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CIVIL & ENVIRONMENTAL ENGINEERING

ChargEVal
An agent-based tool for evaluating charging network changes

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Outline for today

- Acknowledgments
- Motivation & goals for an EV infrastructure evaluation tool
- Modeling EV charging choices
- ChargEVal: an agent-based tool for evaluating charging network changes

Acknowledgments

Pacific Northwest Transportation Consortium (PacTrans)

Locating fast charging stations for safe and reliable intercity electric vehicle travel in Washington

National Science Foundation

Dynamic discrete choice modeling of plug-in electric vehicle use and charging using stated preference data

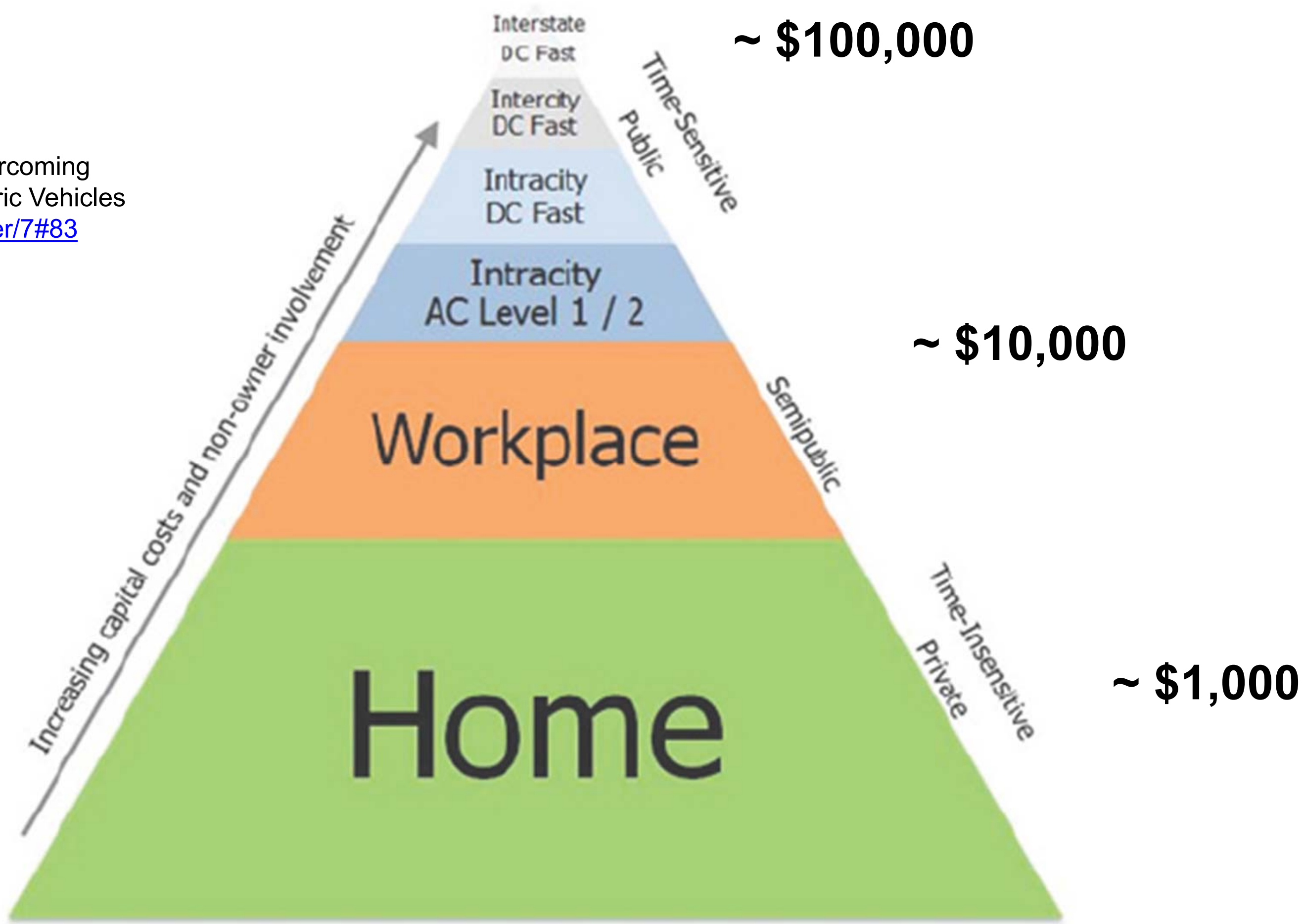
Washington State DOT

Simulation Environment to Optimize Public Investments in Electric Vehicle Charging Infrastructure

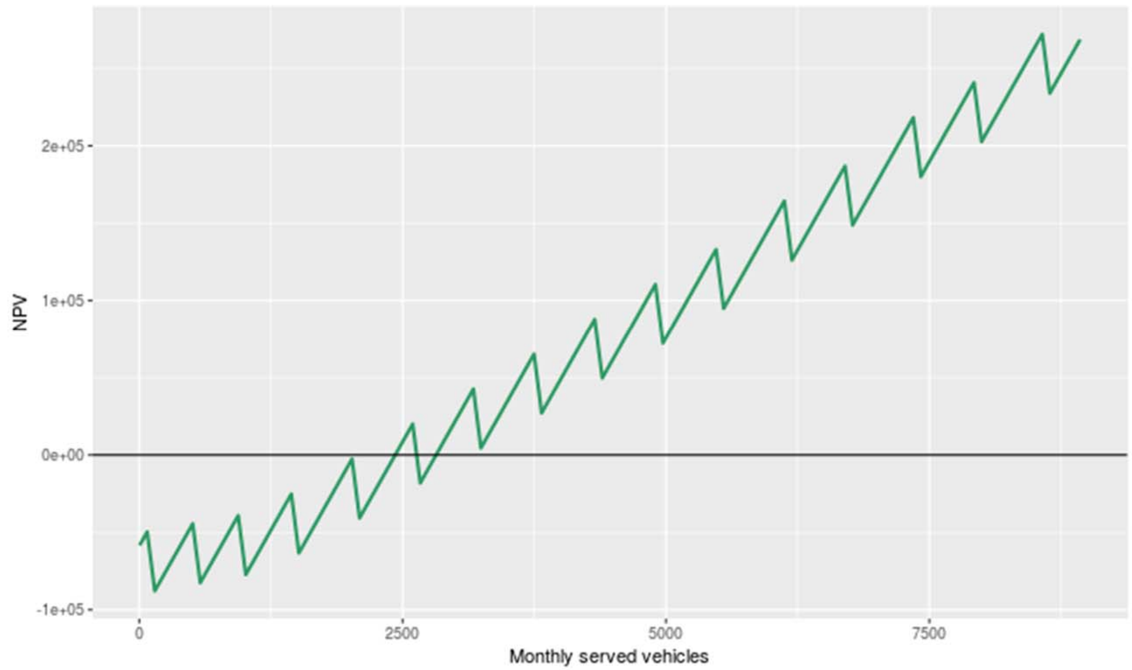
WSDOT Research Report No. WA-RD 818.1

Why do we need a decision support tool?
Public charging, especially fast charging, is expensive.

