Reverse Engineering to Estimate Subsurface Utility Infrastructure Density for Financing Smart City Infrastructure

Final presentation

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ACADEMIC PROJECT MENTOR: CUSP Prof. Debra Laefer

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Meet Our Team!

Terri C. Matthews	Director, Town+Gown, NYC@DDC
Debra Laefer	Academic Project Mentor, NYU
Yutong Lan	CUSP Student, Econ Background
Zihao Liu	CUSP Student, Math Background
Zihao Wu	CUSP Student, Finance Background

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Stakeholders

Government Agencies

- NYC Department of Transportation
- NYC Department of Environmental Protection (Public Utility)
- NYC Department of Information Technology & Communications
- NYC Department of Design and Construction
- NYC Department of City Planning
- Metropolitan Transportation Authority

Private Utilities

- Con Edison
- National Grid
- Verizon, Spectrum, and others

Members of the Public

- Residents
- Business Owners
- Elected Officials/Community Boards

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Estimated report time: 30mins

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Why Are We Doing This?

Figure 1. Water Street in Manhattan. Photo: T.Matthews, 2023

Figure 2. Street excavation equipment parked on Water Street. Photo: T.Matthews, 2023

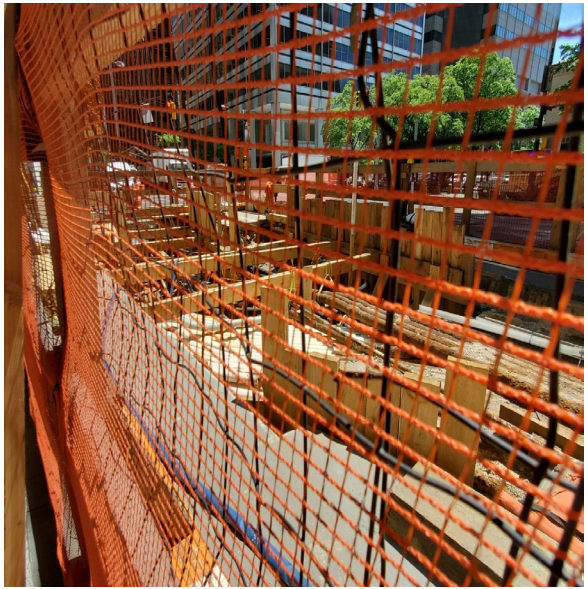

Figure 3. These can be avoided if we have subsurface utilidors! Photo: T.Matthews, 2023

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What is Utilidor?

Utilidor is an underground utility access system used primarily for the **location** of various utility transmissions infrastructure assets, which permits easier access for their maintenance without repeated street excavation. Utility transmission assets can include services for water, electricity, gas and telecommunications.

Located underground, typically under the roadway, the utilidor provides a convenient way to manage and maintain this infrastructure while **reducing disruption to surface traffic on roads and sidewalks.**

Figure 4. Disney Magic Kingdom Utilidors. Adapted from "Beneath The Magic: What Happens In The Magic Kingdom Utilidors?" by L.Sikes, 2020, WDW Blog. Retrieved from https://www.wdw-magazine.com/beneath-the-magic-what-happens-in-the-magic-kingdom-utilidors/

Problem Definition

Goal:
Creating the foundation to support eventual financing of utilidors, which are public-private assets that require a mix of public and private utility money.
(1) Construction (= debt)
(2) Operation and maintenance

Problem Addressing:
Not enough subsurface infrastructure data therefore we **reverse** surface density map to estimate underground density map

What We Accomplished

- Developed a methodology to estimate subsurface utility infrastructure density within NYC
- Generated subsurface densities by Community District to permit a subsequent estimation of a utility pricing gap within NYC
- Utilized the estimation of the pricing gap to support development of revenue sources for financing

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From Literature Review

- **Establish Relationship: Of Population density and Subsurface density**
  (Frederiksen, 1981)
  As well as per capita income v.s. subsurface density

- **Establish Methodology: Calculate urban underground space use density in cities on average** (Bobylev, 2015)
  Generate a citywide density map of the community districts , blocks and buildings

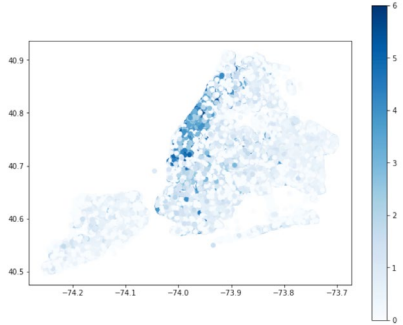
- **Establish Methodology: Cost evaluation is critical when utilizing subsurface PROW to improve surface PROW efficiency, so that the marginal cost of implementing solutions is not greater than the marginal increase in mobility**
  (Bertaud, 2018)
  The fact that urban commuters only pay a small fraction of their trip costs makes this evaluation eve more difficult

From Literature Review

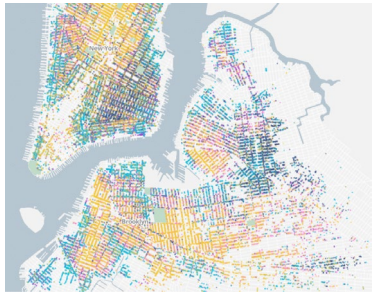
- **Establish How to Act: Emphasized that the history of subsurface space to hydrogeology is the basis of the current urban structure and organization that affects the urban outlook.** (Tann, Metje, Admiraal, Collins, 2018)
  This is a discussion on the “gap” and possible financing mechanisms in this article that gave rise to our project.

