Electrification of the Freight System in Minnesota: Barriers, Opportunities, and a Multicriteria Planning Tool

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PART 1: Barriers and Opportunities in Adoption of Electric Trucks

PART 2: A Multi-criteria Decision Analysis Tool for Charging Station Locations Planning
Part 1
Barriers and Opportunities in Adoption of Electric Trucks
**BARRIERS TO ELECTRIC TRUCKS ADOPTION**

1. **Technical Performance**
   - Infrastructure
   - Driving Range
   - Charging Time
   - Battery Cost and Life Cycle

2. **Operational Performance**
   - Charging Pattern (overnight vs. *en route*)
   - Loading Capacity
   - Repair Facilities and Technicians

3. **Economics Barriers**
   - Initial purchase cost
   - Battery replacement cost
   - Independent operators and small businesses may not afford it

4. **Utility Perspective**
   - Grid Capacity
   - Upgrading Cost
   - Business Model Uncertainty
Electric Trucks’ Benefits and Opportunities

1. Economic Benefits

- At current battery price ($135/kWh), class 8 operating 300 miles/day:
  - 13% lower ownership cost than diesel trucks ($1.51 vs $1.73 per mile)
    ➔ Initial cost payback in 3.2 years
    ➔ $200,000 saving in 15 years
- At 2030 battery price ($60/hWh):
  - 40% lower ownership cost

Why regional and long-haul trucks are primed for electrification now. Lawrence Berkeley National Lab.(LBNL), 2021.
2. **Environmental Benefits**
   - GHG reduction is another $0.29 saving per mile
   - Lower GHG emissions improves the health and livability of communities

3. **Operational Benefits**
   - Energy regeneration and better maneuverability in traffic congestion
   - Taking more direct routes through urban areas (better routing, time/mileage saving)
   - Potential operation in low-emission zones in urban areas
   - Extended operation time window in urban areas due to less noise

4. **Opportunities for Policies and Incentives**
   - Financial support: purchase cost incentives, energy incentives
   - Promotional policies: routing, low-emission zoning, extended operation time windows
Part 2
A Multi-criteria Decision Analysis Tool For Charging Station Locations Planning
OBJECTIVE

1. Identify the corridors of Minnesota highway network where public charging stations are most needed

2. Optimize the location and type of e-truck charging stations on Minnesota highway network
CRITERIA STRUCTURE

- Access for e-truck users
  - Truck volume (HVAADT)
- Environmental conditions
  - Land cover
  - Distance to water resources
  - Flood risk
- Proximity to other facilities
  - Proximity to gas stations
  - Proximity to truck stations
  - Proximity to DC fast charging stations
- Power supply
  - Grid network
  - Solar energy
- Land use
  - Land price
  - Land ownership

Environmental conditions:
- Proximity to DC fast charging stations
- Flood risk
- Distance to water resources
- Proximity to truck stations
- Proximity to gas stations

Proximity to other facilities:
- Proximity to DC fast charging stations
- Flood risk
- Distance to water resources
- Proximity to truck stations
- Proximity to gas stations
EXPERT SURVEY

- Objective: to estimate criteria weights based on expert knowledge
- Method: pairwise comparison of the criteria
- Recipients: experts and stakeholder (MnDOT, ATRI, FMRI, ATA, HDR, etc.)
- Responses: 16 responses with 11 meeting the consistency conditions
CRITERIA WEIGHTS (SURVEY RESULTS)

Criteria

Access for e-truck users

- Truck volume (HVAADT) 0.36
- Land cover 0.02
- Distance to water resources 0.03
- Flood risk 0.06

Environmental conditions

- Proximity to gas stations 0.05

Proximity to other facilities

- Proximity to truck stations 0.16
- Proximity to DC fast charging stations 0.03

Power supply

- Grid network 0.20
- Solar energy 0.03

Land use

- Land price 0.04
- Land ownership 0.02

Proximity to other facilities

- Environmental conditions 0.11
- Power supply 0.23
- Land use 0.06

Environmental conditions

- Proximity to DC fast charging stations 0.03

Proximity to other facilities

- Truck volume (HVAADT) 0.36
- Land cover 0.02
- Distance to water resources 0.03
- Flood risk 0.06