National Research Council (2015). Overcoming Barriers to Deployment of Plug-in Electric Vehicles
https://www.nap.edu/read/21725/chapter/7#83



Utilization is key to charging station economics, but hard to achieve.



- High capital costs
- High fixed costs
  - demand charges
- Low utilization

*Need **SCALE** to make a standalone business case.*
~ hundreds of vehicles / station / day

Interactive Tool:
https://queueingmodel.shinyapps.io/queueingapp/

Jabbari, P., & MacKenzie, D. EV Everywhere or EV Anytime? Co-locating multiple DC fast chargers improves both operator cost and access reliability. TRB Paper No. 17-05991, Transportation Research Board 96th Annual Meeting. (2017). https://cpb-us-e1.wpmucdn.com/sites.uw.edu/dist/d/4543/files/2017/02/Jabbari-MacKenzie-17-05991.pdf

Our goal was to help WSDOT evaluate alternative investments in Washington's DC fast-charging network

We aimed to develop a decision support tool that:

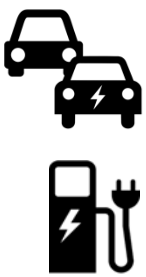
- Is compatible with real world processes for prioritizing projects
  - Augments, rather than replaces, expertise
- Reports on multiple performance indicators
  - eVMT, charging power, waiting time, etc.
- Permits evaluation of multiple concurrent investments
- Explicitly captures travelers' decisions about vehicle use and charging

ChargEVal fills a different niche than incumbent tools

	Considers ODs	Considers Vehicle Choice	Considers Charging Behavior	Considers Traffic & ICEVs	Data Needs
MJ Bradley	No	No	No	No	Light
EVI-Pro	Yes	No	No	No	Moderate
BEAM	Yes	Yes	Yes	Yes	Heavy
ChargEVal	Yes	Yes	Yes	No	Moderate

Background:
Modeling vehicle and charging choices by PEV drivers

We model two related sets of choices



1. ***PEV use:*** *whether PEV owners use their PEV for a trip*
2. ***Charging choice:*** *whether to charge or not at each opportunity*

d_i

Attributes of ***owners***, ***trips***, ***vehicles***, *and* ***charging opportunities***.

X_i

Summary of long-distance charging modeling

1. State of charge and ability to complete travel as planned are primary predictors of charging choices.

2. Detour distance, charging power, and amenities are also significant predictors.

Our charging choice model captures the quantitative relationship between these attributes and the probability of charging.

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ChargEVal Simulation Framework

https://chargeval.readthedocs.io

ChargEVal integrates several key components

1. Long Distance Travel Demand Model
   – Predicts the number of trips for each OD pair in WA on any given day

2. Vehicle Choice Decision Model
   – Predicts the probability of choice of EV for a certain trip.

3. Agent-based Model
   – Simulate statewide EV travel

4. Charging Choice Decision Model
   – Find probability of charging at a station

We begin by simulating long-distance trips made by EVs each day

Average Daily Trip Generation Rate

- Gravity model based on population and distance
- Estimated as a negative binomial model
- Provides an estimate of monthly trip generation rate
- Data from INRIX, calibrated using highway traffic volumes

→

Simulate number of trips between O & D

- Based on random draw from the negative binomial model from before

→

Simulate # of trips by HHs owning EVs

- Random draw based on number of EVs in ZIP vs number of HHs in ZIP

→

Simulate EV usage choices

- This is a function of HH characteristics, trip details, EV type, charging opportunities
- Based on prior empirical work in our lab

For trips made by EVs, we simulate charging behavior along the way

Simulate state of charge along route

- Based on distance along shortest path

EV station consideration

- When EV approaches a charging station along its route

Charging choice

- Random draw with probability based on state of charge, cost, and amenities
- Overlaid with some deterministic rules, e.g. always charge if charger is available and next leg is infeasible

Charging duration

- Vehicles are assumed to charge to 80%

The core of our decision support tool is an agent-based simulation

- Agents
  - Electric Vehicles in WA state (source: WA Department of Licensing)
  - WA Road network (source: WSDOT)
  - EVSEs (source: Alternative Fuels Data Center)

- Environment
  - Bounded by State of WA – 2D / 3D

- Time
  - 24 hours with 1 min time-steps

Our simulation is implemented in GAMA

- "GAMA is a modeling and simulation development environment for building spatially explicit agent-based simulations." - https://gama-platform.github.io/
  - Multiple application domains
  - High-level and intuitive agent-based language (GAML)
  - GIS and data-driven models
  - Declarative user interface