- **Establish How to Act: Mayor’s office should coordinate with various department to evaluate and identify potential locations for future utility tunnels.** (Matthews, 2023)
  This is a discussion of the pros but also possible difficulties of implementing underground utilidor.

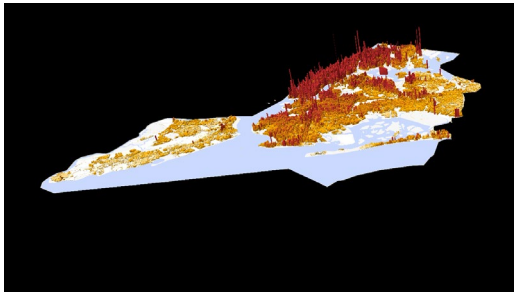
Methodology



New York **Building Lot Density** Map



New York **Road Surface Area Density** Map



New York **Subsurface Density map**

&

Transformation method by Alain Bertaud: Created surface density metrics and match them with road surface area from LION to show how to convert surface density to subsurface density.

Subsurface Density = Building Lot Density / Road Area

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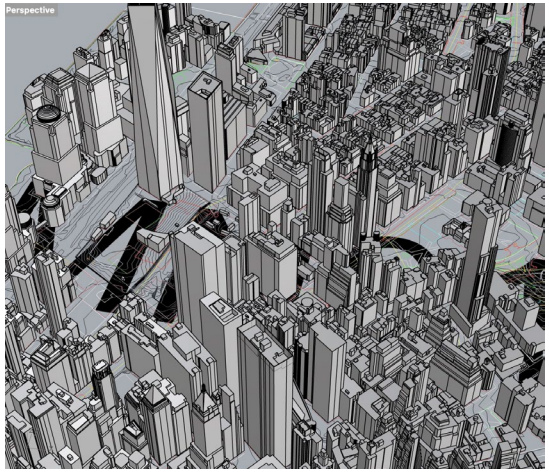
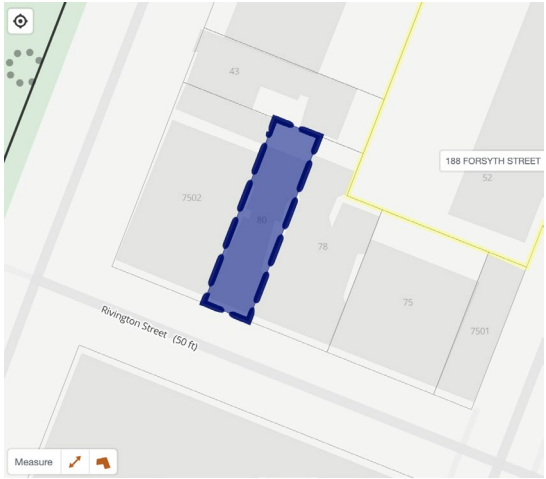
Data processing

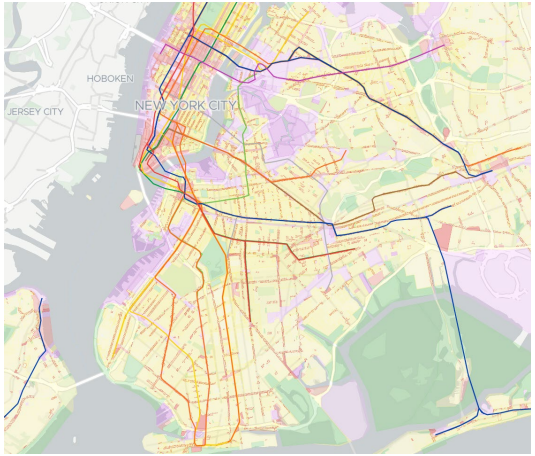
The three datasets were processed using Rhino7, Python, and ArcGIS Pro(filtering missing data).



NYC 3D Model by Community District



NYC PLUTO DATA



LION Single Line Street Base Map

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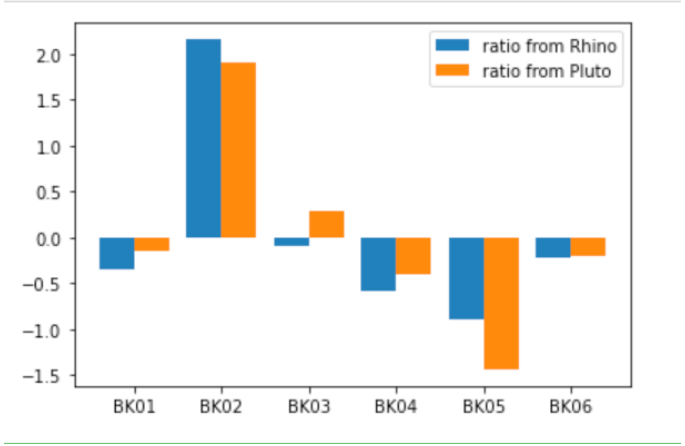
Cross validation Calculation



