TRANSIT-GYM: A Simulation and Evaluation Engine for Analysis of Bus Transit Systems

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Motivation

- Public-transit systems face several operational challenges:
  - changing ridership patterns requiring optimization of fixed line services
  - optimizing vehicle-to-trip assignments to reduce maintenance and operation codes
  - ensuring equitable and fair coverage to areas with low ridership
- Optimizing these objectives presents a hard computational problem due to the size and complexity of the decision space.
- State-of-the-art methods formulate these problems as variants of the vehicle routing problem and use data-driven heuristics for optimizing the procedures. However, the evaluation and training of these algorithms require large datasets that provide realistic coverage of various operational uncertainties.
- *TRANSIT-GYM* can bridge this gap by providing the playground for quickly designing and executing transit scenarios, focusing on variation of demand models, variations of route networks, and variations of vehicle-to-trip assignments.

Contributions

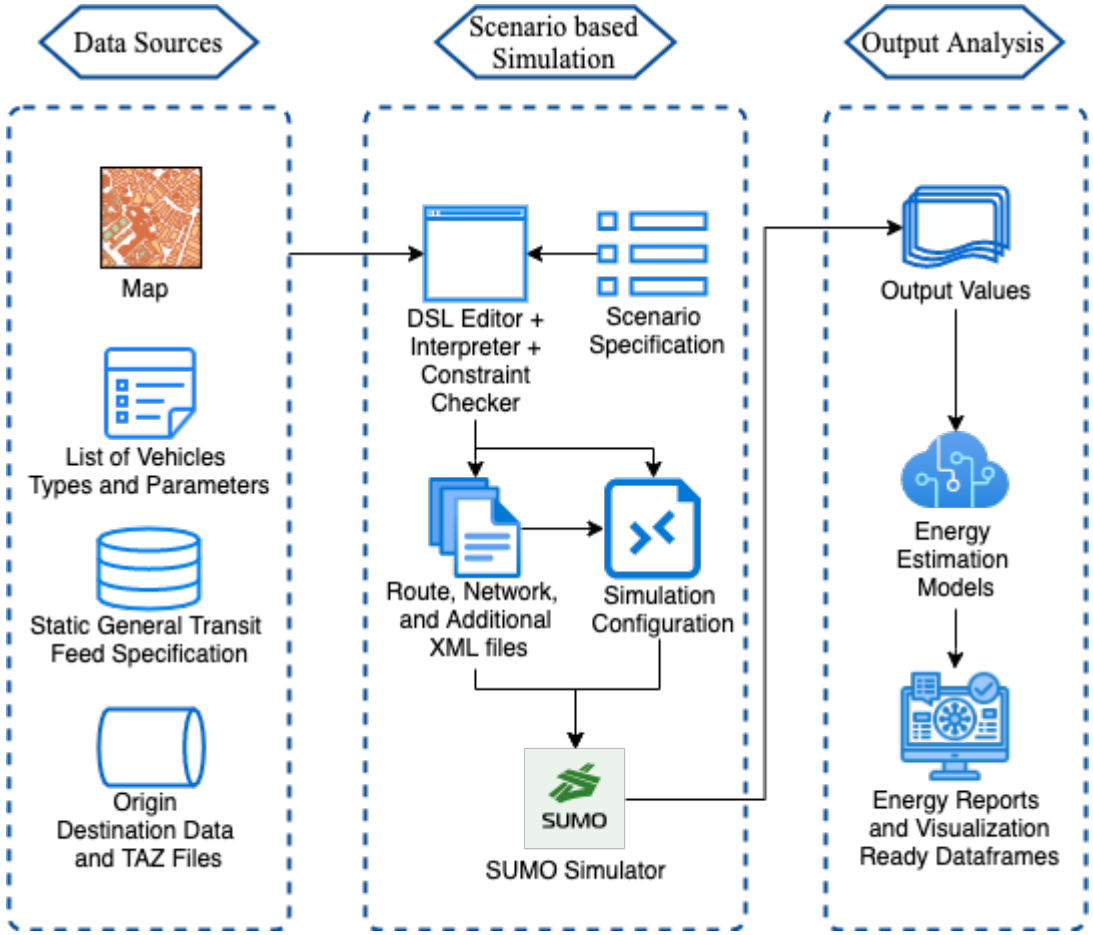
- The central contribution of this work is a domain-specific language and associated experimentation tool-chain and infrastructure to enable subject-matter experts to intuitively specify, simulate, and analyze large-scale transit scenarios and their parametric variations.
  - A novel domain-specific language that allows intuitive specification and variation of transit scenarios.
  - A methodology to construct and calibrate street maps that conform to real-world transportation infrastructure.
  - A toolchain that automatically configures simulations from the scenarios specified using the above domain-specific language.
  - A customized general-purpose simulation specifically for transit scenarios.
- An integrated microscopic energy consumption model that also helps to analyze the energy cost of various transit decisions made by the transportation agency of a city.