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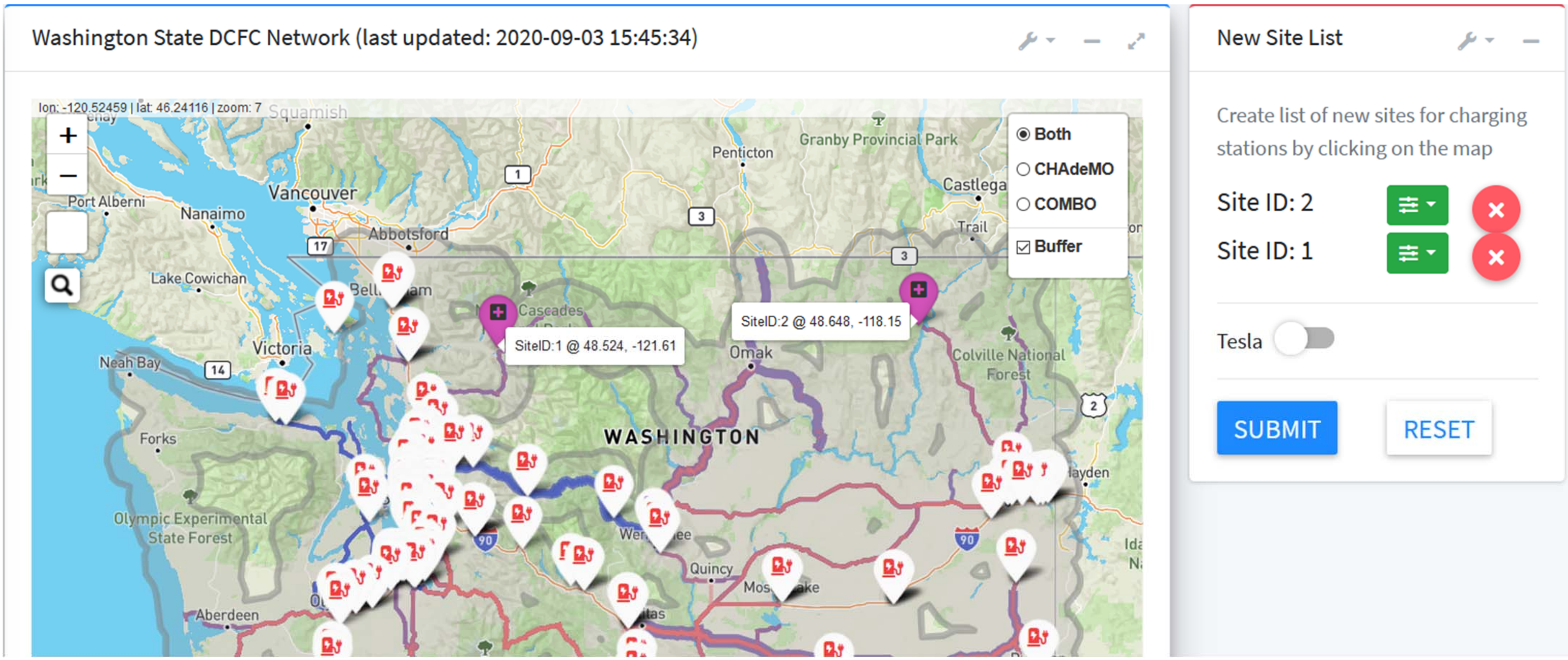
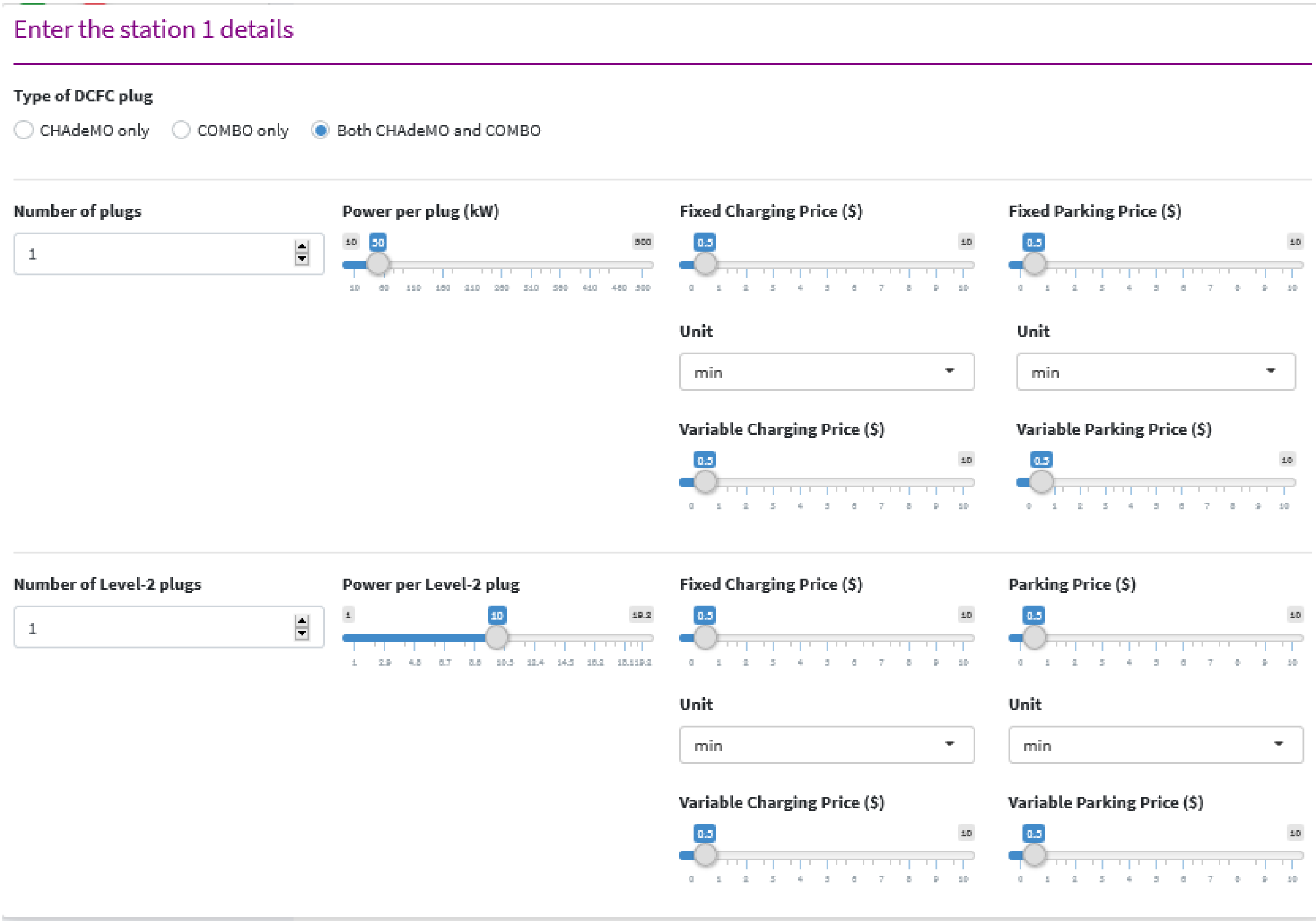
ChargEVal Web Tool

