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A Graph Theory Approach for Public Transit Connectivity in New York City

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Introduction & Rationale

Transit Deserts in NYC

- The concept of a “transit desert” developed from a study that explored the correlation between transit dependency and transit deserts [4].
- Transit deserts are defined by not having access to rapid transit within 1 mile of one’s residence [3].
- Nearly 29% of New York City households are underserved by transportation services [3].
- Boroughs outside the city’s center center such as Bronx, Brooklyn, and Queens struggle with this the most.

Understanding the Residential Impact

- Transit deserts isolate low-income individuals and communities.
- Prohibits access to job opportunities, healthcare, and food supplies.
- Adequate transportation options must be developed to accommodate these residents.

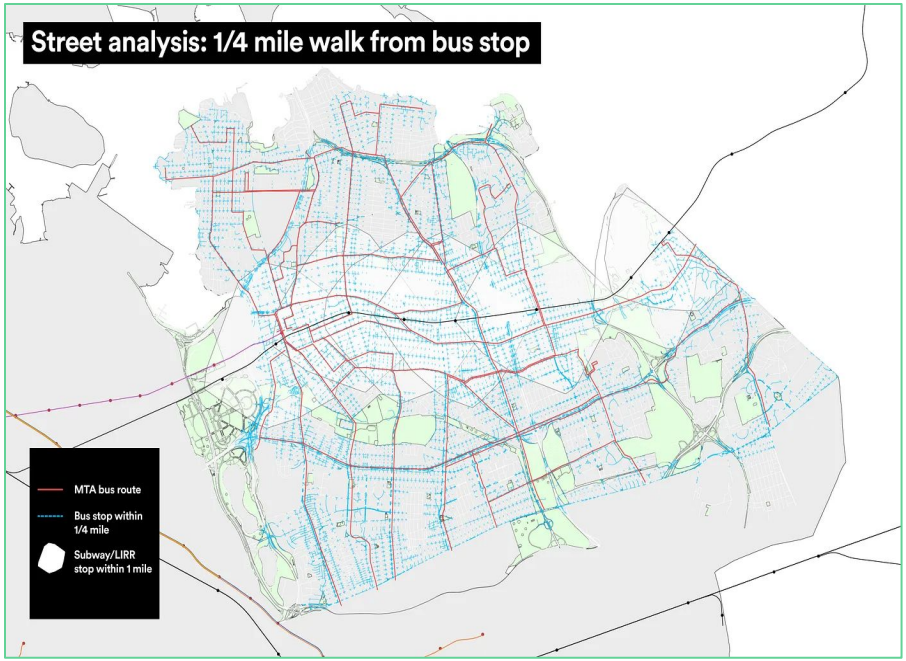

Fig. 1 Northeastern Queens Transit Desert

Note: Reprinted from Zhou, K. (2022). Humans of the northeastern Queens Transit Desert. Retrieved from https://medium.com/data-mining-the-city-2022/humans-of-the-northeastern-queens-transit-desert

Bus Route Eliminations in Boroughs

- As of March 2023, MTA decided to reroute multiple Queens buses, resulting in the elimination of over 1,500 bus stops [5].
- Whether this was for the best or the worst, we have yet to see the end-of-year impact.
- MTA will continue to make these drastic changes, however, underserved communities must be kept in consideration.

Courtesy of MTA

Background & Prior Research

Graph Theory Applications in Transportation

- Graph Theory is the study of mathematical structures (graphs) which are used to visualize relationships between objects [2].
- Creates networks through edges (lines) and vertices (points).
- Models systems based on cycles and connection.
- In the context of transit, graph theory allows for a network analysis.

