BU Sustainability:
Water Bottle Filling Station
Team C Final Report

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Github:
https://github.com/BU-Spark/ds-bu-sustainability-water/tree/team-c_extension/sp24-team-c

Google Drive:
https://drive.google.com/drive/folders/1ExecnOdKO9yKk2YWYW_YnMzOl95Xk9Fv

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Introduction

The topic of this project is to evaluate the best locations for installing new water bottle stations for our Boston University campus. This project is meaningful because it not only supports environmental sustainability by reducing the use of disposable plastic bottles but also helps ensure that students have easy access to drinking water, promoting better hydration and wellness on campus. Here is a brief introduction of this report.

Base Analysis

In our base analysis part, we make some initial filter and processing for original wifi data and station & kitchen data, the 3 most important filters are:

1. Exclude all floors with existed water stations, exclude all floors with kitchens
2. Building type selection:Exclude Parking, specific Housing, and Commercial buildings. For residential buildings, only include large dormitory style
3. Exclude dining hall floor.

The code related to our base analysis are [wifi_data_process.ipynb] ,[produce_kitchen_station_tables.ipynb] and [seperate_covered_floor_or_not.ipynb]. After coding we get [covered_floors.csv] and [uncovered_floors.csv]. [Ccovered_floors.csv] includes all floors with kitchen and existing water stations while [uncovered_floors.csv] excludes all floors with kitchen and existing water stations .Both sheets are source files for extension analysis.

We also post our answer to key question 1 and 2 into the base analysis part.

Extension Analysis

In our extension analysis part , we list hourly mean density, hourly max density(per hour), air condition (Mechanical ventilation) and high volume as factors for new water bottle selection. We also build a weight score standard based on factors above . Using this weight score standard, we

choose the top 50 highest weight floors from [uncovered_floors.csv] as new station candidates, which are saved as [selected_candidates.csv]

Besides, we make some pie charts and bar charts as visualization for covered floors sheet, uncovered floors sheet and select candidates sheet. We also post our answers of key questions 3 to 5 into the extension analysis part (since our extension analysis is related to most key questions). All the codes for this part can be found in [final_selection_and_visualization.ipynb].

The most important outcome for this extension analysis is the weight score standard we build, here is the detail:

Weight for selecting new water bottle station =

(mean density × 1 + max density × 0.3) × volume factor × ventilation factor

Volume factor is: 10 if high volume, else 1

Ventilation factor is: 1 if Mechanical Ventilation is 'Yes', 2 if Mechanical

Ventilation is 'Partial', 3 if Mechanical Ventilation is 'No'

Then in the **future scope** section, we talk about 4 potential suggestions for future enhancements, they are: 1. Broader Scope of Environmental Factors, 2. Enhanced User Feedback Mechanisms , 3.Integration of Real-Time ,4.Data Consider multiple water stations on larger floors.

The **Individual Contribution** is the last section, which shows each member's contribution for this project.

Base Analysis

- Inventory of known/existing filling stations
- Inventory of campus buildings and rooms with kitchens
- BU Wifi Data for foot traffic
- BU Floor Descriptions (Useful for foot traffic data)
- BU High Volume Event spaces

These hyperlinks include what the client gave us at the beginning of semester, and they are also our original data for analysis. We separate base analysis into 5 parts before answering : Wifi data for foot traffic processing, Kitchen and Station Table processing, Exclude covered floor (water station & kitchen floor), Add high volume and air condition and Delete dining hall. Then we post answer to key question 1& 2 in this part.

1.Wifi data for foot traffic processing

Here our first step is to build some analysis for wifi data. See in BU Wifi Data for foot traffic , we find this is a huge data sheet, which show the wifi foot traffic for certain location (building description & building floor) and certain time (date and hour), here we make two filter steps, the processes can be seen in our [wifi_data_process.ipynb]

Step A: We get the average and max density cnt (density cnt refers to the number of people in the space at a given point in time) for each floor per hour, instead of showing many dates and hours. We also get the average and max density ratio.

This step simplifies the analysis by condensing a lot of time data, helping us quickly spot regular and peak usage trends. By focusing on average and maximum values, we get a clear view of daily and peak usage, which is crucial for properly placing water bottle stations.

Step B: We exclude some building types. We exclude Parking, specific Housing, and Commercial buildings from consideration. We make this selection because specific Housing, and Commercial buildings are normally

private buildings, which make new water stations meaningless. For parking buildings the reason is people usually just park their car and leave, which means they do not want to drink on the parking floor. For residential buildings, we only include large dormitory style into consideration because other residential buildings are not open to the public.

date	hour	building_floor	building_desc	latitude	longitude	building_type	density_cr	capacity	dc_ratio
3/31/2021	1	4	209 BAY STATE ROAD	42.3507	-71.1028	Residential	1	8	0.13
3/31/2021	1	2	200-202 BAY STATE ROAD	42.3503	-71.1026	Residential	1	12	0.08
3/31/2021	1	2	184 BAY STATE ROAD	42.3503	-71.1019	Residential	1	6	0.17
3/31/2021	1	3	190 BAY STATE ROAD	42.3503	-71.1021	Residential	1	9	0.11
3/31/2021	1	3	161 BAY STATE ROAD	42.3506	-71.1009	Residential	1	5	0.2
3/31/2021	1	4	163 BAY STATE ROAD	42.3506	-71.1009	Residential	2	3	0.67
3/31/2021	1	3	163 BAY STATE ROAD	42.3506	-71.1009	Residential	1	3	0.33
3/31/2021	1	2	159 BAY STATE ROAD	42.3506	-71.1008	Residential	6	6	1

Figure 1 several first rows of [BU Wifi Data for foot traffic]

After dealing with original wifi data, we get [updated_wifi_data.csv] as our processed wifi data, which will be used in later steps.

building_floor	building_desc	latitude	longitude	building_type	capacity	mean_density_cnt	max_density_cnt	average_dc_ratio	max_dc_ratio
1	771 COMMONWEALTH AVENUE	42.351	-71.108	Student Support	73	25.44899797	309	0.348616411	4.232876712
2	771 COMMONWEALTH AVENUE	42.351	-71.108	Student Support	92	30.47722567	283	0.331274192	3.076086957
1	775 COMMONWEALTH AVENUE	42.3509	-71.109	Student Support	534	78.56353344	534	0.147122722	1
1	1 UNIVERSITY ROAD	42.3512	-71.11	Academic	307	51.58559521	351	0.168031255	1.143322476
1	745 - 755 COMMONWEALTH AVENUE	42.3505	-71.1073	Academic	129	40.2194126	319	0.311778392	2.472868217
2	745 - 755 COMMONWEALTH AVENUE	42.3505	-71.1073	Academic	60	10.39021281	81	0.173170213	1.35
1	264-270 BAY STATE ROAD	42.3507	-71.1054	Academic	58	25.8062755	227	0.444937509	5.819344828

Figure 2 several first rows of updated_wifi_data.csv

2.Kitchen and Station Table processing

Now we want to make some filters for existing bottle section sheet Inventory of known/existing filling stations and kitchen sheet Inventory of campus buildings and rooms with kitchens. These two sheets include lots of information, however some information is useless for our analysis so we make some filters.

For the existing water bottle sheet, we combine address A and B into building description (a full address) , and only keep floor,building description, room, quantity, data installed and station type. For the kitchen sheet, only keep the floor, building code, building description and room.

The process of this step can be seen in

[produce_kitchen_station_tables.ipynb]. After running this code, we get [Stations.csv] and [Kitchens.csv] as our processed station and kitchen data, which will be used in later steps.

