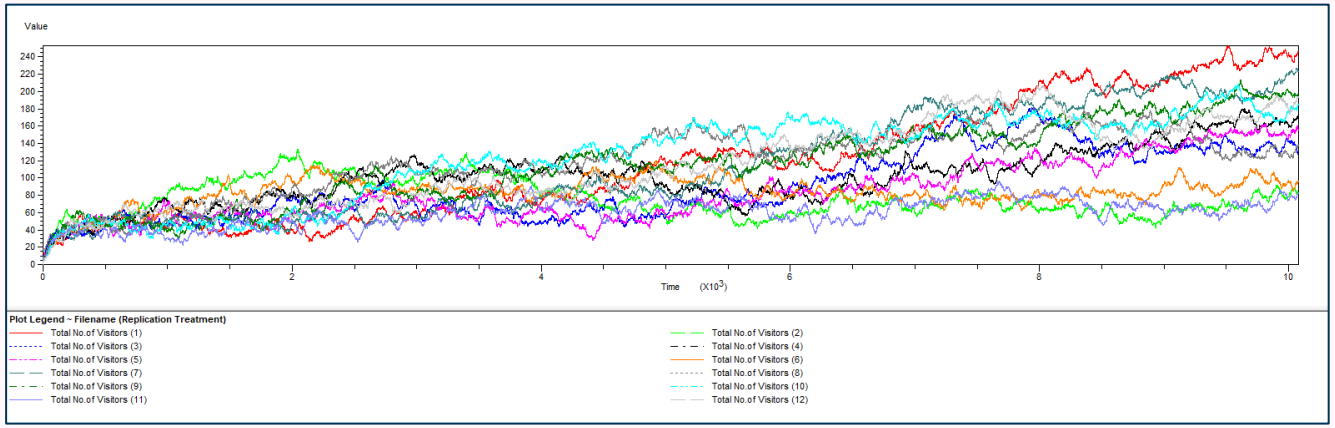
- Point estimator: Average total time spent by visitors
- Assumption: tolerance of +- 5 minutes i.e. $\varepsilon = 5$, and 90% confidence interval.
- An initial sample of size $R_0 = 10$ is collected and by omitting the 10th replication (outlier), the population variance estimated is $S_0 = 9.7$ minutes, therefore:

$$R \geq \left(\frac{Z_{\frac{\alpha}{2}} S_0}{\varepsilon}\right)^2 = \left(\frac{1.6449 \times 9.7}{5}\right)^2 = \mathbf{10.18} \quad i.e. \quad R(11,12,13 \ldots)$$

Fine tuning

Replication, R	11	12	13
$\left(\frac{t_{\frac{\alpha}{2},R-1} S_0}{\varepsilon}\right)^2$	$\left(\frac{t_{0.05,10} S_0}{\varepsilon}\right)^2 = 12.36$	$\left(\frac{t_{0.05,11} S_0}{\varepsilon}\right)^2 = 12.14$	$\left(\frac{t_{0.05,12} S_0}{\varepsilon}\right)^2 = 11.95$
Difference	12.36-11 =1.36	**12.14-12 = 0.14**	13-11.95 = 1.05

Updated No. of Visitors vs. Time Plot



Conclusion

- Final Replication Number = 12
- Final Replication Length = 7-day

Output Analysis
Is the satisfactory metrics met?

Satisfactory Metrics: Can the existing approach meet 100% tourist' waiting no longer than 1 hour?

$$Satisfactory\% = \frac{Min(Good\ TotalWait)}{Min(Good\ TotalWait) + Max(Bad\ TotalWait)}$$

Where Good TotalWait = Entity.WaitTime <= 60 minutes and Bad TotalWait = Entity.WaitTime > 60

Configurations	Baseline	Equal	Inequal	Closing the Gap	Widening the Gap	Extreme Test
Performance Metrics	Docks = 80 Bicycles = 80	Docks = 160 Bicycles = 160	Docks = 160 Bicycles = 80	Docks = 160 Bicycles = 120	Docks = 240 Bicycles = 80	Docks = 450 Bicycles = 150
Satisfactory %	34.2%	36.0%	78.5%	45.3%	83.9%	100%
Average Total Wait Time	190.57 mins	194.14 mins	19.97 mins	61.15 mins	3.01 mins	0 mins
Min Bad TotalWait	1373	1399	0	168	0	0
Max Bad TotalWait	2043	2124	674	1692	533	0
Min Good TotalWait	1063	1192	2462	1402	2786	3120
Max Good TotalWait	1846	1900	3329	3094	3329	3346

Bicycle Count Stats for Docks = 450 and Bicycles = 150 were collected:

Attraction Location	Bicycle (Average Count)	Bicycle (Min Avg Count)	Bicycle (Max Avg Count)
A	128.65	82.97	168.21
B	186.37	100.02	**238.52 (~240)**
C	154.86	87.27	229.91
D	126.26	75.07	161.08

Conclusion

- Baseline configuration **does not meet** satisfactory metrics
- To meet 100% satisfactory requirement, we need at least 240 docks + 20% safety margin = **288 docks and 150 bicycles**.
- **Not recommended:** High cost of building and more space for docks are required

Output Analysis
Is the happiness metrics met?

