Feasibility study for deployment of mobile autonomous charging pods (MAPs) for charging operations

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- Based on charging profiles and available technologies, the industry could require approximately **40 million chargers** across China, Europe, and the United States, representing an estimated **$50 billion dollars** of cumulative capital investment through 2030 [1].

- The European Union will need a cumulative **25 million chargers** and roughly **$15 billion dollars** of investment during the same period [2].

Rise of future mobility

- **Autonomous Vehicles (AVs)-** Driverless vehicles that do not require human assistance.
    - Mercedes is bringing Level 3 autonomous driving in US
    - Volkswagen is partnering with Mobileye to use AVs in public transport

- **Shared Mobility-** Shared ownership of vehicles that reduce costs and maintenance of vehicles.

- **Modular Vehicles-** Multiple pods that can form variable length platoons and cater to diverse needs.

Figure - Illustrations of AVs and modular vehicle concepts [3][4][5]

- Lack of **human drivers** to make the physical connection.

- **High utilization**, **less idle time** for charging.

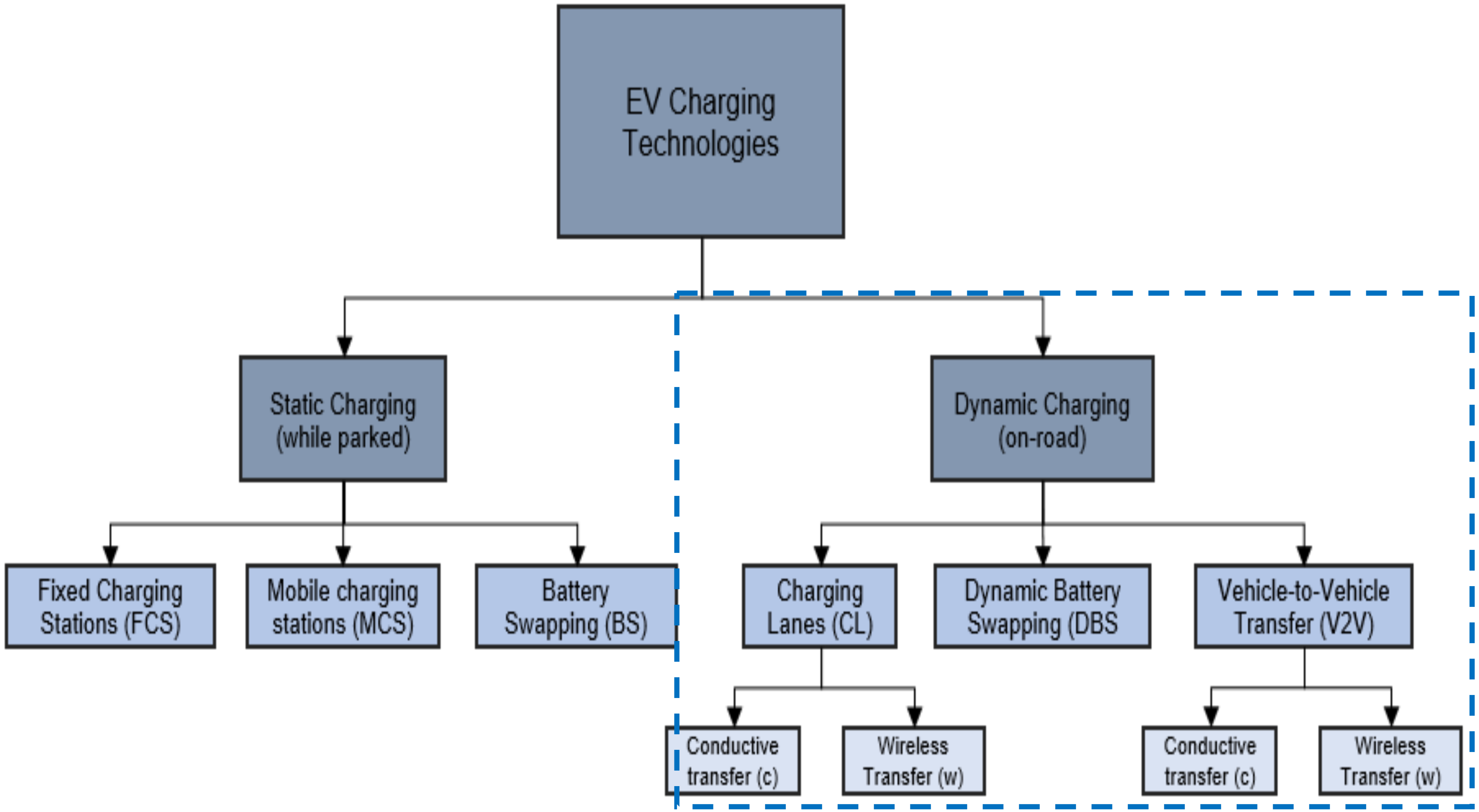
- Loss of **time** and **profit** from routing and queuing at charging stations [6].

Research Questions

- What are the **optimal charging methods** suitable for current and future of transportation like **AVs and shared mobility**?

- How do different charging methods compare with each other in terms of **flexibility** and **adaptability** to cater to new trends in transportation?

Charging Topology



Comparison of dynamic solutions

Charging method	**Cost**	**Deployability**	**Flexibility**	**Charging Efficiency**	**Current status**
Charging lanes (w)	Very High	Very Hard	Low	Low	Pilot
Charging lanes (c)	Very High	Very Hard	Low	High	Pilot
V2V charging (w)	Moderate	Moderate	Very High	Low	Development
V2V charging (c)	Moderate	Moderate	Very High	High	concept
Dynamic battery swapping	High	Very Hard	High	Very High	concept

Dynamic Charging

Vehicle to Vehicle charging- Employs use of other vehicles to provide charging.

Benefits of charging lane without costly infrastructure.

a) Vehicle requests charge
b) Charger Vehicle dispatched
c) Provide required charge
d) Charger EV returns to station

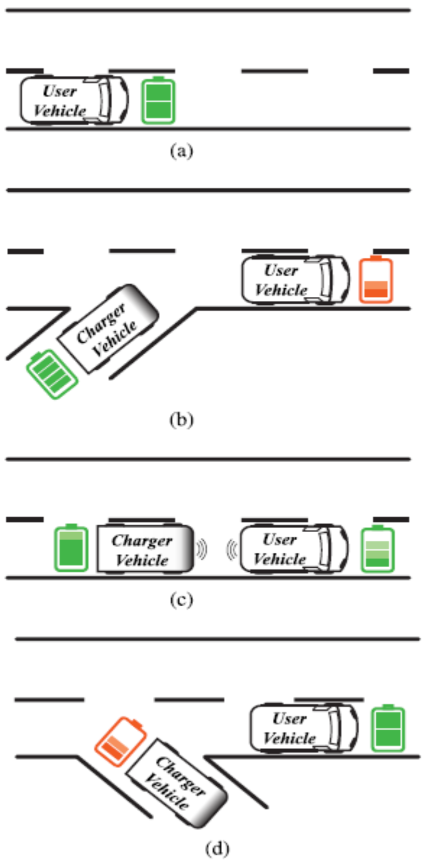


Figure- Vehicle to Vehicle charging of EVs [10]

Mobile Energy Disseminator- Use of refurbished buses to act as charging stations.