Floor	Building Description	Space@Bu room	Quantity	Date Installed
1	1 UNIVERSITY ROAD	190A	1	
1	1 UNIVERSITY ROAD		1	
3	1 UNIVERSITY ROAD	390	1	
2	1 UNIVERSITY ROAD	284	1	
1	100 ASHFORD STREET	191	1	
3	100 BAY STATE ROAD	329	1	2012
6	100 BAY STATE ROAD	691A	1	2012
5	100 BAY STATE ROAD	591D	1	2012
-1	100 BAY STATE ROAD	B91	1	2012
1	100 BAY STATE ROAD	191B	1	2012
4	100 BAY STATE ROAD	491A	1	2012
1	1019 COMMONWEALTH AVENUE	198	1	
5	1019 COMMONWEALTH AVENUE	591	1	2023-07-23 00:00:00
6	1019 COMMONWEALTH AVENUE	691	1	2023-07-23 00:00:00
2	1019 COMMONWEALTH AVENUE	291	1	2023-07-23 00:00:00
3	1019 COMMONWEALTH AVENUE	394	1	2023-07-23 00:00:00
4	1019 COMMONWEALTH AVENUE	491	1	2023-07-23 00:00:00

Floor	Building Code	Building Description	Room #
1	623	1 UNIVERSITY ROAD	104
1	623	1 UNIVERSITY ROAD	150G
1	623	1 UNIVERSITY ROAD	150K
10	500	10 BUICK STREET	1001
5	500	10 BUICK STREET	505
5	500	10 BUICK STREET	506
5	500	10 BUICK STREET	507
5	500	10 BUICK STREET	508
5	500	10 BUICK STREET	509
5	500	10 BUICK STREET	510
5	500	10 BUICK STREET	511
5	500	10 BUICK STREET	512
5	500	10 BUICK STREET	513
5	500	10 BUICK STREET	514
5	500	10 BUICK STREET	515
5	500	10 BUICK STREET	516

Figure 3 and 4. Previews of [Stations.csv](left) and [Kitchens.csv](right)

3. Exclude covered floor (water station & kitchen floor)

Floors with existing water bottle stations or kitchens should be excluded from consideration for new bottle station choosing because (1) these places already have access to drinking water, which makes additional stations less useful. Resources should be given to where they're most needed , (2) kitchen floors are usually private floors, so kitchens can serve as water sources for people who have access to these floors.

To realize this, we use [seperate_covered_floor_or_not.ipynb] to combine [Stations.csv] and [Kitchens.csv] into [covered_floors.csv]. Then we use [seperate_covered_floor_or_not.ipynb] to separate [updated_wifi_data.csv] into [covered_floors.csv] and [uncovered_floors.csv].

[covered_floors.csv] and [uncovered_floors.csv] are the only two source files we will use in extension analysis, and all the new station candidates will be selected from [uncovered_floors.csv], but here are still two additional steps I do not mention for how to form [uncovered_floors.csv]. These steps are called **4.add high volume and air condition** and **5. Delete dining hall** as described below.

building_floor	building_desc	latitude	longitude	building_type	capacity	mean_density_	max_density	average_dc_ratio	max_dc_ratio	Residential Building Typ	Mechanical Ventilation
1	915 COMMONWEALTH AVENUE	42.3518	-71.1165	Student Support	204	80.63353488	353	0.395262426	1.730392157		Yes
1	33 HARRY AGGANIS WAY	42.3532	-71.1178	Residential	84	79.65136535	370	0.94823054	4.404761905	Large Dormitory-Style	Yes
1	775 COMMONWEALTH AVENUE	42.3509	-71.109	Student Support	534	78.56353344	534	0.147122722	1		Yes
2	890 COMMONWEALTH AVENUE	42.3505	-71.1156	Academic	238	73.77037838	367	0.309959573	1.542016807		Yes
1	2 SILBER WAY	42.3497	-71.1009	Academic	87	73.43170503	417	0.844042587	4.793103448		Yes
1	1019 COMMONWEALTH AVENUE	42.3523	-71.1214	Residential	50	72.45283836	661	1.449056767	13.22	Large Dormitory-Style	Yes
2	595 COMMONWEALTH AVENUE	42.3496	-71.0997	Academic	213	72.19832014	645	0.338959249	3.028169014		Yes

building_floc	building_des	latitude	longitude	building_t	capacity	mean_den	max_dens	average_d	max_dc_r	Residentia	Mechanica	Room Nar	Candidacy	High Volu	high_volumn
-1	700 COMMC	42.3493	-71.104	Residentia	0	53.27402	363	inf	inf	Large Don	Partial				FALSE
c	925 COMMC	42.3522	-71.1177	Athletic	0	48.95452	375	inf	inf	Yes		Agganis A	Maybe	Yes	TRUE
1	949 COMMC	42.3519	-71.1187	Academic	45	45.24887	432	1.005531	9.6	Yes					FALSE
3	925 COMMC	42.3522	-71.1177	Athletic	29	41.11186	1857	1.41765	64.03448	Yes					FALSE
2	8 ST. MARY'	42.3492	-71.1061	Research	145	39.0977	402	0.269639	2.772414	Yes					FALSE
2	750 COMMC	42.3498	-71.108	Academic	227	36.25578	318	0.159717	1.400881	Yes					FALSE
2	540 COMMONWEALTH AVENUE			Academic	38	35.29475	404	0.928809	10.63158	Yes					FALSE
1	700 COMMC	42.3493	-71.104	Residentia	171	33.36714	314	0.195129	1.836257	Large Don	Partial				FALSE

Figure 5 and 6 . preview of [covered_floors.csv] (up)and [uncovered_floors.csv] (down)

4.Add high volume and air condition

Souring from [High Volume Event Spaces.xlsx - Sheet1.csv] and [inventory of campus buildings and rooms with kitchens] , we also added [Mechanical Ventilation] and [high_volumn] into [uncovered_floors.csv]. Coding about this step is in [seperate_covered_floor_or_not.ipynb].

We do this because we think air conditioning(which implies by Mechanical Ventilation) and high volume are two important factors for choosing new water bottle stations. High-volume environments typically indicate that a location is active and busy, such as gyms, stadiums, or concert stages. In these places, physical activity is common, and the demand for drinking increases. Air conditioning is critical because poor air quality can heighten dehydration, making access to water especially important in such environments. Therefore, locations with inadequate mechanical ventilation are prioritized for new water stations to ensure hydration needs are met efficiently.

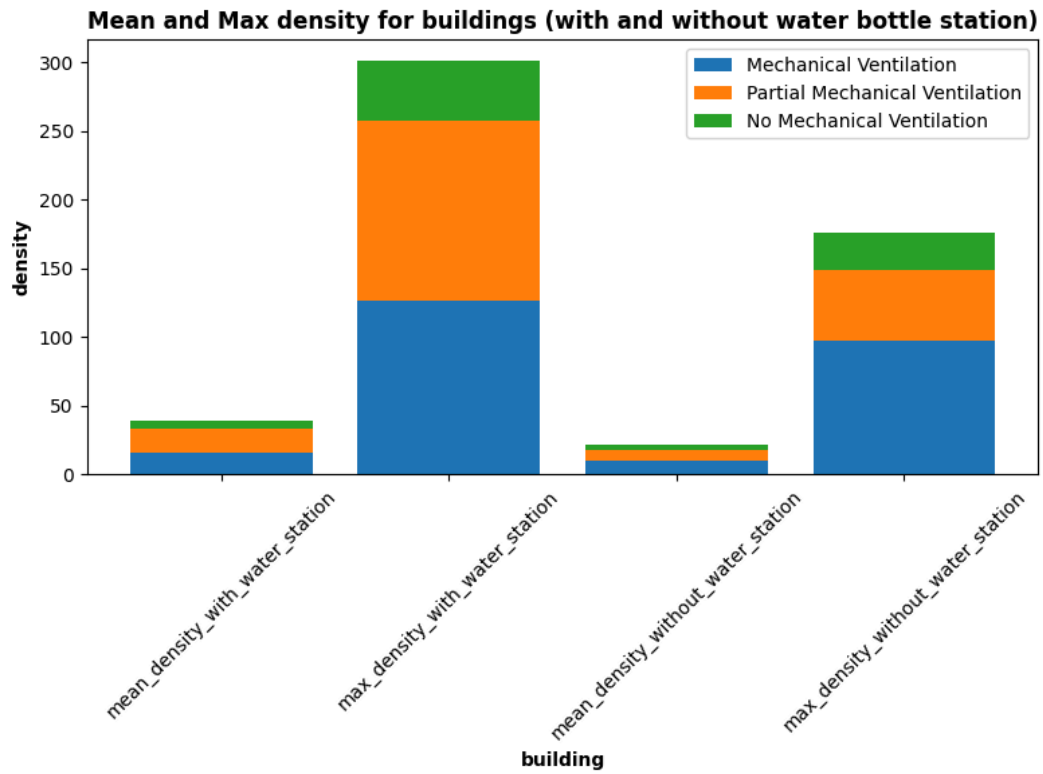


Figure 7. Average Mean and max density for buildings with mechanical ventilation conditions labeled.

5. Delete dining hall

We excluded dining hall floors from bottle station choosing because people can get various beverages when they having their meal in dinning hall, so water station is useless in these places. A more detailed report can be found in [Mannually_exlcuded_report.pdf] .

