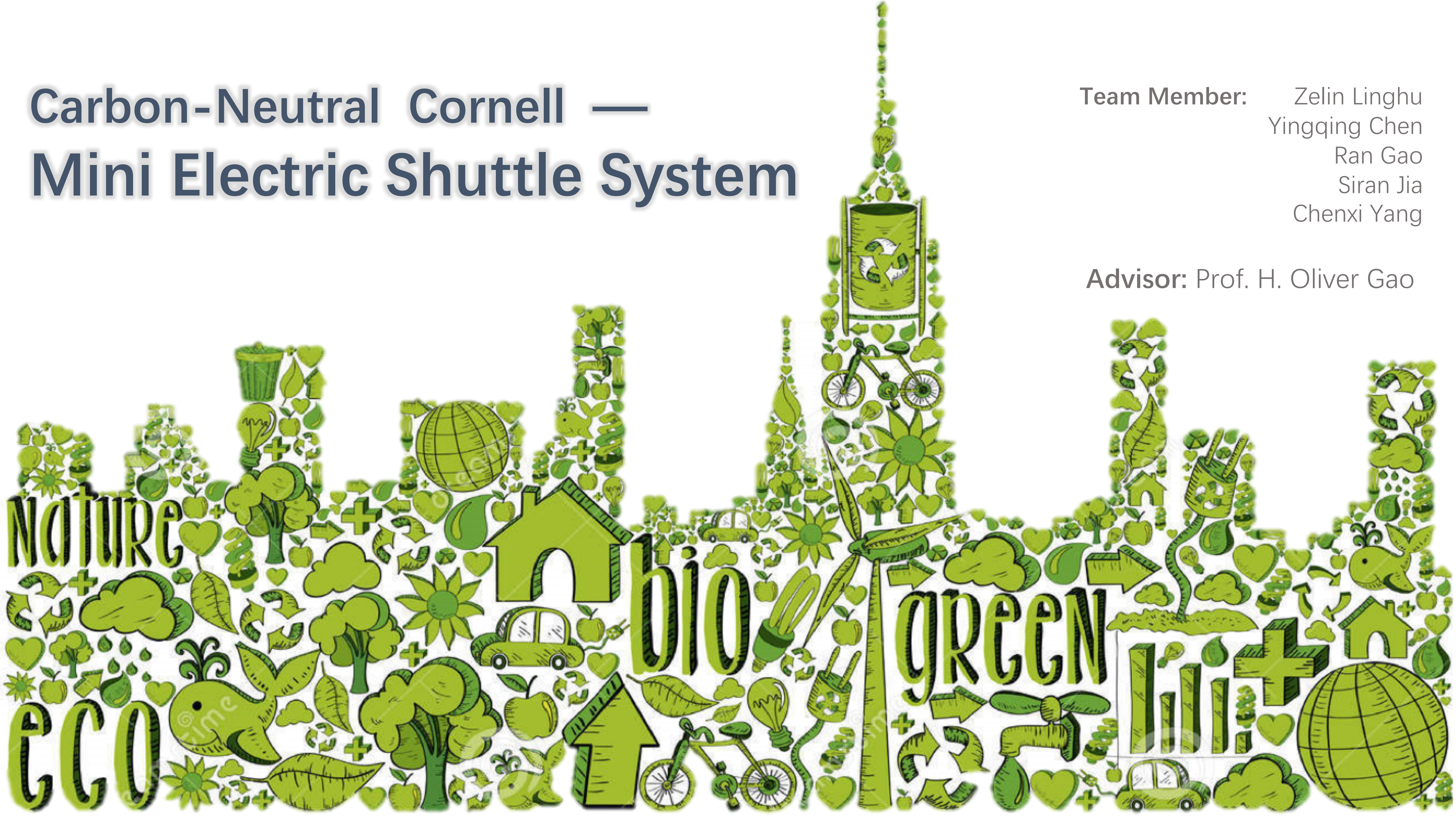
Carbon-Neutral Cornell —
Mini Electric Shuttle System