Buses follow specific route, user can follow bus/truck to get the required charge wirelessly.

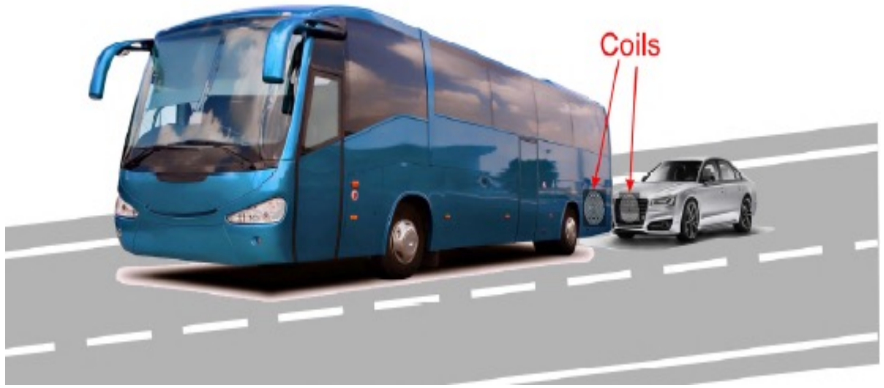


Figure- Wireless charging through buses (MEDs) [11]

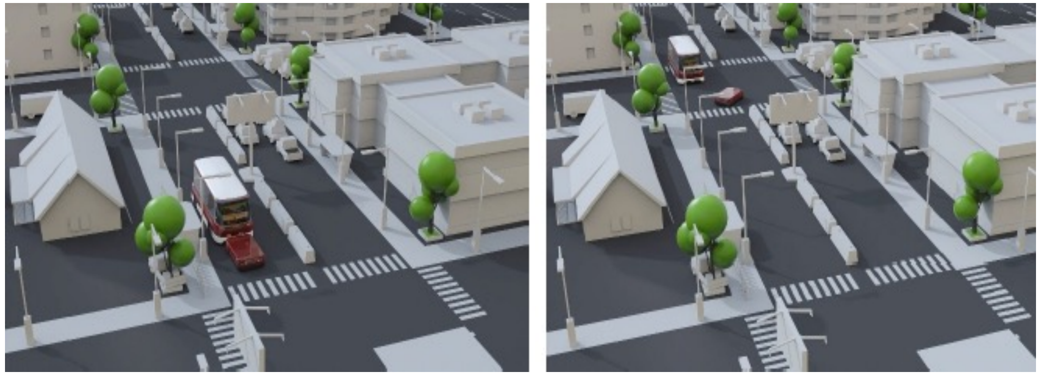
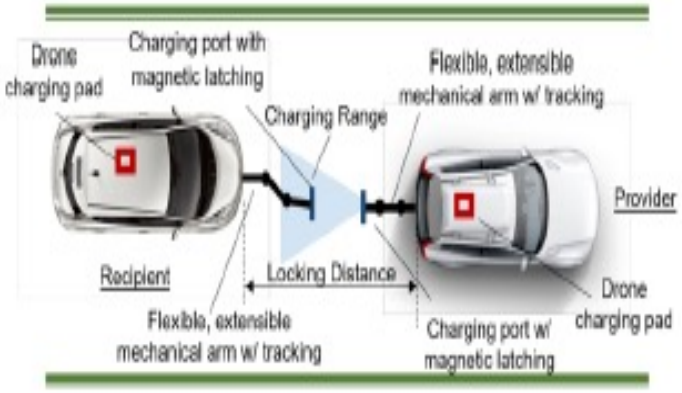


Figure- Charging of EV buses through mobile pods [13]

Vehicle to Vehicle charging (V2V)-

- Conductive Transfer- Allows for high energy transfer and high efficiency.
- Can be achieved through drones or charger arms.



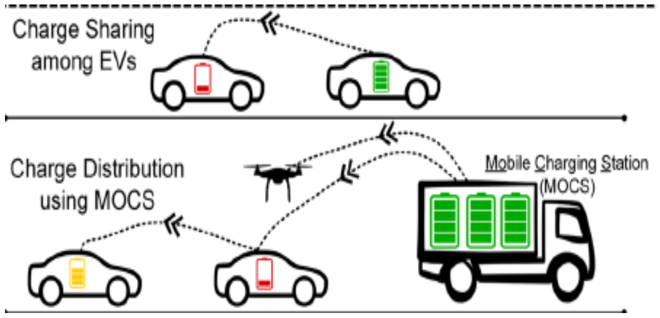
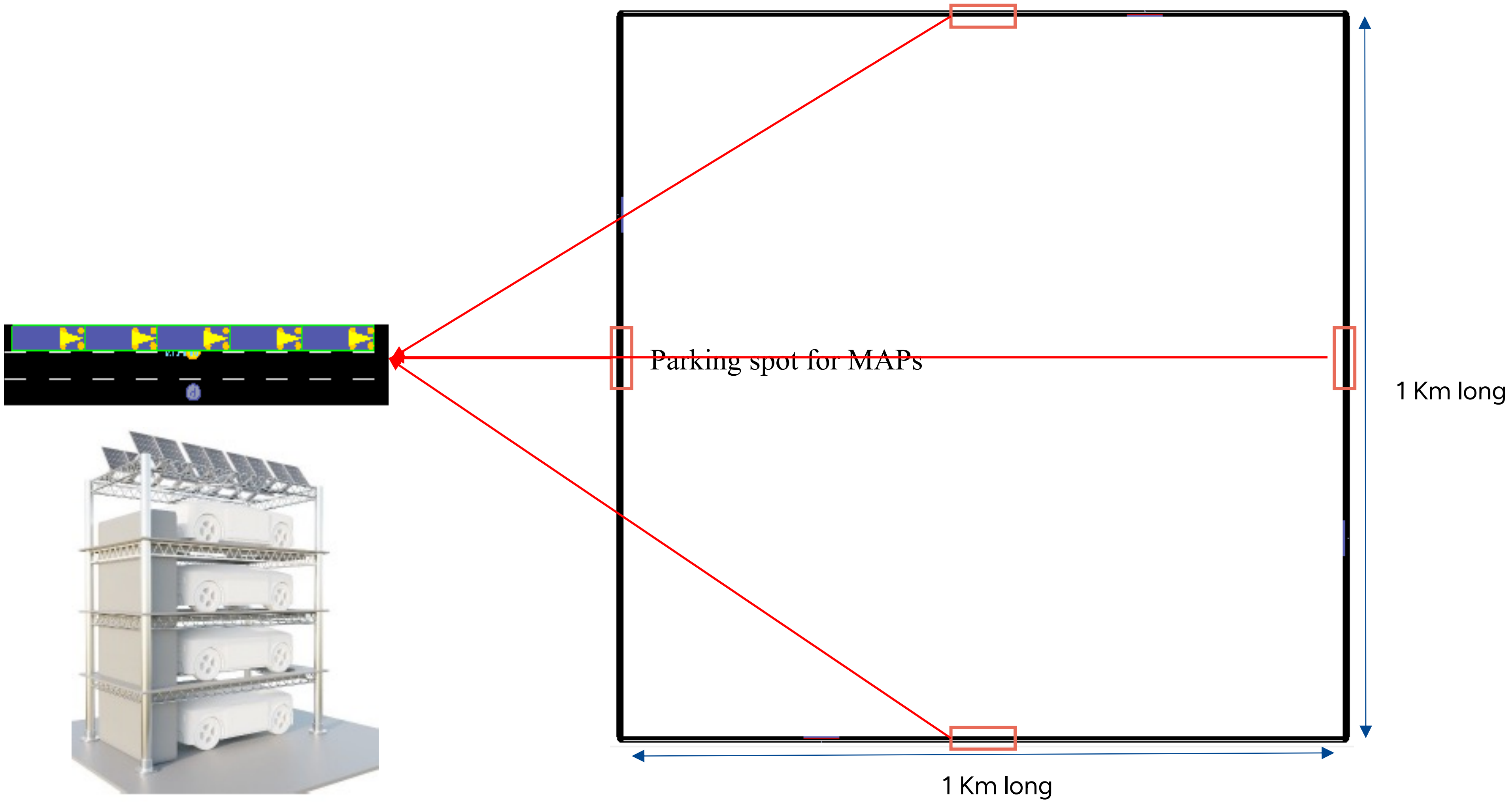


