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Detroit Subway Line

Annapurni Subramanian
Michelle Zhou
Malcolm Gaynor

Problem Statement

Design Optimal Subway Line for Detroit, MI

- ➔ Station Placement
- ➔ Network Flow

Why does it matter?

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Daily News

Study: Detroit is the Worst Metro Area for Commuters in 2022

Metro Detroit is the worst city in the U.S. for commuters mostly due to the costs of driving in the area, according to a new study by the real estate website listwithclever.com.

By **Tim Keenan** - May 4, 2022

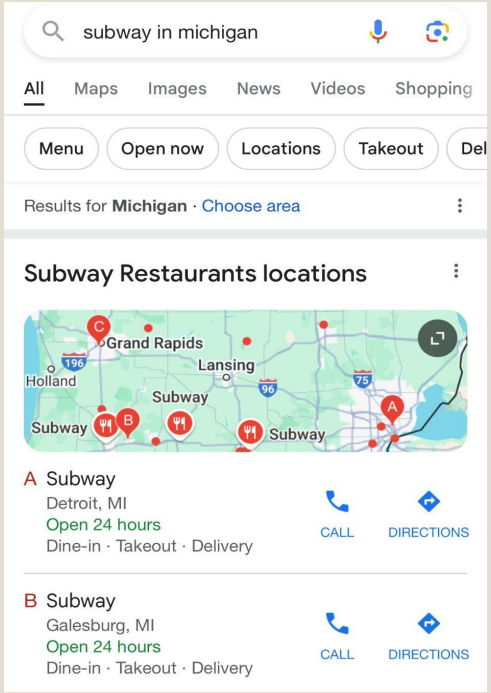
METRO DETROIT

How Detroit ended up with the worst public transit

Off the rails

By Ryan Felton

Mar 11, 2014 at 10:56 am



Data

Station Placement Data

Data Source: Michigan's home & work population data based on geocodes from US Census Bureau

Process to get candidate stations:

- Used geocodes (state + county + block) to filter Detroit data from the entire Michigan dataset
- In total 324 census blocks in Detroit becomes candidate stations
- Get latitude/longitude for each station using shapefiles
- Precalculated distance between each candidate stations

Key Considerations

- Airport, concert venue, university, museums, and football stadium.

Network Flow Data

Algorithm randomly assigns individuals from residential census blocks to work locations.

Future Flexibility:

- Real-world data can replace synthetic assumptions to enhance precision.

Station Placement Formulation

- **Objective:** Minimize the total distance traveled by individuals to ensure efficient commuting and connectivity to high-density population and job centers.
- **Assignment:** Each individual is assigned to their closest home station and work station.
- **Station Selection:** Out of 324 candidate stations, 25 are strategically selected.
- **Key Locations:** Stations are built near key landmarks such as airports, universities, stadiums, and cultural venues.

$$min \quad \sum_{i=1}^{I}\sum_{k=1}^{K} d1_{ik} \cdot a_{ik} + \sum_{j=1}^{J}\sum_{k=1}^{K} d2_{jk} \cdot b_{jk}$$

Subject to:

$$\sum_{k=1}^{K} a_{ik} = p_i, \quad \forall i \in \{1, \ldots, I\} \tag{1}$$

$$\sum_{k=1}^{K} b_{jk} = w_j, \quad \forall j \in \{1, \ldots, J\} \tag{2}$$

$$\sum_{k=1}^{K} c_{mk} = 1, \quad \forall m \in \{1, \ldots, M\} \tag{3}$$

$$a_{ik} \leq M \cdot x_k, \quad \forall i \in \{1, \ldots, I\}, \forall k \in \{1, \ldots, K\} \tag{4}$$

$$b_{jk} \leq M \cdot x_k, \quad \forall j \in \{1, \ldots, J\}, \forall k \in \{1, \ldots, K\} \tag{5}$$

$$c_{mk} \leq M \cdot x_k, \quad \forall m \in \{1, \ldots, M\}, \forall k \in \{1, \ldots, K\} \tag{6}$$