Cross validation result						
Density from DCP 3D MODEL	36.81836569	65.73728729	39.77941479	34.1031122	30.61089658	38.41869853
Density from PLUTO	1.466339946	2.510099888	1.695279956	1.33671999	0.813844025	1.441550016

Kolmogorov-Smirnov Test： p-value of 0.93

$$Density = \frac{Volume}{Bottom\ area}$$

$$Density = \frac{Building\ area}{Lot\ area}$$

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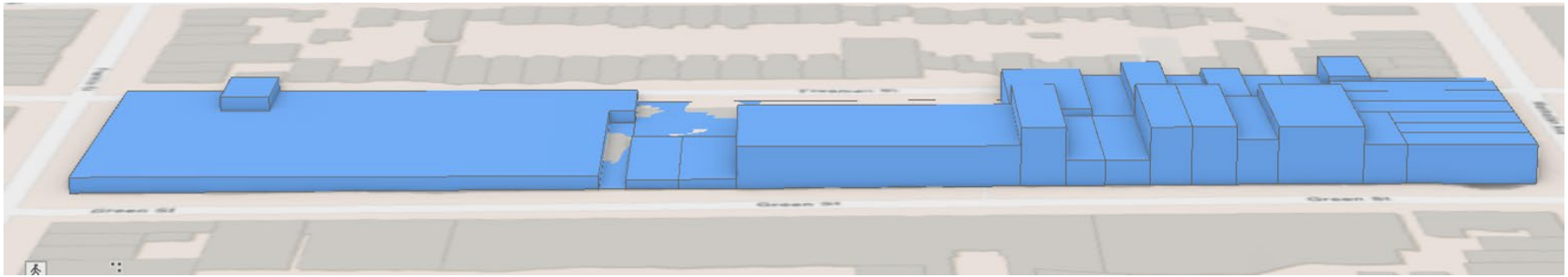
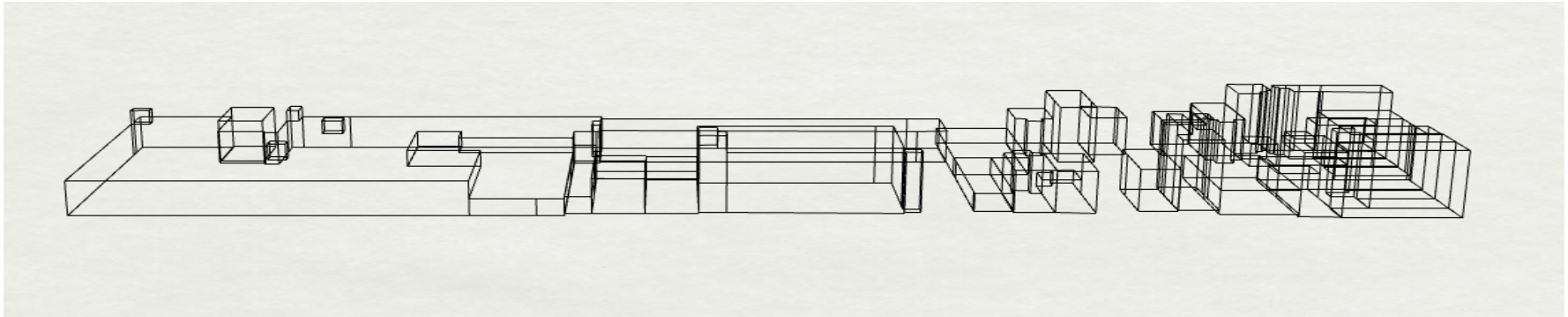
Cross validation：3D AND PLUTO front view





