Geography IA

Does Vancouver, a mid-latitude coastal city, have a defined urban heat island? What factor(s) influence the temperature pattern(s) in Vancouver?

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Fieldwork Question/Geographical Context

Does Vancouver, a mid-latitude coastal city, have a defined urban heat island? What factor(s) influence the temperature pattern(s) in Vancouver?

My hypothesis is that Vancouver will have a defined urban heat island (UHI) forming around the central business district (CBD) in downtown due to the high building density. Areas with a higher building density should have a positive correlation with higher temperatures as a result of their low albedo values compared to areas with high vegetation density. Additionally, the urban surface roughness also changes air patterns in a way that makes heat diffusion less effective; for example, blocking and slowing down wind which limits cooling by convection. Areas with a high density of tall buildings may also exhibit the urban canyon effect where the multiple surfaces for the energy from sunlight to reflect and be absorbed greatly increases the rate of heating within certain areas. Thus, according to the urban heat island theory, an increased building density should result in areas of higher temperature and the opposite should be true for areas with higher vegetation densities.

The fieldwork investigation was carried out to gather data. From this data, I will be able to draw conclusions regarding the existence of an urban heat island and formulate potential factors that may influence the temperature patterns in Vancouver. This geography internal assessment is related to the urban environment and social stresses section in the syllabus. The fieldwork was carried out across the city of Vancouver with individual locations falling into a grid that was drawn over a map of the city (see Fig. 1).

From the perspective of geographical context, Vancouver is a coastal city surrounded by bodies of water from 3 sides, the Pacific Ocean from the west, the English Bay to the north and the Fraser River from the south. Due to this limited land, Vancouver's central business district (CBD) or downtown is both densely populated and full of skyscrapers. Additionally, the area outside the CBT (or the uptown) faces rapid development as land that was once forests become urban living spaces. Another factor that may contribute to the fieldwork investigation is Vancouver's spatial continuity. Being a city with many important historical sites with heritage value, its spatial continuity changes slowly as buildings are adapted instead of demolished and rebuilt from the ground up.