Team Member: Zelin Linghu
Yingqing Chen
Ran Gao
Siran Jia
Chenxi Yang

Advisor: Prof. H. Oliver Gao

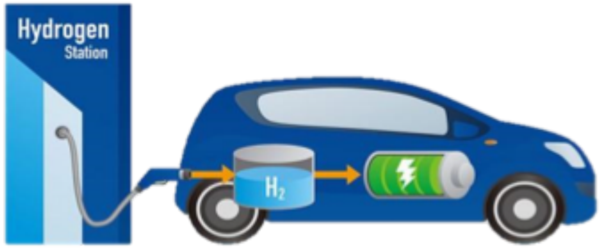


Feasible Solutions

Electric Shuttle

Mini Electric Shuttle

Shared Electric Bike



Fuel-Cell Vehicle

Feasible Solutions

Measurement	Normalized Score				User Dependencies		Final Score			
	ES	MES	SEB	FCV	Min	Weight	ES	MES	SEB	FCV
Range	5	4	4	4	3	3	15	12	12	12
Price	1	3	5	1	1	5	5	15	25	5
Maintenance	2	4	2	1	1	4	8	16	8	4
Safety	5	3	2	5	2	5	25	15	10	25
Flexibility	2	5	5	4	2	3	6	10	10	8
Legality	4	3	0	3	1	2	8	6	0	6
Final							**67**	**74**	**65**	**60**

Literature Review

Optimization

- Vehicle Routing Problem
- Minimize Total Cost satisfying certain demand level
- Constraints: Charging capacity, Environmental Factors,Service Radius of EV Stations, etc.

Simulation

- Simio - Object oriented discrete event simulation
- Graphic modeling enables user to rebuild and present the scenario

Existing Instances

- Drive Electric Northern Colorado (DENC)
- University Charging Stations (Columbia, Stanford, Yale)

Methodology

Collect Information

- **Knowledge**
  Literature
  Database
  Project Docs

Define solution MES

- **Field Work**
  Observation
  Immersion
  Engagement

Mathematical Modeling

- **Optimzation**

Mixed Integer LinearProgramming

Input feasibility check for scenario analysis

Flow Simulation

- **Transportation Flow Simulation – Simio**
- Bus route modeling

Vehicle and passenger transportation

Optimal Plan

Evaluation

Mathematical Model

Set/Indices

N	set of nodes in the campus;
C	set of interchanges in the campus
i,j	indices of nodes;
n	route number;

Parameters

s	average time for stopping at a node;
d_{ij}	travel demand from node i to node j;
R_{max}	maximum number of routes on the network, i.e., 5;
L_{ij}	bus travel distance between node i and node j;
l_{ij}	walking distance between node i and node j;
v	average bus travelling speed;
v'	average walking speed;
t	rush hour duration per day;
T	bus service life;
P	power of bus battery;
r_p	rate of power;
H	hourly wage for drivers;
I	infrastructure investment for each stop;
I_c	investment for each electrical bus;

Objective Functions

Min $\quad c = C_{driver} + C_{infra} + C_{power} + C_{bus},$ (1)

s.t. $\quad \sum_{j \in N} X_{0jn} = 1 \text{ for n} = 1 \text{ to } R_{max},$ (2)

$\sum_{i \in N} X_{i0n} = 1 \text{ for n} = 1 \text{ to } R_{max},$ (3)

$\sum_{i \in N, i \neq j} X_{ijn} - \sum_{i \in N, i \neq j} X_{jin} = 0 \text{ for j} \in N, \text{n} = 1 \text{ to } R_{max},$ (4)

$\sum_{i \in N} X_{ijn} \leq 1 \text{ for j} \in N, \text{n} = 1 \text{ to } R_{max},$ (5)

$\sum_{i \in N} X_{jin} \leq 1 \text{ for j} \in N, \text{n} = 1 \text{ to } R_{max},$ (6)

$\frac{l_{ij}}{v'} \geq \frac{L_{ij}}{v} \text{ for } i, j \in N, \ i \neq j$ (7)

$\frac{\sum_{i,j \in N, i \neq j,} f_n * X_{ijn} * L_{ij} * W}{v} \geq \sum_{i,j \in N, i \neq j,} X_{ijn} * d_{ij} \text{ for n=1 to } R_{max},$ (8)