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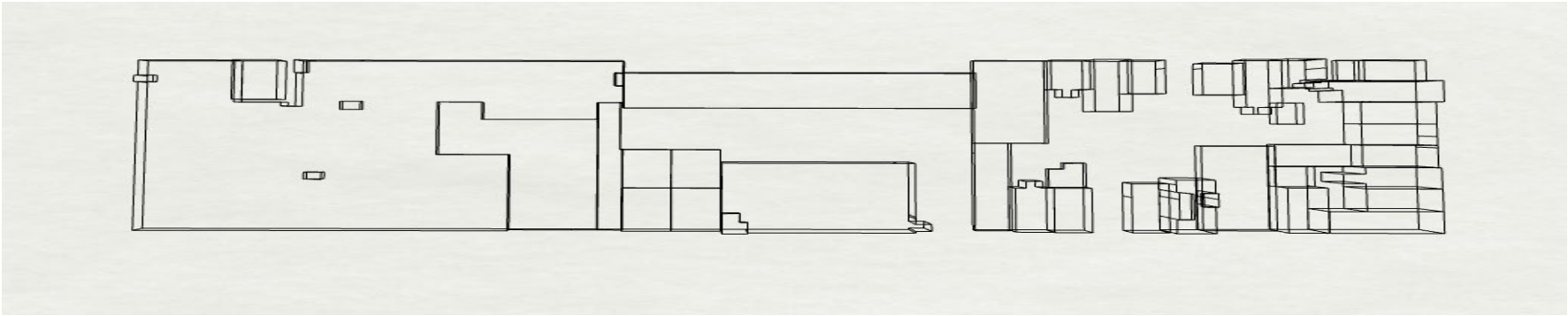
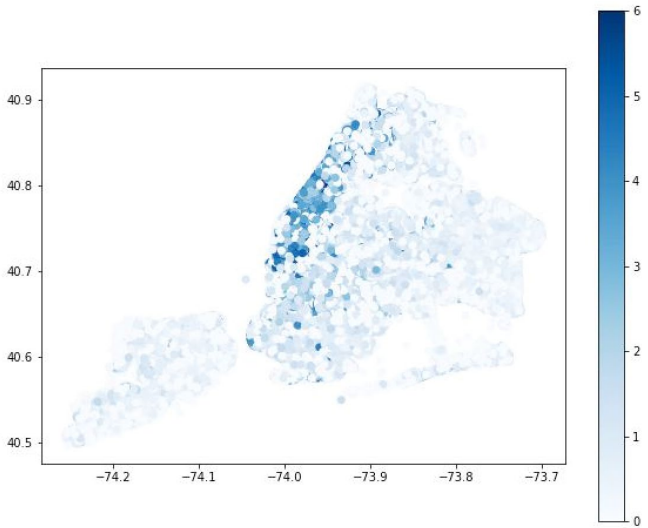
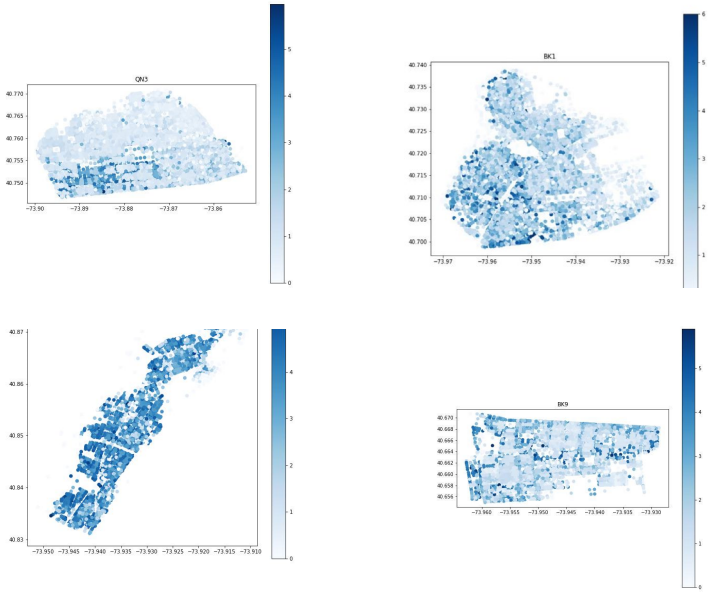
Cross validation：3D AND PLUTO top view