Figure- Peer-to-Peer Car charging proposed in [12]

Proposed idea

Figure- Illustration of charging pods (credits: Bing image creater)


Parking spot for MAPs
1 Km long
1 Km long

KIA Soul EV 64

- Battery capacity- **64 Kwh**
- Weight- **1830 kg**

Scale factor 100 →

Simulation parameters

- Battery capacity- **640 wh**
- Weight- **18 kg**

Charging pod

- Battery capacity- **2000 wh**
- Weight- **5 kg**

Recent energy density= **700 Wh/kg**

EV battery makes up-to **25% of EV weight**

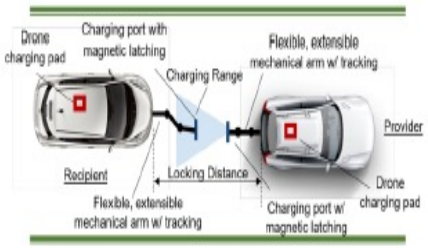
Scaling charging time

Real World

- Charging time= **20 minutes**
- Travel time = 3.5 hrs = **210 minutes**
- Ratio of charging to travel time = 20/210 = **0.095**

Simulation

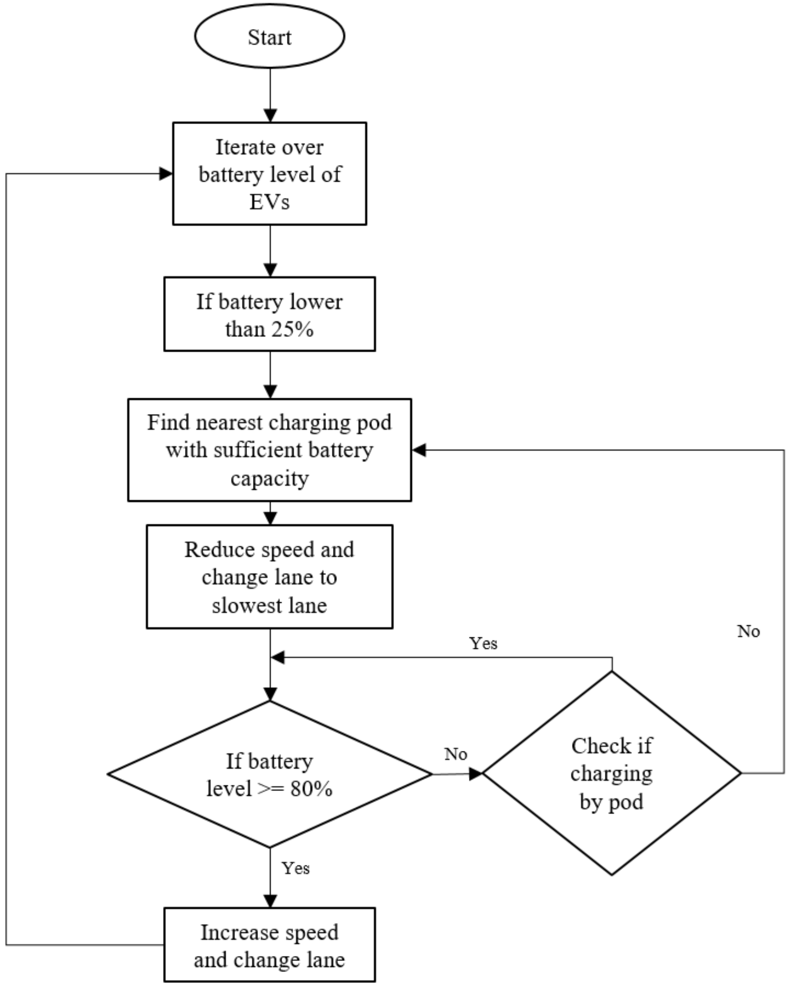
- Travel time- **18.03 minutes**
- Ratio of charging to travel time = **0.095**
- Charging time = **2 minutes**