Now we have already made a basic analysis , in the Extension analysis part , we will decide factors and weight for the new station selection standard , answer key questions, and make some figure display. [covered_floors.csv] and [uncovered_floors.csv]will be source sheets for extension analysis. But we can answer key questions 1 and 2 in the base part.

Key Question 1: Establish how many students and employees are impacted by each current water filling station and kitchen

Answer : From our filtered water station and kitchen listcovered_floors.csv, we found the hourly mean and max foot traffic(mean_density_cnt and max_density_cnt) of these floors. This gives a rough idea of how many people each water filling station affects.

We sort hourly mean density as high to low to see how many students and employees are impacted by each current water filling station and kitchen. Figure 8 is the screenshot to display top15 mean density covered floors, while figure 9 is the bar chart to display top15 mean density covered floors and figure 10 is the bar chart to display top15 mean density covered floor with max density also shown.

building_fl	building_desc	latitude	longitude	building_ty	capacity	mean_density_cnt
1	915 COMMONWEALTH AVENUE	42.3518	-71.1165	Student Su	204	80.63353488
1	33 HARRY AGGANIS WAY	42.3532	-71.1178	Residentia	84	79.65136535
1	775 COMMONWEALTH AVENUE	42.3509	-71.109	Student Su	534	78.56353344
2	890 COMMONWEALTH AVENUE	42.3505	-71.1156	Academic	238	73.77037838
1	2 SILBER WAY	42.3497	-71.1009	Academic	87	73.43170503
1	1019 COMMONWEALTH AVENUE	42.3523	-71.1214	Residentia	50	72.45283836
2	595 COMMONWEALTH AVENUE	42.3496	-71.0997	Academic	213	72.19832014
1	275 BABCOCK STREET	42.3528	-71.1204	Residentia	250	69.18003565
1	1010 COMMONWEALTH AVENUE	42.3513	-71.121	Academic	92	62.83898377
1	163-179 AMORY STREET	42.3502	-71.1136	Administra	103	62.57086306
-1	64-86 CUMMINGTON MALL	42.3487	-71.104	Academic	0	59.99750652
1	595 COMMONWEALTH AVENUE	42.3496	-71.0997	Academic	245	59.59259443
3	595 COMMONWEALTH AVENUE	42.3496	-71.0997	Academic	269	53.81736928
1	590 COMMONWEALTH AVENUE	42.3484	-71.1002	Research	326	53.01517739
1	1 UNIVERSITY ROAD	42.3512	-71.11	Academic	307	51.58559521
4	595 COMMONWEALTH AVENUE	42.3496	-71.0997	Academic	314	49.82912045

Figure 8: the screenshot to display top15 hourly mean density covered floors

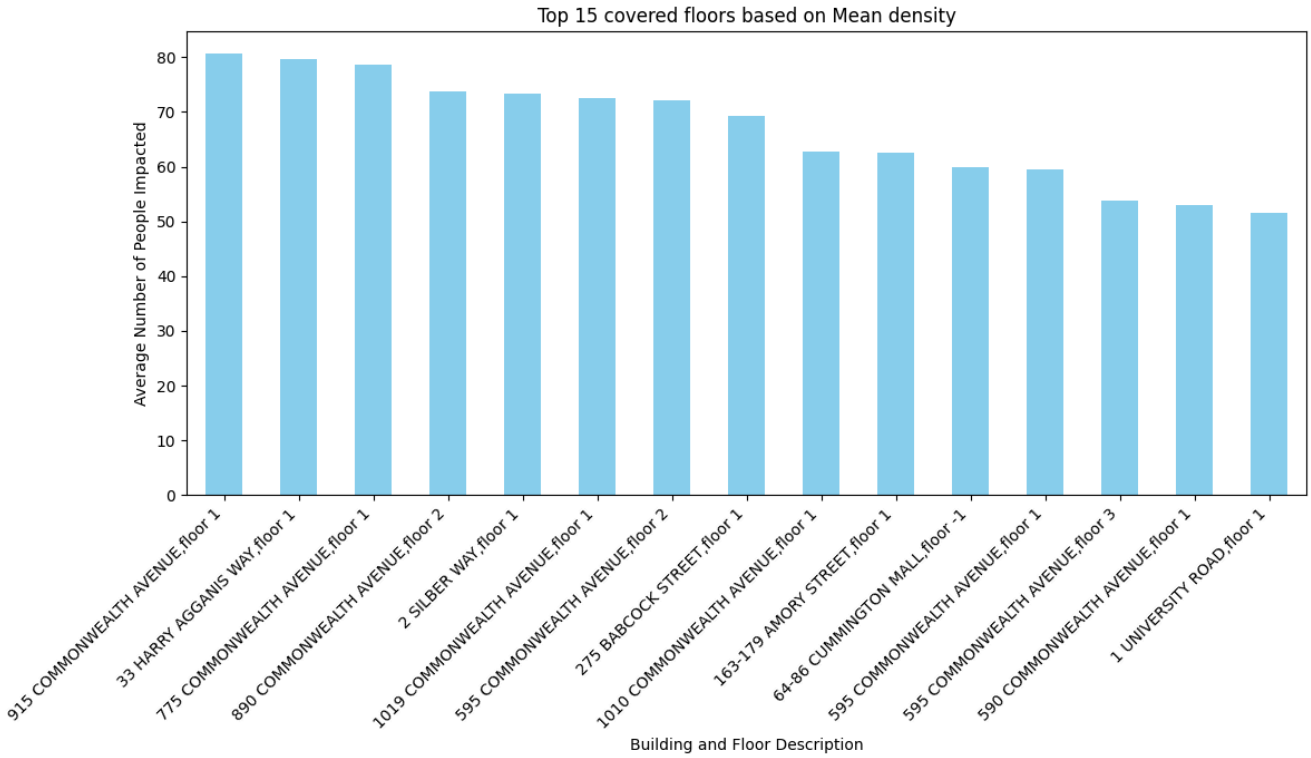
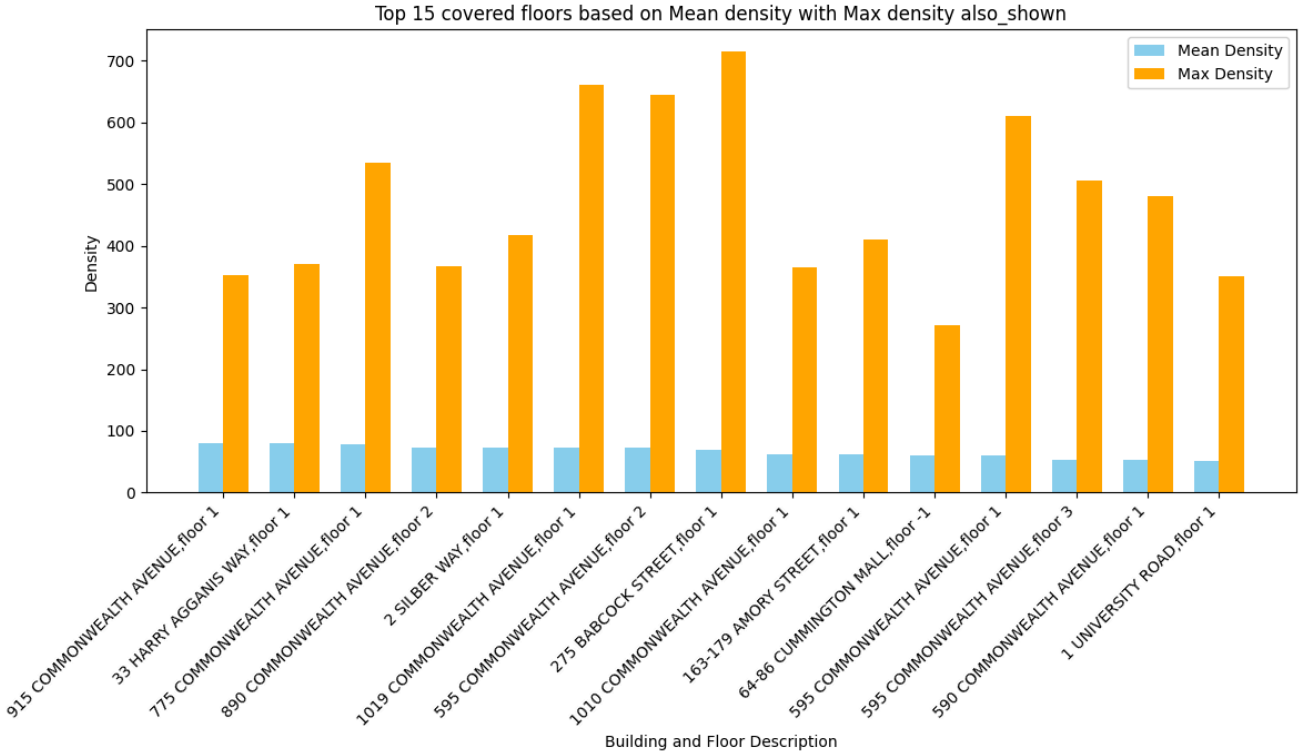


Figure 9 (up) and 10 (down)



Key Question 2: Establish a full list of the factors and criteria for installation of new filling stations.