Density map at the individual district level



New York city



59 Districts

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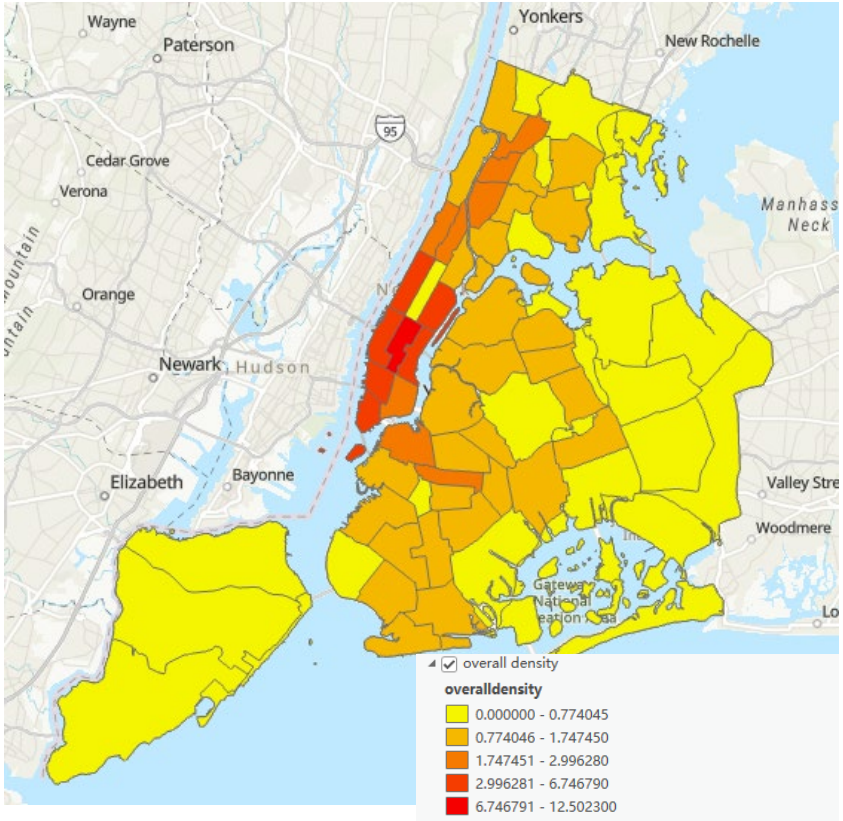
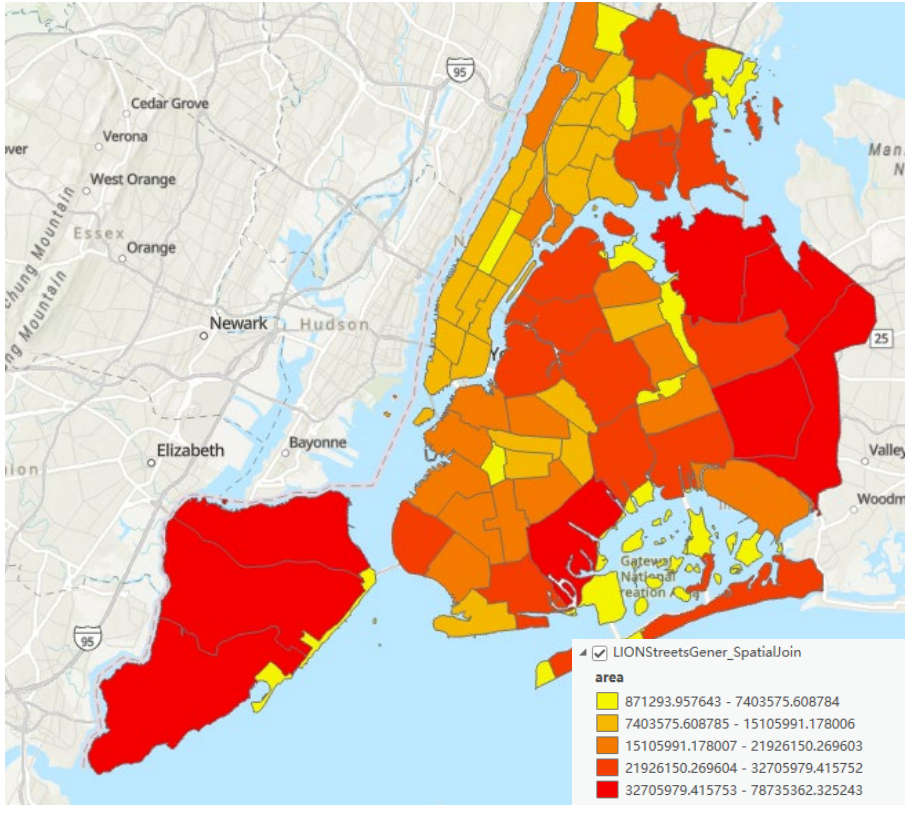
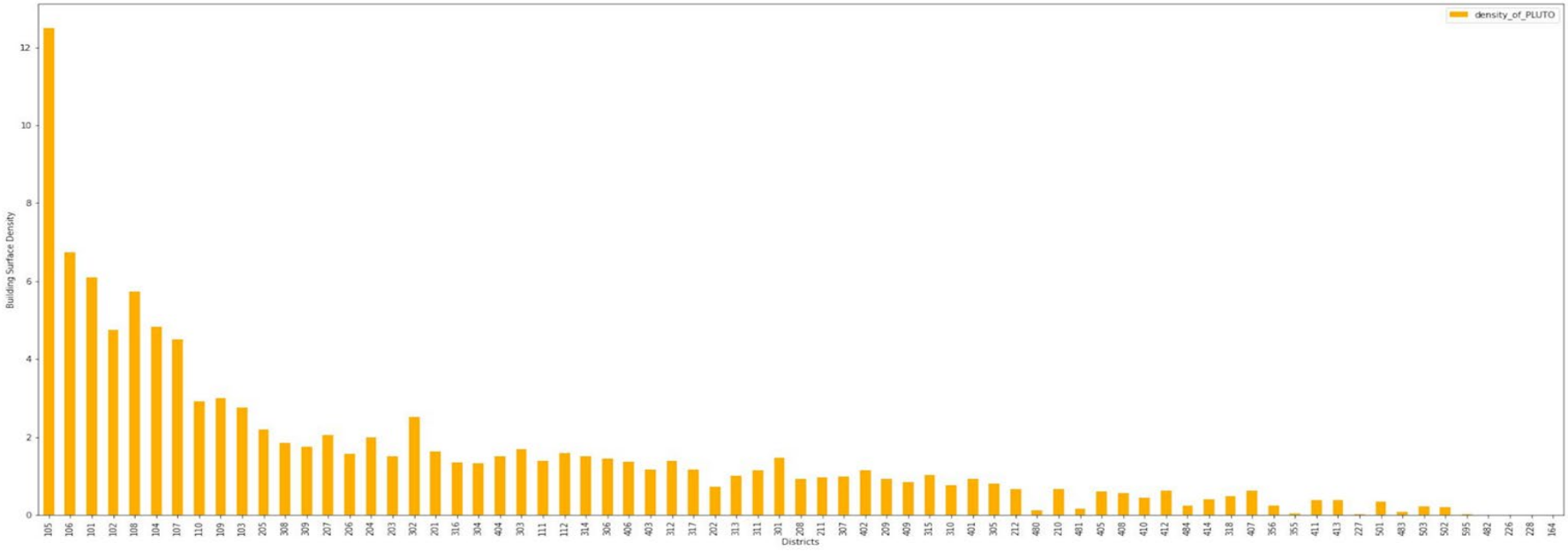
Surface density map