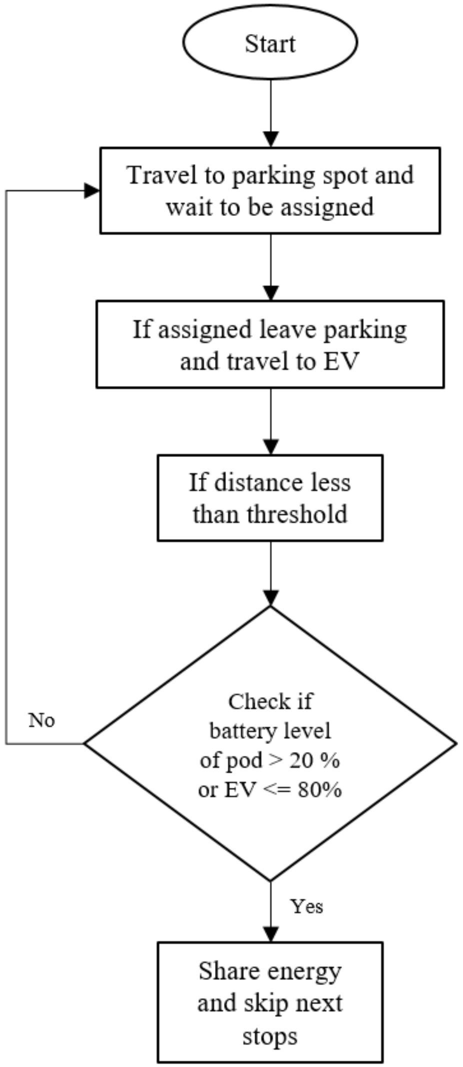
Simulation Scenarios

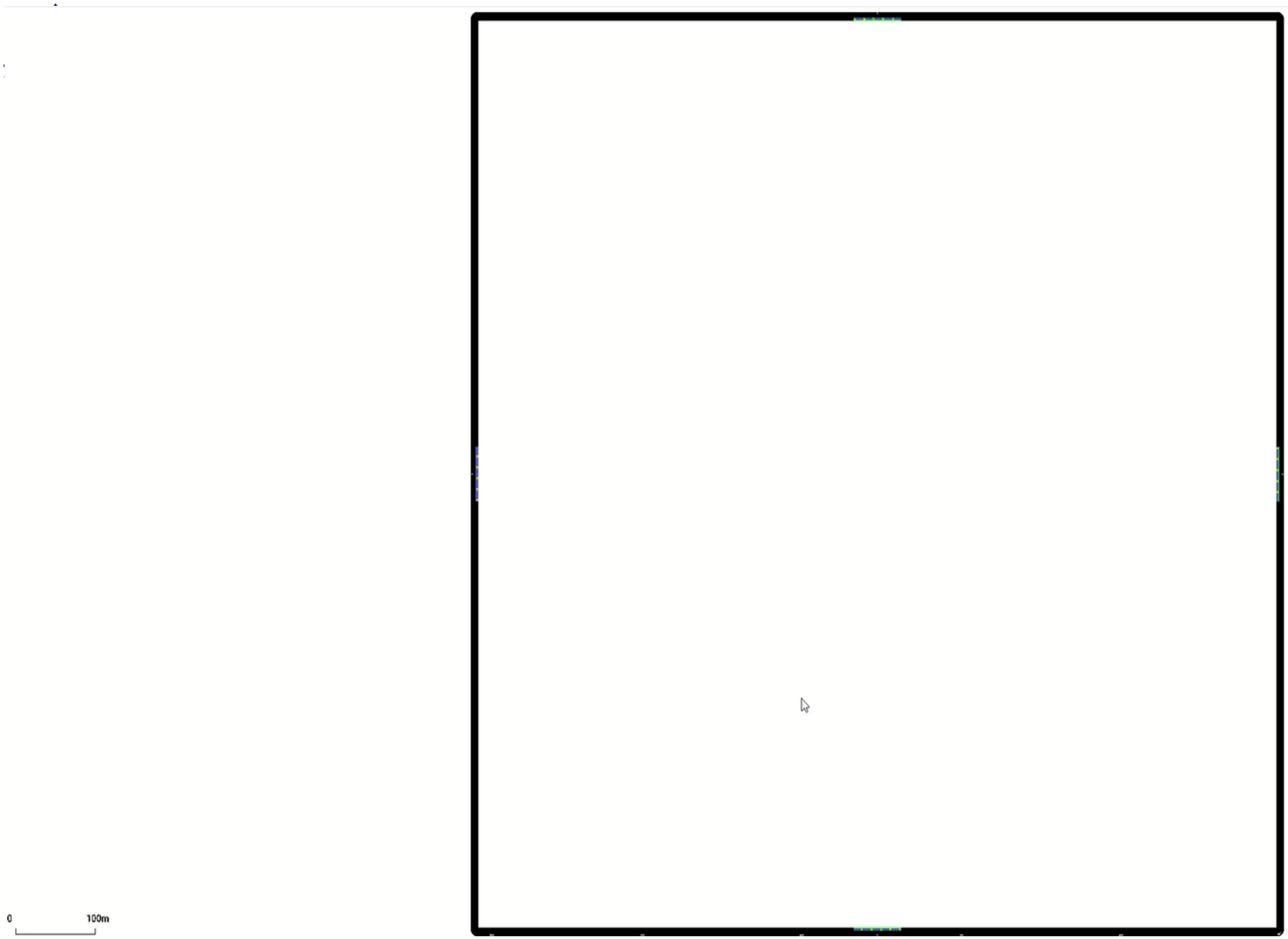
- **Case Study 1- Max no of EVs**
  - **Determining max number of EVs that can be supported by 20 MAPs in a network**
- **Case Study 2- Optimal Charging strategy**
  - **Determining the optimal charging strategy- Pods travelling to EVs vs EVs travelling to pods**
- **Case Study 3- Benchmark comparison**
  - **Comparison with benchmark scenario- No pods vs pods**
  - **Congestion, travel time, speed etc**

Electric vehicle charging algorithm



Charging pod algorithm




0
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Case Study 1- Max number of Electric vehicles served

Max battery capacity of EVs- **640 Wh**

SOC level of EVs- **Gaussian distributed**

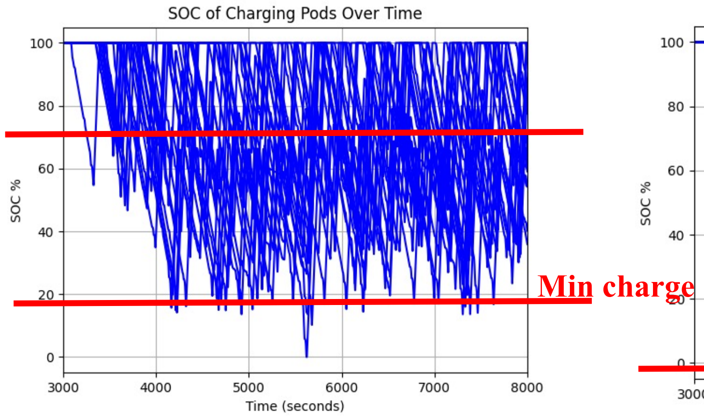
No of MAPs **- 20 (5 on each edge)**

Objectives-

- SOC level is maintained above **0%** for all EVs and MAPs
- Only **< 1.5%** of EVs are fully discharged (**> 98.5% can operate without fully discharging**)
- Depends on context (SOC level, SOC of pods, efficiency etc)