Answer: We separate the full list into the filter section and factor section.

Filter section: as I mentioned in base analysis before, with following exclusion:

A. Exclude covered floor (water station & kitchen floor)
B. Exclude Parking ,Housing, and Commercial buildings . For residential buildings we only consider large dorm-style residences
C. Exclude dining hall floors

Now we get uncovered_floors.csv for further new station choosing.

Factor section : We list the following four factors for installation of new filling station consideration.

A. Mean Density (Foot Traffic) (hourly)
B. Max Density (Foot Traffic) (hourly)
C. Air Condition (Mechanical Ventilation)
D. High Volume

High mean density tells us when and where most people usually gather together. High max density density tells us where most people gather at the busiest time. More people implies more requirements for water bottle stations. We can see from figure 11 that both mean and max density are larger for floors with water stations.

High-volume environments typically indicate that a location is active and busy, such as gyms, stadiums, or concert stages. In these places, physical activity is common, and the demand for drinking increases. Air conditioning is critical because poor air quality can heighten dehydration, making access to water especially important in such environments. Therefore, locations with inadequate mechanical ventilation and high volume are prioritized for new water stations to ensure hydration needs are met efficiently.

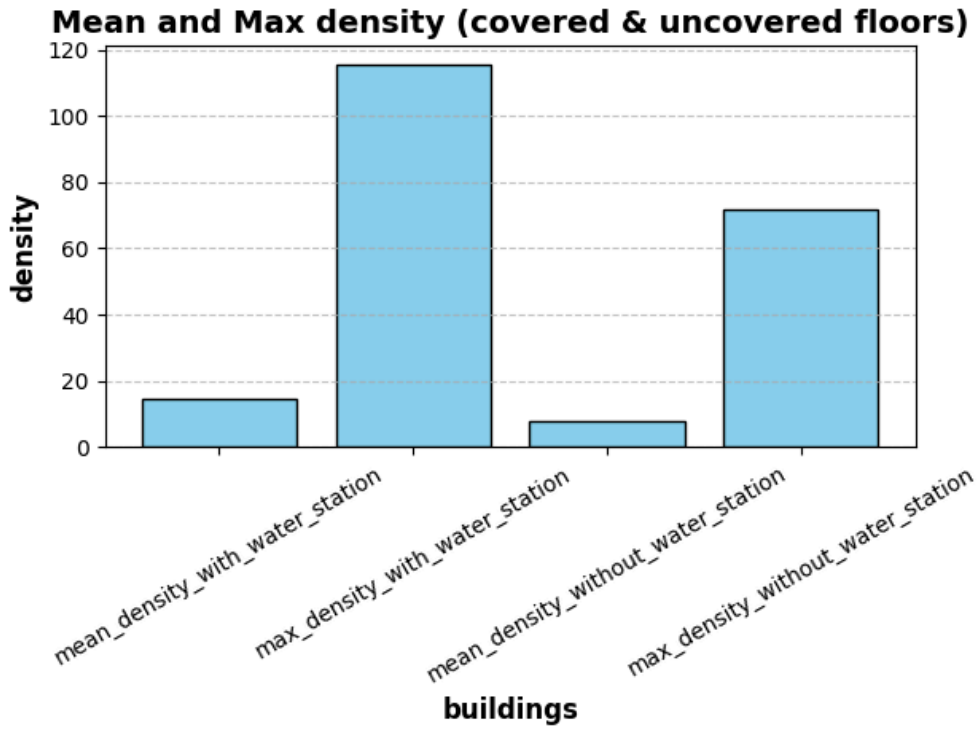


Figure 11 : Average mean and max density for covered & uncovered floors

Extension analysis

We make some initial data process and get [covered_floors.csv] and [uncovered_floors.csv] , which means floors with and without station and kitchen. [**final_selection_and_visualization.ipynb**] is the only code part for extension analysis. Now we want to answer key questions 3 to 5.

Key Question 3 :Determine criteria and factors for new, high-priority water filling station locations.

Answer: As we explained in the key question 2, we make some filters and get uncovered_floors.csv and then take **mean density, max density, air condition and high volume** as factors.

Then we build a **weight score standard** based on these factors , and select top 50 weight score floors from uncovered_floors.csv and define them as new candidates.

All codes about building this new standard and choosing new stations can be found in final_selection_and_visualization.ipynb, and the new candidate list is selected_candidates.csv.

Here is the details about this weight score standard:

Weight ={ [mean density] X 1 + [max density] X 0.3 }

{	{
X 1 if not high volume	X 1 if Mechanical Ventilation is 'Yes'
X 10 if high volume	X 2 if Mechanical Ventilation is 'Partial'
}	X 3 if Mechanical Ventilation is 'No'
	}

Here is another expression for our weight score standard:

Weight Calculation Formula:

Weight for selecting new water bottle station =

(mean density × 1 + max density × 0.3) × volume factor × ventilation factor

Where:

For Volume factor:

If a high volume environment, then it is 10

If not a high volume environment, then it is 1

For Ventilation factor:

If Mechanical Ventilation is 'Yes', then it is 1

If Mechanical Ventilation is 'Partial', then it is 2

If Mechanical Ventilation is 'No', then it is 3

In determining the placement of new water bottle stations, the weighting system is carefully designed to prioritize hydration needs based on environmental and usage factors. The mean density of an area is given a higher weight than the maximum density, as it more accurately reflects the consistent usage and need over time, rather than peak usage, which may be occasional. Poor mechanical ventilation, represented by conditions where ventilation is partial or absent, is heavily weighted to address the higher risk of dehydration in poorly circulated air environments. Furthermore, high volume areas are assigned the greatest weight. These locations, such as busy gyms or concert venues, typically see a large number of occupants engaging in activities that increase hydration needs, thereby prioritizing them for water station installation to ensure adequate access to water.

Now we sort weight as priority for choosing new candidates and the uncovered floors with top 50 weight scores are shown in selected_candidates.csv.

Here is the more detail explanation for selected_candidates.csv :

- [building_floor, building_desc, latitude, longitude] : Building floor number, building address and geographical position of selected new stations, all these four parameters show location information of selected new stations.

- [building_type] : building type of selected new station. Totally there are 6 building types for selected new stations :Academic, Residential, Athletic, Research, Student support and Administrative. [Residential Building Type] shows [Large Dormitory-Style] for Residential building types. These two parameters provide building type information of selected new stations.

- [capacity, mean_density_cnt, max_density_cnt, average_dc_ratio, max_dc_ratio] : This set of parameters provides insights into the population dynamics within the newly selected stations.Capacity is

the maximum population that a floor can accommodate per hour. Mean Density Count (mean_density_cnt) represents the average population per floor per hour, indicating the usual level of activity. Maximum Density Count (max_density_cnt) shows the peak population for each floor per hour, showing the maximum number of people present during the busiest times. Average Density Ratio (average_dc_ratio can be calculated as mean density count divided by capacity, this ratio helps gauge the average usage of the space relative to its capacity. Maximum Density Ratio (max_dc_ratio) is calculated as maximum density count divided by capacity, offering a measure of how crowded the station can get at peak times.These metrics collectively provide valuable information on access frequency and congestion levels at the selected new stations.

- [Mechanical Ventilation] : This parameter indicates the air conditioning quality in the newly selected stations based on the status of mechanical ventilation. If 'Mechanical Ventilation' is 'Yes', the floor has an excellent air conditioning performance. If 'Mechanical Ventilation' is 'Partial', the floor has a moderate air conditioning performance. If 'Mechanical Ventilation' is 'No', the floor has a poor air conditioning quality.