Background

- *Model Integrated Computing*
- *Cyber-Physical Systems Wind Tunnel*
- *SUMO*
- *Energy Estimation Models*

Methodology & Scenario construction

- *Simulation Platform Setup & Data Sources*
- *Scenario-Based Simulation*



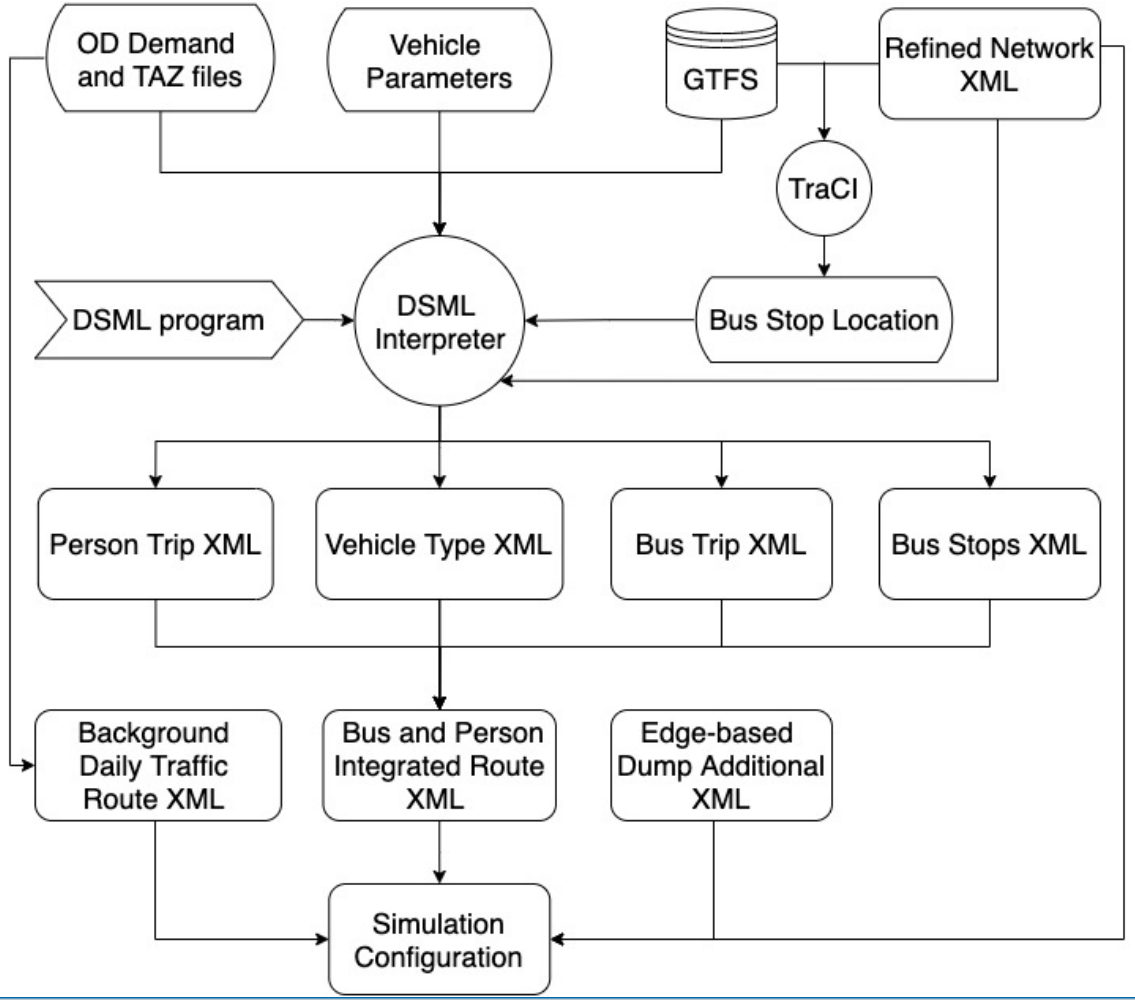
Methodology & Scenario construction

- *Scenario Construction*

```
1   import "network.Chattanooga"
2   import "vehicle.BUS_type.xlsx"
3   import "gtfs.latest"
4   import "td.OD_person.od"
5
6   simulation configuration 1 {
7           time [0000:1200]
8           schedule weekday
9           output_sampling_period 3600
10          vehicleassignment {
11                  block 101:"Gillig_103"
12          }
13  }
14
15  simulation configuration 2 {
16          time [0000:1200]
```