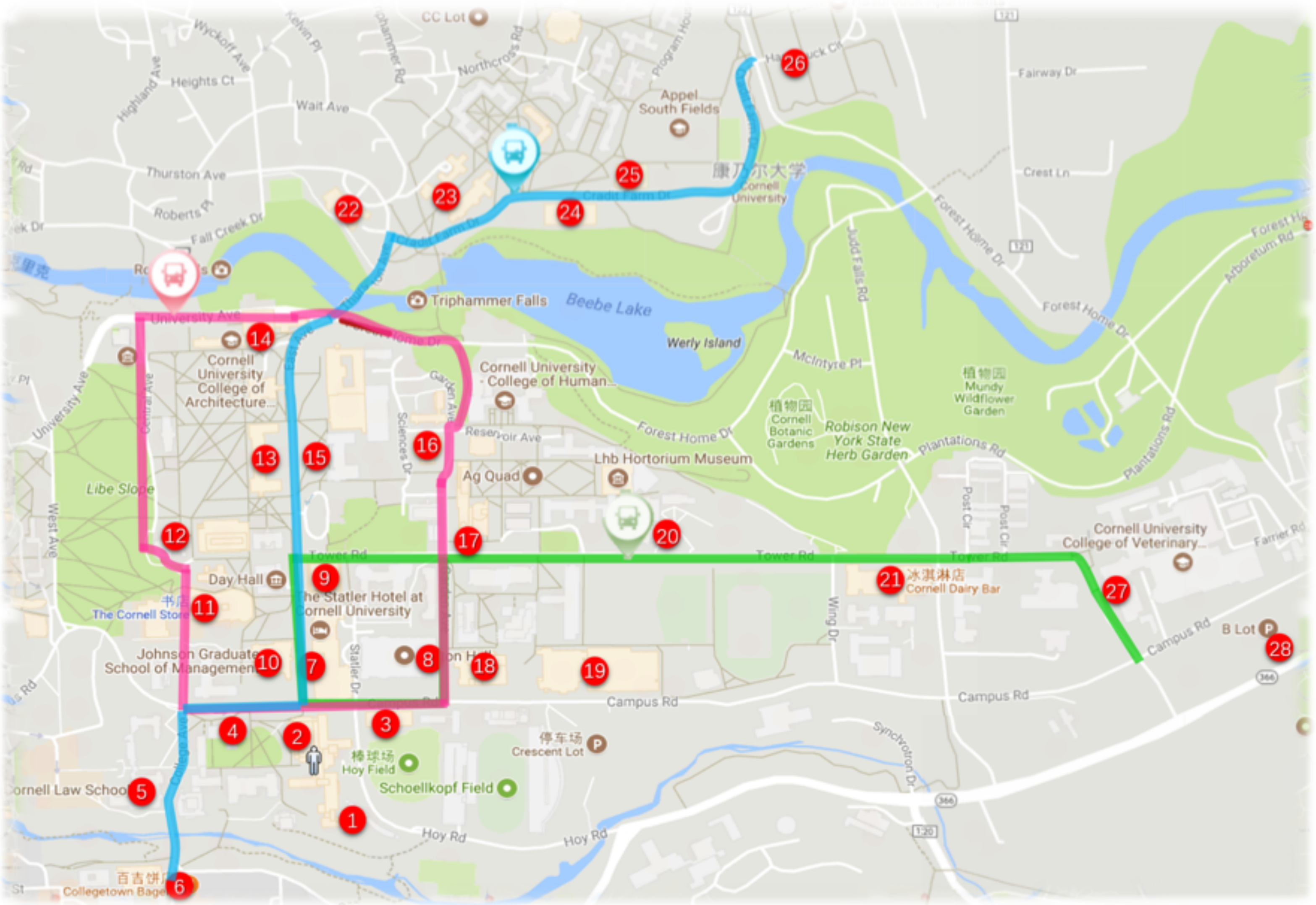
$C_{driver} = \sum_{n=1}^{R_{max}} f_n * h * t * T,$ (9)

$C_{infra} = \left(\sum_{i,j \in N, n=1}^{R_{max}} X_{ijn} + R_{max}\right) * I,$ (10)

$C_{power} = \sum_{n=1}^{R_{max}} f_n * t * T * P * r_p,$ (11)

$C_{bus} = \left(\sum_{n=1}^{R_{max}} f_n * t + R_{max}\right) * I_c,$ (12)

