MI Energy
Michigan Agency for Energy
Michigan Energy Office

STAKEHOLDER ENGAGEMENT MEETING
Electric Vehicle Charger Placement Optimization in Michigan

March 14, 2018
1 – 3 PM

Agenda

- Welcome
- Introductions (Michigan Energy Office)
- MSU Project Team Presentation
- Discussion
- Questions

Introduction

- Michigan Agency for Energy (MAE) planned two grants to support work with MDEQ in VW Settlement.
  - Project 1 (awarded to MSU): Electric Vehicle (EV) Charger Placement Optimization
    - Optimized plan for EV charger placement along Michigan highways
    - Economic development impacts on areas of proposed placement
  - Project 2 (upcoming): Incentives for Accelerated Deployment of Electric Vehicle Charging Infrastructure
    - Review Michigan EV policies to identify barriers and opportunities
    - Identify and recommend incentives accelerating deployment of EV charging infrastructure, especially at locations identified by Project I
    - Examine impact of selected MAE EV charging infrastructure incentives
    - Gap analysis of Project I results

Introduction: Tentative Timeline

Feb. 2018	• Project 1 Kick-Off
March 2018	• Project 1 Stakeholder Mtg
April 2018	• Project 1 Interim results for optimized placement • Stakeholder Mtg
May 2018	• Project 2 Kick-Off • Stakeholder Mtg
June 2018	• Project 2 results (Michigan EV policies & recommended incentives) • Stakeholder Mtg
July-Aug. 2018	• Announce Light Duty Emission Vehicle Supply Equip (EVSE) Prog • Stakeholder Mtg
Aug.-Sept. 2018	• Roll-out EVSE Project and Post RFP

Introduction: Tentative Timeline, cont.

Sept. 2018	• Project 1 Results • Stakeholder Mtg
Sept. 2018	• EVC Infrastructure Mtg at NASEO Annual Conference in Detroit
Oct 2018-Sept 2019	• EVSE/Project 2 Stakeholder Mtg
Sept. 2019	• Project 2 Results

Introduction: Meeting Impetus

- EV Charger Placement Optimization Project
  - Principal Investigators:
    - Mehrnaz Ghamami — Civil and Environmental Engineering
    - Ali Zockaie — Civil and Environmental Engineering
    - Steven Miller — Economics

- Stakeholder input to determine optimization model use cases and variables for project team to examine, such as:
  - Network to model
  - Input variables and their values

- Stakeholder input will shape the final optimized placement plan informing MAE EV charging infrastructure investments.

Electric Vehicle Charger Placement Optimization Project

Dr. Mehrnaz Ghamami
Dr. Ali Zockaie
Dr. Steven Miller

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March 14, 2017

This study is commissioned and funded by the

Michigan Energy Office.

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Introduction

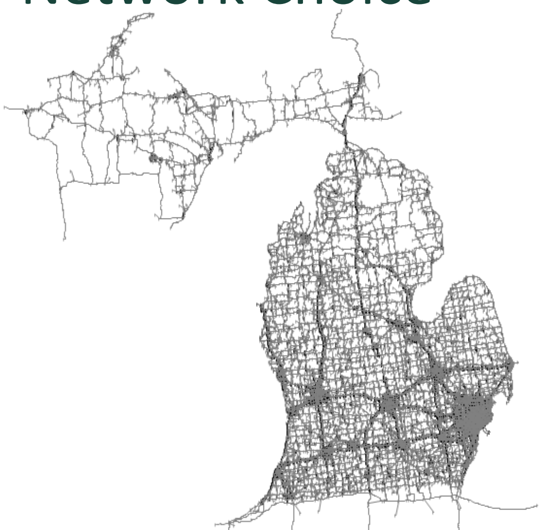
- In 2016, transportation was responsible for 29% of the total energy used in US.
- EV is a potential solution to decrease fuel consumption and emissions.
- Problems associated with EV:
  - Higher purchase cost compared to conventional vehicles
  - Lack of enabling infrastructure
- Recent studies have shown infrastructure availability is key to increase market share of electric vehicles, specifically for intercity trips.

Problem Statement

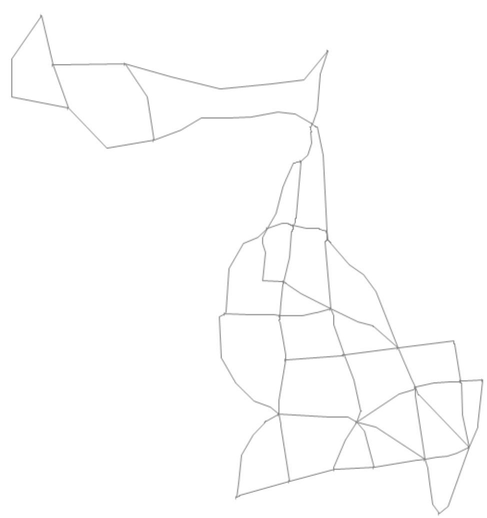
- Find the optimal infrastructure investment to support electric vehicle travel:
    - **Where** to deploy charging stations?
    - **How many** charging outlets must be built at each station?