Happiness Metrics: Can the existing approach ensure that at least 80% tourists are happy which means the average wait time should be <= 15 minutes ?

$$Happiness\% = \frac{Min(Good\ AvgWait)}{Min(Good\ AvgWait) + Max(Bad\ AvgWait)}$$

Where Good AvgWait= (Entity.WaitTime / Tourist.NumWaits) <= 15 and (Entity.WaitTime / Tourist.NumWaits) > 15

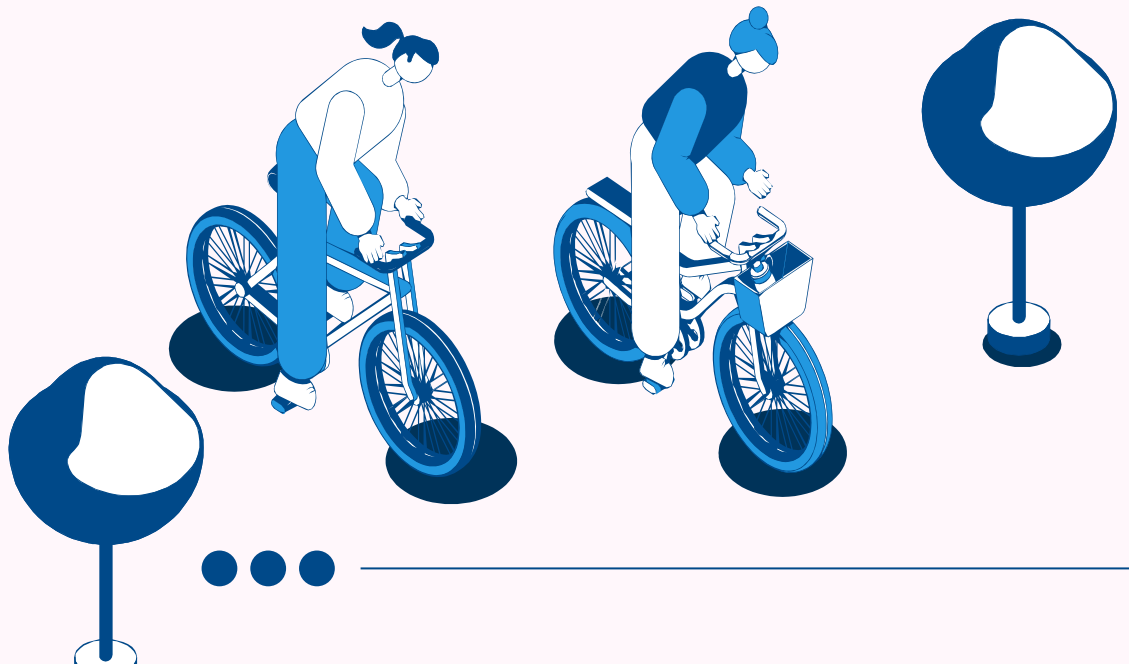
Configurations (Right)	Baseline	Previous Optimized for Inequal Configuration	Increase docks	Final Optimized
Performance Metrics (Bottom)	Docks = 80 Bicycles = 80	Docks = 160 Bicycles = 80	Docks = 180 Bicycles = 80	Docks = 175 Bicycles = 80
Happiness %	34.1%	78.1%	82.9%	80.4%
Average Avg Wait Time	58.73 mins	6.18 mins	2.36 mins	2.47 mins
Min Bad AvgWait	1399	0	0	0
Max Bad AvgWait	2046	688	560	642
Min Good AvgWait	1060	2448	2716	2640
Max Good AvgWait	1785	3329	3329	3329

Conclusion

- Baseline configuration **does not meet** happiness metrics
- To meet 80% tourists' happiness, **175 docks and 80 bicycles** is required.
- **Recommended ->** More docking areas without purchasing more bikes, more sensible investment

Conclusion & Recommendations

- The simulation is a non-terminating solution with two parts: tourist generation and change of attraction
- Best fitted input distribution identified, warm-up period and replication number estimated.
- Verification and validation completed with face validity
- The current configuration with 80 docks and 80 bicycles -> **Not feasible**
- To meet 100% satisfactory requirement: 288 docks and 150 bicycle -> **Not recommended**, high cost for building.
- To meet 80% tourists' happiness: 175 docks and 80 bicycles -> **Recommended**, requires only expanding the docking areas without purchasing more bikes



Improvement Opportunities

- To analyse confidence interval of avg total time spent and avg wait time
- Combine AI with simulation through weather forecasting/ attraction demand forecasting