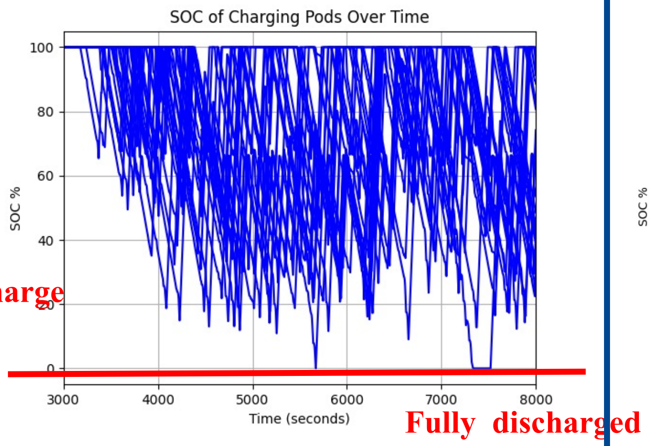
Case Study 1- SOC of MAPs

65 Vehicles



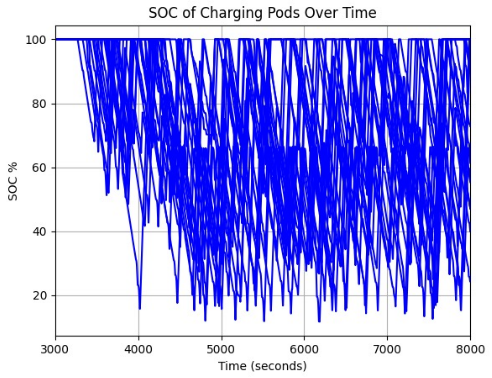
Fully Discharged pods (0%) = **1**

70 Vehicles



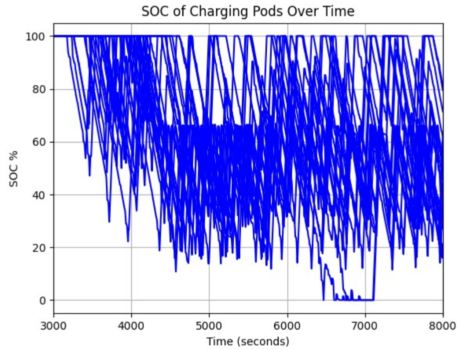
Fully Discharged (0%) = **2**

75 Vehicles



Fully Discharged (0%) = **0**

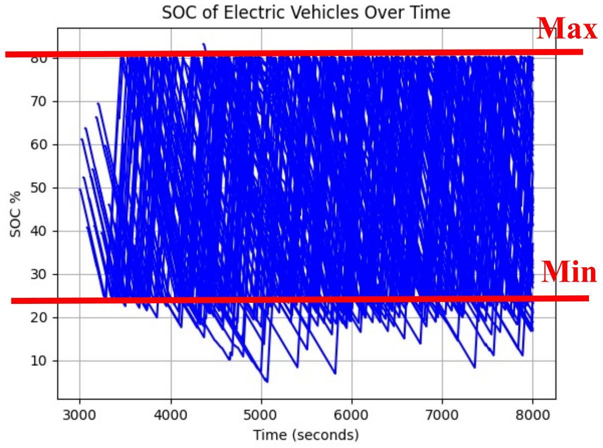
80 Vehicles



Fully Discharged (0%) = **2**

Case Study 1- Max number of Electric vehicles served

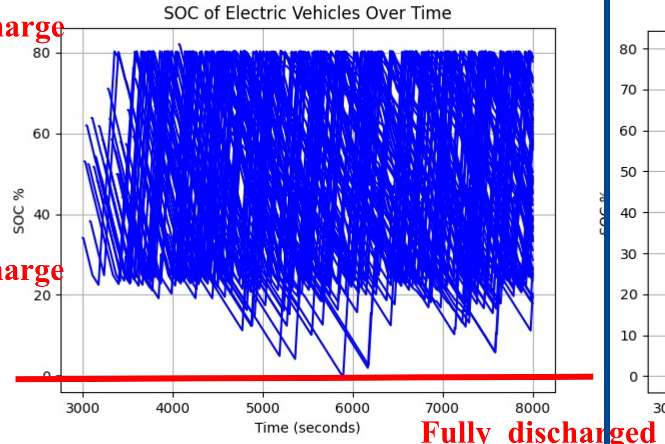
65 Vehicles



Less than 10% = **7.7%**

Fully Discharged (0%) = **0**

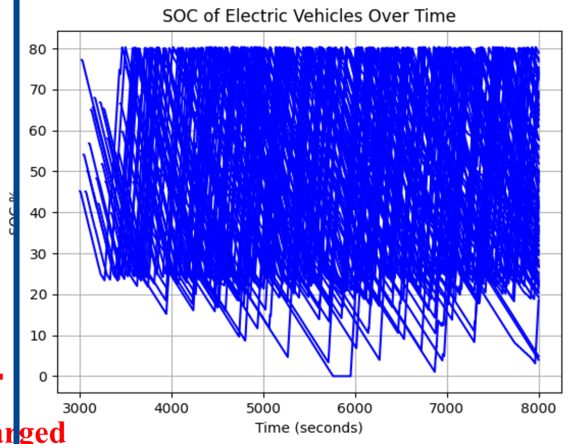
70 Vehicles



Less than 10% = **8.5%**

Fully Discharged (0%) = **1.4 %**

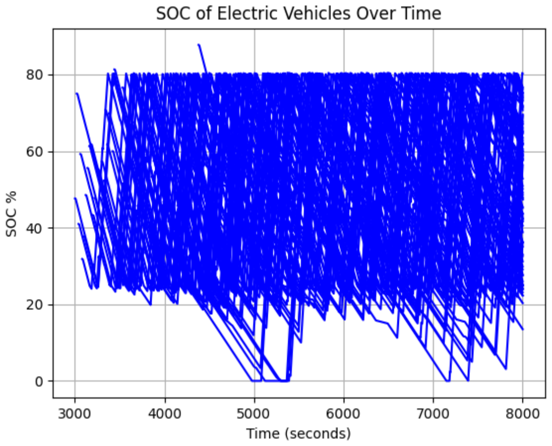
75 Vehicles



Less than 10% = **20%**

Fully Discharged (0%) = **1.3%**

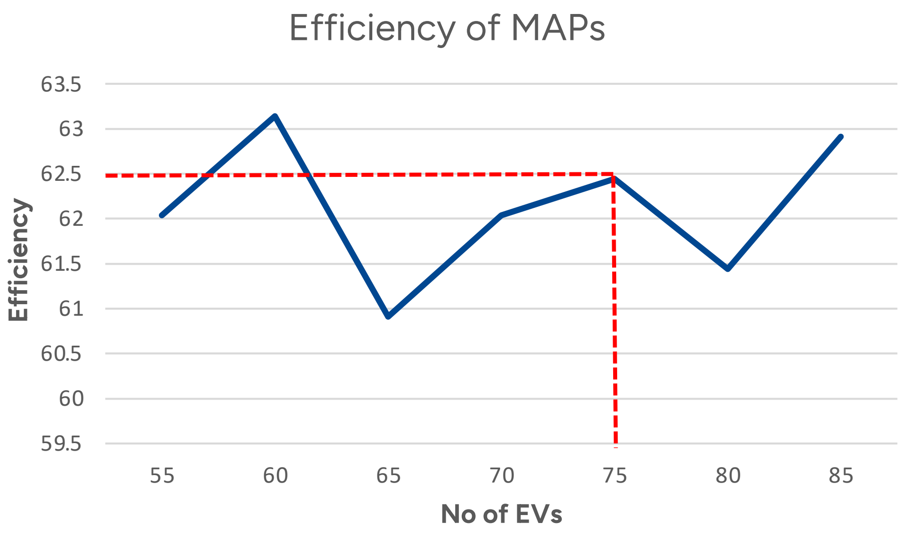
80 Vehicles

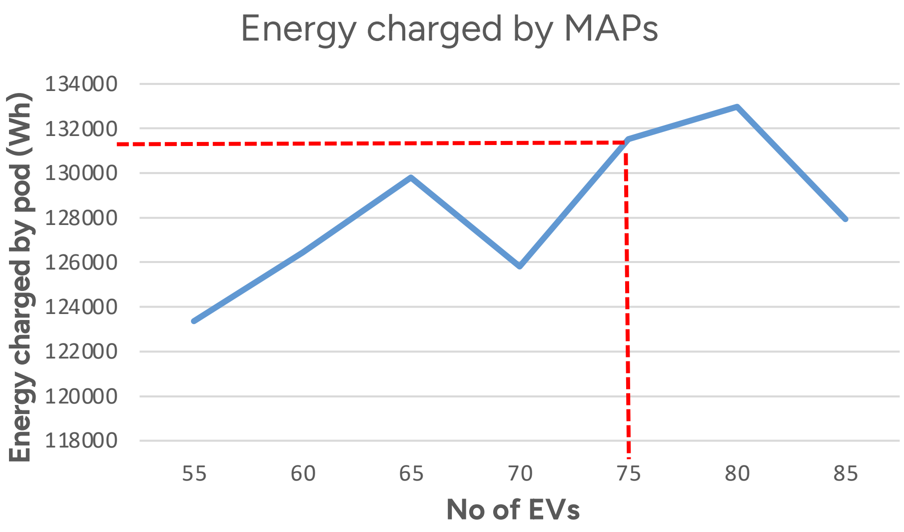


Less than 10% = **12.5%**

Fully Discharged (0%) = **7.5%**

Case Study 1- Energy and efficiency





Efficiency- (Energy shared with EVs/ Energy supplied by charging stations) = **62.5 %**

Max energy charged= **13 GWh** (scaled up)

Results and Discussion

- A max of **75 EVs** can be served by **20** charging pods
- **3.75 EVs** per MAP with battery capacity of **3.125** times EV battery
- Max efficiency of **63%** and max energy shared of **13.3 GWh**
- Affect of different battery capacities on no of EVs served.

