

Capstone Project
IBM Data Science Professional Certificate

Project Report
The Battle of Manhattan and Downtown Toronto Neighborhoods
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Table of Content

1. Introduction
2. Data
3. Methodology
4. Results
5. Discussion
6. Conclusion

1. Introduction

New York City and Toronto are financial capitals of their respective countries and remarkably diverse north American cities. They obviously have their similarities, but do they have similar neighborhoods as well? This is what I would like to answer in this project.

I will compare and group into clusters the neighborhoods of Manhattan and Downtown Toronto, central boroughs of New York City and Toronto.

Manhattan with its 40 neighborhoods is the most densely populated of the five boroughs of New York City and serves as the city's economic and administrative center. Downtown Toronto with its 19 neighborhoods is the main central business district of Toronto with the Canada's largest concentration of skyscrapers and businesses that form Toronto's skyline.

I will use the Foursquare API to get the most common venue categories in each of 59 neighborhoods and then group the neighborhoods into clusters with k-means clustering algorithm.

Clusters will be presented in tables and maps using Folium (Python library for visualizing geospatial data).

Data necessary for the analysis (borough name, neighborhood name, latitude, and longitude) will be taken from New York University (spatial data repository), Wikipedia, and Cognitive Class websites.

2. Data

Data set that needs to be prepared has 59 rows and 4 columns (borough name, neighborhood name, latitude, and longitude), and represents 40 Manhattan and 19 Downtown Toronto neighborhoods.

Sources that were used for data set preparation are:

- New York University (spatial data repository for New York City)
https://geo.nyu.edu/catalog/nyu_2451_34572
- Wikipedia (list of postal codes of Canada)
https://en.wikipedia.org/wiki/List_of_postal_codes_of_Canada:_M
- Cognitive Class (geospatial coordinates for Toronto)
http://cocl.us/Geospatial_data

3. Methodology

Methodology section is divided into following paragraphs presenting the project steps:

- A) Importing libraries
- B) Downloading and transforming New York City data
- C) Preparing Manhattan data
- D) Downloading and transforming Toronto data
- E) Preparing Downtown Toronto data
- F) Merging Manhattan and Downtown Toronto data
- G) Exploring neighborhoods in Manhattan and Downtown Toronto with Foursquare
- H) Clustering Manhattan and Downtown Toronto neighborhoods with k-means
- I) Presenting clusters

A) Importing libraries

In the first step of the project necessary libraries, packages and services were imported:

- BeautifulSoup (package for parsing HTML and XML documents)
- HTML.parser
- Requests (HTTP library)
- JSON (library to handle JSON files)
- Pandas (library for data analysis)
- Numpy (library for working with arrays)
- Nominatim (geocoding service from GeoPy)
- Matplotlib (plotting library)
- KMeans (clustering library)
- Folium (library for visualizing geospatial data))

B) Downloading and transforming New York City data

New York City data were downloaded with "wget" command directly from Cognitive Class website (JSON file): https://cocl.us/new_york_dataset

The original data source is the spatial data repository of New York University (see chapter 2): https://geo.nyu.edu/catalog/nyu_2451_34572

All relevant data in JSON file are in the features key that looks like this:

```
{'type': 'Feature',  
  'id': 'nyu_2451_34572.1',  
  'geometry': {'type': 'Point',  
    'coordinates': [-73.84720052054902, 40.89470517661]},  
  'geometry_name': 'geom',  
  'properties': {'name': 'Wakefield',  
    'stacked': 1,  
    'annoline1': 'Wakefield',  
    'annoline2': None,  
    'annoline3': None,  
    'annoangle': 0.0,  
    'borough': 'Bronx',  
    'bbox': [-73.84720052054902,  
      40.89470517661,  
      -73.84720052054902,  
      40.89470517661]}}
```

Data above were transformed by looping through and filling in the data frame one row at a time with information on borough, neighborhood, latitude, and longitude. Here are the top 5 rows:

	Borough	Neighborhood	Latitude	Longitude
0	Bronx	Wakefield	40.894705	-73.847201
1	Bronx	Co-op City	40.874294	-73.829939
2	Bronx	Eastchester	40.887556	-73.827806
3	Bronx	Fieldston	40.895437	-73.905643
4	Bronx	Riverdale	40.890834	-73.912585

Table 1: New York City data set

C) Preparing Manhattan data

Manhattan data set was prepared by selecting Manhattan as “Borough”. It has 40 different neighborhoods. Here are the top 5 rows:

	Borough	Neighborhood	Latitude	Longitude
0	Manhattan	Marble Hill	40.876551	-73.910660
1	Manhattan	Chinatown	40.715618	-73.994279
2	Manhattan	Washington Heights	40.851903	-73.936900
3	Manhattan	Inwood	40.867684	-73.921210
4	Manhattan	Hamilton Heights	40.823604	-73.949688

Table 2: Manhattan data set

D) Downloading and transforming Toronto data

Toronto data were taken from Wikipedia page (List of postal codes of Canada) and Cognitive Class website (Geospatial coordinates for Toronto).

Table from Wikipedia page was scraped by Beautiful Soup package (for parsing HTML and XML documents) and Requests library (HTTP library). Rows with not assigned borough were not considered. Here are the top 5 rows of the Wikipedia table as data frame:

	Postal Code	Borough	Neighbourhood
0	M3A	North York	Parkwoods
1	M4A	North York	Victoria Village
2	M5A	Downtown Toronto	Regent Park, Harbourfront
3	M6A	North York	Lawrence Manor, Lawrence Heights
4	M7A	Downtown Toronto	Queen's Park, Ontario Provincial Government

Table 3: Table from Wikipedia

Missing longitude and latitude values were taken from the csv file (geospatial data for Toronto from Cognitive Class website) and combined with the previous table. Here are the top 5 rows of the combined table:

	Borough	Neighborhood	Latitude	Longitude
0	North York	Parkwoods	43.753259	-79.329656
1	North York	Victoria Village	43.725882	-79.315572
2	Downtown Toronto	Regent Park, Harbourfront	43.654260	-79.360636
3	North York	Lawrence Manor, Lawrence Heights	43.718518	-79.464763
4	Downtown Toronto	Queen's Park, Ontario Provincial Government	43.662301	-79.389494

Table 4: Toronto data set

E) Preparing Downtown Toronto data

Downtown Toronto data set was prepared by selecting Downtown Toronto as "Borough". It has 19 different neighborhoods. Here are the top 5 rows:

	Borough	Neighborhood	Latitude	Longitude
0	Downtown Toronto	Regent Park, Harbourfront	43.654260	-79.360636
1	Downtown Toronto	Queen's Park, Ontario Provincial Government	43.662301	-79.389494
2	Downtown Toronto	Garden District, Ryerson	43.657162	-79.378937
3	Downtown Toronto	St. James Town	43.651494	-79.375418
4	Downtown Toronto	Berczy Park	43.644771	-79.373306

Table 5: Downtown Toronto data set

F) Merging Manhattan and Downtown Toronto data

Manhattan and Downtown Toronto data sets were merged with the append function. Total number of neighborhoods is 59 (40 Manhattan and 19 Downtown Toronto neighborhoods).

G) Exploring neighborhoods in Manhattan and Downtown Toronto with Foursquare

Neighborhoods in Manhattan and Downtown Toronto were explored with a function that gets nearby venues using the Foursquare API.

Foursquare API provides location-based experiences with diverse information about venues, users, photos, and check-ins. The API supports real time access to places,

Snap-to-Place that assigns users to specific locations, and Geo-tag.