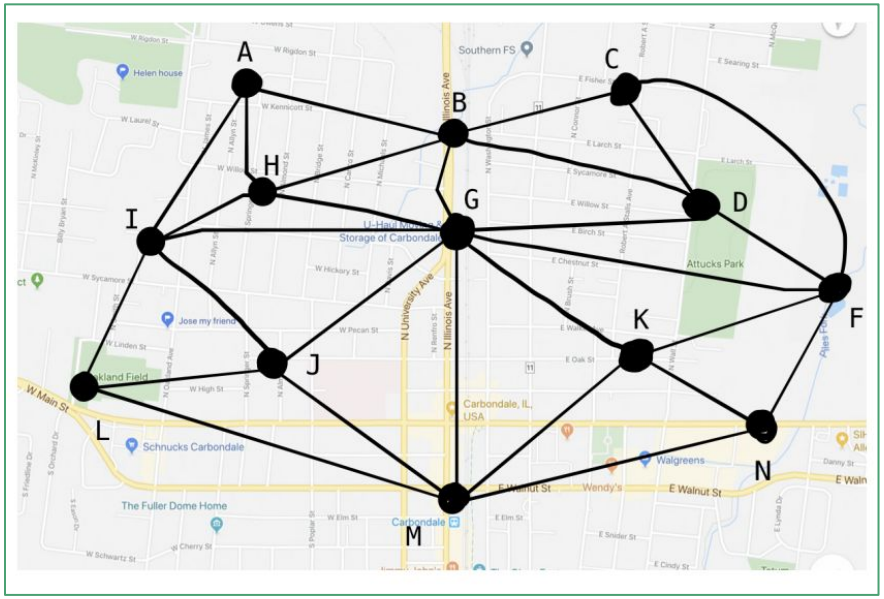

Fig 2. Graph of NYC Stations

Note: Reprinted from Alnassar, I. (2019). *Applications of Graph Theory for Controlling City Infrastructure* [master's thesis) Southern Illinois University, Carbondale, Illinois.

Using Spanning Trees for Bus Path Problems

- Spanning trees are the minimum cost subgraphs connecting all nodes in an undirected graph.
- If a network is disconnected then a minimum spanning tree (MST) is computed for each connected component.

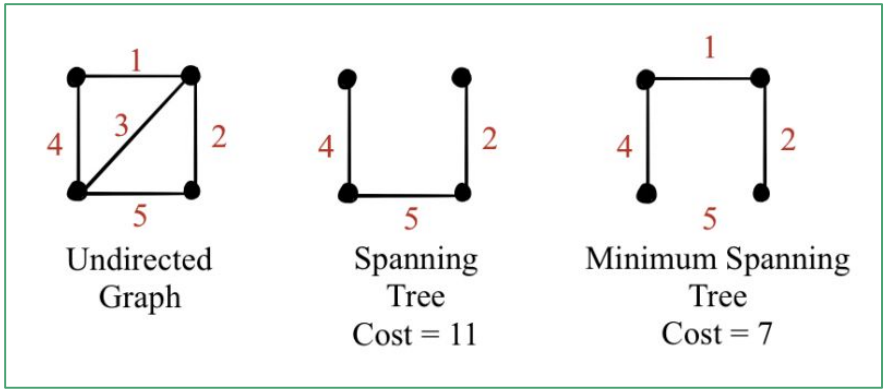

Figure 3. Minimum Spanning Tree

Note: Reprinted from Alnassar, I. (2019). *Applications of Graph Theory for Controlling City Infrastructure* [master's thesis) Southern Illinois University, Carbondale, Illinois.

Kruskal's Algorithm

- Kruskal’s algorithm builds a MST by adding edges with minimum weight (associated value) without forming cycles.
- The MST is the spanning tree where the cost is minimum among all other spanning trees.