Future Work

- Case Study 1- Max no of EVs
  - Determining max number of EVs that can be supported by 20 MAPs in a network

- Case Study 2- Optimal Charging strategy
  - Determining the optimal charging strategy- Pods travelling to EVs vs EVs travelling to pods

- Case Study 3- Benchmark comparison
  - Comparison with benchmark scenario- No pods vs pods
  - Congestion, travel time, speed etc

Suggestions Welcome

Thank You for your time

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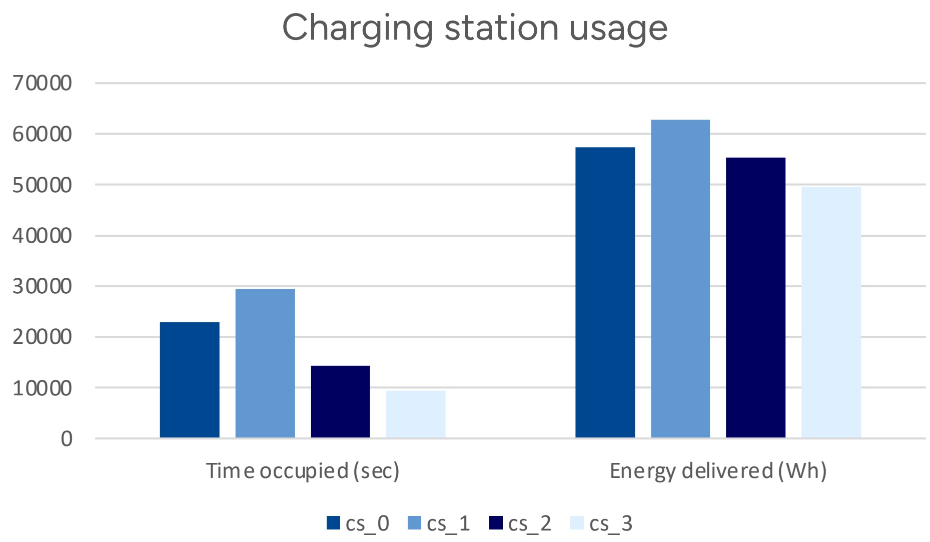
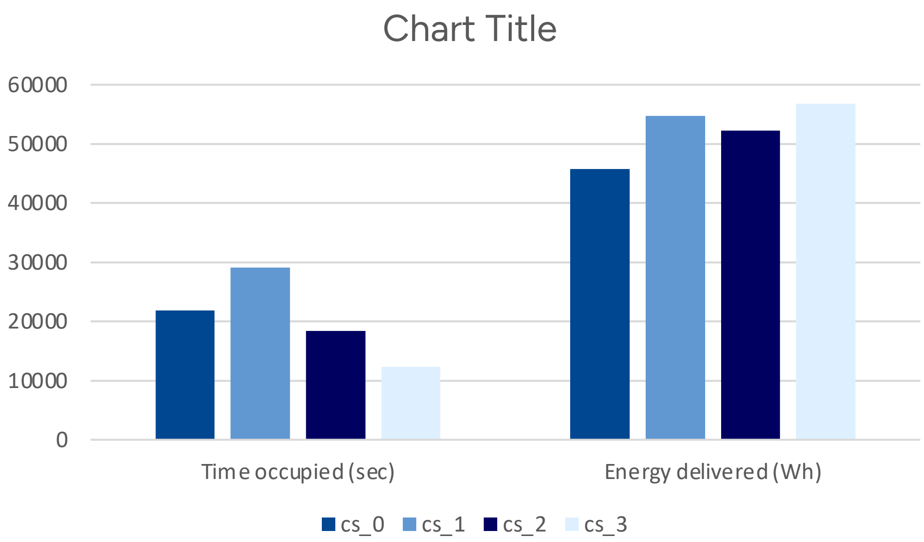
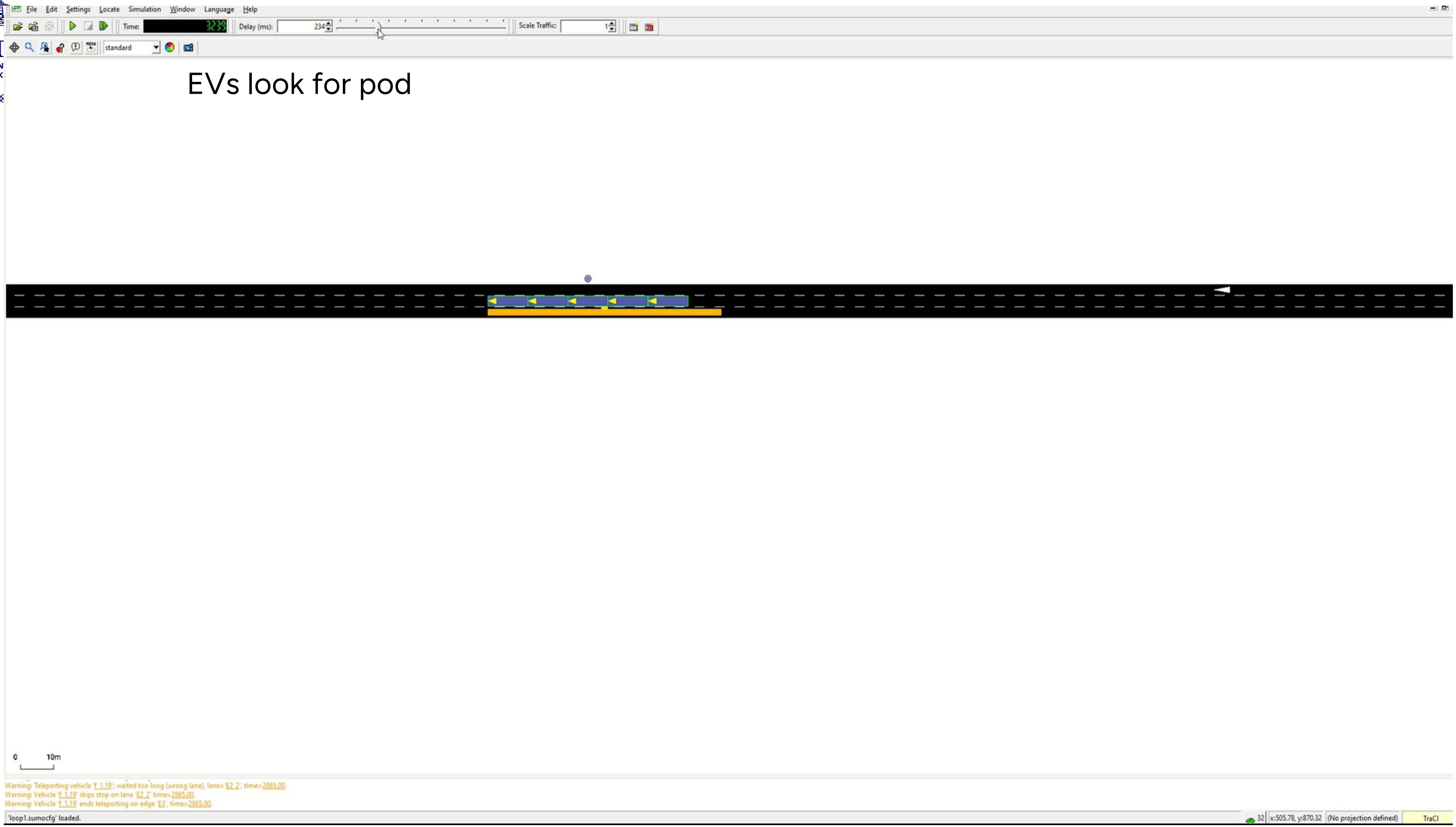
Backup slides