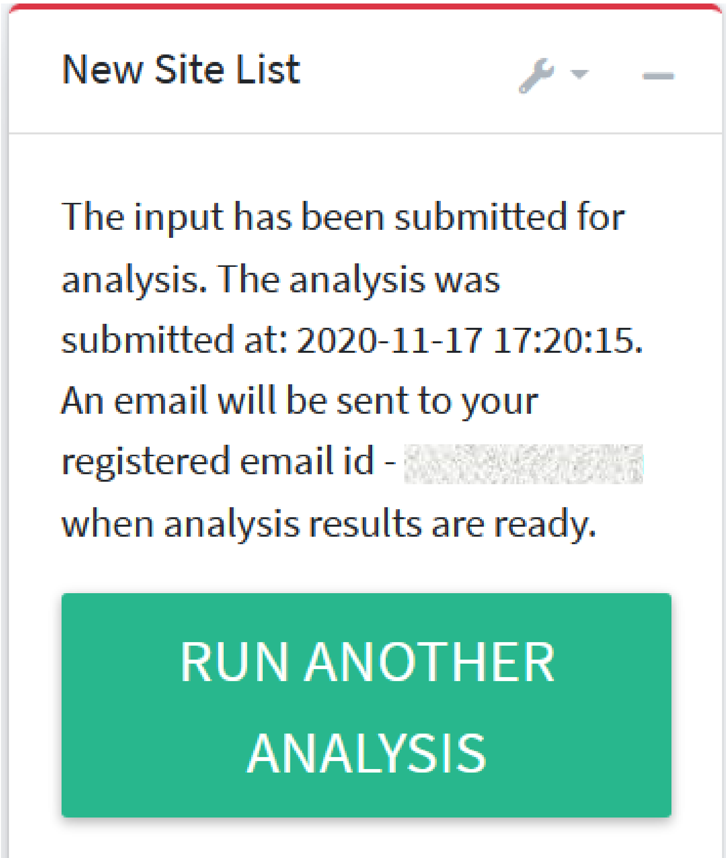
EV infrastructure designer allows user to specify locations of new charging stations by clicking on the map



User can specify the characteristics of each station



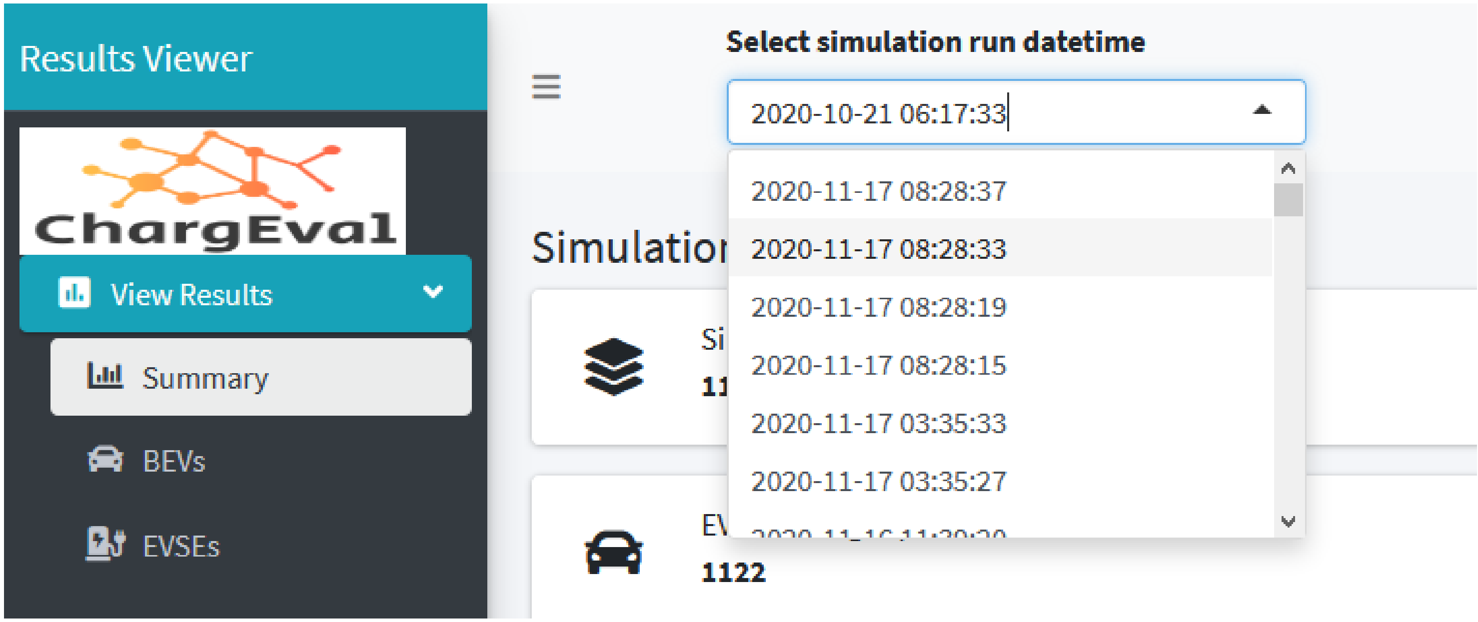
User submits scenario for analysis



- Message on submission shows the submission time.
- Further analysis can be submitted, and will be queued and executed in order*.

* While the analysis processing is in order, the trip generation and agent-based modeling processes run in dedicated Amazon EC2 instances, and therefore run in parallel.