- [Room Name, Candidacy, High Volume] : Information for high volume places, with their room name, whether they are candidacy or not and whether the place is high volume place or not, these information comes from 'High Volume Event Spaces.xlsx - Sheet1.csv'

- [weight]:Weight score based on our standard, we use this weight score to decide new selected stations. Higher weight score means higher priority to be chosen. Here is our weight score standard:

- Weight for selecting new water bottle station = (mean density × 1 + max density × 0.3) × volume factor × ventilation factor

- Volume factor is: 10 if high volume, else 1
- Ventilation factor is: 1 if Mechanical Ventilation is 'Yes', 2 if Mechanical Ventilation is 'Partial', 3 if Mechanical Ventilation is 'No'

Figure 12 is the screenshot to display top15 selected new stations based on weight. Figure 13 is the bar chart to display top15 selected new stations based on weight . Figure 14 is the bar chart to display top15 selected new stations based on weight with mean density also shown. Figure 15 is the bar chart to display top15 selected new stations based on weight with max density also shown.

weight	uilding_floc	building_desc	latitude	longitude	uilding_typ	capacity	mean_density_cnt	max_density_cnt
1703.998059	3	285 BABCOCK STREET	42.354	-71.1203	Athletic	1138	9.599805933	536
1614.545178	c	925 COMMONWEALTH AVENUE	42.3522	-71.1177	Athletic	0	48.95451777	375
598.2118556	3	925 COMMONWEALTH AVENUE	42.3522	-71.1177	Athletic	29	41.11185557	1857
493.6014381	3	775 COMMONWEALTH AVENUE	42.3509	-71.109	ıdent Supp	144	14.26014381	117
324.3480467	-1	700 COMMONWEALTH AVENUE	42.3493	-71.104	Residential	0	53.27402333	363
262.952264	2	100 ASHFORD STREET	42.3546	-71.1236	Athletic	48	23.85226405	797
255.134273	1	700 COMMONWEALTH AVENUE	42.3493	-71.104	Residential	171	33.36713651	314
174.8488739	1	949 COMMONWEALTH AVENUE	42.3519	-71.1187	Academic	45	45.24887387	432
161.3063834	4	617-621 COMMONWEALTH AVENUE	42.3497	-71.1013	Academic	30	6.068794459	159
159.6977046	2	8 ST. MARY'S STREET	42.3492	-71.1061	Research	145	39.09770461	402
156.4947511	2	540 COMMONWEALTH AVENUE			Academic	38	35.29475113	404
140.1428073	4	285 BABCOCK STREET	42.354	-71.1203	Athletic	32	12.64280733	425
132.1275374	2	285 BABCOCK STREET	42.354	-71.1203	Athletic	917	11.52753737	402
131.6557755	2	750 COMMONWEALTH AVENUE	42.3498	-71.108	Academic	227	36.25577546	318
124.5108067	t	675 - 725 COMMONWEALTH AVENUE	42.3502	-71.1046	Research	0	9.155403364	177

Figure 12: the screenshot to display top15 selected new stations based on weight

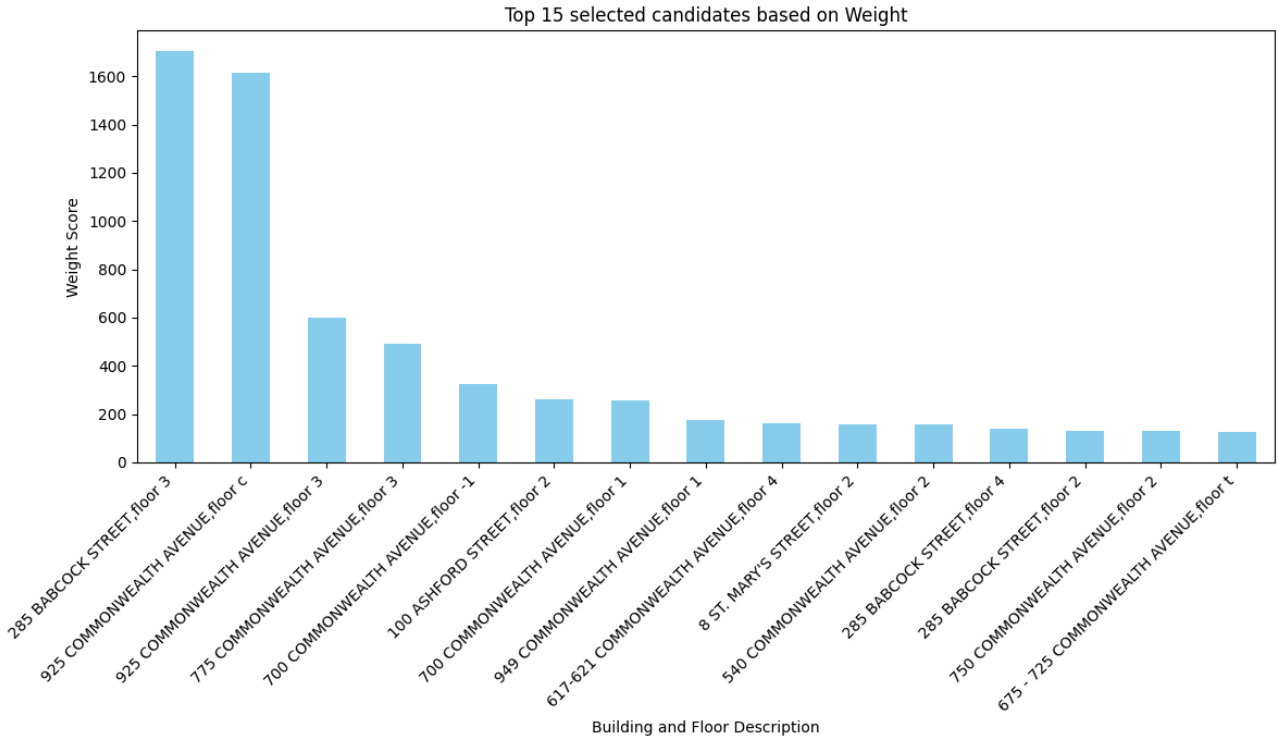
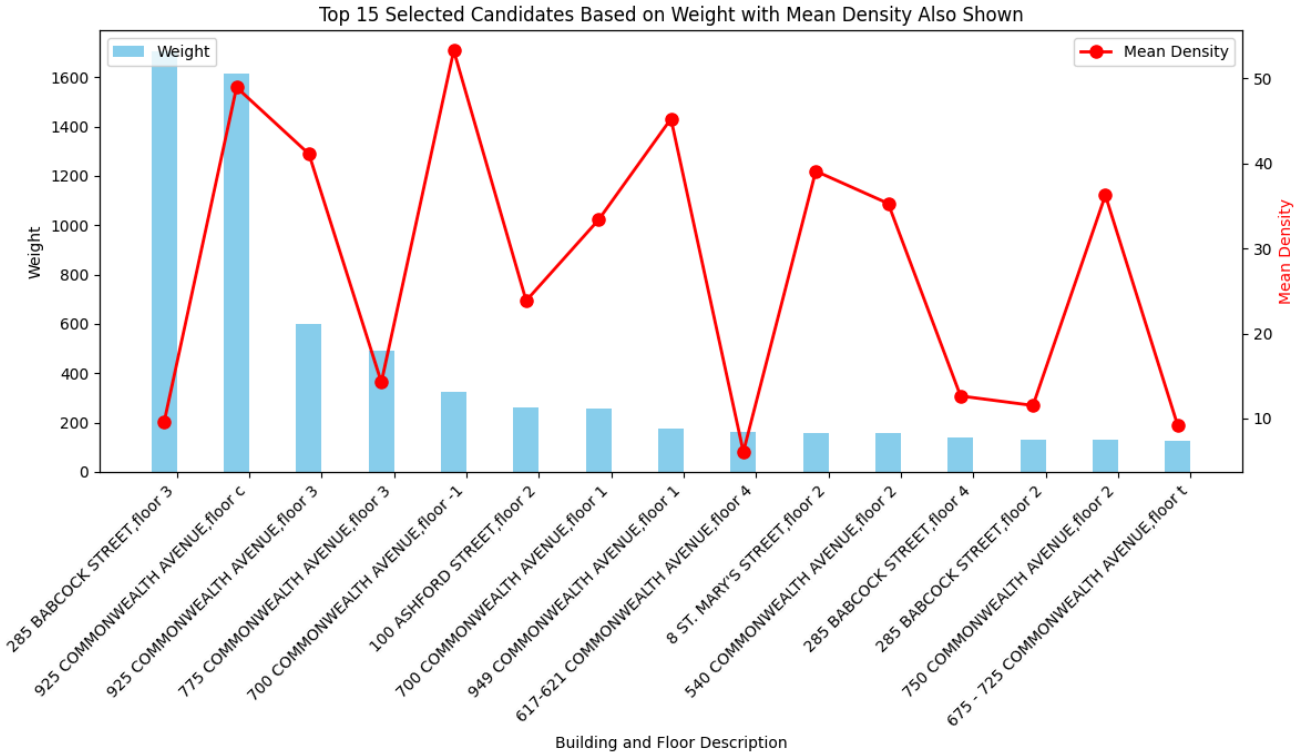


