Assessing Deficiencies in NYC's Mobility System Network Through Citi Bike Data

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Motivation

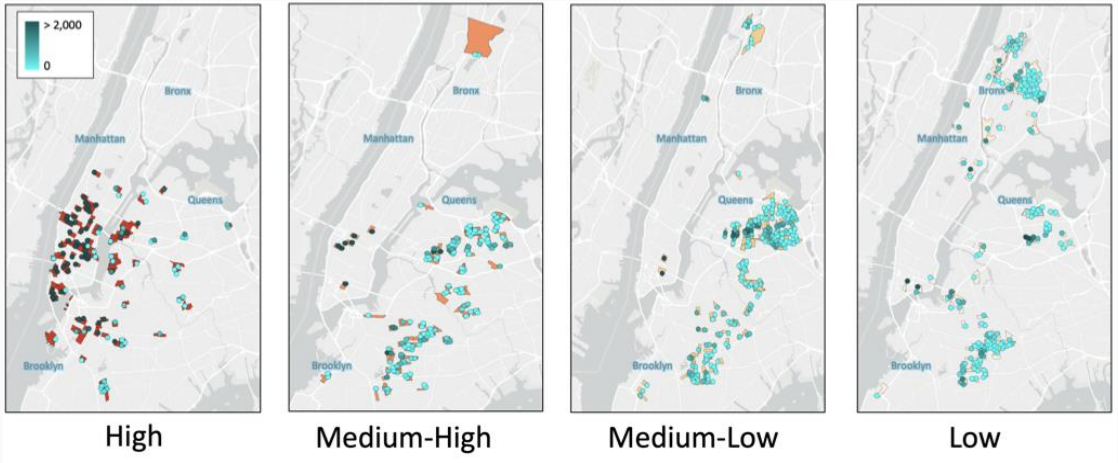
- ~4.1 days per year lost on traffic
- Daily subway ridership at **65%**
- Subway satisfaction is at **49%**
- **33,130,892** citi bikes trips per year.
- Launched in 2013 with **6000** bikes, now at **35,000**.

Where does the NYC mobility network fail to provide adequate metro accessibility?

Can cycling behaviour serve as a proxy for identifying these critical deficiencies?

- Novelty: This study is the first to integrate actual bike-share usage data with network-analysis metrics to identify weaknesses in the metro system

Related Work



- **Namgung et al. (2025)** — Used **Citi Bike data with spatial accessibility models (wPTAL)** to find **areas poorly served by the subway**; showed that **adding bike stations in Bronx, Queens, and Brooklyn reduces transport inequality.**

- **Ashraf et al. (2021)** — Used **Poisson–Gamma models** on Citi Bike + MTA data; found a **10 % rise in bike trips near stations → ~2.3 % higher subway ridership**, showing bikes **improve first/last-mile access.**

=> Identify weak subway regions using network characteristics, and use data-driven simulation to recommend where to add metro stations

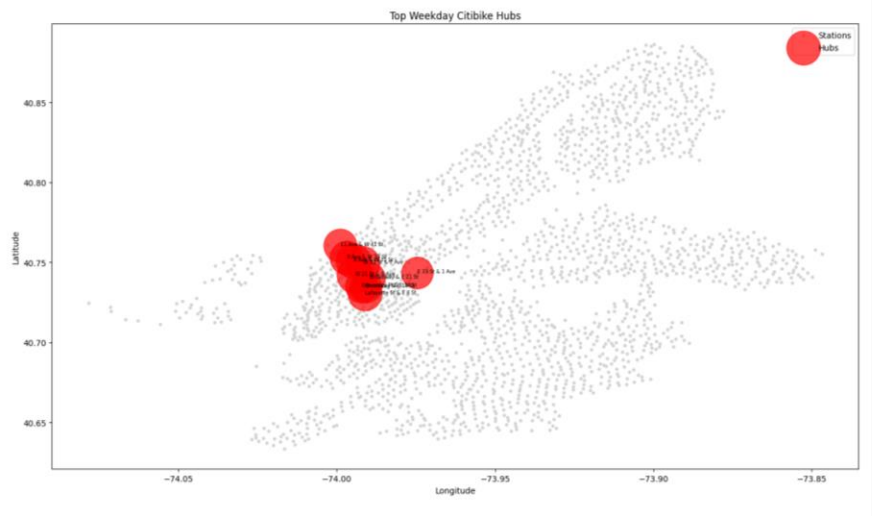
Methodology (CitiBike)