Once notified that results are ready, user can use Results Viewer



Results viewer contains a simulation overview

Simulation Summary

Simulated | Total EVs
1136 | 40667

Built | New EVSEs
134 | 0

CHAdeMO | COMBO Plug Count
295 | 252

EVs finishing trip
1122

EVs stranded
14

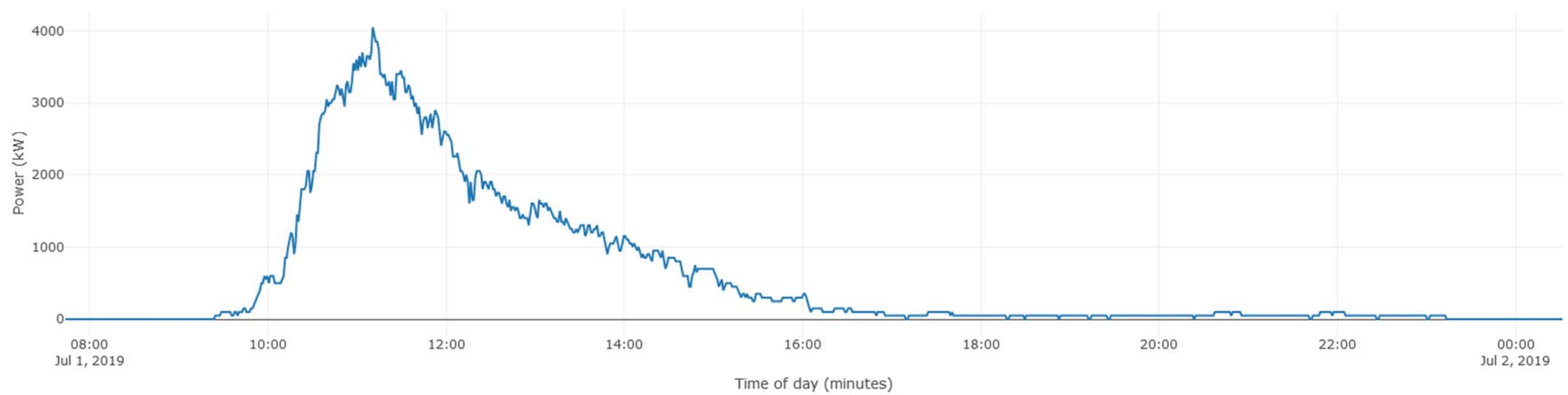
eVMT
127070

Number of charging sessions
785

Number of EVs waiting
431

EVSE Utilization | Wait Time | Charge Time

Plots



Individual EVs can be selected to view origin, destination, simulated trajectory. Stranded EVs can also be identified

List of EVs

Column visibility   Search:

	origin_zip	destination_zip	soc	trip_start_time
	All	All	.	All
1	98253	98005	100	2019-07-01 11:19:55
2	99124	98032	95	2019-07-01 08:56:49
3	98133	98383	100	2019-07-01 14:20:53
4	98006	98664	91	2019-07-01 10:41:32

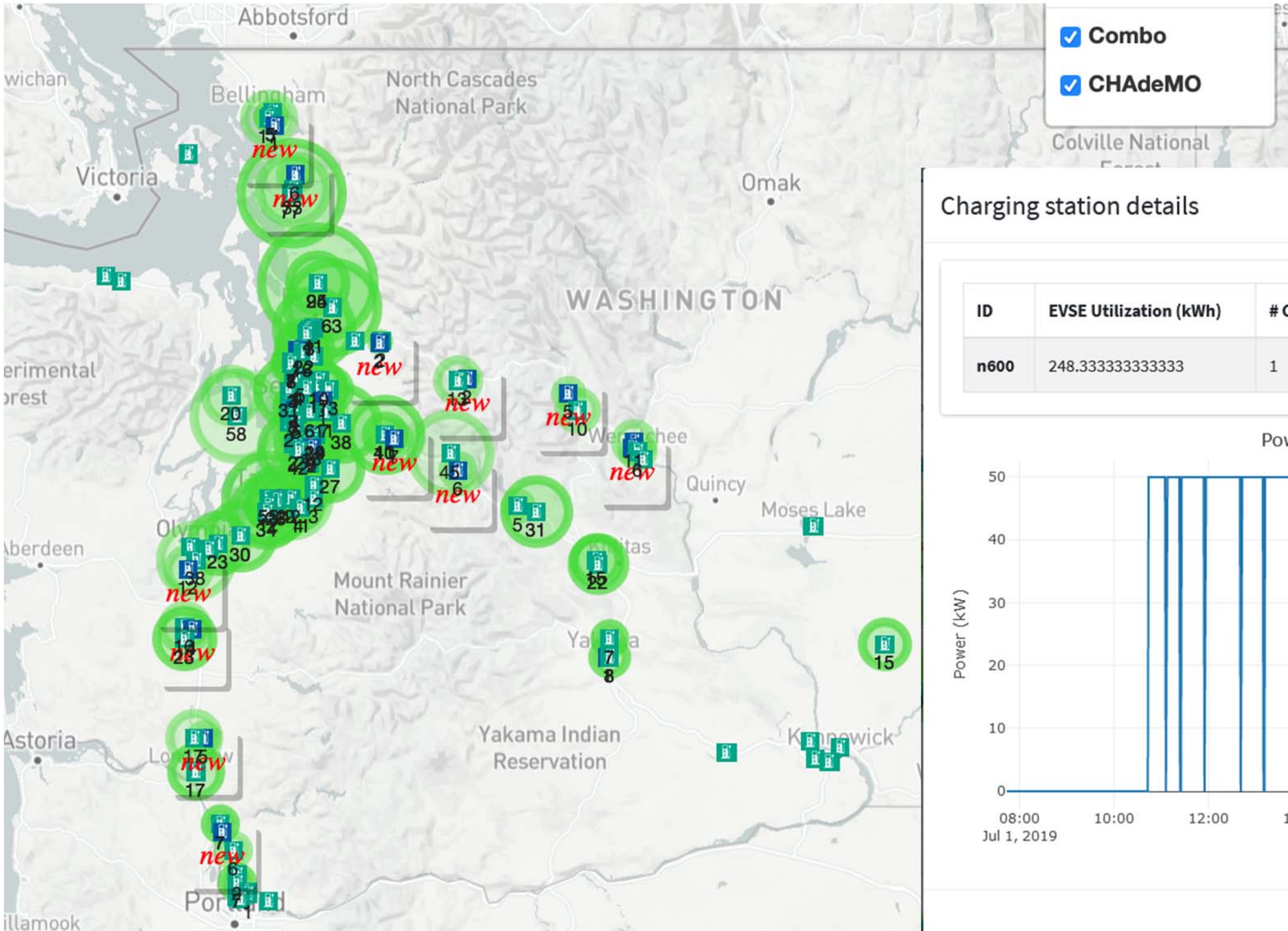
EV trajectory

EV Trajectory Info

Column visibility   Show 100 entries   Search:

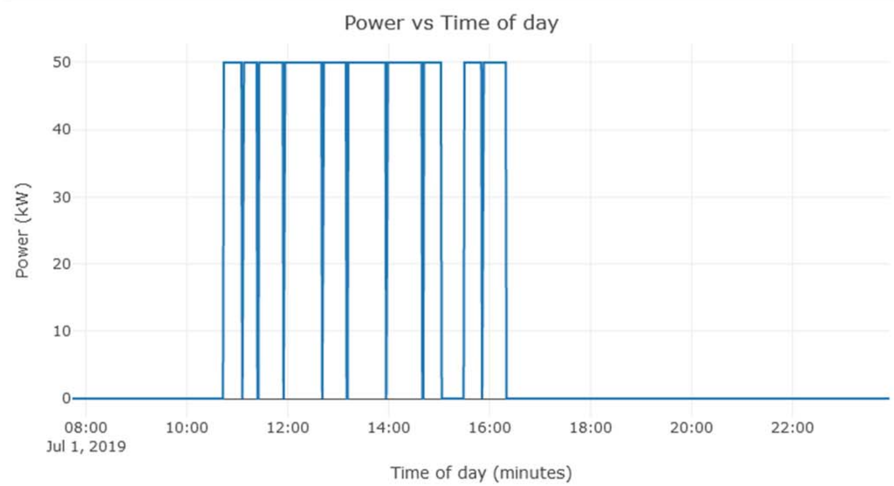
	simulation_ts	veh_id	lat_val	lng_val	soc_val	prob_val	state_val	tocharge_val	speed_val	nearest_evse_id	
	All	All	All	All	All	All	All	All	All	All	All
901	2019-07-01 15:00:00	151800911	48.0778	-119.8488	-0	0	done	false	15.2	charging_station(98)	[charging_station(63),charging_station(105),charging_station(101),cl
902	2019-07-01 15:01:00	151800911	48.0778	-119.8488	-0	0	done	false	15.2	charging_station(98)	[charging_station(63),charging_station(105),charging_station(101),cl
903	2019-07-01 15:02:00	151800911	48.0778	-119.8488	-0	0	done	false	15.2	charging_station(98)	[charging_station(63),charging_station(105),charging_station(101),cl
904	2019-07-01 15:03:00	151800911	48.0778	-119.8488	-0	0	done	false	15.2	charging_station(98)	[charging_station(63),charging_station(105),charging_station(101),cl
905	2019-07-01 15:04:00	151800911	48.0778	-119.8488	-0	0	done	false	15.2	charging_station(98)	[charging_station(63),charging_station(105),charging_station(101),cl

Charging demand profile is simulated for each station



Charging station details

ID	EVSE Utilization (kWh)	# Chademo	# Combo	# EVs Served	# EVs Waited
n600	248.333333333333	1	1	10	8



Dismiss

Concluding Remarks

Potential extensions and refinements

- Extend to other states; inter-state travel
  - Key data need is long-distance travel model or OD matrix
- Improve components models
  - Route choice
  - Vehicle choice
  - Charging choice
- Model effects on EV ownership

An important caveat

- As with any complex simulation tool, ChargEVal is better used for comparison of different alternatives, than for generating point estimates

Next Steps

- We are hosting a hands-on training session on December 16
  - Poll: Are you interested in receiving more information about this training?

  - OR, visit **https://tinyurl.com/ChargEVal-Training to register**

Questions and feedback welcome

- What functionality would you add?

- What limitations appear to you to be most crucial?

Thank you!

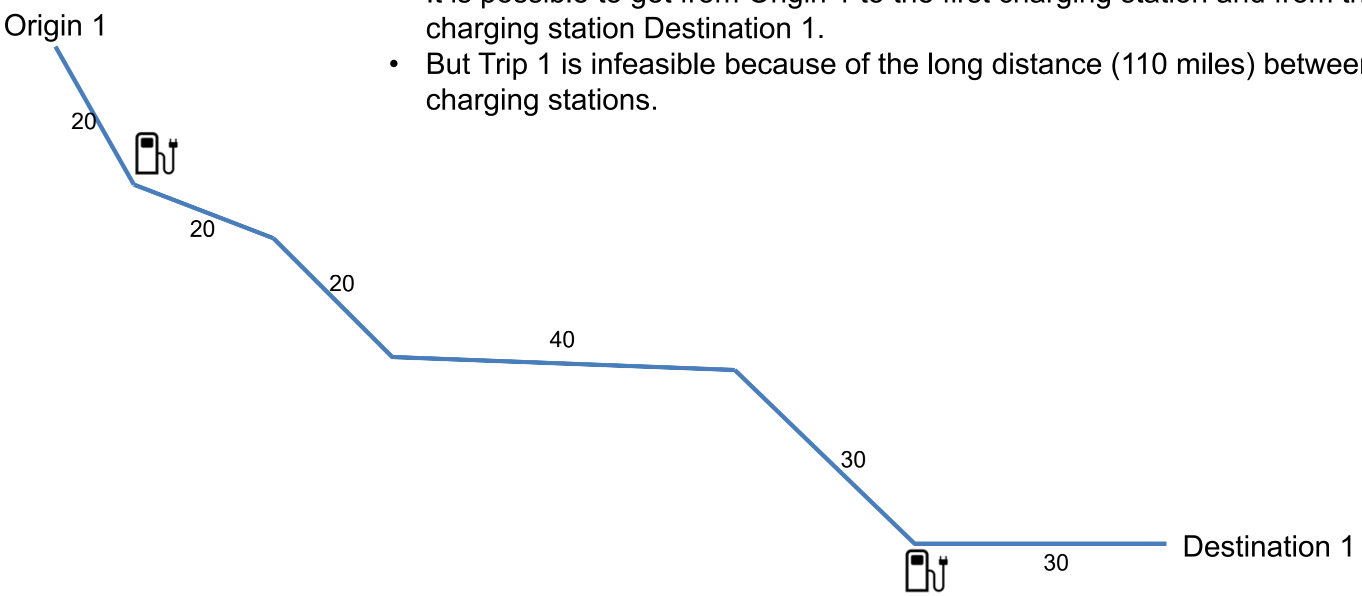
Questions?

Additional Material:
Screening for priority locations

We began with a simple method for determining feasibility of EV travel for all OD pairs in the state

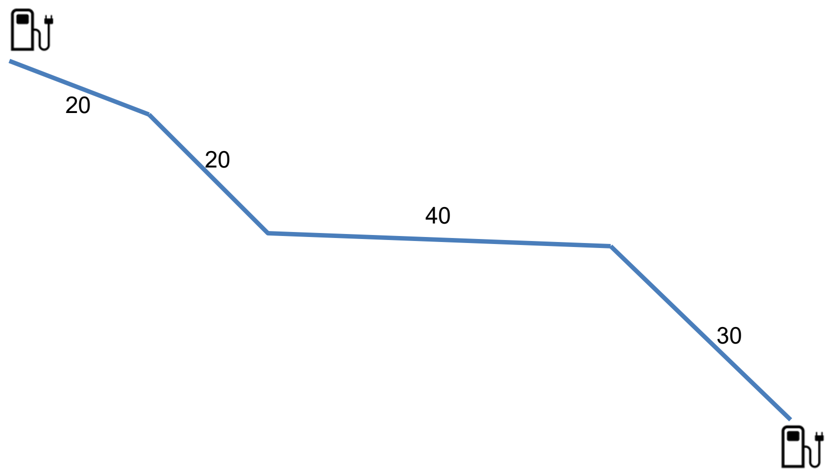
- Calculates shortest path between each OD (ZIP code) pair
- Applies a WSDOT-defined feasibility heuristic of no more than 70 miles between fast-charging stations along that path
- Identifies all infeasible segments along each shortest path
- Overlays all infeasible segments, weighted by travel demand
- Based on all travel, not just EVs

- Trip 1 follows the shortest path from origin 1 to Destination 1.
- It is possible to get from Origin 1 to the first charging station and from the second charging station Destination 1.
- But Trip 1 is infeasible because of the long distance (110 miles) between the two charging stations.