First step was defining Foursquare credentials and version, and then creating the API request URL, making the request, and returning only relevant information for each nearby venue. The function was set to return top 100 venues within a radius of 500 meters. The total number of venues in Manhattan and Downtown Toronto was 4426. Here are the top 5 rows:

	Neighborhood	Neighborhood Latitude	Neighborhood Longitude	Venue	Venue Latitude	Venue Longitude	Venue Category
0	Marble Hill	40.876551	-73.91066	Arturo's	40.874412	-73.910271	Pizza Place
1	Marble Hill	40.876551	-73.91066	Bikram Yoga	40.876844	-73.906204	Yoga Studio
2	Marble Hill	40.876551	-73.91066	Tibbett Diner	40.880404	-73.908937	Diner
3	Marble Hill	40.876551	-73.91066	Dunkin'	40.877136	-73.906666	Donut Shop
4	Marble Hill	40.876551	-73.91066	Starbucks	40.877531	-73.905582	Coffee Shop

Table 6: Manhattan and Downtown Toronto data set with venues

Each neighborhood was then analyzed using one hot encoding with dummy variables that take values of either 0 or 1 if a certain venue category is present in the neighborhood. Rows were then grouped by neighborhood and by taking the mean of the frequency of occurrence of each venue category. This data set was used for k-means clustering. Here are the top 5 rows:

	Neighborhood	Accessories Store	Adult Boutique	Afghan Restaurant	African Restaurant	Airport	Airport Food Court	Airport Gate	Airport Lounge	Airport Service	Airport Terminal	American Restaurant	Antique Shop	Aquarium
0	Battery Park City	0.0	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.013699	0.0	0.0
1	Berczy Park	0.0	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0
2	CN Tower, King and Spadina, Railway Lands, Har...	0.0	0.0	0.0	0.0	0.058824	0.058824	0.058824	0.117647	0.176471	0.117647	0.000000	0.0	0.0
3	Carnegie Hill	0.0	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.011628	0.0	0.0
4	Central Bay Street	0.0	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0

Table 7: Manhattan and Downtown Toronto data set with venue frequency

Data set that displays top 10 venues for each neighborhood was also prepared using a function that sorts the venues in descending order. This data set was used for presentation of clustering results. Here are the top 5 rows:

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
0	Battery Park City	Park	Hotel	Gym	Coffee Shop	Memorial Site	Plaza	BBQ Joint	Sandwich Place	Shopping Mall	Playground
1	Berczy Park	Coffee Shop	Café	Cheese Shop	Restaurant	Bakery	Farmers Market	Cocktail Bar	Beer Bar	Seafood Restaurant	Tailor Shop
2	CN Tower, King and Spadina, Railway Lands, Har...	Airport Service	Airport Lounge	Airport Terminal	Rental Car Location	Harbor / Marina	Coffee Shop	Boat or Ferry	Sculpture Garden	Boutique	Airport Gate
3	Carnegie Hill	Coffee Shop	Café	Yoga Studio	Bookstore	Gym / Fitness Center	Gym	Italian Restaurant	French Restaurant	Cosmetics Shop	Pizza Place
4	Central Bay Street	Coffee Shop	Café	Italian Restaurant	Sandwich Place	Burger Joint	Salad Place	Japanese Restaurant	Bubble Tea Shop	Falafel Restaurant	Korean Restaurant

Table 8: Manhattan and Downtown Toronto data set with top 10 venues

H) Clustering Manhattan and Downtown Toronto Neighborhoods with k-means

Data set with all 59 neighborhoods and the frequency of occurrence of each venue category was analyzed using k-means clustering algorithm.

k-means clustering is a method of vector quantization, that aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean (cluster centers or cluster centroid), serving as a prototype of the cluster.

The number of clusters (k) was set to 6. The resulting clusters were presented in maps and tables (see chapter 4).