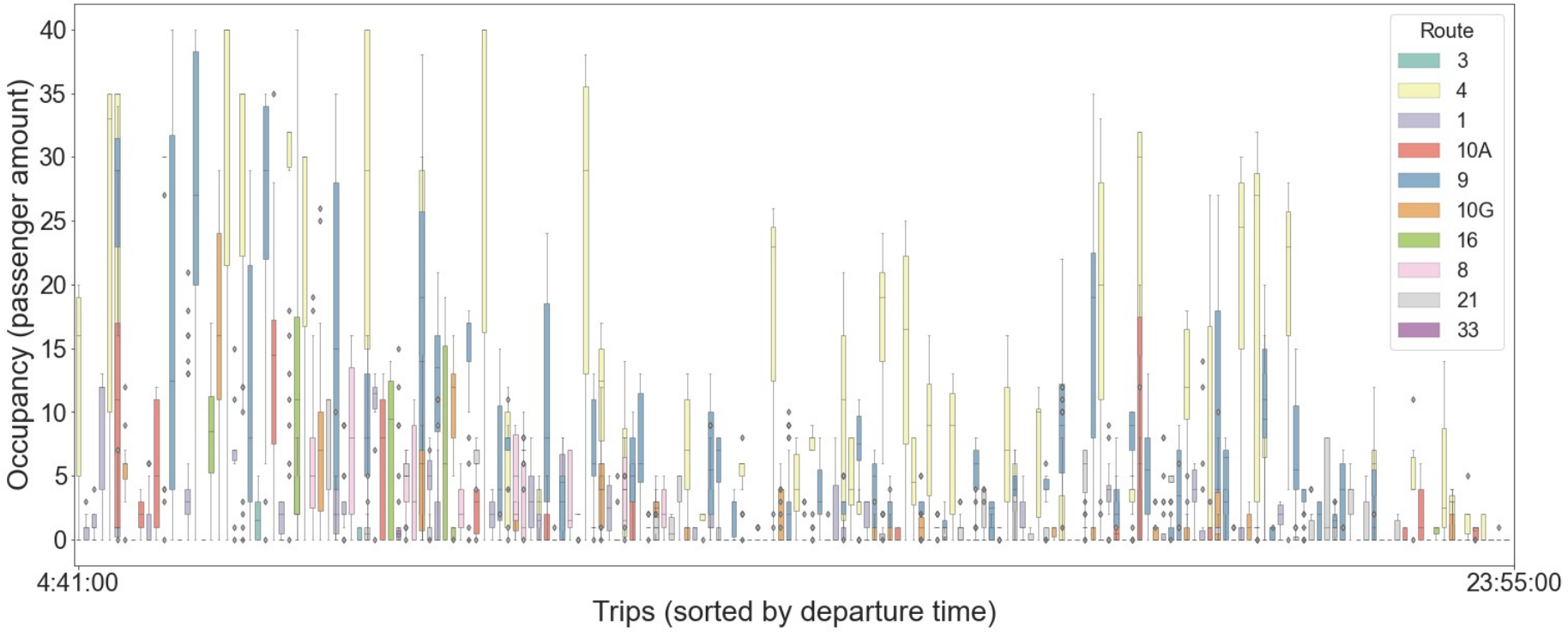
Methodology & Scenario construction

- *Workflow of the Public Transit Simulation*



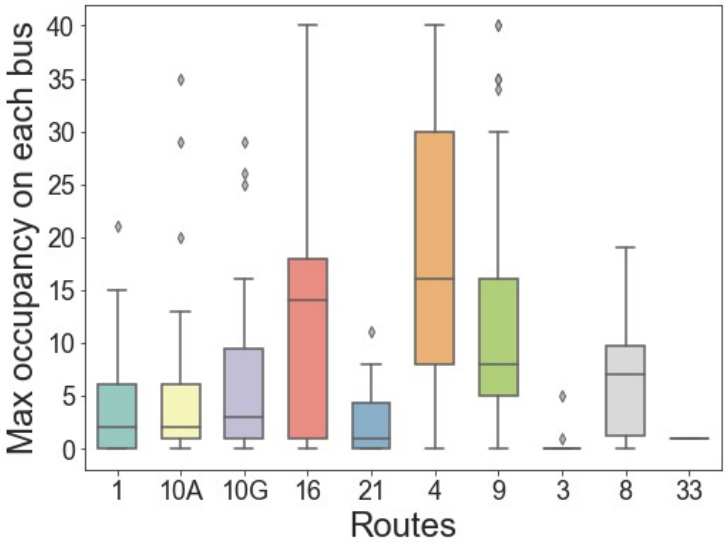