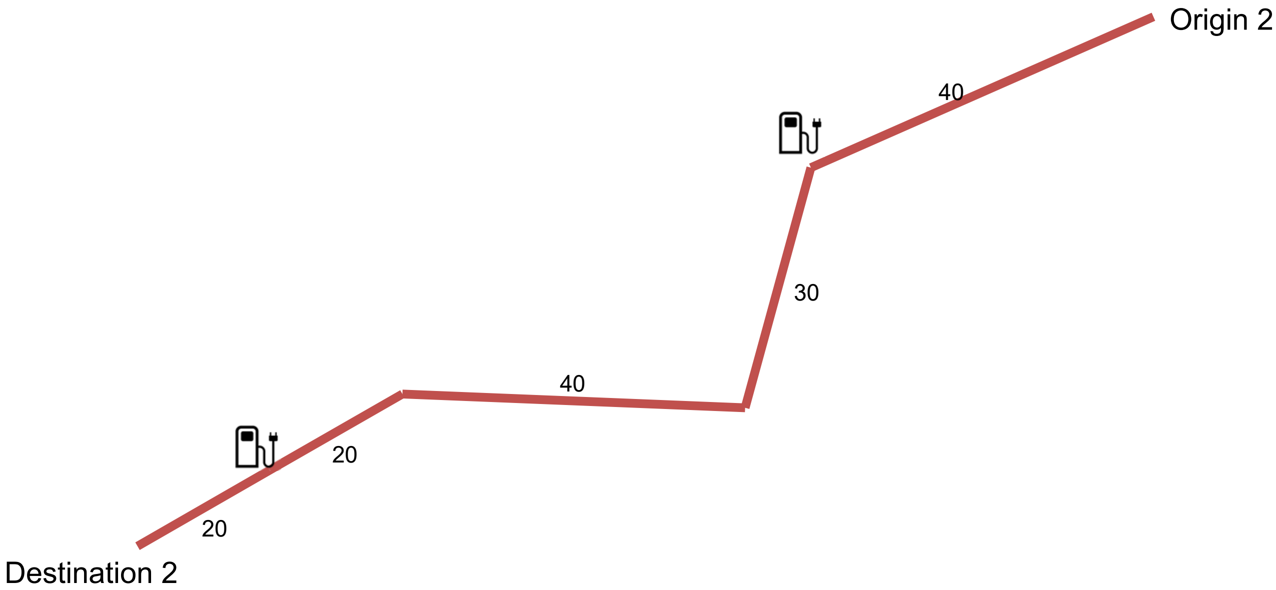


- We refer to the section between the two charging stations as the infeasible segment. This is what we focus on.
- We ignore the feasible segments at either end. They are not what makes Trip 1 infeasible.

Origin 1

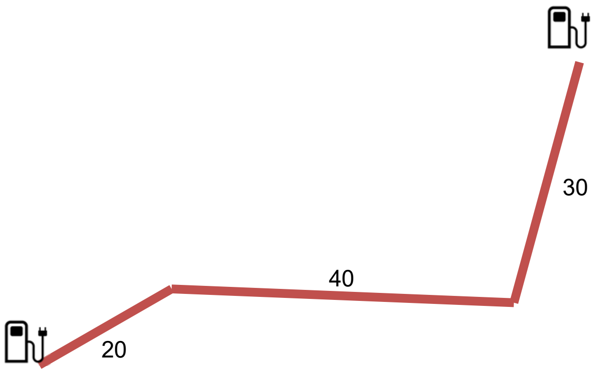


Destination 1



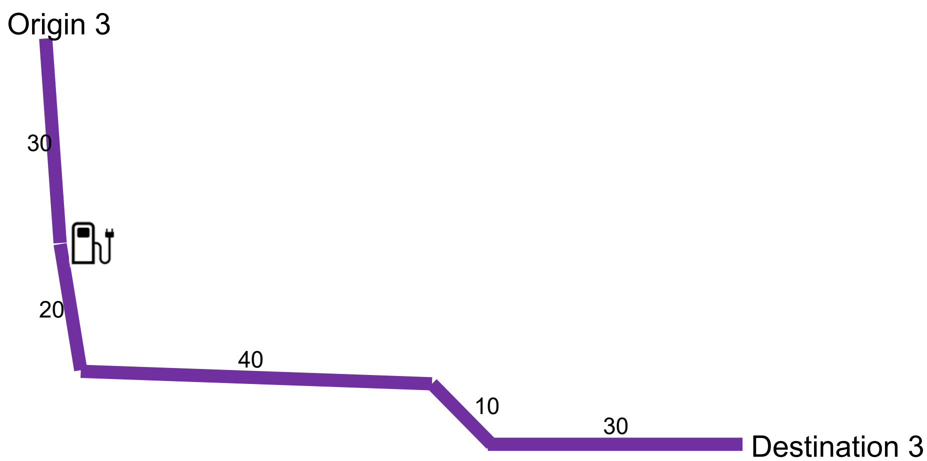
- The thicker lines represent higher demand for travel between Origin 2 and Destination 2
- Like Trip 1, Trip 2 is infeasible because of the long distance between the two charging stations