- Main scenarios for charging station placement:
    - Emissions Reduction
    - Vehicle Traffic (i.e. Passenger, fleet vehicles, etc.)
    - Tourism

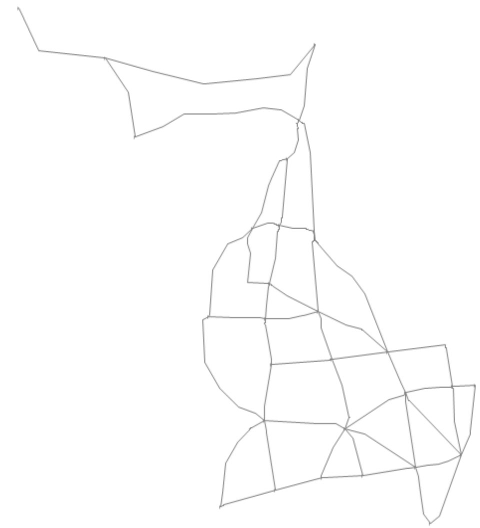
Network Choice



(a) Original Michigan road network from MDOT



(b) Intercity network with detailed UP

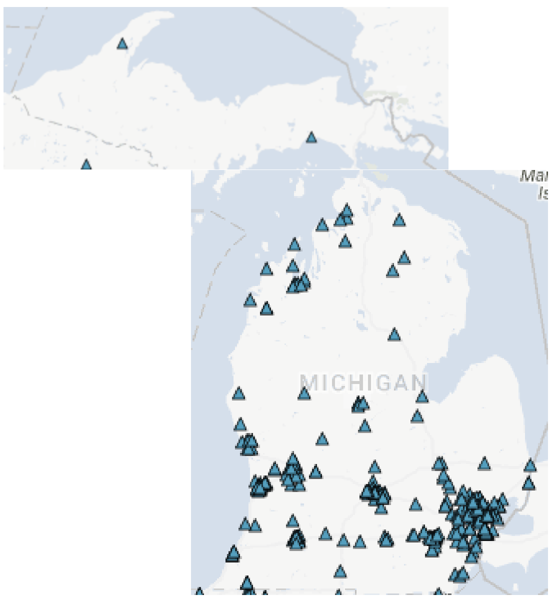


(c) Intercity network with simplified UP

- Original road network simplified to represent travel between cities.
  - Cities selected by population and spatial distribution.
  - Simplified model created by assigning demand from detailed state model to nearest city.
- Detailed UP network: Focuses on highways, contains six cities
- Simplified UP network: Focuses on population only, contains four cities

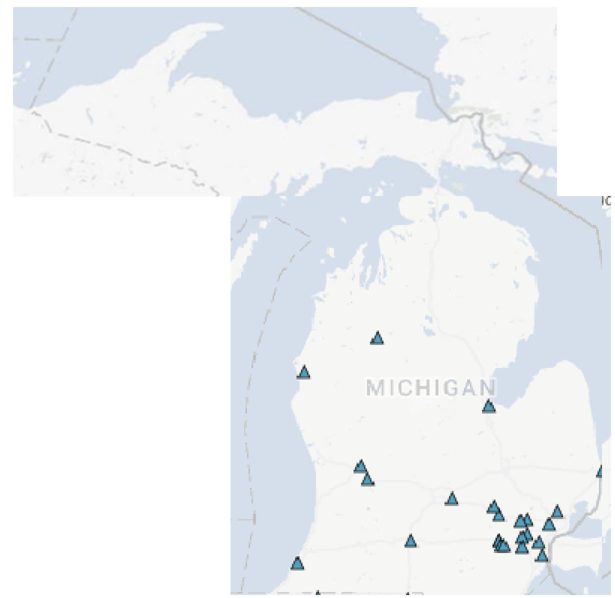
Existing Charging Network (Excludes Private Stations)

Current location of charging stations
Level 2



- 328 electric stations
- 782 charging outlets in Michigan
- (10 planned outlets in 6 stations)

Current location of charging stations
Level 3 (DC fast)



- 24 electric stations
- 92 charging outlets in Michigan

Source: https://www.afdc.energy.gov/locator/stations/

Project Data Requirements

- Current charging infrastructure locations (Alternative Fuel Data Center)
- Michigan road network (MDOT)
- Intercity travel demand (MDOT)
- Intercity bus and truck travel data
  - *Consult with MDOT*
- The data on variability of tourism travel demand
  - *Consult with MDOT*
  - *Analyze seasonal loop detectors travel data*
- Performance functions for Michigan highways relating link travel time to link flow
  - *Consult with MDOT*

Project Data Requirements, cont.

