Reimagining Manhattan: A Mathematical Modeling Approach to Superblock Development

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ArcGIS StoryMap
for full pilot program information and growth strategy animation

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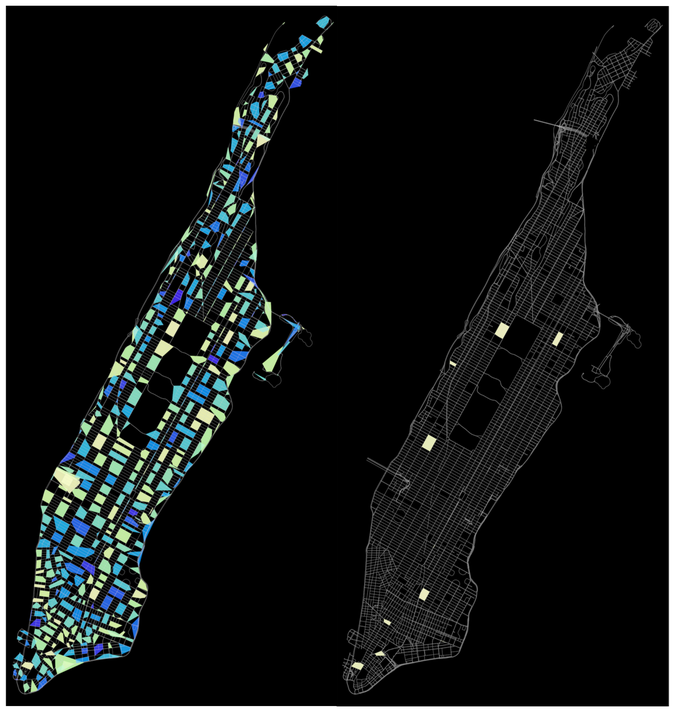


Figure 5-1: (Left) Fully-Realized Development, and (Right) Potential Pilot Program Development based on a Seeded Growth Strategy.

01 Introduction

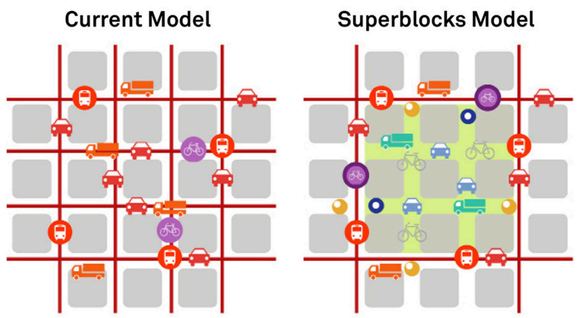


Figure 1 : Superblock model diagram (Image by Ajuntament de Barcelona)

Objective and Aim:

- The project aims to develop a proposal for integrating superblocks into Manhattan's urban street layout by:
  1) Developing a model for Superblock Suitability Score;
  2) Demonstrating a growth strategy to pilot and connect superblocks for a full urban layout transformation.

How can we design a superblock program for Manhattan that prioritizes communities and enhances urban life?

Superblock and POI Definition

- A city block, residential block, or urban block, refers to the smallest collection of buildings enclosed by streets.
- Superblocks involve grouping several city blocks, restricting or pacifying through traffic on interior streets, and transforming these spaces into bike lanes, green corridors, and public spaces.
- Points of Interest (POI): locations of objects in urban areas, such as cafés, galleries, and parks, which influence superblock suitability.
- POI Categories: Catering, Shops & Entertainment; Arts, Culture & Tourism; Education, Work & Care; Space Openness & Comfort; Penalty

02 Data Collection and Processing

- Turning Manhattan into a graph of nodes, representing street intersections, and edges, representing streets, with OSMnx [2].
- Using data from Open Street Maps (OSM), **87 POI features** are counted in **400m radii** around each of the **4594 nodes** in Manhattan (400m= approx. a five-min walking time).
  - Nodes without features in the fixed radii are indicated with "0" value counts in all features, encouraging immediacy of POI feature distributions.
- Features falling under the same POI category were first min-max normalized, added, and normalized again to reflect the category score.

03 Methodology

POI Node-to-Edge Weighting

- Normalized category scores are utilized to compute final Superblock Suitability Score, with given alpha and beta parameters, and only considering penalties if they are above the mean penalty score:

$$s(n_i) = \alpha||w_i||_\infty + \beta_{i_1} w_{i_1} + \beta_{i_2} w_{i_2} + \beta_{i_3} w_{i_3} + \beta_{i_4} w_{i_4} - \beta_{5_i} p_i$$

$$p_i \neq 0 \iff p_i > \bar{p}$$

- Graph edges use node scores and lengths, passed through a sigmoid-like function, for a geospatially-aware weighting function:

$$f(e_{ij}) = \frac{1}{1 + e^{-l + \frac{s(n_i)+s(n_j)}{2}}}$$

Multilevel Leiden Clustering

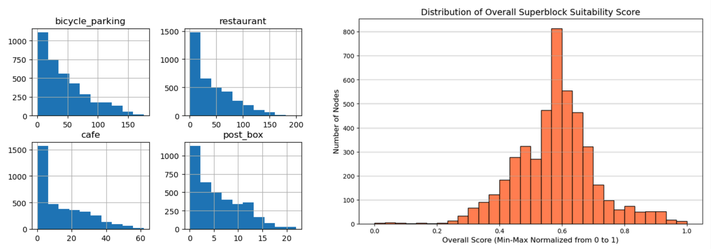
- The Leiden Community Detection Algorithm [3] is used on two levels:
  - Level 1: Processes geographic regions of Manhattan, to incentivize seeded growth strategy of superblock development.
  - Level 2: Creates superblocks based on densely connected sub-communities, utilizing POI information.
- Algorithm optimizes Graph modularity, a measure of edge density and edge distributions across each community cluster:

$$Q = \frac{1}{2m} \sum_{i,j} \left[f(e_{ij}) - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j)$$

04 Results and Analysis

Superblock Suitability Score Normalization

- After processing each of our 4 POI categories and additional penalty category (i.e. parking lots) and normalizing our scores, a normal distribution of final suitability scores is recovered:



Figures 4-1 : (Left) Value-count distribution of example features in POI categories, and (Right) Distribution of Final Superblock Suitability Scores. Despite count-value data having long tailed-distributions, our final weighted score recovers a normal distribution of Suitability across geographic locations in Manhattan.

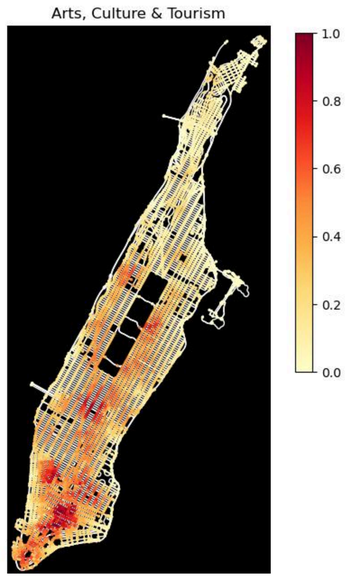
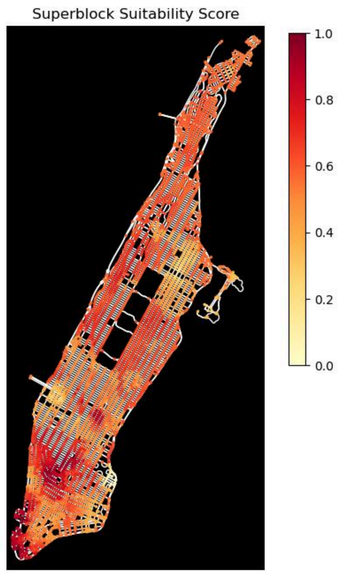


Fig 4.2 - normalized POI scores for the "Arts, Culture, Tourism" category. For non-historic POI, Lower Manhattan receives significantly higher scores. Higher score= higher interest



Figures 4-3 : Overall Weighted Superblock Suitability Score. Upon score weighting, Suitability Scores are more evenly distributed across Manhattan.

05 Implementation

Seeded Growth Strategy and Pilot Programs

- To demonstrate potential urban planning development of superblocks over time, a seeded growth strategy was developed to encourage geographically- and characteristically-diverse developments across Manhattan.
  - Utilizes first level of Multilevel stategy to generate geographic regions, while the second layer encodes high-density subregions in the regional context.
- Pilot superblocks (first round of development) of particular interest to urban planners to research, design, implement, and assess initial transformations of Manhattan city blocks.

06 Next Steps

Optimizing for Global Suitability

- Choices for suitability score calculation parameters and edge weighting function are largely heuristic;
  - more experimentation is needed to fully understand how edge weight transformations modify the final selection of pilot-program superblocks.
- Leiden Algorithm approach also retains many individual parameters for community detection;
  - Need to develop a way to integrate optimization choices with built-in Leiden model parameters.

Assessing Pilot Program and Growth Strategies

- How do certain pilot program choices motivate future superblock development dynamically?
- How do different growth strategies improve/exacerbate air pollution, congestion, and larger urban sustainability problems?

References: [1] S. Eggimann. "The potential of implementing superblocks for multifunctional street use in cities." In: Nat Sustain (2022). DOI: https://doi.org/10.1038/s41893-022-00855-2. [2] G. Boeing. "Modeling and Analyzing Urban Networks and Amenities with OSMnx. Working Paper". In: (2024). URL: https://geoffboeing.com/publications/osmnx-paper/. [3] V. A. Traag, L. Waltman, and N. J. van Eck. "From Louvain to Leiden: Guaranteeing well-connected communities." In: Scientific Reports, 9(1), 5233. (2019). DOI: https://doi.org/10.1038/s41598-019-41695-z.

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