Origin 2

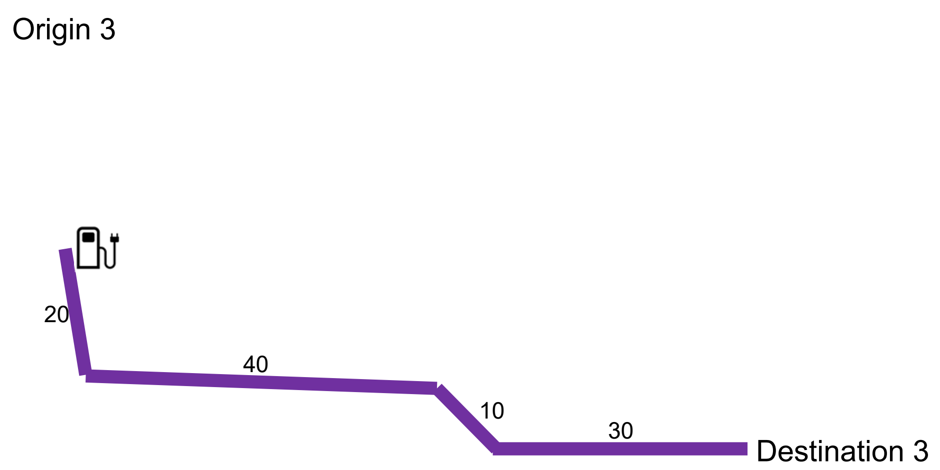


Destination 2

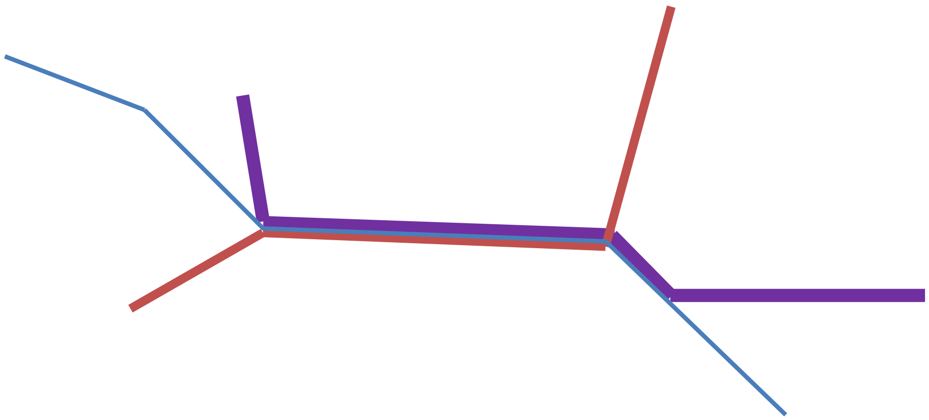
- We again focus on the infeasible segment, and ignore the feasible segments that are already adequately served



- Trip 3 is infeasible because of the long distance between the charging station and the destination

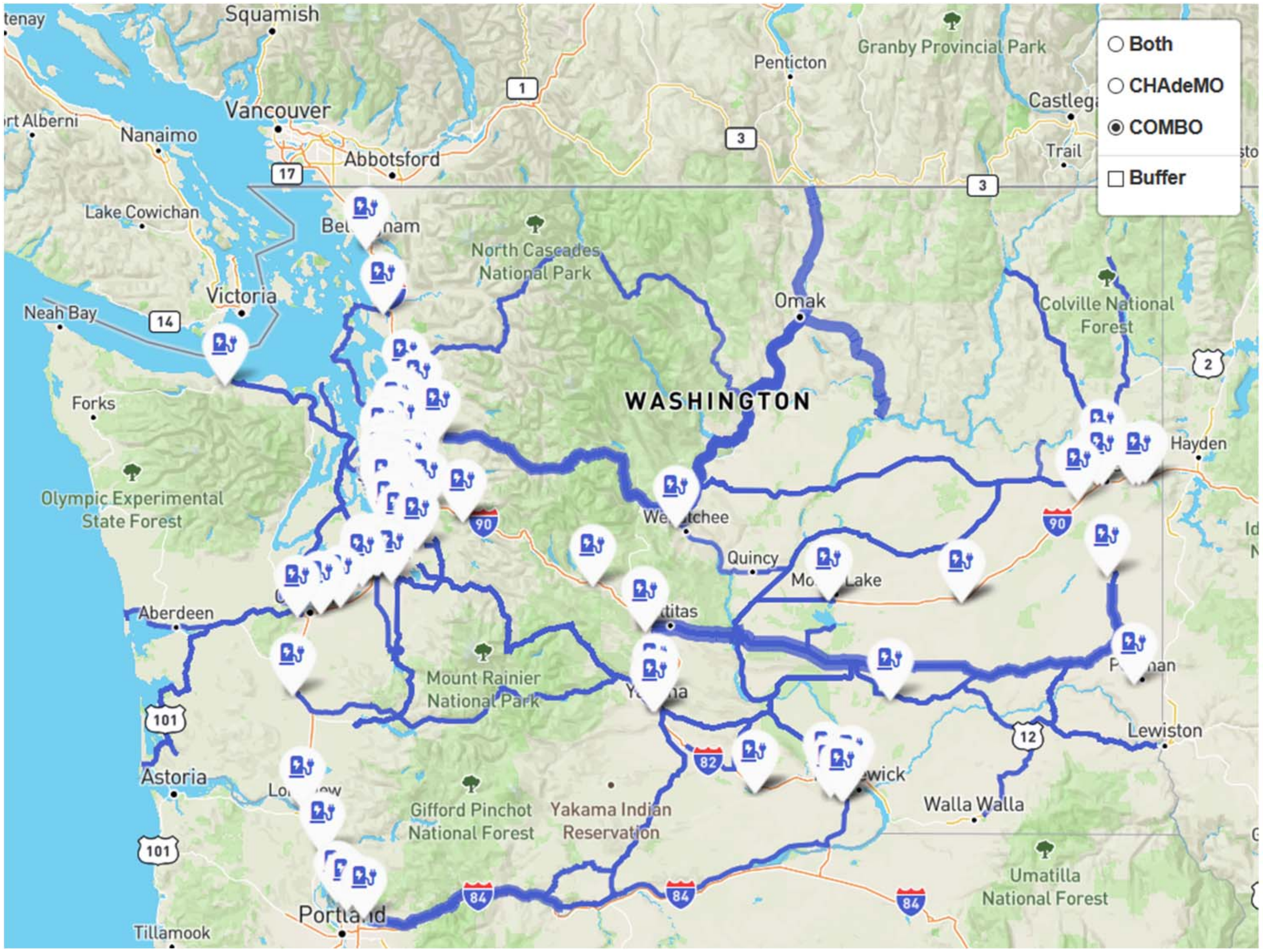


- We again focus on the infeasible segment, and ignore the feasible segments that are already adequately served



- We overlay all of the infeasible segments, based on all O-D pairs (ZIP codes) in the state
- The “potential demand” on each highway link is the sum of the demands on each infeasible segment using that link

Washington infeasibility map for SAE Combo charging



Washington infeasibility map for CHAdeMO charging