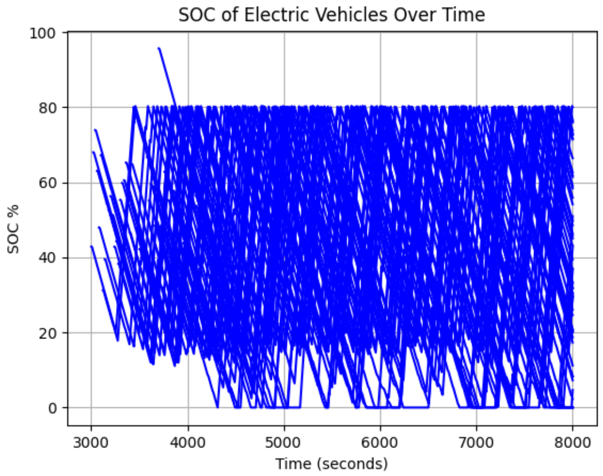


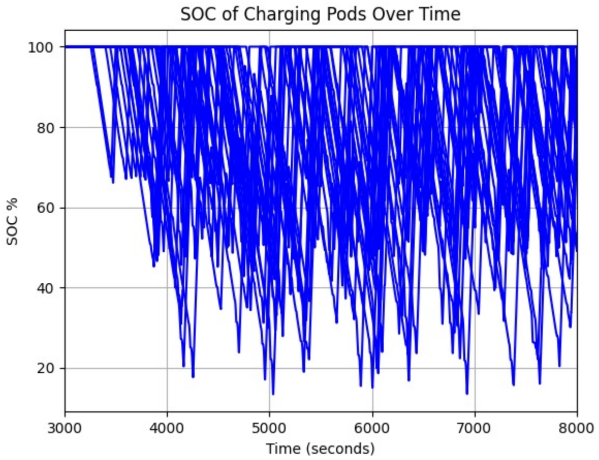
EVs look for pod



Case Study 2

55 Vehicles

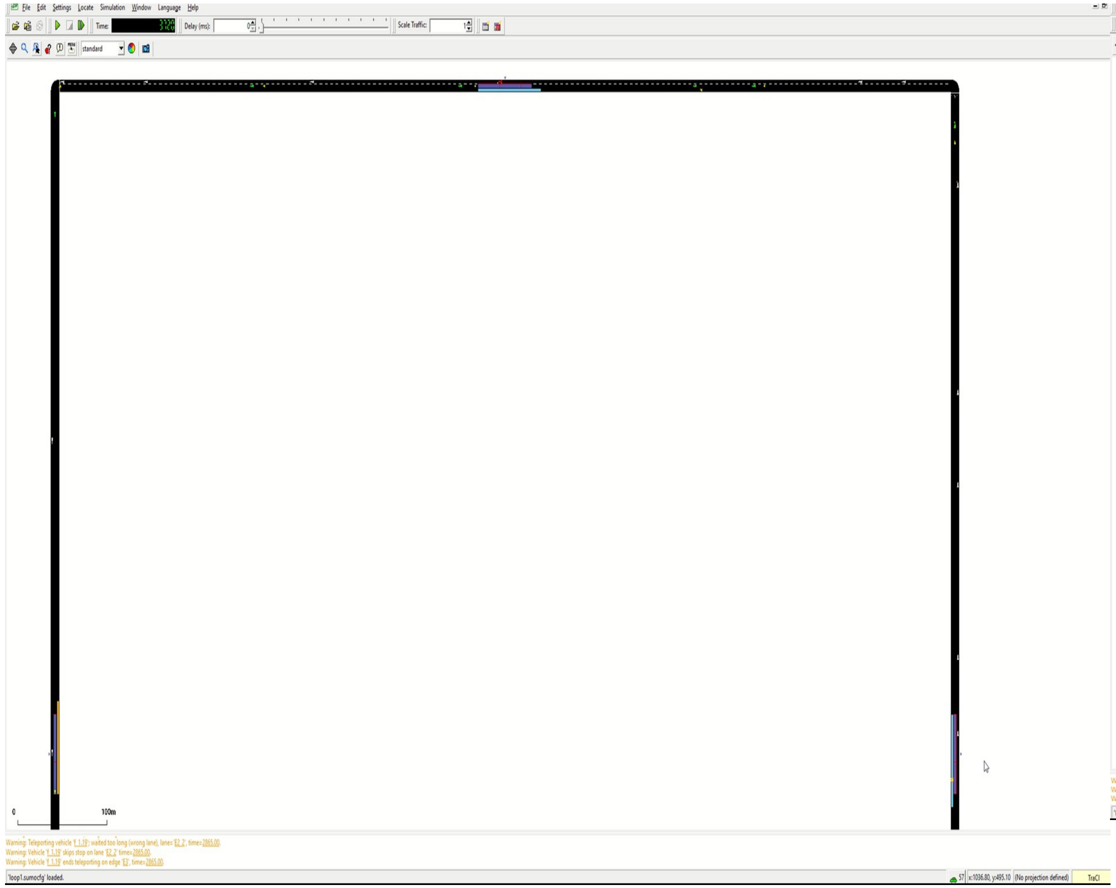


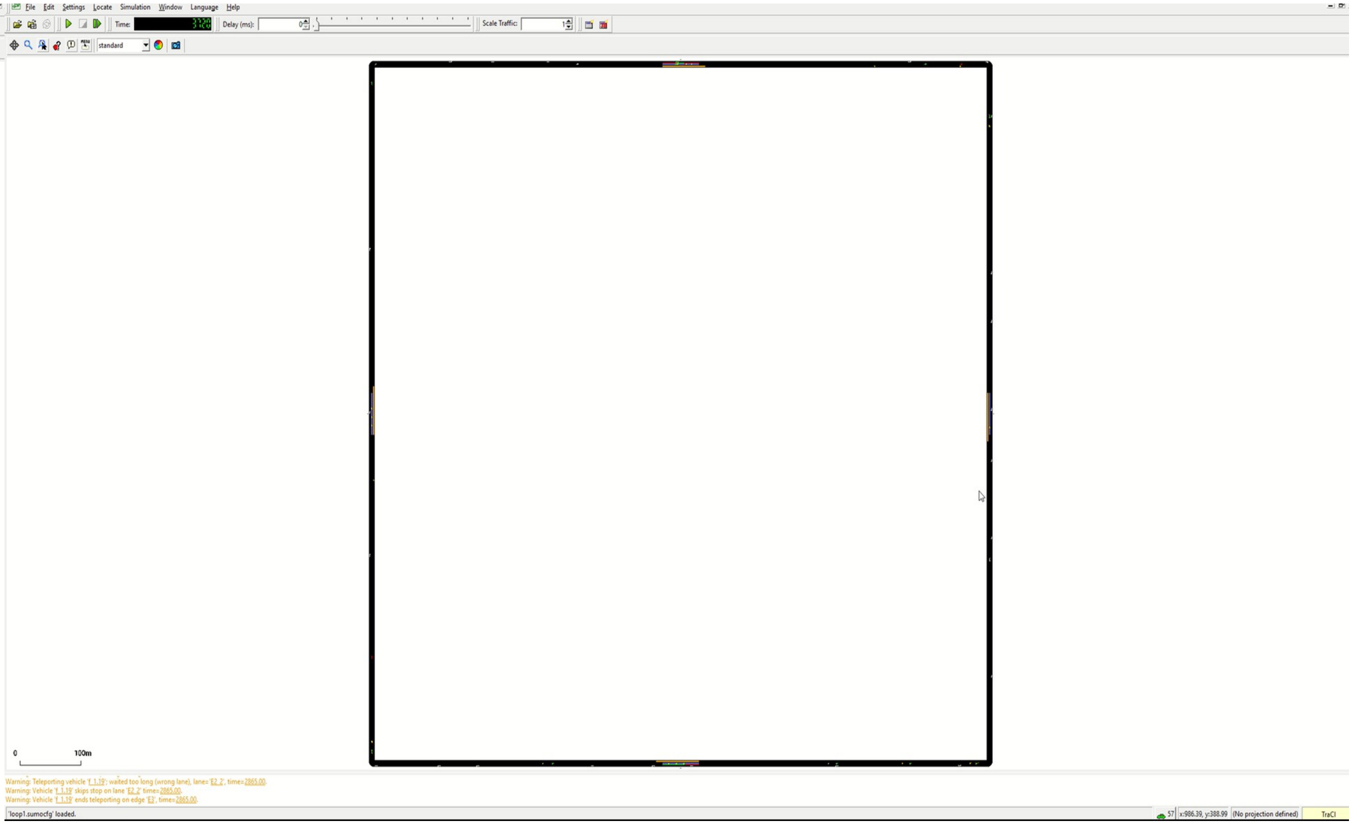


Efficiency- 64.47 %

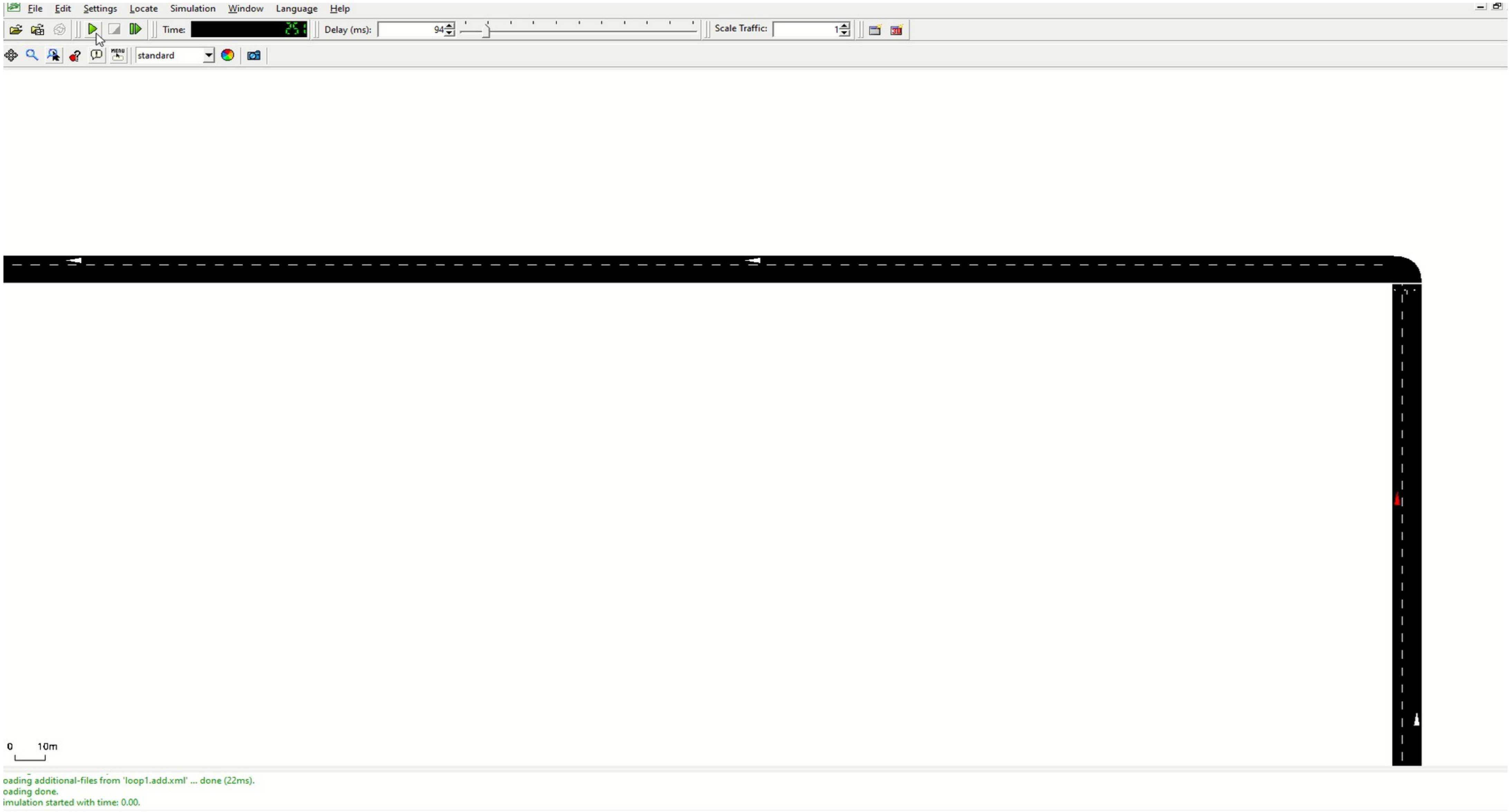
Max energy charged= 12 GWh (scaled up)

EVs look for pod issue





NO pods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Research Questions

- Use Cases
- KPIs
- Possible benefits
- Scaling issues,

- Methodology?
- Potential comparison scenarios for simulation

- Optimization parameters??
- Other comments from energy perspectives

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