Results and discussion

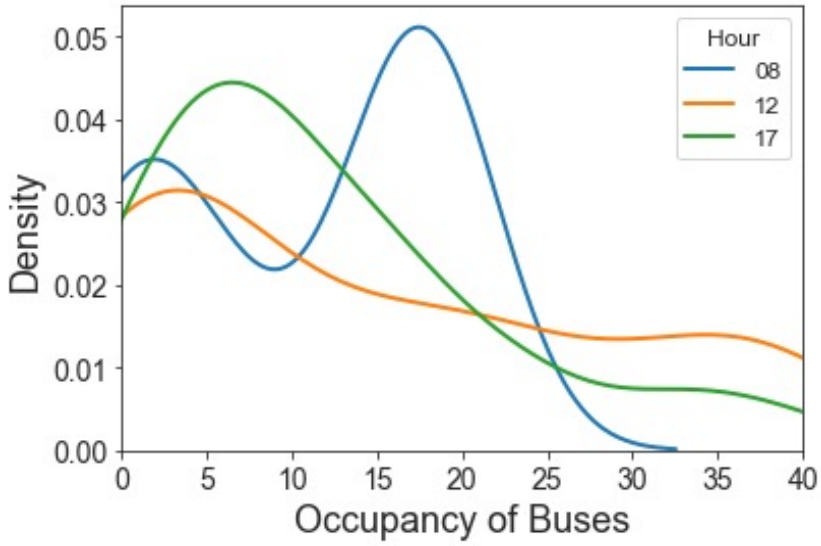
- *Simulation Output Analysis*
  - Passenger occupancy of each bus along the bus stops by trips across 24 hours