$$\sum_{k=1}^{K} x_k \leq 25 \tag{7}$$

$$\sum_{m=1}^{M} d3_{mk} \cdot c_{mk} \leq 0.02 \tag{8}$$

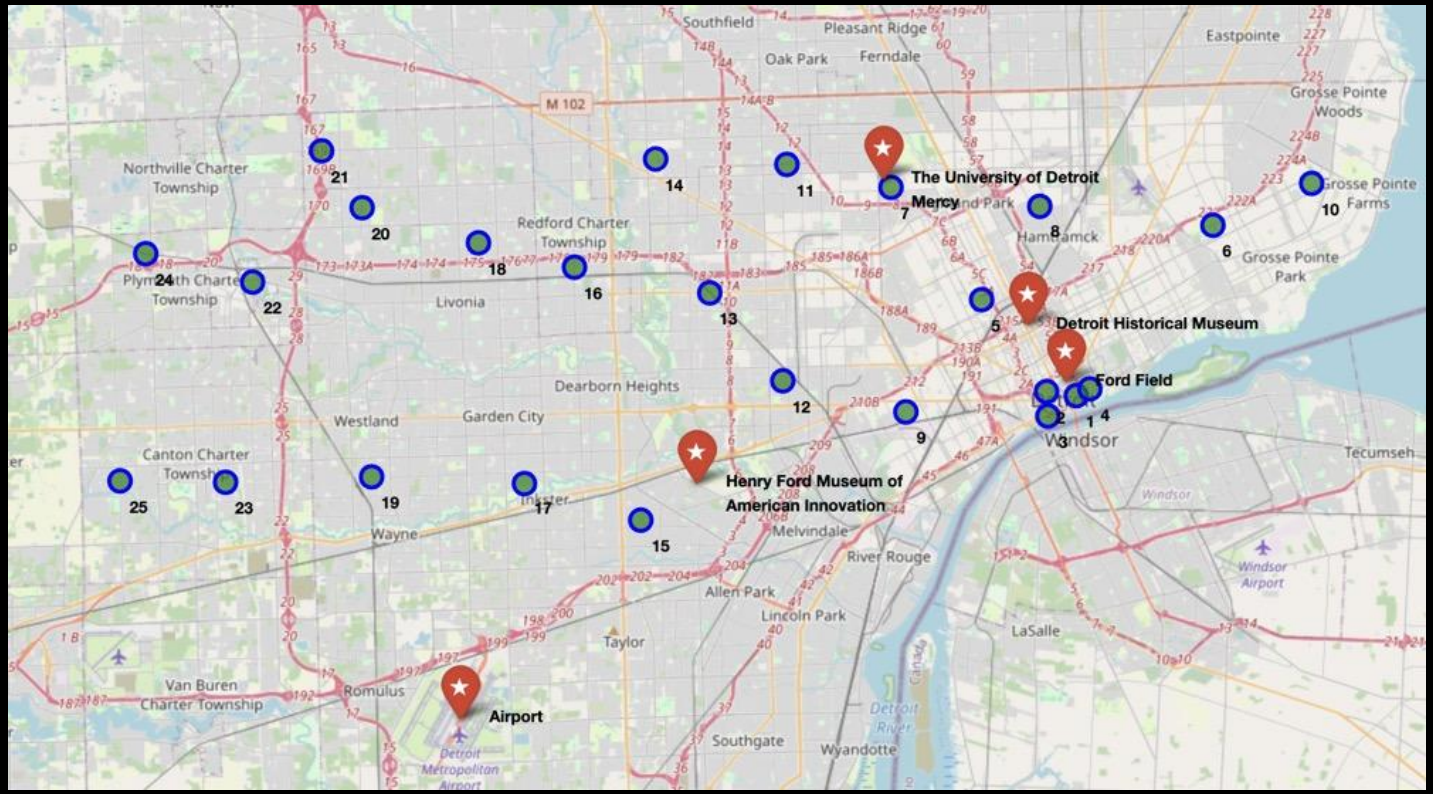
$$a_{ik} \geq 0, \quad \forall i \in \{1, \ldots, I\}, \forall k \in \{1, \ldots, K\} \tag{9}$$

$$b_{jk} \geq 0, \quad \forall j \in \{1, \ldots, J\}, \forall k \in \{1, \ldots, K\} \tag{10}$$