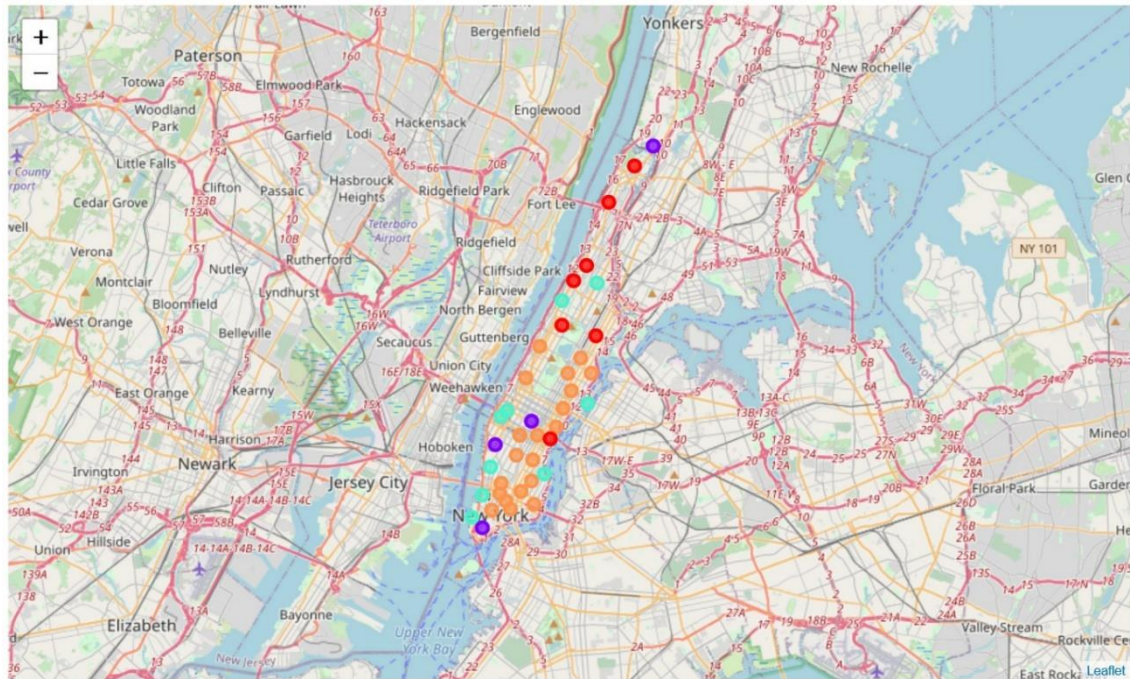
I) Presenting clusters

As mentioned above, the clusters were presented in tables and maps in Manhattan and Downtown Toronto area using Folium (see chapter 4).

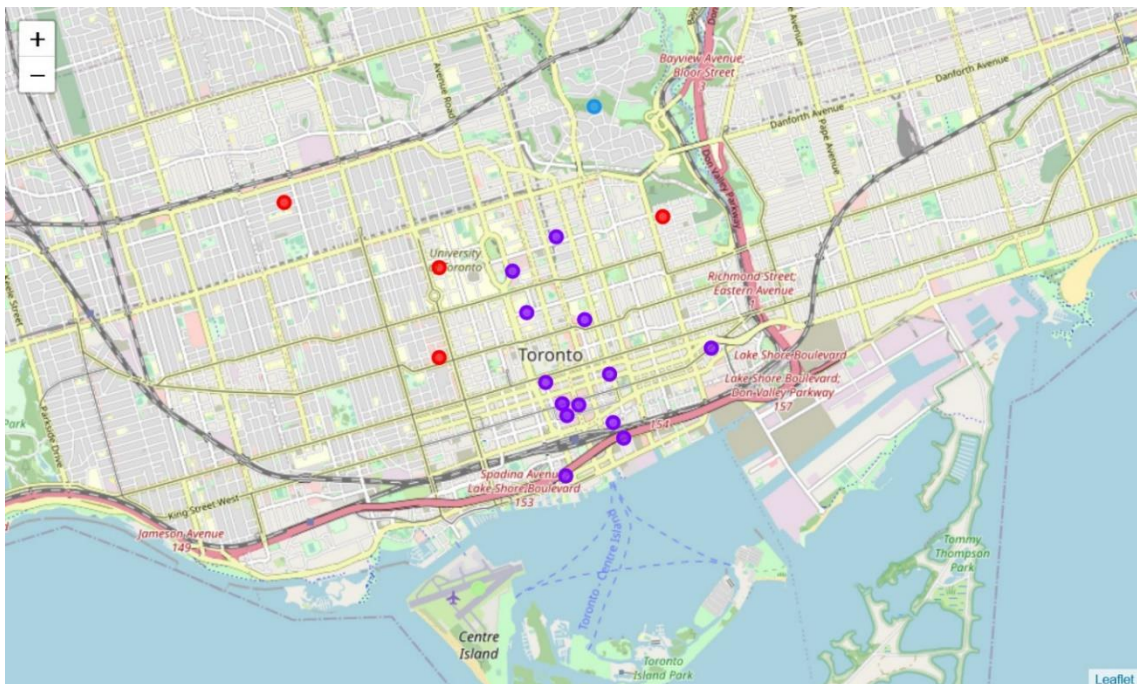
Folium is a powerful library which visualizes data that has been manipulated in Python on an interactive leaflet map. It enables both the binding of data to a map for choropleth visualizations as well as passing rich vector/raster/HTML visualizations as markers on the map.