Dataset: CitiBike system data; trip data for August 2024

- Consider only member rides, remove outliers
- Aggregated over weekday & weekend
- Fully connected graph (station pairwise trips) with self-edges

Characterization:

- Find hubs using edge weights (trip counts), and closeness centrality
- Calculate average trip time per edge, per cycle type



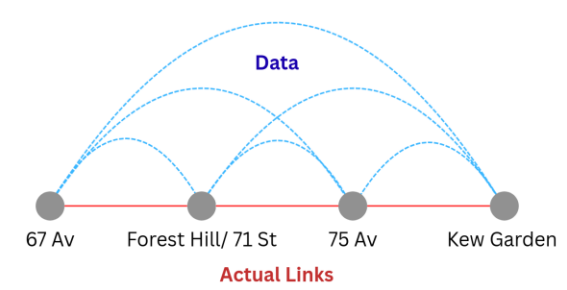
Methodology (Subway)

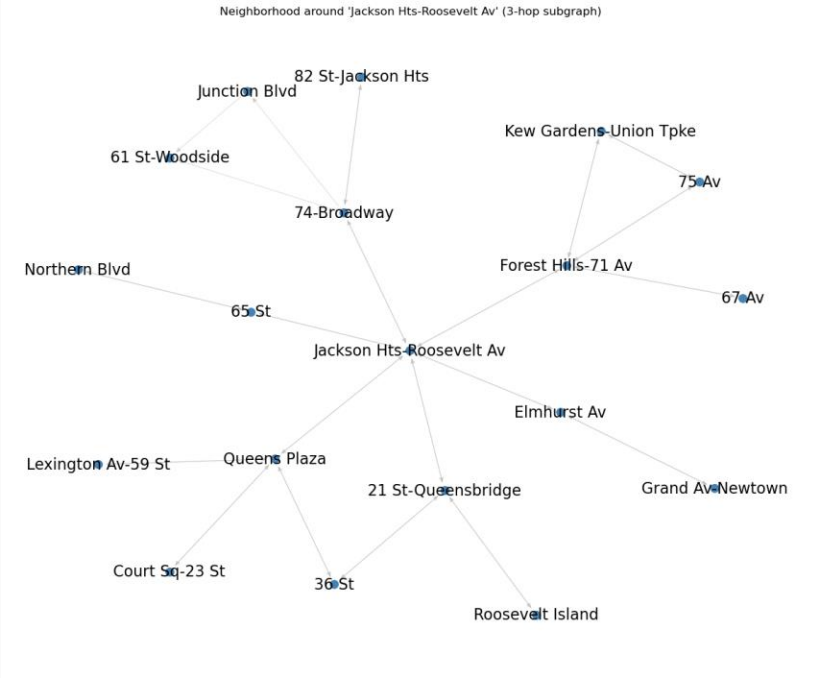
Dataset: MTA Subway stations dataset and MTA Subway Origin-Destination Ridership Estimate: 2024

- Aggregated over weekday-weekend in a month (August 2024)
- Aggregation between stops over the actual transport data