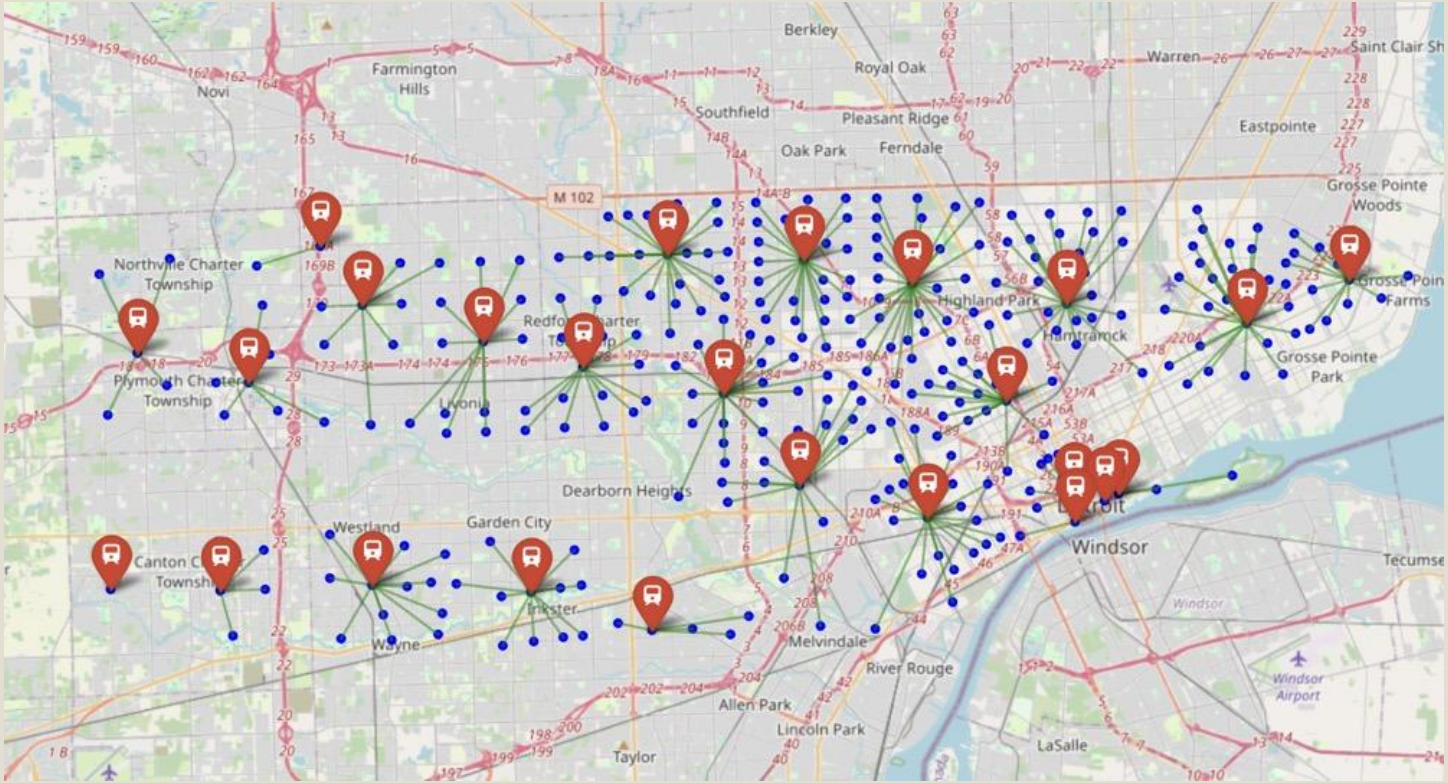
$$x_k \in \{0, 1\}, \quad \forall k \in \{1, \ldots, K\} \tag{11}$$

$$c_{mk} \in \{0, 1\}, \quad \forall m \in \{1, \ldots, M\}, \forall k \in \{1, \ldots, K\} \tag{12}$$

Results & Discussions



Results & Discussions



Network Flow Formulation

- **Objective:** Minimize the total distance traveled by commuters, weighted by the flow of people between stations. This ensures reduced commuting times.
- **Station Connection Limits:** Each station has exactly 2 connections to maintain network simplicity and functionality.
- **Flow Balance:** Total flow into a station equals the total flow out plus the work demand at that station.