4. Results

Results of “The Battle of Neighborhoods” are maps of clusters in Manhattan and Downtown Toronto which were presented using Folium map (see below).



Map 1: Map of clusters in Manhattan



Map 2: Map of clusters in Downtown Toronto

Six clusters of Manhattan and Downtown Toronto neighborhoods were also

presented in tables with top 10 venue categories of each neighborhood:

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
2	Washington Heights	Café	Bakery	Spanish Restaurant	Mobile Phone Shop	Chinese Restaurant	Deli / Bodega	Coffee Shop	Tapas Restaurant	New American Restaurant	Bank
3	Inwood	Mexican Restaurant	Lounge	Café	Restaurant	Caribbean Restaurant	Park	Deli / Bodega	American Restaurant	Chinese Restaurant	Pizza Place
4	Hamilton Heights	Pizza Place	Café	Coffee Shop	Mexican Restaurant	Yoga Studio	Bakery	School	Caribbean Restaurant	Sandwich Place	Chinese Restaurant
5	Manhattanville	Coffee Shop	Seafood Restaurant	Bar	Italian Restaurant	Chinese Restaurant	Mexican Restaurant	Gastropub	Sushi Restaurant	Supermarket	Lounge
7	East Harlem	Mexican Restaurant	Bakery	Thai Restaurant	Latin American Restaurant	Spa	Deli / Bodega	Sandwich Place	Seafood Restaurant	French Restaurant	Taco Place
25	Manhattan Valley	Coffee Shop	Mexican Restaurant	Thai Restaurant	Pizza Place	Bar	Farmers Market	Bakery	Korean Restaurant	Latin American Restaurant	Furniture / Home Store
36	Tudor City	Mexican Restaurant	Café	Park	Deli / Bodega	Coffee Shop	Sushi Restaurant	Diner	Seafood Restaurant	Thai Restaurant	Dog Run
46	Christie	Grocery Store	Café	Park	Coffee Shop	Baby Store	Candy Store	Diner	Athletics & Sports	Italian Restaurant	Nightclub
51	University of Toronto, Harbord	Café	Bookstore	Restaurant	Bar	Japanese Restaurant	Sandwich Place	Bakery	College Arts Building	Coffee Shop	Dessert Shop
52	Kensington Market, Chinatown, Grange Park	Café	Coffee Shop	Bar	Vietnamese Restaurant	Mexican Restaurant	Vegetarian / Vegan Restaurant	Dumpling Restaurant	Gaming Cafe	Bakery	Arts & Crafts Store
56	St. James Town, Cabbagetown	Pizza Place	Coffee Shop	Market	Café	Italian Restaurant	Restaurant	Park	Bakery	Pub	Pet Store

Table 9: Cluster 1 (marked in red on the maps)