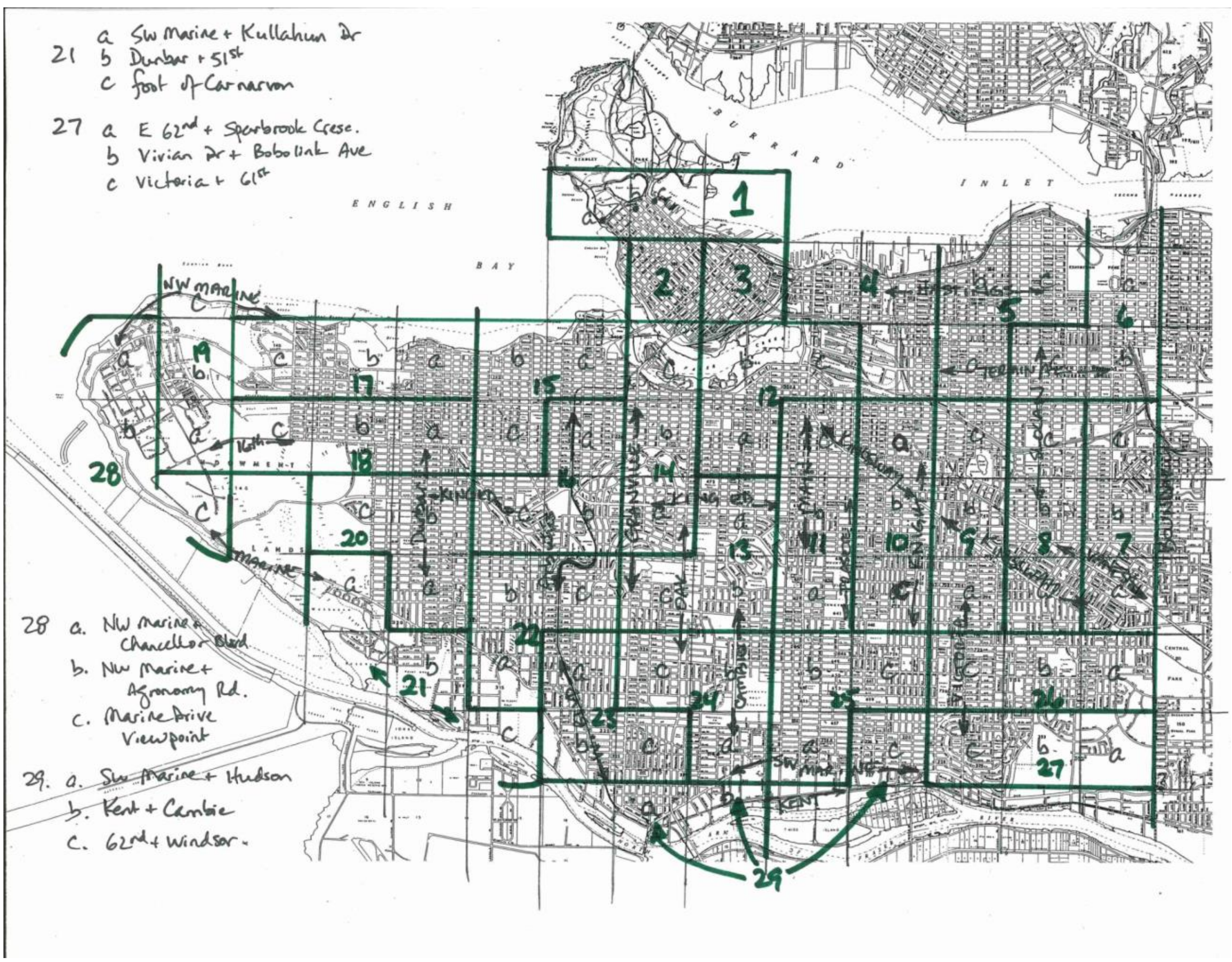
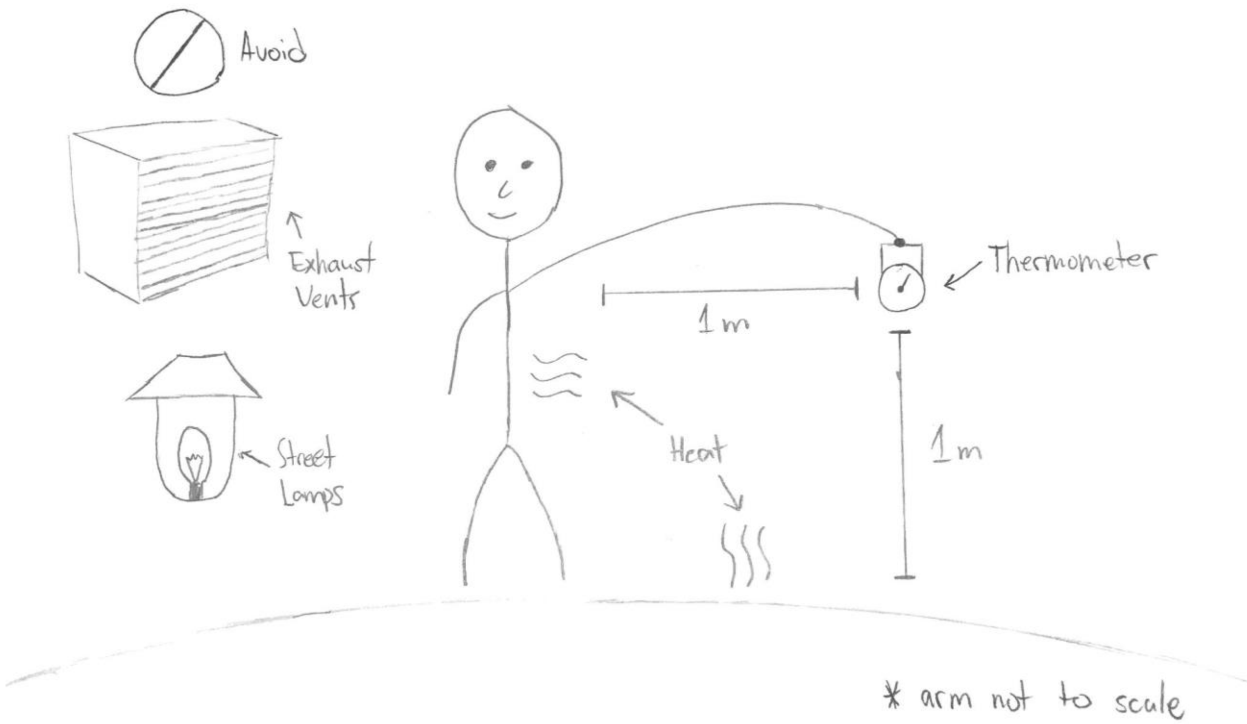