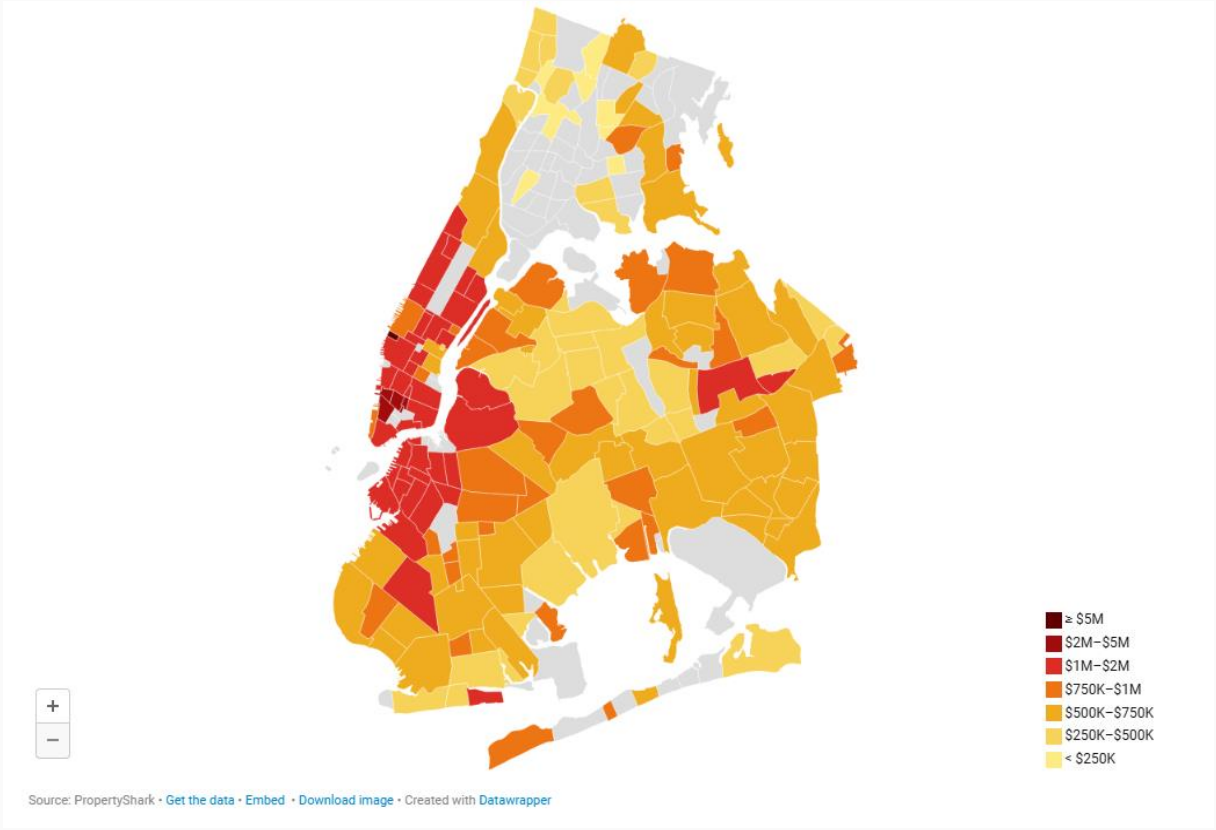
Key Network Characterization Metrics Used:

- Component reachability, Betweenness, Efficiency and Flow strength





Methodology (Subway)