- Grid specification data
  - *Consult with utility companies*
- Socio-demographics of each candidate point for charging station
  - *Consult with online sources, local agencies and site visits*
- Emissions data
  - *Consult with state agencies*
  - *Calculating via emission estimation tools*

Model Formulation

1- Objective function

   1.1 – Current model assumptions

2- Detour time calculation

3- User equilibrium

4- Flow conservation

5- Tracking state of fuel and feasibility

6- Refueling and waiting time in stations

7- Feasibility

1- Objective Function

Charging stations cost · Value of time · Detour time

- $\min \sum_{m\in M}\sum_{i\in N'^{m}_{2}}\left(C^{m}_{Pi}x^{m}_{i} + z^{m}_{i}C^{m}_{si}\right) + \gamma_t\left(\sum_{i\in N'^{m}_{1}\cup N'^{m}_{2}}\pi_i + TT_d\right)$

Charging spots cost · Waiting time and charging time

- The objective function aims to minimize the investment cost (charger, grid, construction, land, etc.) and also the users' travel time (refueling, waiting and detour time) cost.

- Decision variables:
  - x_i^m: Availability of charging **station** at location *i* for vehicle in class m
  - z_i^m: Number of charging **spots** in location *i* for vehicle in class m

1.1 Current Model Assumptions

- Vehicles start their trip with fully charged batteries.
- Vehicles are fully charged after using a charging station.
- No charging for conventional vehicles.
- For any market share, we assume that users are uniformly distributed among all origin-destination pairs.
- The network is simplified to consider major roads that connects cities with population more than 50,000.
- Value of time is 18 $/hr, but we can differentiate between in vehicle travel time and waiting in queue time

2- Detour Time Calculation

- The traffic assignment (user equilibrium) problem is solved **for the proposed set of charging stations** to calculate the travel times (exclude refueling time).
- Then, the assignment problem is solved for a large enough set of charging stations where **no vehicle deviates from its path for refueling purposes**.
- The difference will provide us the **total detour time**.

3- User Equilibrium

- The travel time along each route consists of two terms:
  - **delay** at charging stations
  - travel time along the **links** of each route

- **UE Definition**: users behave selfishly to minimize their own travel time. Therefore, if a route has a higher travel cost relative to the **minimum feasible route**, it would not be selected by any traveler.
- It should be noted that due to congestion on links and charging stations travelers can not choose their route independently.
- The route with **minimum cost** is selected for each origin-destination. If the cost associated with a route is not minimum, its flow would be **zero** and nobody will choose that route.

4- Flow Conservation

- Flow conservation ensures that the total demand for each OD-pair and vehicle class is assigned to a set of feasible routes.
- The total **demand for a station** is found by summing up the **incoming flows** over all routes crossing one station.
- By summing up the flow of all routes that are crossing a certain link, the **link flows** are found.
- The **travel time** on the links would be known based on the **link flows**.

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5- Tracking State of Fuel and Feasibility

- The model **differentiates** between passing by a station **without using it for refueling** and the case that an EV **actually uses** a charging station for refueling.
- When an electric vehicle uses a charging station, it gets charged to its **maximum capacity**.
- The fuel consumption for traveling each link changes based on the **class** of vehicle and the **congestion** on the links.
- If the state of fuel for a class of EVs becomes **negative** along a route, this route is **infeasible** and will have **no flow** from that class of EVs.
- Track SOF: The SOF is represented by a variable, which is decreased from one node to another node based on the link's consumption rate, and is increased once a charging station is used.

6- Refueling and Waiting Time in Stations

- Total **energy demand** at each stations is calculated by tracking the state of fuel of each vehicle using that station and the fact that they will fully charge their battery before leaving the station.
- The total required energy for each station will be calculated using the above factors.
- Based on the **capacity** of charging stations in terms of the **power** and **number of spots**, the refueling time and the average waiting time for an available charger can be calculated.

Project Output

- **Optimum locations** for charging stations along highways with:
  - Analysis of different scenarios based on emissions, demand patterns, certain vehicle classes and market share.
  - Estimated demand and average waiting time for recharging.

- The potential **economic development impacts** in the area from charging station implementation with:
  - Information about the socio-demographics of selected locations.
  - Comparison of proposed charging stations with similar new developments.
  - Recommendations on appropriate developments types for building and installing charging stations.

Project Output, cont.

- Expected energy consumption and greenhouse gas **reductions** considering vehicle and fuel production emissions in the determined optimum location map.

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Questions about Assumed Variables

- Different types of electric vehicles
  - *Currently assuming 40 and 150 kWh.*
  - *What battery sizes should we consider?*
- Types and cost of EV chargers in the market
  - *Currently assuming fixed costs.*
  - *Any suggestion on how can we acquire such costs?*
- Existing electrical grid infrastructure along network
  - *Any suggestion on how to obtain and include this information?*
- Origin-destination travel demand
  - *Currently based on 2012 data.*
  - *Is there any newer data or its seasonal variation?*

Questions about Assumed Variables, cont.

- Maximum distance from any point to nearest candidate charging station
  - Currently set to 25 miles.
  - *Any preference? Should 50 miles be considered?*
- Network aggregation for computational efficiency
  - *Any suggestions or comments on the examined network?*
- What other parameters should be considered in making EV charging infrastructure investments?
  - (i.e. Power supply, EV charger, battery, etc.)
- Are there any additional variables that should be considered?

Thank you!

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