Power supply

- Grid network 0.20
- Solar energy 0.03

Land use

- Land price 0.04
- Land ownership 0.02

Proximity to other facilities

- Environmental conditions 0.11
- Power supply 0.23
- Land use 0.06

Environmental conditions

- Proximity to gas stations 0.05

Proximity to other facilities

- Environmental conditions 0.11
- Power supply 0.23
- Land use 0.06

Environmental conditions

- Proximity to gas stations 0.05
GIS Analysis of the Criteria (Sample)

Truck Traffic Volume

Truck Stations

Power Substations
# Power Supply Analysis

## Proximity to electrical substations (50%)

<table>
<thead>
<tr>
<th>Proximity to electrical substations</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5 miles to Interstate/Freeway (Functional Class 1 &amp; 2)</td>
<td>10</td>
</tr>
<tr>
<td>0.5 - 1 mile to Interstate/Freeway (Functional Class 1 &amp; 2)</td>
<td>9</td>
</tr>
<tr>
<td>&lt; 0.5 miles to Remaining US Highways/Trunk Highways (not an interstate/freeway) (Functional Class 3)</td>
<td>8</td>
</tr>
<tr>
<td>0.5 - 1 mile to Remaining US Highways/Trunk Highways (not an interstate/freeway) (Functional Class 3)</td>
<td>7</td>
</tr>
<tr>
<td>&lt; 0.5 miles to Other Principal Arterial (Functional Class 4)</td>
<td>4</td>
</tr>
<tr>
<td>0.5 - 1 mile to Other Principal Arterials (Functional Class 4)</td>
<td>3</td>
</tr>
</tbody>
</table>

## Capacity of electrical substations (30%)

<table>
<thead>
<tr>
<th>Power capacity of electrical substations</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest Voltage 115kV (20+ MW Power Capacity)</td>
<td>10</td>
</tr>
<tr>
<td>Lowest Voltage 69kV (10+ MW Power Capacity)</td>
<td>7</td>
</tr>
</tbody>
</table>

## Power reliability (20%)

<table>
<thead>
<tr>
<th>Power reliability</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>3+ substations within a 5-mile buffer</td>
<td>10</td>
</tr>
<tr>
<td>2 substations within a 5-mile buffer</td>
<td>7</td>
</tr>
<tr>
<td>1 substation within a 5-mile buffer</td>
<td>3</td>
</tr>
<tr>
<td>0 substations within a 5-mile buffer</td>
<td>1</td>
</tr>
</tbody>
</table>
POWER SUPPLY ANALYSIS (CONT.)
GIS Analysis of the Criteria (cont.)

- Bodies of Water
- Solar Radiation
- Flood Risk
- Gas Stations
- DC Chargers
1. The state was divided to pixels of ¼ acre
2. A 0-10 score was calculated for each pixel based on:
   – GIS analysis of the criteria
   – Criteria weights
3. Pixels with score >8 are identified as candidate locations for charging station
TOP CORRIDORS FOR ELECTRIFICATION

- I-35 from Albert Lea to Duluth
- I-94 from Lakeland to Fargo
- I-90 from La Crosse to Luverne
- US 10 from Cottage Grove to Moorhead
- US 169 from Elmore to Grand Rapids
Next Steps

• The identified locations are candidate locations only
• Further analysis is needed to:
  – Remove/merge duplicates
  – Fill gaps in major freight corridors
• An optimization model will be developed considering:
  – Truck origin-destination trips
  – Charging capacity and cost
  – Budget and other constraints
CONCLUSIONS

• Adoption of electric trucks will not be easy at the beginning, proper government policies and incentives are needed

• Among several barriers, we study the planning and optimization of charging stations

• Our approach is general and can be applied to other locations and/or with different sets of criteria
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