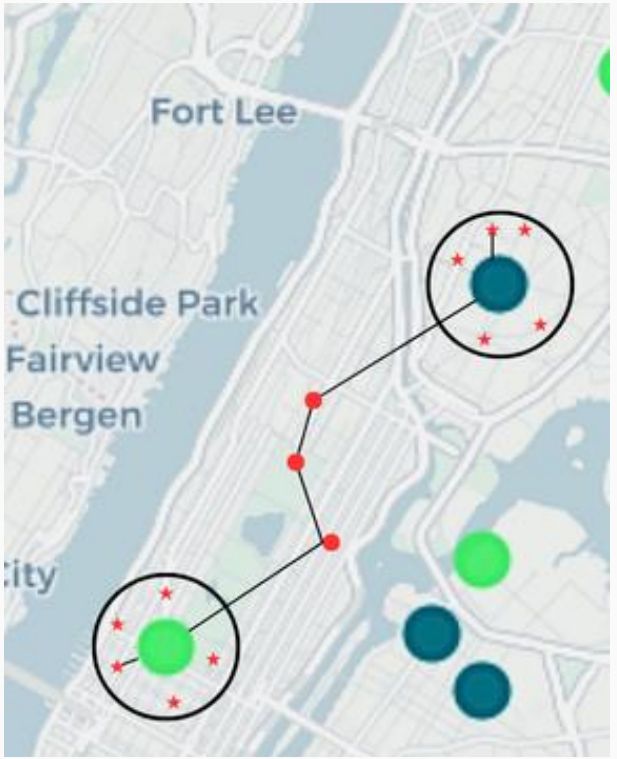
Finding Virtual Stations

Location	Key Reason
Coast off Roosevelt Island (40°46'11"N, 73°55'40"W)	Poor-medium income area, high city bike strength, lacks metro connectivity, strengthens island connectivity
Steinway/31 Av (40°45'40"N, 73°55'01"W)	Low income area, good bike strength, increases regional connection
North Brooklyn (40°41'14"N, 73°56'30"W)	High bike strength and closeness, low subway reachability and strength
Brooklyn Navy Yard (40°41'53"N, 73°58'50"W)	High bike strength, closeness, port worker region
South Bronx (40°49'27"N, 73°54'50"W)	Low bike and metro usage, improves the network
South Manhattan (40°43'17"N, 73°59'01"W)	High bike strength and closeness, very low subway strength, very populous area
South Manhattan (40°43'33"N, 73°59'00"W)	Generally low connection for subway, high synergy with previous virtual station, increase metro connectivity

Methodology (Simulation)

GOAL: Does a virtual station save travel time compared to using existing metro or direct biking?

- Selected **10** random points within **1km** of source location
- Calculate Avg. Time via 3 scenarios:
  - Scenario A: Virtual Station
  - Scenario B: Existing metro
  - Scenario C: Direct Biking
- Walking and biking time is provided by **Google Maps API**
- Distance from virtual station to the nearest actual metro station is calculated using **haversine distance**



Results (Simulation)

Destination	Bike	Subway	Subway (Virtual)	Δ Subway (%)
Roosevelt Island Coast	42:52	62:13	66:41	7.18%
Steinway St / 31 Av	42:34	55:38	56:59	2.43%
North Brooklyn (Gates / Throop Av)	52:00	65:47	64:48	-1.49%
Brooklyn Navy Yard (Flushing / Navy St)	50:40	60:39	57:42	-4.86%
South Bronx (161 St / Melrose Av)	56:11	73:16	70:27	-3.84%
South Manhattan (Houston / Clinton St)	41:16	53:00	51:42	-2.45%
South Manhattan (Ave A / St. Marks Pl)	41:17	52:27	53:16	1.56%

Table 8: Average Travel Times Between Subway and Virtual Subway Scenarios

- In all cases, on average, cycling remains faster
- In **4 of 7** cases, adding virtual stations slightly improved travel times, but the change was not significant.

Summary

Q1. Where does the NYC metro network fail to provide adequate metro accessibility?

- Weak connectivity persists in western Queens and south Brooklyn, where even with simulated stations, accessibility remains low.

Q2. Can cycling behavior serve as a proxy for identifying these critical deficiencies?

- Cycling often remains faster than new metro links, but is a good proxy, and revealed the bad connectivity of the NYC metro – helped identify branching pattern of Metro

Limitations

- Citi Bike data doesn't span NYC
- We don't consider schedules
- We don't consider the bus network
- Methodology rather subjective, could be automated/ improved
    - We could have added more virtual stations and positioned them more strategically in locations that minimize transfer times.
- Comparatively higher bike usage in areas that are rich

References

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https://www.tomtom.com/traffic-index/ranking/?country=MX%2CUS%2CCA

Ashraf, M. T., Hossen, M. A., Dey, K., El-Dabaja, S., Aljeri, M., & Naik, B. (2021). Impacts of Bike Sharing Program on Subway Ridership in New York City. *Transportation Research Record: Journal of the Transportation Research Board*, *2675*(9), 924-934. https://doi.org/10.1177/03611981211004980 (Original work published 2021)