Road area map



Surface density bar Chart from Pluto by CDs



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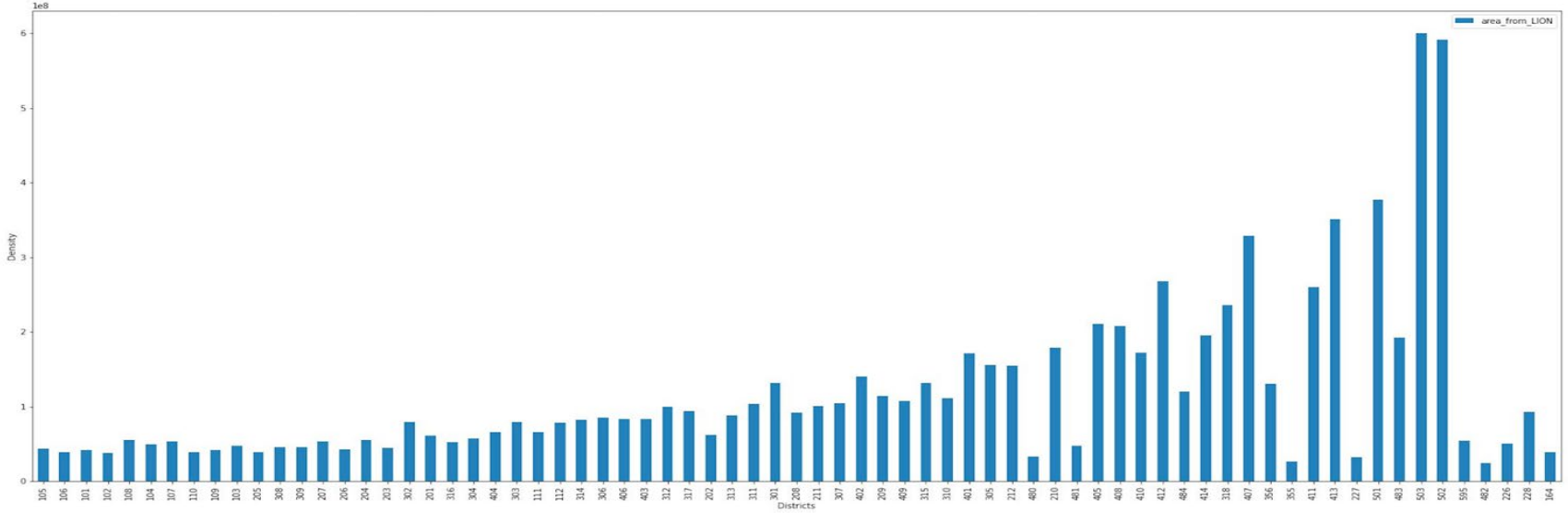
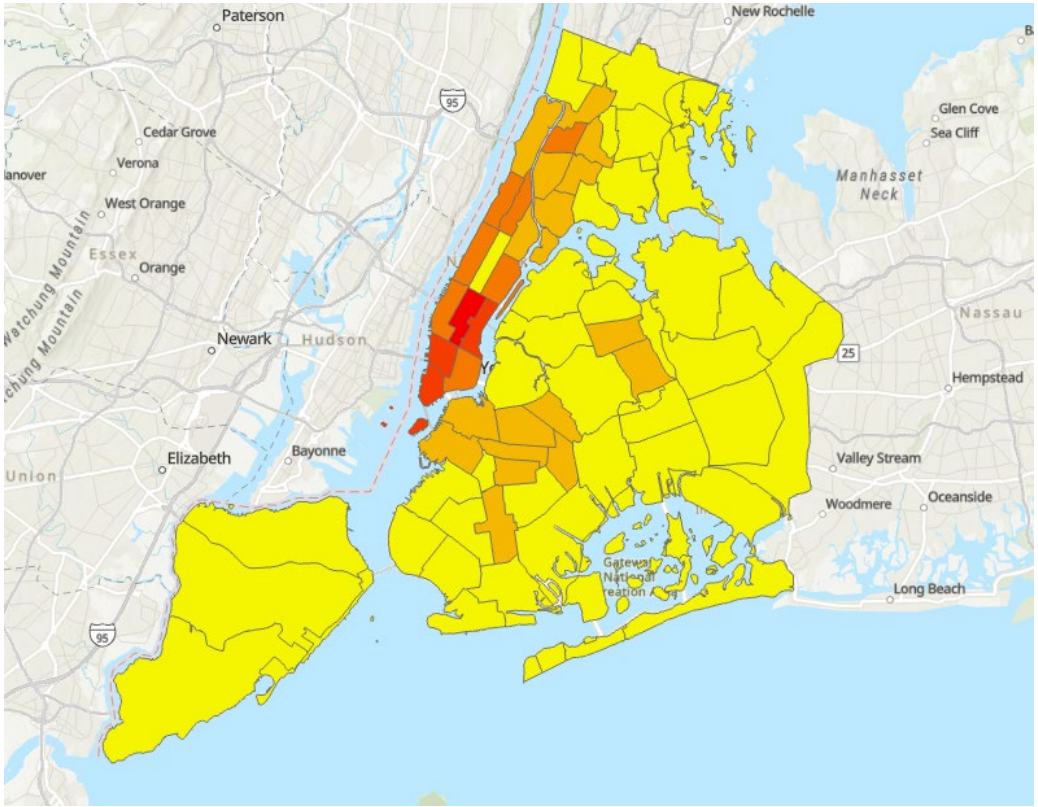
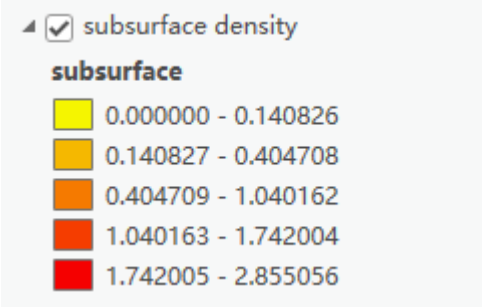
Road area bar chart from LION by CDs