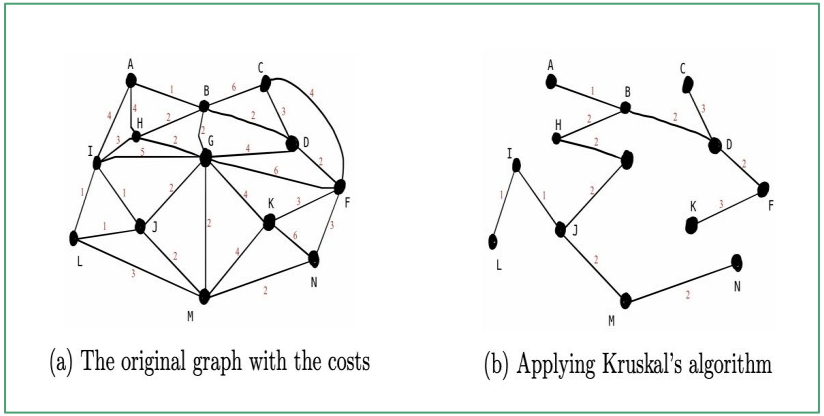

Figure 4. Kruskal’s Algorithm

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Research Methods

Finding Minimum Spanning Tree Plugin in QGIS

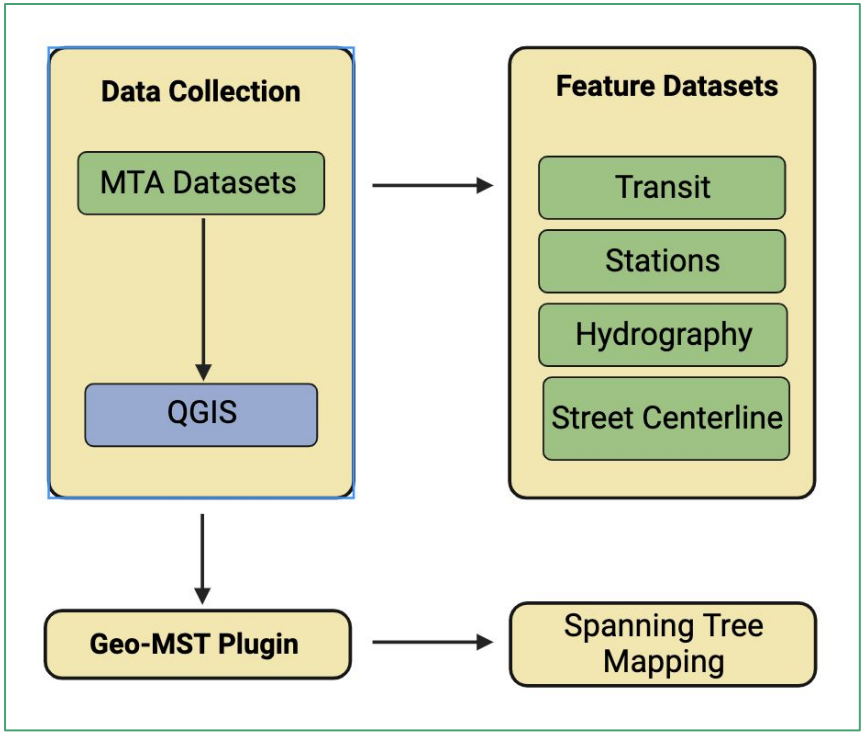

Figure 5. Methodology and Analysis Process

Results & Discussion

Overview of NYC Bus Routes

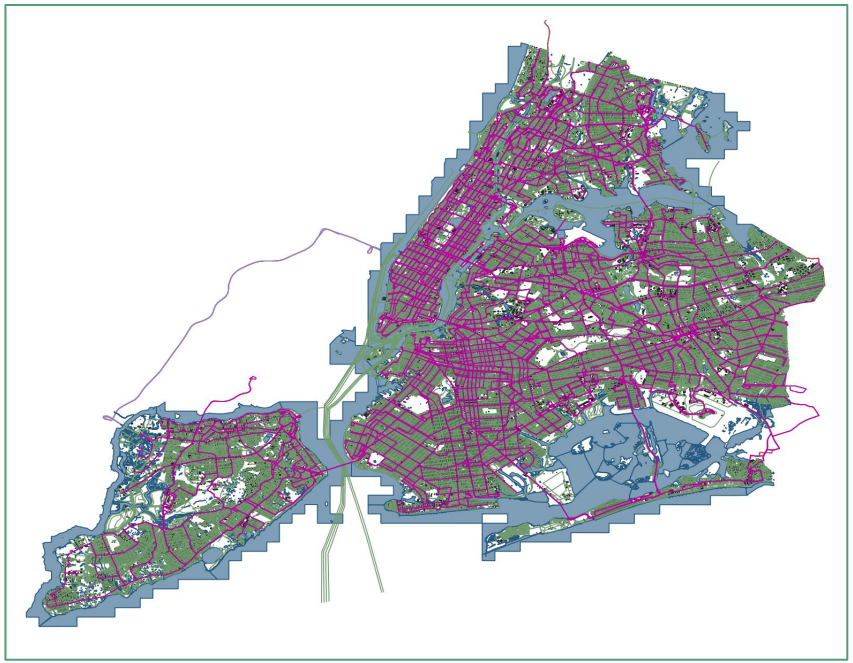

Figure 6a. New York City Bus Routes

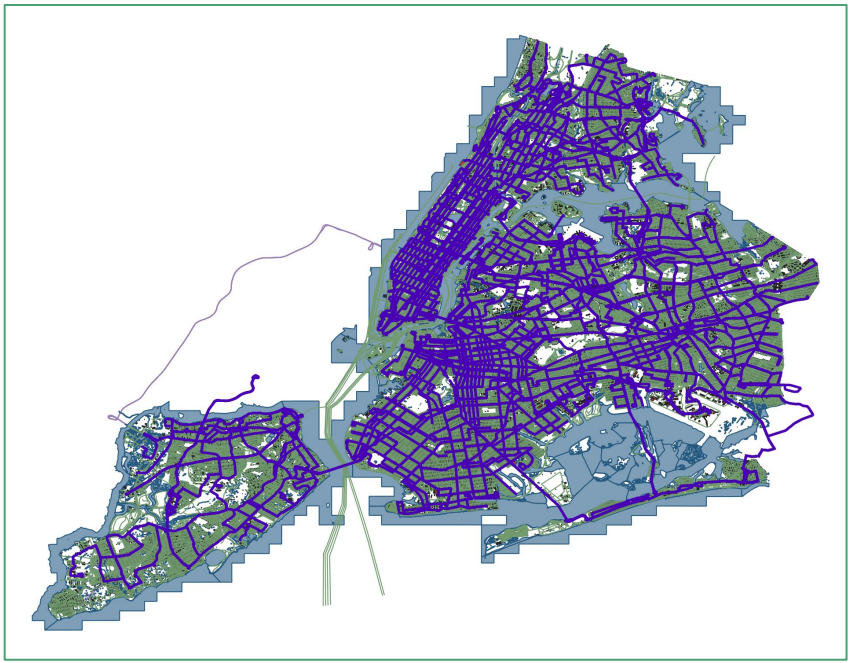