Scenario Designs



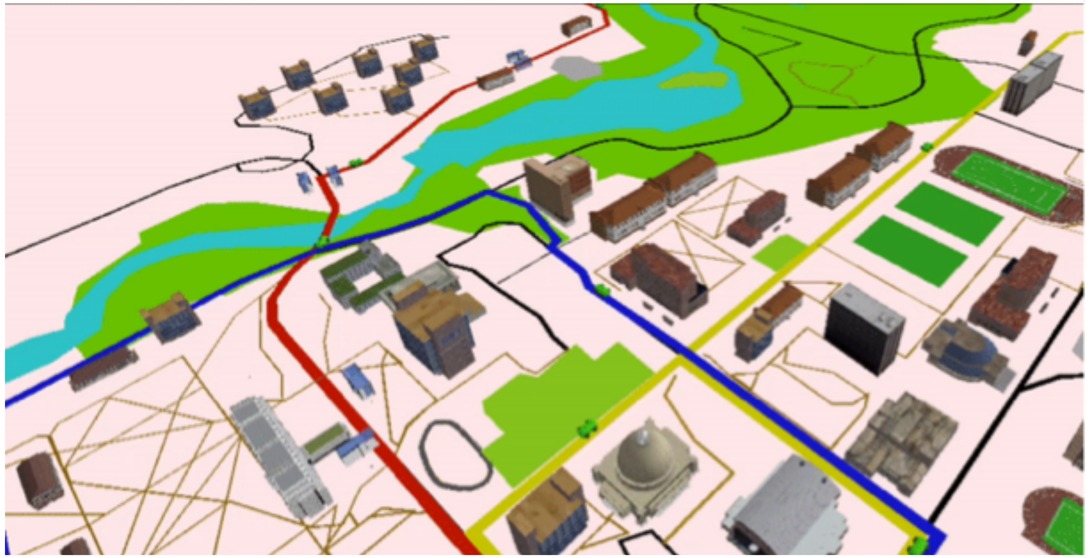
PROS

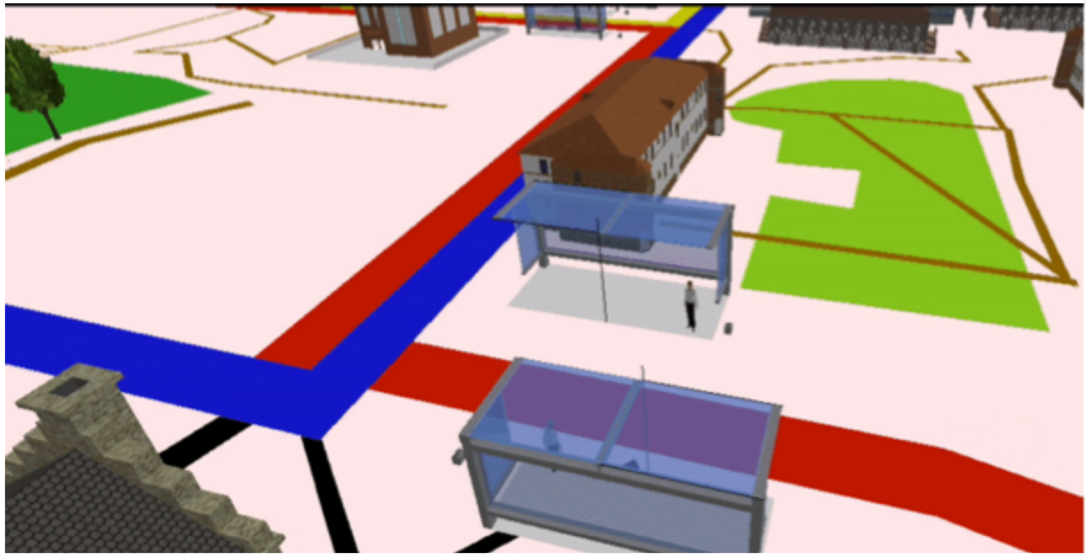
- Covers more buildings on Campus
- Covers both central area and surrounding area
- Drives through walkways