Results and discussion

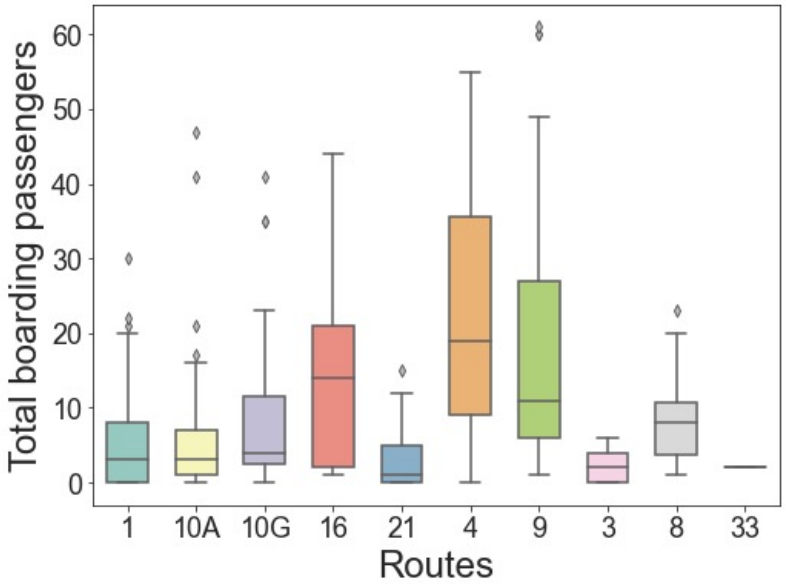
- *Simulation Output Analysis*
  - Maximum passenger occupancy of each bus along the bus stops by routes across 24 hours (left). Distributions of bus occupancy between specific hours on route 4 (right)

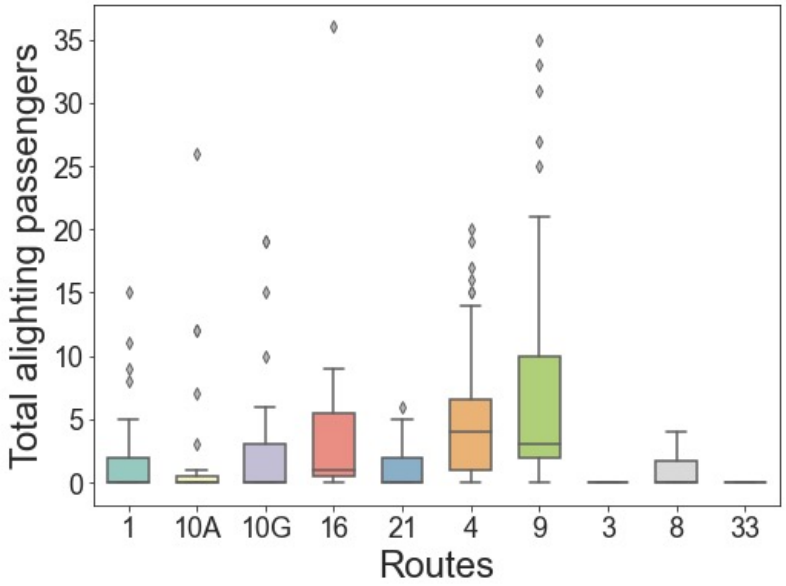




Results and discussion

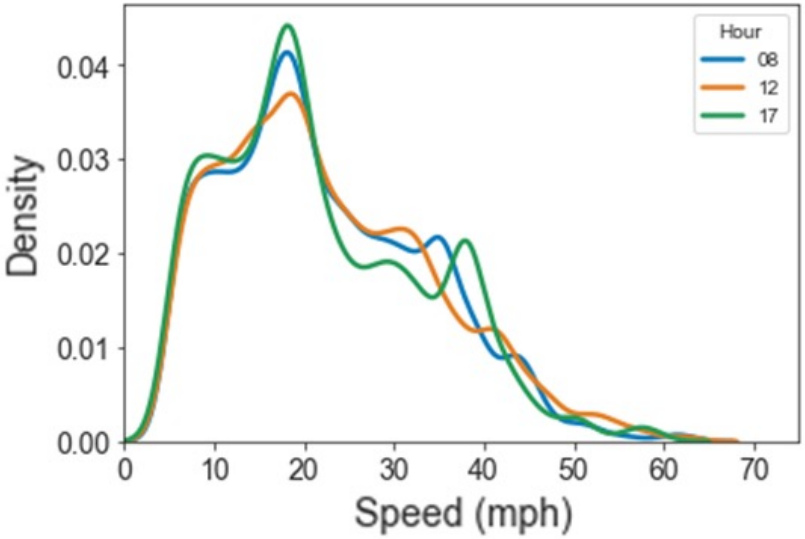
- *Simulation Output Analysis*
  - The total boarding passengers (left) and the total alighting passengers of each bus by routes across 24 hours (right)