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
0	Marble Hill	Coffee Shop	Gym	Discount Store	Sandwich Place	Yoga Studio	Pizza Place	Steakhouse	Big Box Store	Supplement Shop	Donut Shop
15	Midtown	Coffee Shop	Clothing Store	Bakery	Hotel	Theater	Sporting Goods Shop	Sandwich Place	Japanese Restaurant	Sushi Restaurant	Bookstore
17	Chelsea	Coffee Shop	Art Gallery	American Restaurant	Ice Cream Shop	Bakery	Hotel	Italian Restaurant	Cocktail Bar	Bar	Bookstore
29	Financial District	Coffee Shop	Pizza Place	Cocktail Bar	Steakhouse	Sandwich Place	Café	Gym / Fitness Center	Bar	Salad Place	American Restaurant
40	Regent Park, Harbourfront	Coffee Shop	Café	Park	Bakery	Pub	Theater	Breakfast Spot	Performing Arts Venue	Farmers Market	Bank
41	Queen's Park, Ontario Provincial Government	Coffee Shop	Yoga Studio	Portuguese Restaurant	Bar	Beer Bar	Sushi Restaurant	Smoothie Shop	Café	Sandwich Place	Chinese Restaurant
42	Garden District, Ryerson	Clothing Store	Coffee Shop	Café	Cosmetics Shop	Bubble Tea Shop	Japanese Restaurant	Hotel	Pizza Place	Middle Eastern Restaurant	Ramen Restaurant
43	St. James Town	Coffee Shop	Café	Cocktail Bar	Restaurant	American Restaurant	Gym	Park	Lingerie Store	Clothing Store	Beer Bar
44	Berczy Park	Coffee Shop	Café	Cheese Shop	Restaurant	Bakery	Farmers Market	Cocktail Bar	Beer Bar	Seafood Restaurant	Tailor Shop
45	Central Bay Street	Coffee Shop	Café	Italian Restaurant	Sandwich Place	Burger Joint	Salad Place	Japanese Restaurant	Bubble Tea Shop	Falafel Restaurant	Korean Restaurant
47	Richmond, Adelaide, King	Coffee Shop	Café	Restaurant	Hotel	Clothing Store	Gym	Thai Restaurant	Steakhouse	Bar	Salad Place
48	Harbourfront East, Union Station, Toronto Islands	Coffee Shop	Aquarium	Café	Restaurant	Hotel	Scenic Lookout	Fried Chicken Joint	Brewery	Italian Restaurant	Bar
49	Toronto Dominion Centre, Design Exchange	Coffee Shop	Hotel	Café	Restaurant	Salad Place	Japanese Restaurant	Seafood Restaurant	Italian Restaurant	American Restaurant	Concert Hall
50	Commerce Court, Victoria Hotel	Coffee Shop	Café	Restaurant	Hotel	American Restaurant	Gym	Japanese Restaurant	Italian Restaurant	Seafood Restaurant	Beer Bar
55	Stn A PO Boxes	Coffee Shop	Café	Beer Bar	Hotel	Pub	Seafood Restaurant	Italian Restaurant	Japanese Restaurant	Restaurant	Creperie
57	First Canadian Place, Underground city	Coffee Shop	Café	Hotel	Japanese Restaurant	Gym	Restaurant	Salad Place	Seafood Restaurant	Steakhouse	American Restaurant
58	Church and Wellesley	Coffee Shop	Japanese Restaurant	Sushi Restaurant	Gay Bar	Restaurant	Yoga Studio	Hotel	Mediterranean Restaurant	Men's Store	Café

Table 10: Cluster 2 (marked in violet on the maps)

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
54	Rosedale	Park	Playground	Trail	Yoga Studio	Eastern European Restaurant	Dog Run	Doner Restaurant	Donut Shop	Drugstore	Dry Cleaner

Table 11: Cluster 3 (marked in blue on Downtown Toronto map)