Figure 13 (up) and 14 (down)



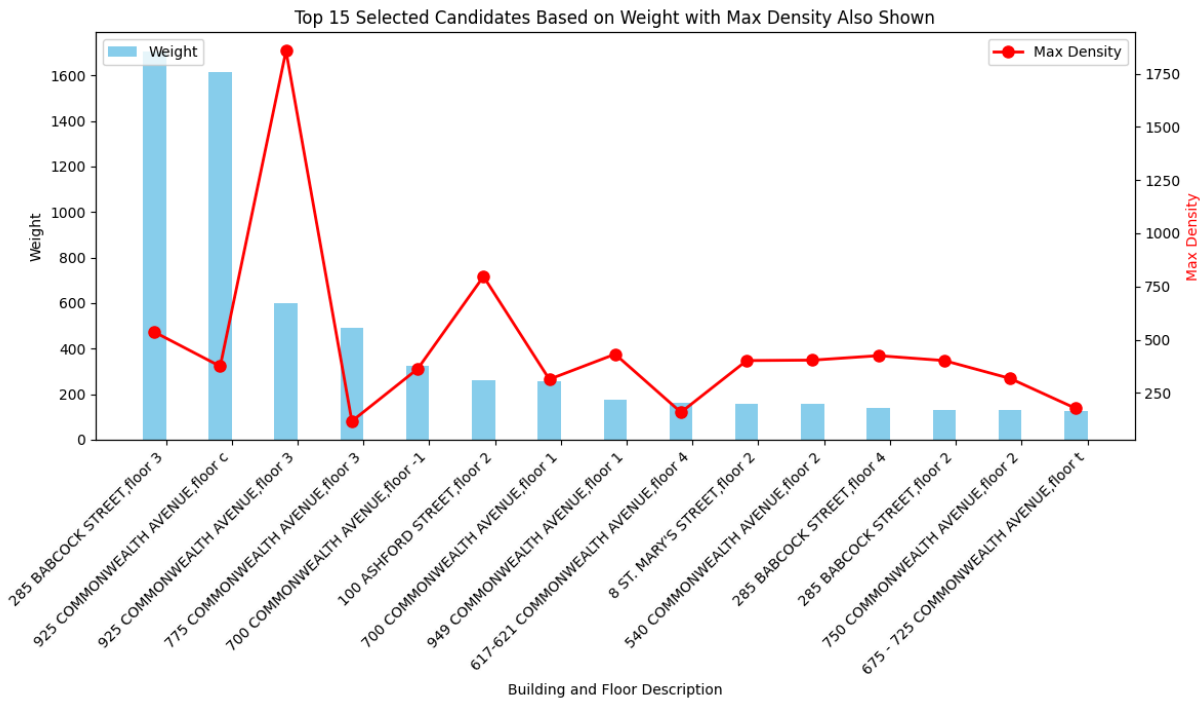


Figure 15

Figure 16 and Figure 17 in the next page are two pie charts showing the distribution of building types and Mechanical Ventilation. We can find that more than half of the selected buildings are academic and residential buildings (large dormitories only) . Also we can find that buildings with ‘no’ and ‘ partial’ Mechanical Ventilation ‘no’ accounts for about 40 percent of all selected buildings, here I put the detailed number.

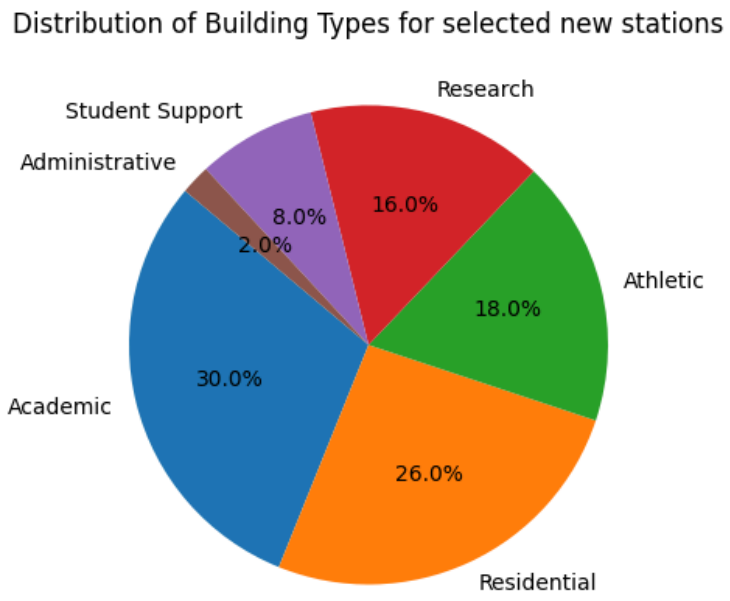
```
Distribution_of_Building_Types:

Academic : 15          Residential : 13        Athletic : 9

Research : 8           Student Support :4      Administrative : 1

Distribution_of_Mechanical_Ventilation:

Yes : 27               No : 12                 Partial : 7
```



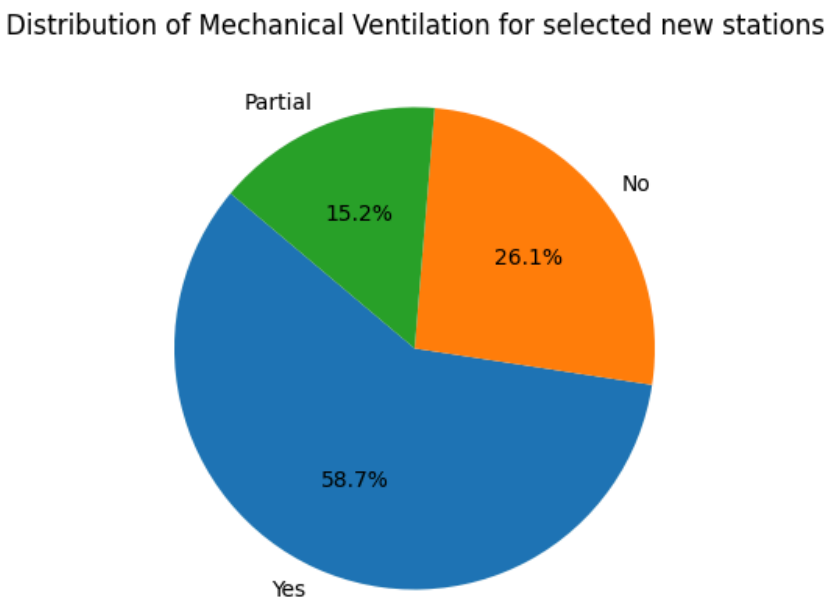


Figure 16 (up) and 17 (down)

Key Question 4:Establish how many students and employees would have access to each of the new filling stations

Answer: As we mentioned in the last question, we build a new weight standard for finding new stations and we get selected_candidates.csv. The hourly mean and max foot traffic (mean_density_cnt and max_density_cnt) in this sheet is the estimation of how many students and employees would be impacted by proposed new filling stations.