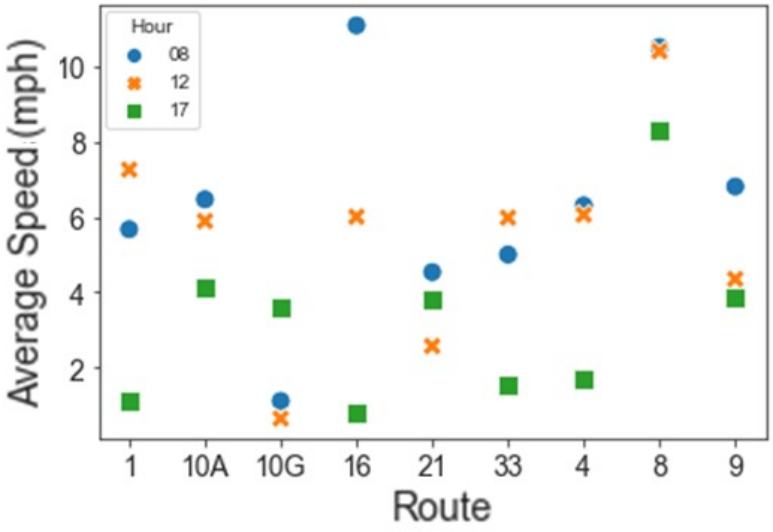




Results and discussion

- *Simulation Output Analysis*
  - Distributions of bus speed (left), average speed of buses on route 4 during three specific hours (right)





Results and discussion

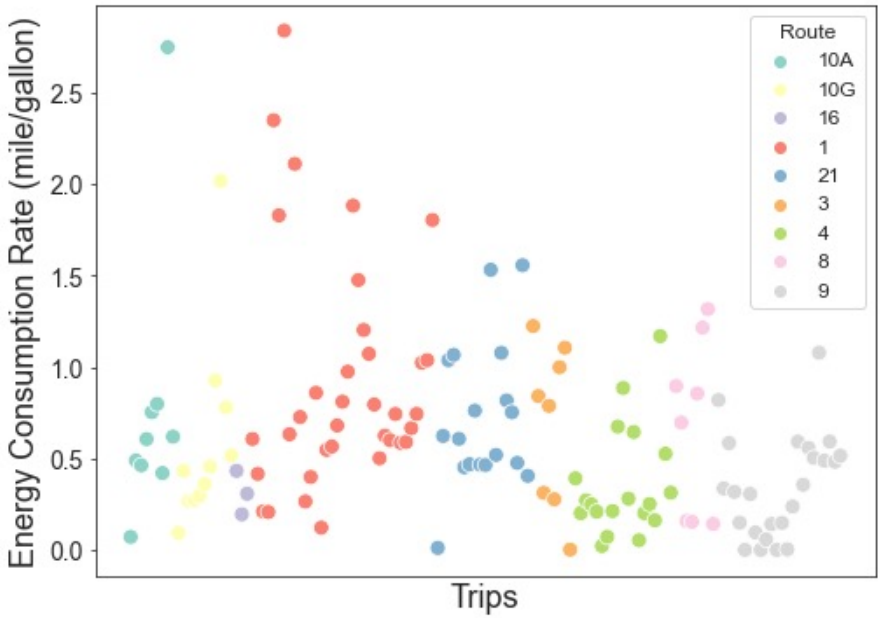
- *Scenario Analysis of Energy Consumption*