CONS

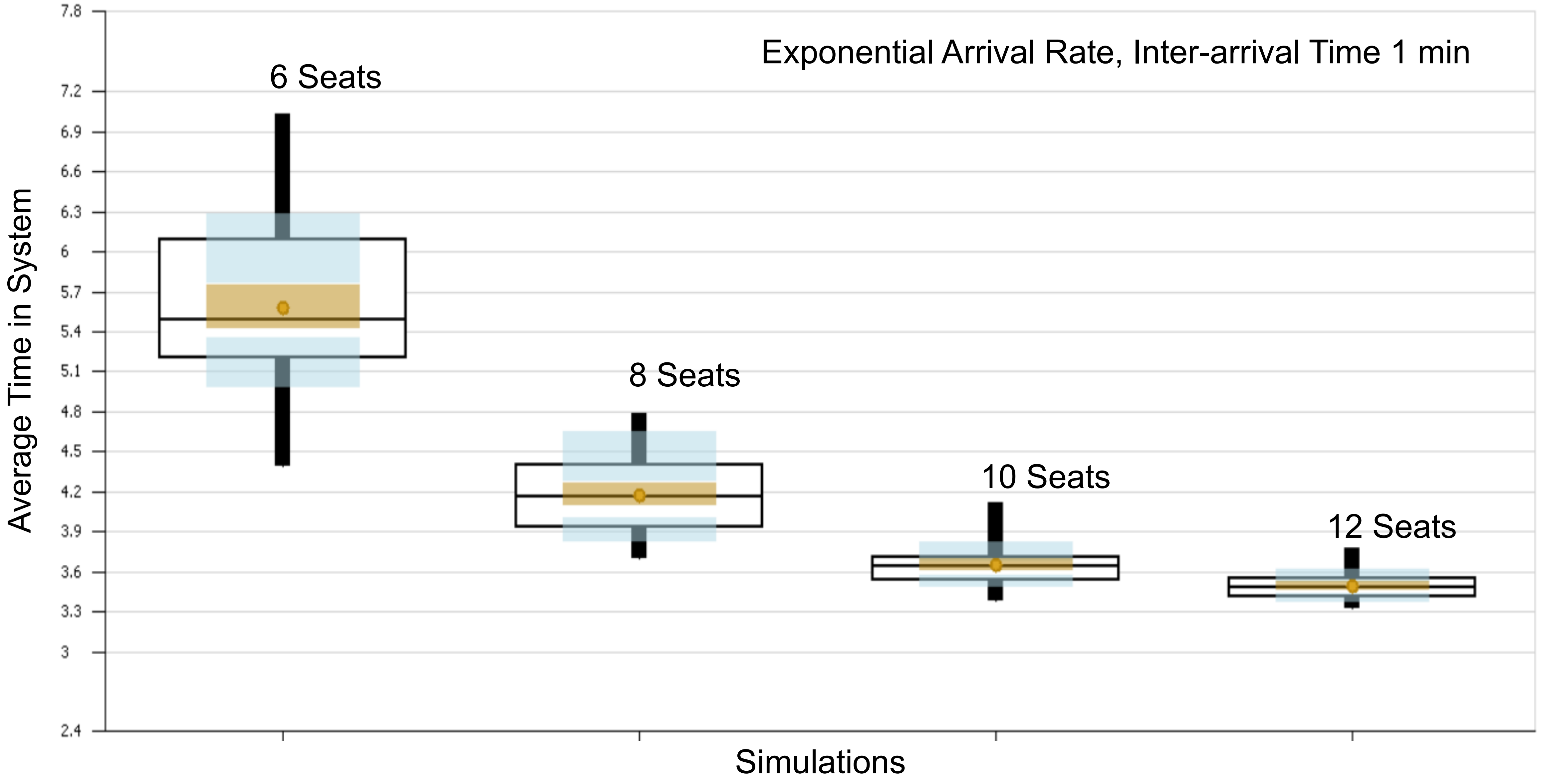
- Inconvenient for transfer
- May need extra walking
- No parking lots near originating stations