$$min \quad \sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{j=1}^{I}\sum_{z=0}^{1} f_{ijlz} \cdot d_{ij}$$

Subject to:

$$x_{ij} = x_{ji}, \quad \forall i, j \in \{1, \ldots, I\} \tag{1}$$

$$\sum_{j=1}^{I} f_{ljl1} = p_l, \quad \forall l \in \{1, \ldots, L\} \tag{2}$$

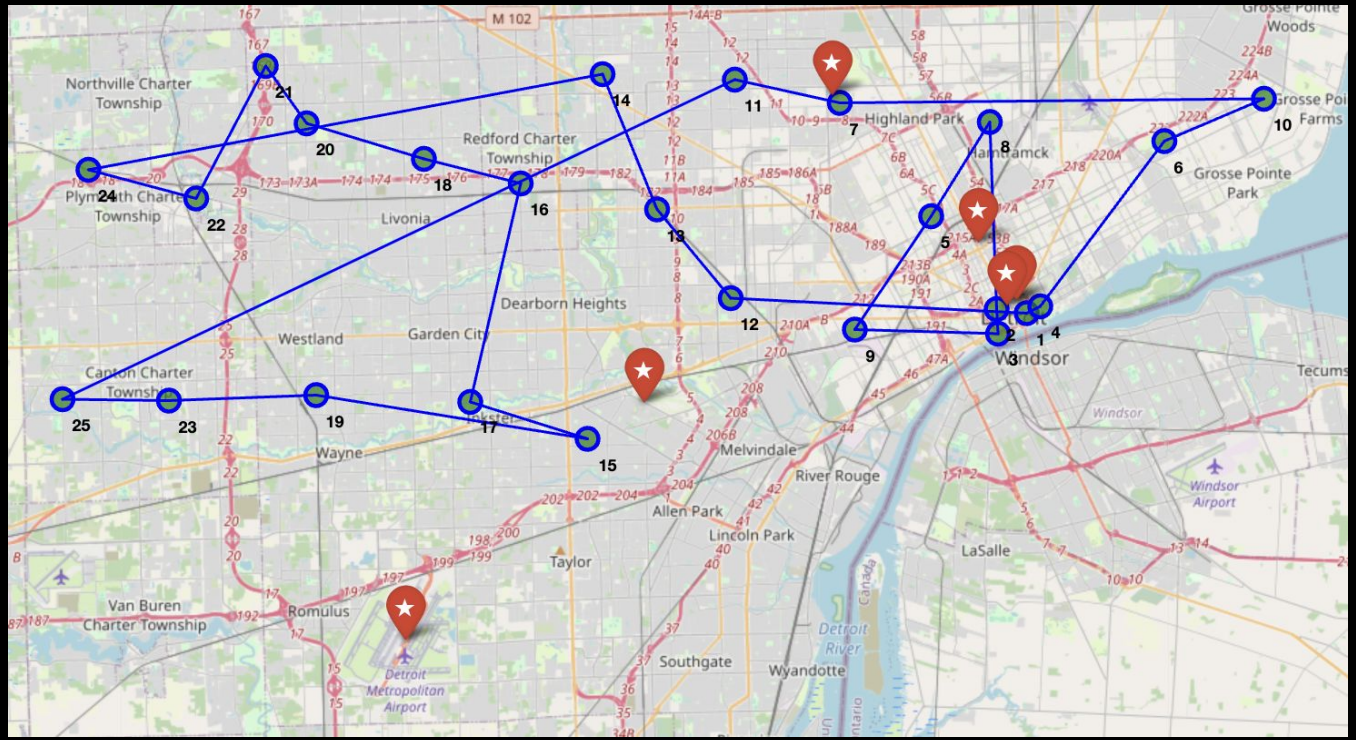
$$\sum_{j=1}^{I} f_{ijl0} \geq b_{lu}, \quad \forall l \in \{1, \ldots, L\}, u \in \{1, \ldots, I\} \tag{3}$$