TABLE I: Estimated energy consumption rate for buses within the same period

Route No.	Trip No.	Energy consumption rate (mile/diesel equivalent gallon)					
		Original demand			Reduced demand		
		Diesel	Hybrid	Electric	Diesel	Hybrid	Electric
1	1	1.0	1.3	11.6	1.2	1.8	5.0
	2	2.7	4.3	11.7	2.8	4.7	10.7
	3	2.3	3.3	10.8	2.7	4.6	10.4
	4	1.1	1.5	8.1	1.5	2.7	6.3
3	5	1.6	2.0	14.9	1.9	2.9	9.5
	6	3.7	5.0	15.9	4.2	6.4	16.8
	7	1.2	1.5	11.4	3.3	5.5	14.6
4	8	2.0	2.8	11.4	1.4	2.0	5.0
	9	2.3	3.1	14.0	2.4	3.7	10.2
9	10	2.8	3.8	14.0	2.5	3.9	10.9
	11	2.1	3.4	9.4	2.3	3.7	8.0
10A	12	2.5	3.4	14.2	2.5	4.0	10.7
	13	2.8	4.2	12.8	3.0	4.7	10.7
10G	14	2.4	4.0	9.5	2.8	4.5	9.6
	15	0.9	1.1	8.1	2.3	3.7	8.4

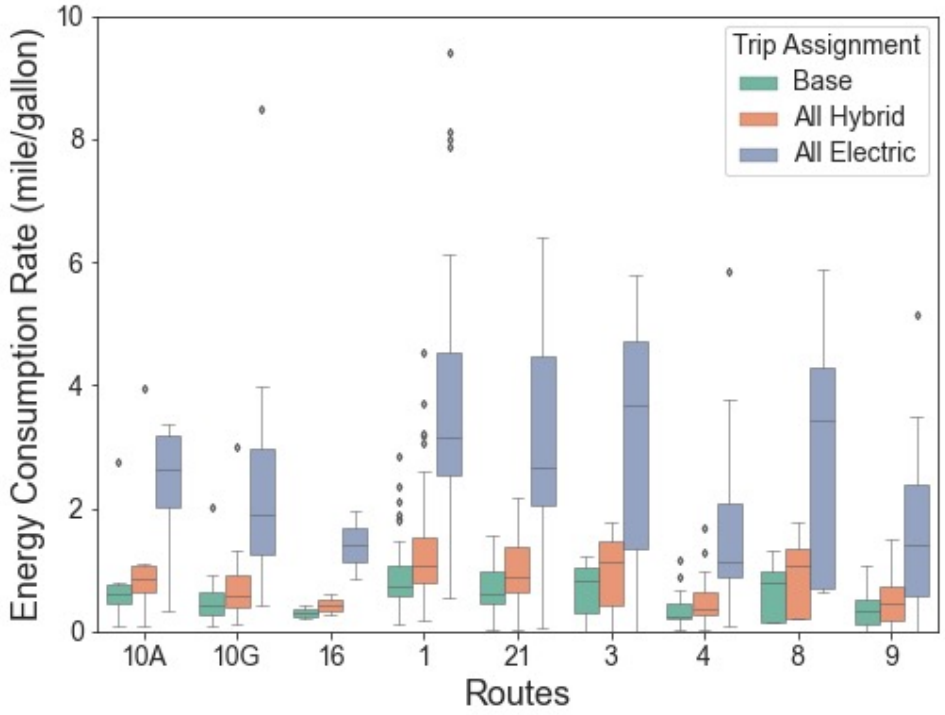
Results and discussion

- *Scenario Analysis of Energy Consumption*
  - Energy consumption rate for buses in half a day



Results and discussion

- *Scenario Analysis of Energy Consumption*
  - Energy consumption rates for buses in different trip assignment scenarios



Conclusions and future work

- *TRANSIT-GYM* is freely available on GitHub: *https://github.com/smarttransit- ai/transit-simulator*.
- Several extensions to *TRANSIT-GYM*
  - integrating transportation planning with transit simulation and energy consumption estimation together as a co-simulation using Vanderbilt's CP-SWT framework
  - developing a richer scenario modeling language to incorporate more specific transit use-cases
  - increasing performance of our simulation through partitioned traffic simulations,
  - scaling our simulations for broader cloud integration
  - incorporating certain sensitive attributes at the passengers to evaluate whether the simulation scenarios lead to equitable and fair coverage to areas with low rider-ship
  - enhancing visualization of experiment and analysis results

Acknowledgement

Thank you!