Models & Results





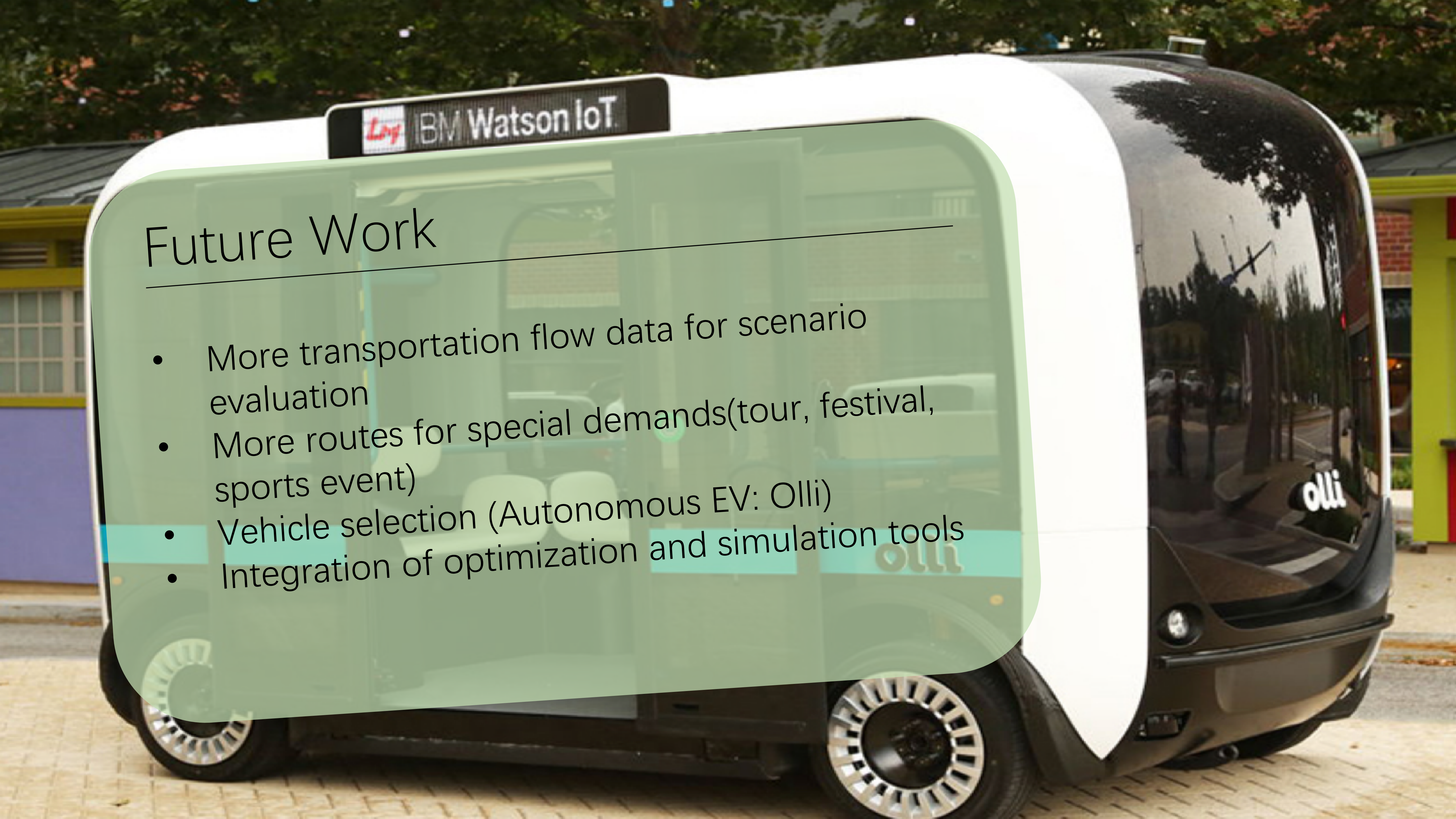
Models & Results



Conclusion

Mini Electric Shuttle System

- **Idea**
- **Flexibility**
  - Reach the walkway, stop nearer to the building entrance
  - High frequency and less waiting time
  - Dynamic scheduling and routing based on time-dependent demand
  - Special dispatches for visitor and events
  - Dismountable battery
- **Feasibility**
  - Lower transporter and infrastructure investment
  - Based on existing network, stations and parking lots
  - A variety of vehicle selections
  - Long operation time per charging



Future Work

- More transportation flow data for scenario evaluation
- More routes for special demands(tour, festival, sports event)
- Vehicle selection (Autonomous EV: Olli)
- Integration of optimization and simulation tools

Thank you