We sort the hourly mean density as high to low to see how many students and employees would have access to proposed new filling stations. Figure 18 is the screenshot to display top15 selected new stations based on mean density. Figure 19 is the bar chart to display top15 selected new stations based on mean density . Figure 20 is the bar chart to display top15 selected new stations based on mean density with max density also shown. Figure 21 is the bar chart to display top15 selected new stations based on mean density with weights also shown.

weight	uilding_floc	building_desc	latitude	longitude	uilding_typ	capacity	mean_density_cnt	max_density_cnt
324.3480467	-1	700 COMMONWEALTH AVENUE	42.3493	-71.104	Residential	0	53.27402333	363
1614.545178	c	925 COMMONWEALTH AVENUE	42.3522	-71.1177	Athletic	0	48.95451777	375
174.8488739	1	949 COMMONWEALTH AVENUE	42.3519	-71.1187	Academic	45	45.24887387	432
598.2118556	3	925 COMMONWEALTH AVENUE	42.3522	-71.1177	Athletic	29	41.11185557	1857
159.6977046	2	8 ST. MARY'S STREET	42.3492	-71.1061	Research	145	39.09770461	402
131.6557755	2	750 COMMONWEALTH AVENUE	42.3498	-71.108	Academic	227	36.25577546	318
156.4947511	2	540 COMMONWEALTH AVENUE			Academic	38	35.29475113	404
255.134273	1	700 COMMONWEALTH AVENUE	42.3493	-71.104	Residential	171	33.36713651	314
115.3772257	2	771 COMMONWEALTH AVENUE	42.351	-71.108	ıdent Supp	92	30.47722567	283
262.952264	2	100 ASHFORD STREET	42.3546	-71.1236	Athletic	48	23.85226405	797
56.02488263	-1	96-100 CUMMINGTON MALL	42.3489	-71.1048	Academic	0	23.32488263	109
54.77361909	5	575 COMMONWEALTH AVENUE	42.3495	-71.0987	Residential	64	22.67361909	107
58.36092985	3	575 COMMONWEALTH AVENUE	42.3495	-71.0987	Residential	64	22.36092985	120
55.94228251	2	300 BABCOCK STREET	42.3542	-71.1212	Athletic	183	21.74228251	114
47.03643787	4	610 BEACON STREET	42.3497	-71.0945	Residential	105	19.73643787	91

Figure 18 : the screenshot to display top15 selected new stations based on mean density

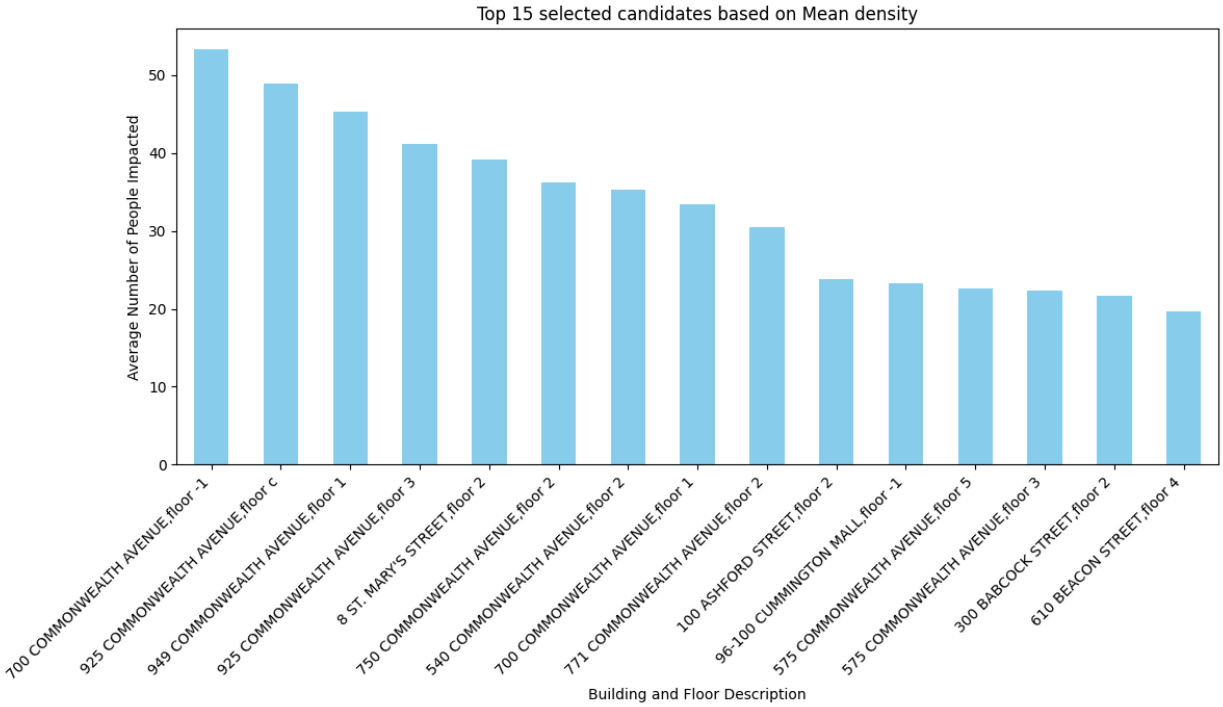
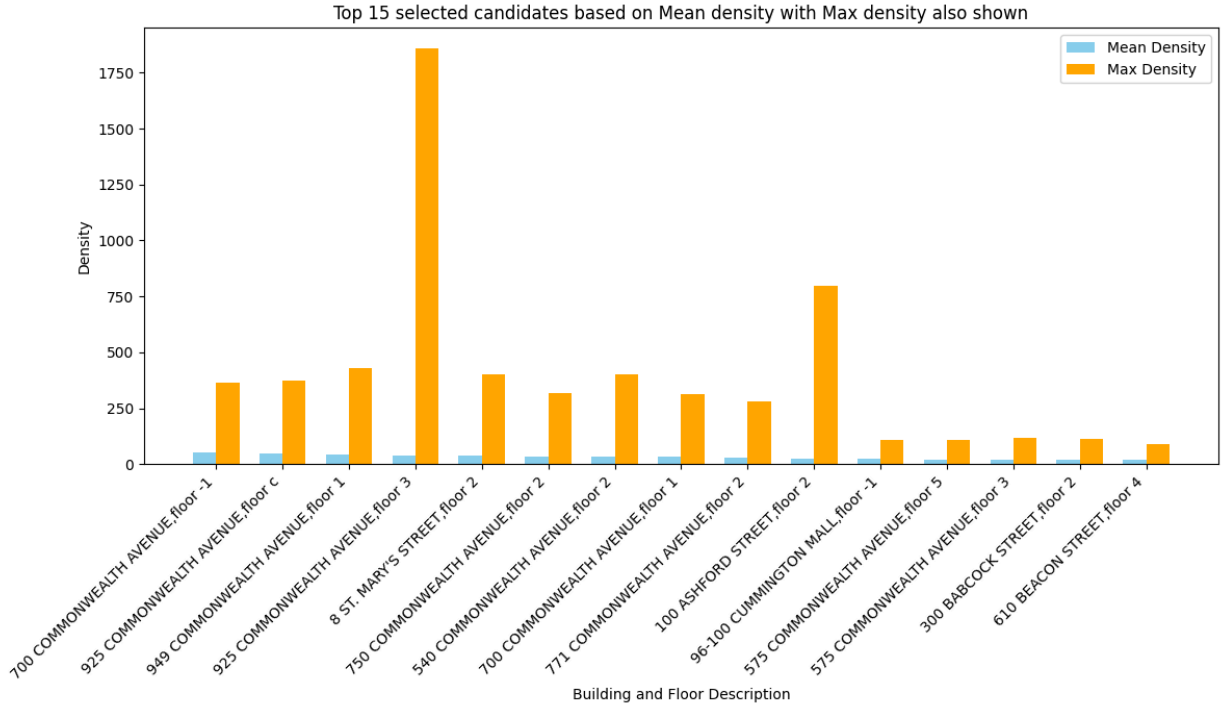


Figure 19 (up) and 20 (down)