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
6	Central Harlem	African Restaurant	Chinese Restaurant	American Restaurant	Cosmetics Shop	French Restaurant	Bar	Seafood Restaurant	Tapas Restaurant	BBQ Joint	Public Art
11	Roosevelt Island	Park	Farmers Market	School	Deli / Bodega	Noodle House	Baseball Field	Sandwich Place	Scenic Lookout	Liquor Store	Supermarket
14	Clinton	Theater	Gym / Fitness Center	Gym	Coffee Shop	Sandwich Place	Italian Restaurant	American Restaurant	Spa	Wine Shop	Hotel
21	Tribeca	Park	Italian Restaurant	American Restaurant	Café	Wine Bar	Coffee Shop	Spa	Greek Restaurant	Bar	Poke Place
24	West Village	Italian Restaurant	New American Restaurant	American Restaurant	Park	Wine Bar	Coffee Shop	Cocktail Bar	Cosmetics Shop	Theater	Jazz Club
26	Morningside Heights	Park	Bookstore	Coffee Shop	American Restaurant	Deli / Bodega	Burger Joint	Mediterranean Restaurant	Café	Supermarket	Donut Shop
28	Battery Park City	Park	Hotel	Gym	Coffee Shop	Memorial Site	Plaza	BBQ Joint	Sandwich Place	Shopping Mall	Playground
37	Stuyvesant Town	Park	Bar	Baseball Field	Helipoint	Cocktail Bar	Harbor / Marina	Coffee Shop	Pet Service	Fountain	Bistro
39	Hudson Yards	Hotel	American Restaurant	Gym / Fitness Center	Italian Restaurant	Nightclub	Restaurant	Gym	Coffee Shop	Café	Dog Run

Table 12: Cluster 4 (marked in turquoise on Manhattan map)

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
53	CN Tower, King and Spadina, Railway Lands, Har...	Airport Service	Airport Lounge	Airport Terminal	Rental Car Location	Harbor / Marina	Coffee Shop	Boat or Ferry	Sculpture Garden	Boutique	Airport Gate

Table 13: Cluster 5 (marked in light green on Downtown Toronto map)

	Neighborhood	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
1	Chinatown	Chinese Restaurant	Bakery	Cocktail Bar	Dessert Shop	Vietnamese Restaurant	Hotpot Restaurant	Salon / Barbershop	Optical Shop	Noodle House	Spa
8	Upper East Side	Italian Restaurant	Coffee Shop	Bakery	Gym / Fitness Center	Juice Bar	Yoga Studio	Hotel	French Restaurant	Exhibit	Spa
9	Yorkville	Italian Restaurant	Coffee Shop	Gym	Bar	Sushi Restaurant	Japanese Restaurant	Mexican Restaurant	Pizza Place	Deli / Bodega	Wine Shop
10	Lenox Hill	Italian Restaurant	Coffee Shop	Sushi Restaurant	Pizza Place	Café	Cocktail Bar	Gym / Fitness Center	Gym	Deli / Bodega	Burger Joint
12	Upper West Side	Italian Restaurant	Coffee Shop	Bar	Wine Bar	Bakery	Indian Restaurant	Mediterranean Restaurant	Vegetarian / Vegan Restaurant	Thai Restaurant	Sports Bar
13	Lincoln Square	Plaza	Italian Restaurant	Café	Concert Hall	Performing Arts Venue	Theater	Indie Movie Theater	Clothing Store	Gym / Fitness Center	Wine Shop
16	Murray Hill	Sandwich Place	Hotel	Coffee Shop	Gym / Fitness Center	Italian Restaurant	American Restaurant	Japanese Restaurant	Bagel Shop	Taco Place	Bar
18	Greenwich Village	Italian Restaurant	Sushi Restaurant	Café	Clothing Store	Indian Restaurant	Dessert Shop	Chinese Restaurant	Ice Cream Shop	Gym	Vietnamese Restaurant
19	East Village	Bar	Pizza Place	Mexican Restaurant	Cocktail Bar	Coffee Shop	Ice Cream Shop	Italian Restaurant	Korean Restaurant	Vegetarian / Vegan Restaurant	Speakeasy
20	Lower East Side	Art Gallery	Chinese Restaurant	Café	Bakery	Grocery Store	Japanese Restaurant	Cocktail Bar	Coffee Shop	Ramen Restaurant	Pizza Place
22	Little Italy	Bakery	Café	Italian Restaurant	Bubble Tea Shop	Coffee Shop	Ice Cream Shop	Sandwich Place	Chinese Restaurant	Salon / Barbershop	Cocktail Bar
23	Soho	Clothing Store	Italian Restaurant	Coffee Shop	Mediterranean Restaurant	Café	Salon / Barbershop	Shoe Store	Boutique	Bakery	Dessert Shop
27	Gramercy	Bar	Coffee Shop	Italian Restaurant	American Restaurant	Pizza Place	Grocery Store	Ice Cream Shop	Cocktail Bar	Playground	Mexican Restaurant
30	Carnegie Hill	Coffee Shop	Café	Yoga Studio	Bookstore	Gym / Fitness Center	Gym	Italian Restaurant	French Restaurant	Cosmetics Shop	Pizza Place
31	Noho	Italian Restaurant	Pizza Place	Hotel	Yoga Studio	Sushi Restaurant	Mexican Restaurant	Sandwich Place	Grocery Store	Art Gallery	French Restaurant
32	Civic Center	Coffee Shop	Gym / Fitness Center	Hotel	Cocktail Bar	Yoga Studio	Spa	French Restaurant	Park	Sushi Restaurant	American Restaurant
33	Midtown South	Korean Restaurant	Hotel	Dessert Shop	Japanese Restaurant	Gym / Fitness Center	Coffee Shop	Bakery	Cosmetics Shop	Flower Shop	Burger Joint
34	Sutton Place	Italian Restaurant	Gym / Fitness Center	Coffee Shop	Park	Pizza Place	Furniture / Home Store	Mediterranean Restaurant	Beer Bar	Beer Garden	Chinese Restaurant
35	Turtle Bay	Coffee Shop	Café	Italian Restaurant	Sushi Restaurant	Seafood Restaurant	Park	Wine Bar	Japanese Restaurant	Deli / Bodega	French Restaurant
38	Flatiron	New American Restaurant	Italian Restaurant	Japanese Restaurant	Gym / Fitness Center	Spa	Furniture / Home Store	Mediterranean Restaurant	Gym	Mexican Restaurant	American Restaurant