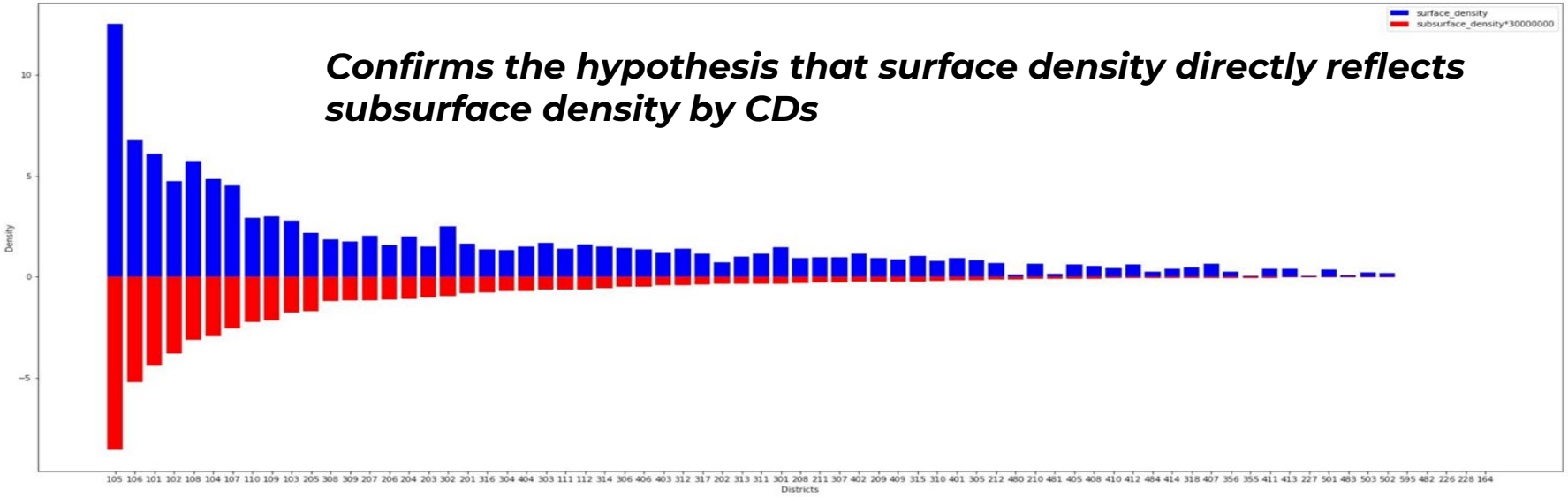


Subsurface density map by district view



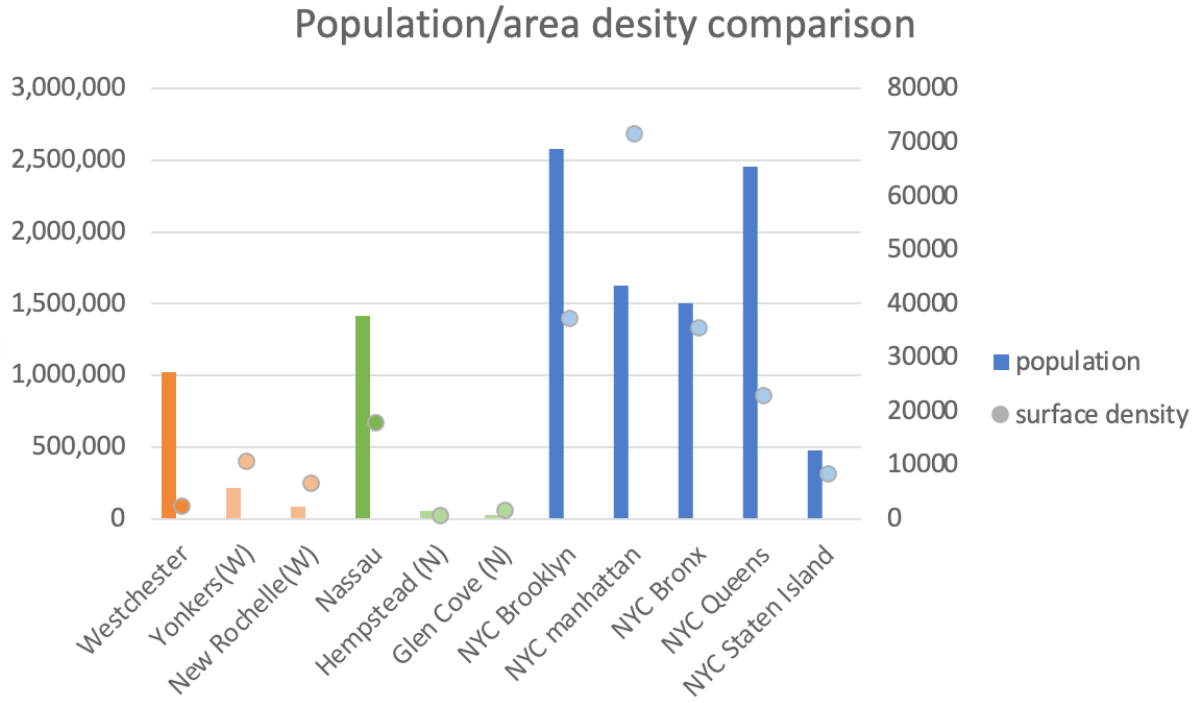


Standardized surface and subsurface densities



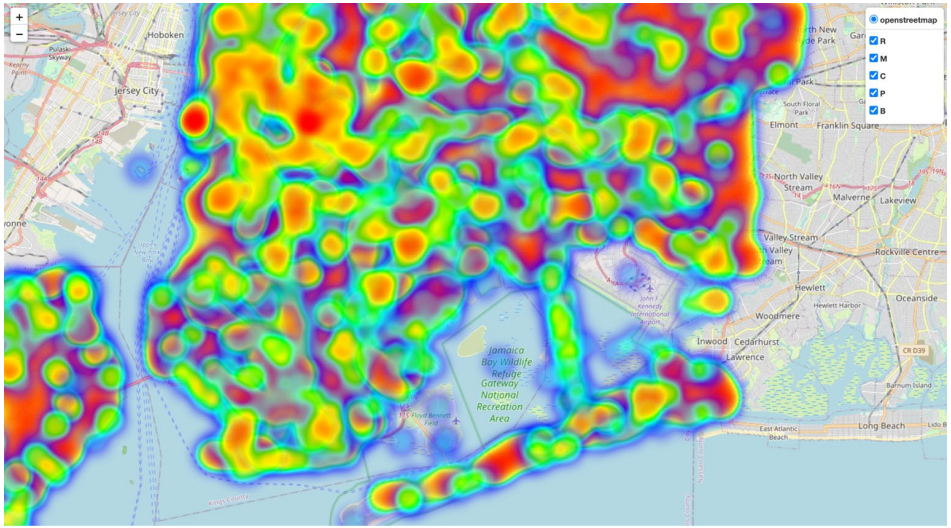
Case study: Westchester and Nassau

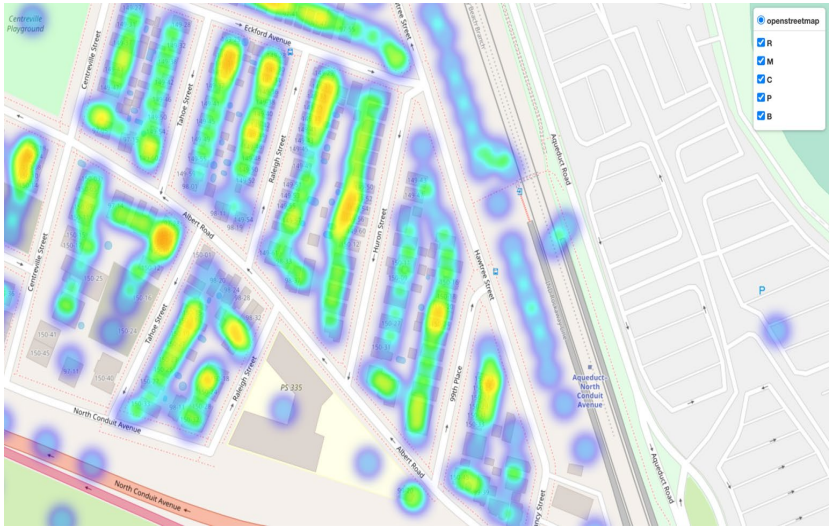
Permits a **subsequent** estimation of a **utility pricing gap within NYC as compared to adjacent counties' surface densities to support development of revenue sources to finance utilidors; some private utilities serve customers in NYC and other adjacent areas within their service areas.**



Interactive Surface Density Heatmap

Created a heat map that can be interacted with, we can obtain more details of the surface density distribution.





Project website and resources

https://zihao-wu999.github.io/reverse-engineering/

https://github.com/Zihao-Wu999/Reverse-Engineering-to-Estimate-Subsurface-Utility-Infrastructure-Density

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Policy recommendations

- **Optimizing land use planning:** Fully utilizing underground PROW space is vital for smart city development. It ensures efficient allocation of underground resources and supports sustainable infrastructure.

- **Supporting technological innovation:** Governments can encourage innovation and research to improve utilidor design and operation. This includes funding R&D, establishing innovation centers, and promoting collaboration for technological advancements.

- **Changing utility tariffs:** Modifying utility tariffs can provide funding for utilidor construction and maintenance. By considering the value of underground PROW and the costs of direct burial, appropriate pricing levels can be established to finance utilidor projects.

Conclusion

Theory proof: We have used **Bertaud**'s economic based theory of surface densities within urban centers to successfully estimate a subsurface density map based on surface building that demonstrates the applicability of this method to New York City.

Visualization tools: Different visualisation tools were obtained, which can support subsequent studies

Future policy development: Theoretical support for maintaining a sustainable revenue base is suggested, for example by changing utility tariffs. This project can also provide support for urban planning optimisation.

Reference

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