Figure 6b. Optimized New York City Bus Routes

Optimized Transit Networks for NYC

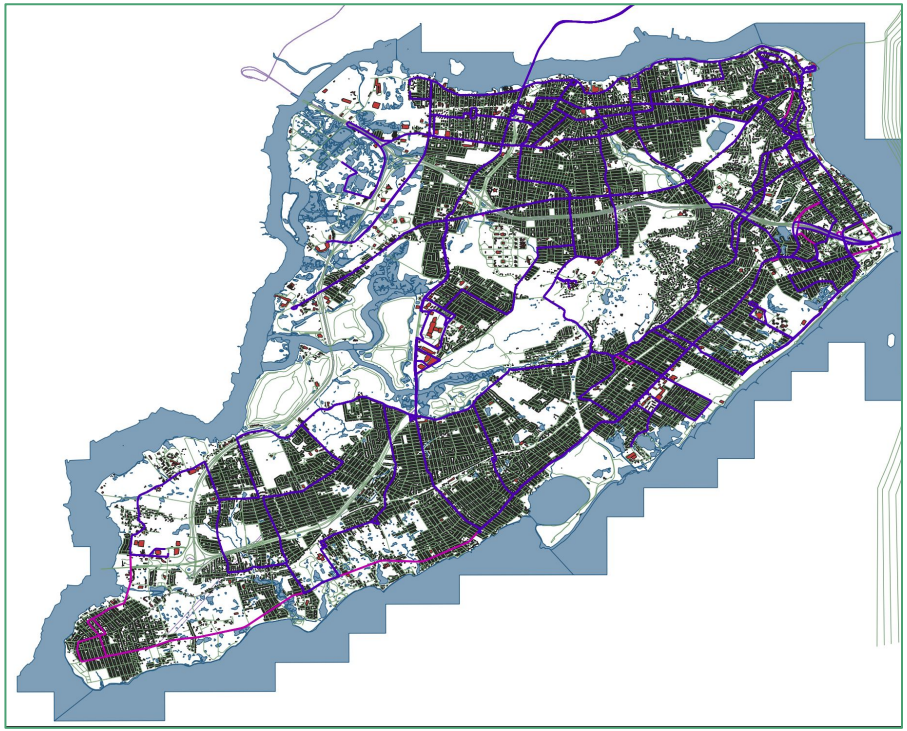

Figure 6c. Optimized Bus Routes in Staten Island

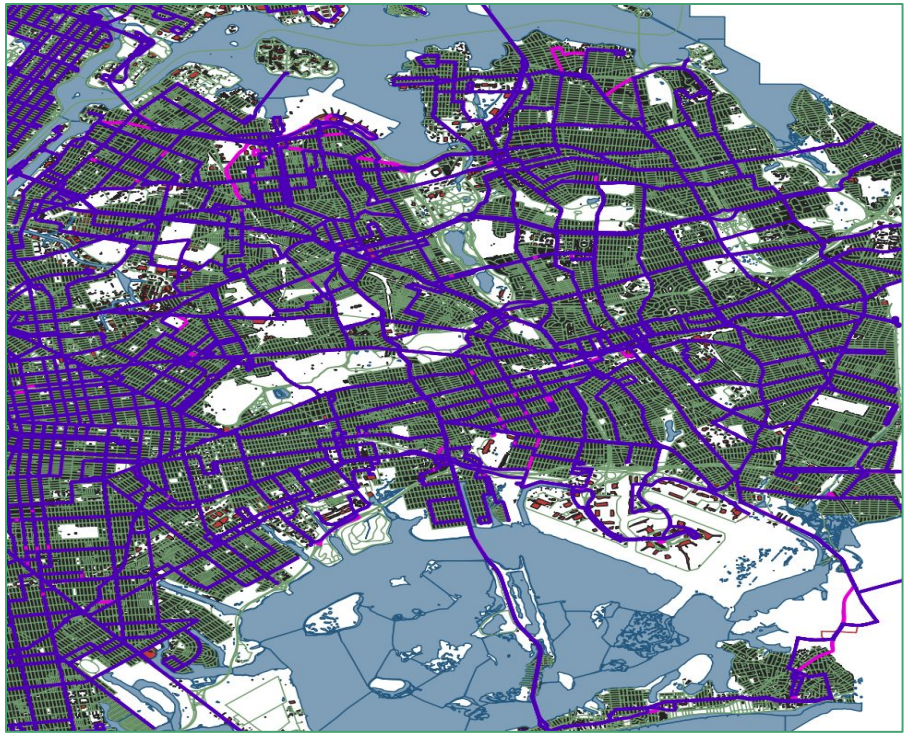

Figure 6d. Optimized Bus Routes in Northeast Queens

Conclusion & Future Directions

Conclusion & Future Directions

- Overall, New York City have shown efforts to be more inclusive of neighborhoods; however, optimization for bus services is still encouraged.
- It is worthwhile to continue experimenting with various algorithms to find better routes for places such as Staten Island, Upper Bronx and Northwest Queens.
- The following can expand current research methods:
    - Conducting a comparative (network) analysis between peak and off-peak hours for NYC bus systems.
    - Modeling change in transit deserts since 2020

Acknowledgements

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Questions?