Table 14: Cluster 6 (marked in orange on Manhattan map)

5. Discussion

Results presented in chapter 4 show six clusters of neighborhoods in Manhattan and Downtown Toronto that were created with k-means clustering based on frequency of venue categories in each neighborhood.

Cluster 1 presents a mix of Manhattan and Downtown Toronto neighborhoods, which means that Manhattan and Downtown Toronto have similar neighborhoods in respect to their top venues (marked in red on the maps).

These are seven Manhattan neighborhoods (Washington Heights, Inwood, Hamilton Heights, Manhattanville, East Harlem, Manhattan Valley and Tudor City) and four Downtown Toronto neighborhoods (Christie, University of Toronto, Kensington Market and St. James Town/Cabbage Town).

Cluster 2 also presents a mix of Manhattan and Downtown Toronto neighborhoods (marked in violet on the maps). These are seventeen similar neighborhoods in total, four Manhattan neighborhoods (Marble Hill, Midtown, Chelsea, and Financial District) and thirteen Downtown Toronto neighborhoods (Reagent Park, Queen's Park, Garden District, St. James Town, Berczy Park, Central Bay Street, Richmond, Harbourfront East, Toronto Dominion Centre, Commerce Court, Stn A PO Boxes, First Canadian Place, Church and Wellesley).

Cluster 3 has only one neighborhood, Rosedale from Downtown Toronto (marked in blue on Downtown Toronto map). It is a neighborhood with a lot of green areas, where Park, Playground and Trail are top venue categories. Therefore, it is no surprise that Rosedale has its own cluster which is not like any other neighborhood.

Cluster 4 has nine neighborhoods, all from Manhattan (marked in turquoise on Manhattan map).

Cluster 5 has only one neighborhood, the one around the airport on Centre Island (marked in light green on Downtown Toronto map). Such result is expected since top venue categories like Airport Service, Airport Lounge or Airport Terminal have nothing to do with other neighborhoods.

Cluster 6 has twenty neighborhoods, all from Manhattan (marked in orange on Manhattan map).

6. Conclusion

Clusters 1 and 2, that are result of k-means clustering algorithm, show that Manhattan and Downtown Toronto have similar neighborhoods.

Therefore, the answer to the initial question whether Manhattan and Downtown Toronto have similar neighborhoods is positive, when one considers top venue categories, extracted by Foursquare API in each of 59 neighborhoods.