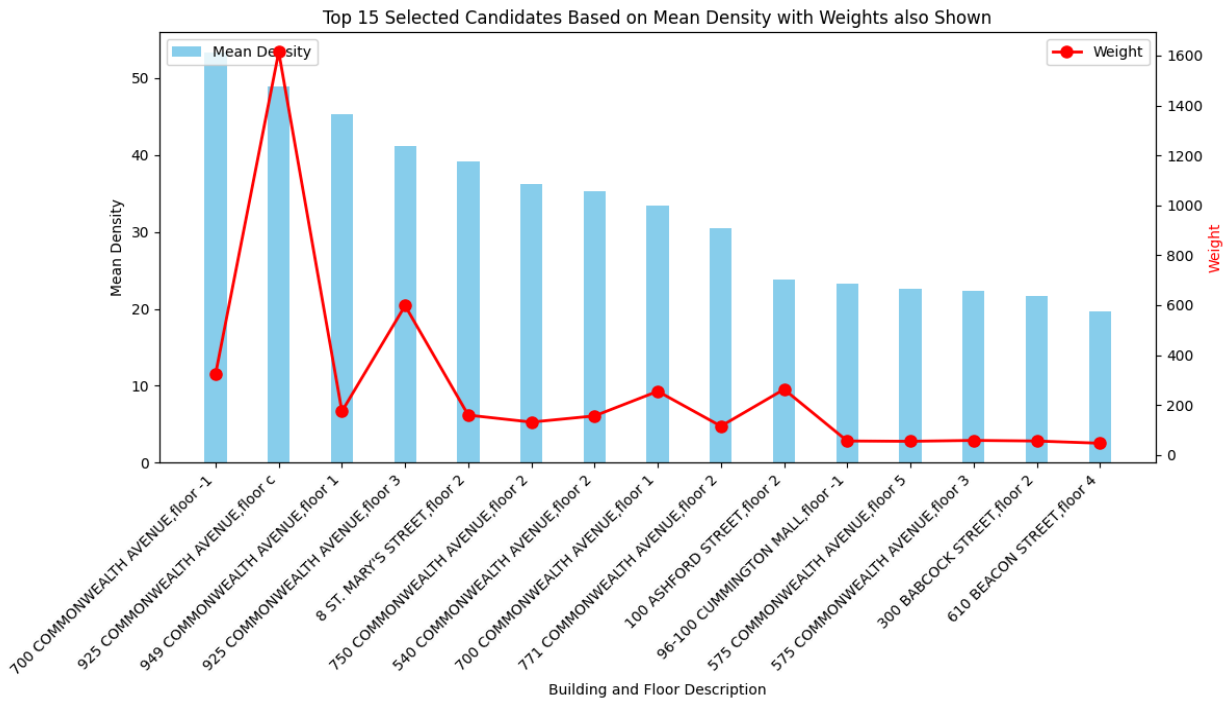


Figure 21

Key question 5:A geospatial map of new water filling stations highlighted by priority (weights)

Answer: We build a html file called Top_15_candidates_map_by_weight.html. When we download this html file and open it, we can see a google map showing the location of top 15 new water stations highlighted by weights as priority. Top 1-5 are marked as green points, rank 6 -10 are marked as orange points , and rank 11-15 are marked as red points.

Figure 22 shows what this map looks like. When we click on new station points, details of that point will show, including building address, building floor, weight score, building type and ranking. Figure 23 and 24 shows top1 and top2 new stations we choose with details shown by clicking on the map.

Figure 22. Top 15 candidate map by weight

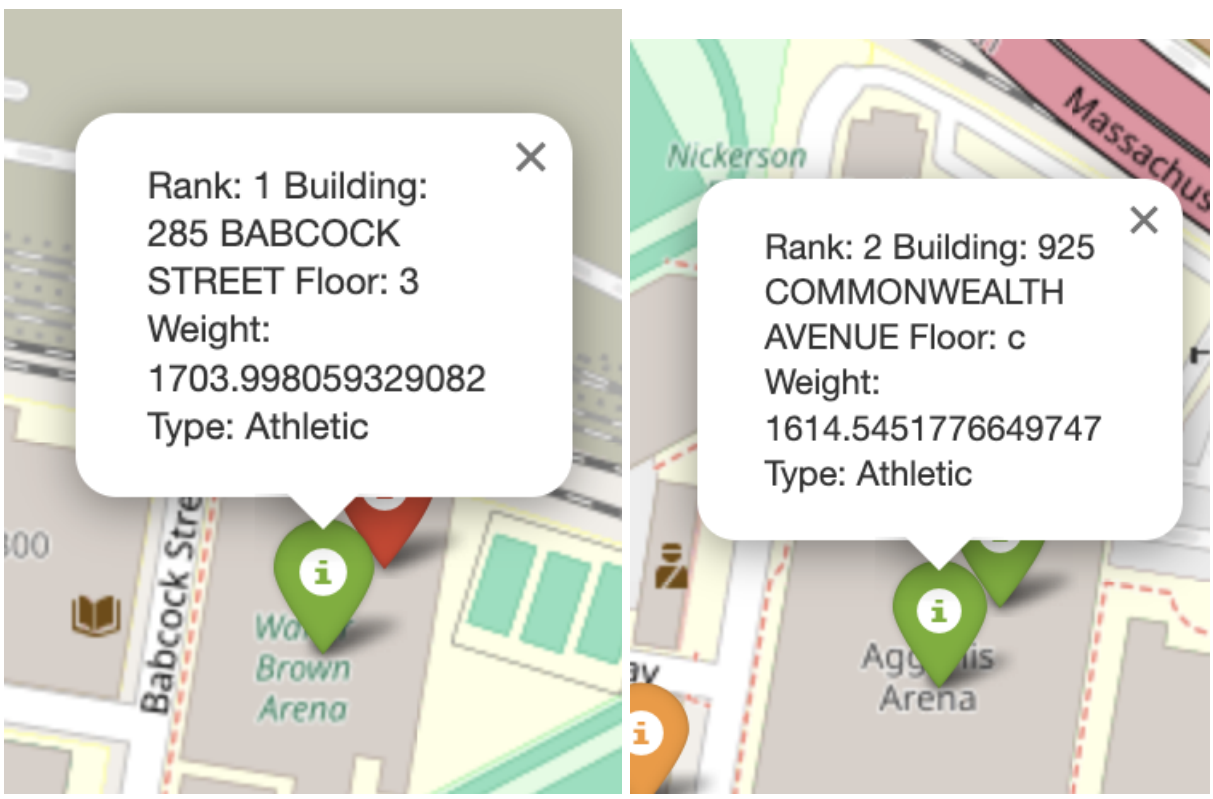


Figure 23 24: details of top 1 top 2 candidates for new station

Future Scope

The successful implementation of the current project provides a robust foundation for future enhancements and expansion in our efforts to optimize the placement of water bottle filling stations across the Boston University campus. Looking forward, there are several avenues for further research and development.

1.**Broader Scope of Environmental Factors**: While current analysis includes mechanical ventilation and volume, additional environmental factors such as temperature variations, seasonal changes, and even special events could be incorporated. This broader scope would allow us to tailor solutions that are responsive to all aspects of the campus environment.

2.**Enhanced User Feedback Mechanisms**: Developing a system for collecting and analyzing feedback from students and staff about the water station locations could provide valuable insights into user satisfaction and usage patterns. This feedback could be used to further refine the placement of new stations and the reevaluation of existing ones.

3.**Integration of Real-Time Data**: Expanding the project to include real-time foot traffic and usage data could significantly enhance the accuracy of our predictions and recommendations. By integrating sensors or using Wi-Fi login data, we can dynamically adjust to changes in building usage patterns and student schedules, ensuring that water stations are optimally placed based on current needs.

4.**Consider multiple water stations on larger floors**: As campus population and facilities expand, large floors in academic buildings, libraries, and student centers may need multiple water stations. Optimizing station placement on these floors is a key future goal.

Individual Contribution

Jingyi Zhang (jyz0328@bu.edu)
Report team process and problem in weekly meetings with client ; make advice and notes for group meeting ; process initial wifi data (filter building type and calculate mean and max density for each floor); build bar charts of top 15 cover floors and selected candidates based on mean density and weight; build initial standard for new station selection ;write early/midterm/final insight reports ; make presentation for early /midterm/final insight to clients.

Houjie Jiang (houjie@bu.edu)
Make advice for each group meeting; process wifi data (exclude parking, add Mechanical Ventilation) ; make bar plot analysis of mean and max density based on covered floor/ uncovered floor and Mechanical Ventilation condition; make pie charts for air condition and building type situation of selected new stations ; write early/midterm/final insight reports.

Tristan Lee (tlee10@bu.edu)
Make advice for each group meeting; separate the foot traffic table (wifi_update) into covered sheet and uncovered sheet ; process covered and uncovered sheet such as exclude parking floor and add mechanical ventilation into account;build new weight score standard for building new station candidates; write early/midterm/final insight reports.

Finn Jenson (fjensen@bu.edu)
Make advice for each group meeting;make important figure analysis to history density data(include top and max population ,population per time, ,population vs capacity , top average mean density etc);build a google map of new water filling stations highlighted by priority (weights) with html form; write early/midterm/final insight reports.

Yida Wang (yidwant@bu.edu)
Make advice for each group meeting; focus on initial kitchen and station data analysis, filter the unneeded data(only remaining address code room floor) ; add high volume or not into uncovered data analysis ;build new weight score standard for building new station candidates; write early/midterm/final insight reports.