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Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	29:33	46:34	50:40
Steinway St / 31 Av	42:33	58:47	58:47
North Brooklyn (Gates / Throop Av)	71:09	95:32	93:19
Brooklyn Navy Yard (Flushing / Navy St)	62:49	84:52	81:38
South Bronx (161 St / Melrose Av)	46:39	105:06	100:11
South Manhattan (Houston / Clinton St)	52:60	70:17	69:28
South Manhattan (Ave A / St. Marks Pl)	57:48	80:32	77:56

Table 1: Average Travel Times from Astoria Park (North Roosevelt Island Coast)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	36:13	42:28	50:59
Steinway St / 31 Av	32:15	33:60	37:05
North Brooklyn (Gates / Throop Av)	59:52	52:55	51:58
Brooklyn Navy Yard (Flushing / Navy St)	52:36	49:10	44:25
South Bronx (161 St / Melrose Av)	47:39	46:58	42:16
South Manhattan (Houston / Clinton St)	39:07	45:17	42:58
South Manhattan (Ave A / St. Marks Pl)	30:28	36:13	36:56

Table 2: Average Travel Times from Central Park Entrance (Columbus Monument)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	47:31	55:32	54:17
Steinway St / 31 Av	48:56	44:11	43:05
North Brooklyn (Gates / Throop Av)	36:42	42:22	40:44
Brooklyn Navy Yard (Flushing / Navy St)	26:36	32:25	29:25
South Bronx (161 St / Melrose Av)	61:47	53:15	52:29
South Manhattan (Houston / Clinton St)	11:48	24:25	22:38
South Manhattan (Ave A / St. Marks Pl)	12:42	21:19	27:09

Table 3: Average Travel Times from Little Italy (Chinatown)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	30:04	47:29	52:13
Steinway St / 31 Av	21:25	30:58	32:32
North Brooklyn (Gates / Throop Av)	47:12	66:38	69:22
Brooklyn Navy Yard (Flushing / Navy St)	59:44	62:33	62:11
South Bronx (161 St / Melrose Av)	58:07	76:25	73:22
South Manhattan (Houston / Clinton St)	51:07	52:10	49:54
South Manhattan (Ave A / St. Marks Pl)	50:29	56:03	56:07

Table 4: Average Travel Times from North Queens (Jackson Heights)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	66:50	81:18	86:02
Steinway St / 31 Av	64:23	69:03	74:12
North Brooklyn (Gates / Throop Av)	32:46	51:44	48:42
Brooklyn Navy Yard (Flushing / Navy St)	30:05	53:50	52:17
South Bronx (161 St / Melrose Av)	91:09	90:01	88:13
South Manhattan (Houston / Clinton St)	36:26	45:43	43:41
South Manhattan (Ave A / St. Marks Pl)	37:52	53:45	59:57

Table 5: Average Travel Times from Red Hook (Brooklyn Bay Area)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	54:36	100:53	109:25
Steinway St / 31 Av	55:36	95:58	96:41
North Brooklyn (Gates / Throop Av)	96:52	111:32	109:52
Brooklyn Navy Yard (Flushing / Navy St)	92:56	95:21	88:00
South Bronx (161 St / Melrose Av)	22:30	67:06	64:54
South Manhattan (Houston / Clinton St)	74:35	99:07	97:51
South Manhattan (Ave A / St. Marks Pl)	71:59	85:01	85:39

Table 6: Average Travel Times from The Bronx (Residential)

Appendix

Destination	Bike	Subway	Subway (Virtual)
Roosevelt Island Coast	35:17	61:19	63:12
Steinway St / 31 Av	32:50	56:28	56:28
North Brooklyn (Gates / Throop Av)	19:30	39:46	39:36
Brooklyn Navy Yard (Flushing / Navy St)	29:52	46:24	45:57
South Bronx (161 St / Melrose Av)	65:28	74:01	71:46
South Manhattan (Houston / Clinton St)	22:47	34:03	35:21
South Manhattan (Ave A / St. Marks Pl)	27:38	34:15	29:05

Table 7: Average Travel Times from West Queens (North Brooklyn)