$$f_{ijlz} \leq M \cdot x_{ij}, \quad \forall i, j \in \{1, \ldots, I\}, l \in \{1, \ldots, L\}, z \in \{0, 1\} \tag{4}$$

$$\sum_{i=1, i \neq j}^{I} x_{ij} = 2, \quad \forall j \in \{1, \ldots, I\} \tag{5}$$

$$\sum_{l=1}^{L}\sum_{i=1, i \neq j}^{I} f_{ijl0} = \sum_{l=1}^{L}\sum_{i=1, i \neq j}^{I} f_{jil1} + \sum_{l=1}^{L} b_{lu}, \quad \forall j \in \{1, \ldots, I\} \tag{6}$$

Results & Discussions

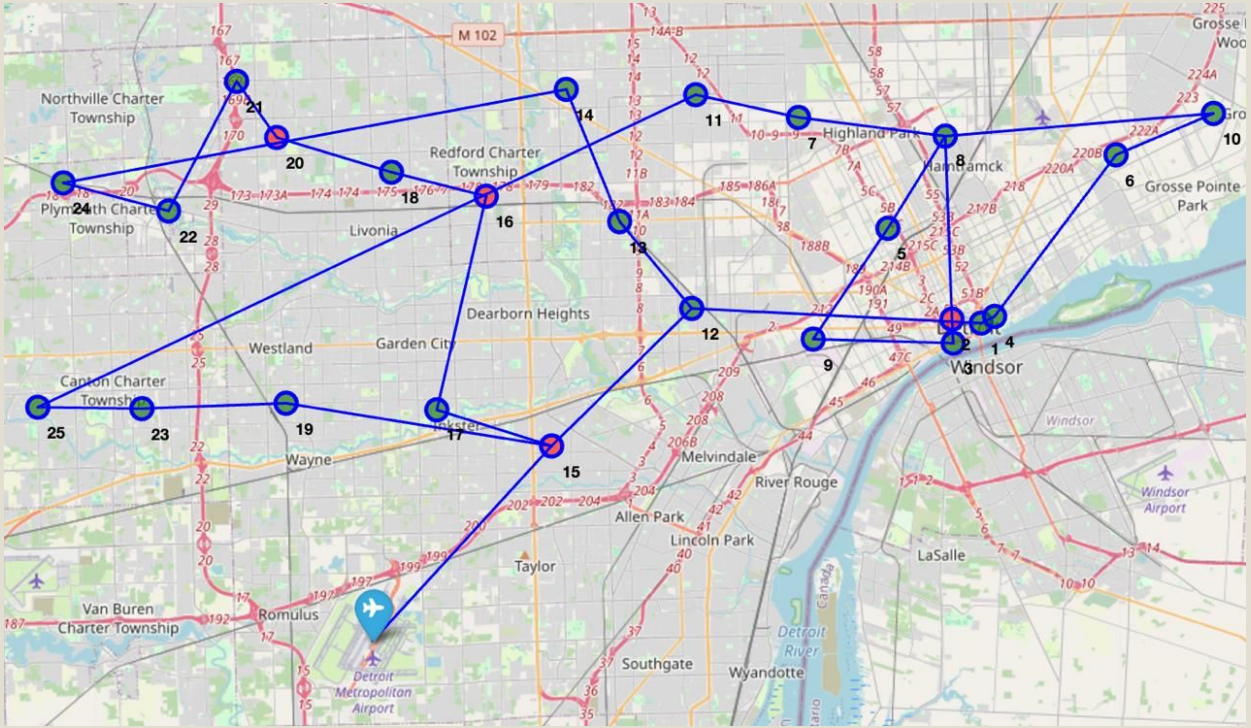


15 to airport as airport express line

15 and 12 for quicker access to downtown

Station 16, 20, 15, and 2 as hub

Results & Discussions



Impact

- Increased commuter convenience
- Decreased travel times and traffic
- Cheap, sustainable transportation
- Attracting people to Detroit (professionals and tourists)

Future Scope

- Replace synthetic data
- Integrating “common sense” additions to the formulation
- Integrate with existing transit systems
- Consider non working population

Questions?


KENDALL
INBOUND
TO ASHMONT & BRAINTREE
VIA PARK & DOWNTOWN CROSSING