Fig. 1: The division of Vancouver into a grid with labeled locations. Source: Ms. Sinclair

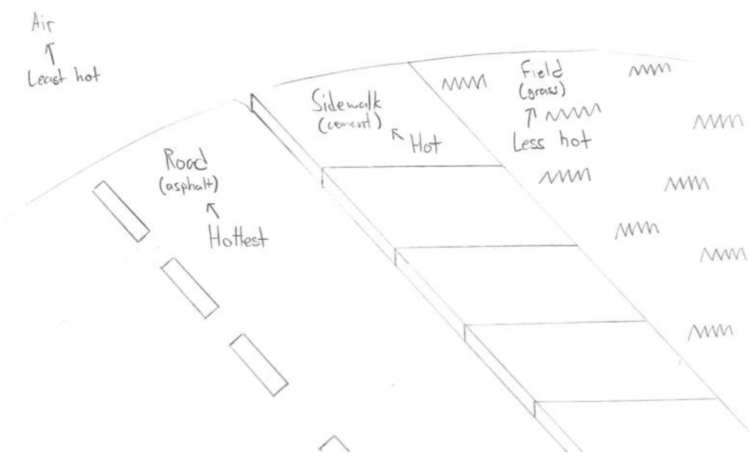
Methods of Investigation

In order to answer the fieldwork question, myself and 56 other classmates paired up and went out across all of Vancouver, British Columbia on May 29th, 2021, during the evening with the purpose of recording temperatures of different sections of Vancouver. We were each assigned to do 3 separate locations, labeled A, B and C on our maps. With the times of 8pm, 8:15pm and 8:30pm being the exact times we were to record temperatures (in respect to locations A, B and C). Systematic sampling was used to define the boundaries of each zone as it is the most straightforward and conducive method. Additionally, all thermometers were calibrated in class and had many constants in our method of taking the temperatures to keep the data as consistent as possible. Eight in the evening is an optimal time to conduct such fieldwork because the temperature differences of a potential UHI would be amplified at night when both the average temperatures are cooler, and the winds are weaker. Providing data that would be easier to both analyze and draw meaningful conclusions.



The methodology of collecting data included having the thermometer 1 meter above the ground and arm's length from the body while holding the top handle. This is due to body heat and heat radiating off the ground material being a potential variable. For example, a cement sidewalk or asphalt road that has been basking in the sun has low albedo and will radiate stored heat and distort the data. The thermometer was also to avoid any nearby exhaust vents or similar objects that would artificially increase the reading, when near buildings, 1 meter is the minimal amount of distance to be kept. We also faced north while recording temperatures as wind is a minor variable. Lastly, other potential variables such as building density, vegetation, slope and distances to large bodies of water were all recorded or noted on a data sheet. Building and vegetation density was qualitatively recorded on a scale of 1-5 with 1 being the lowest and 5 the highest in density.

Written Analysis/Treatment of Information Collected

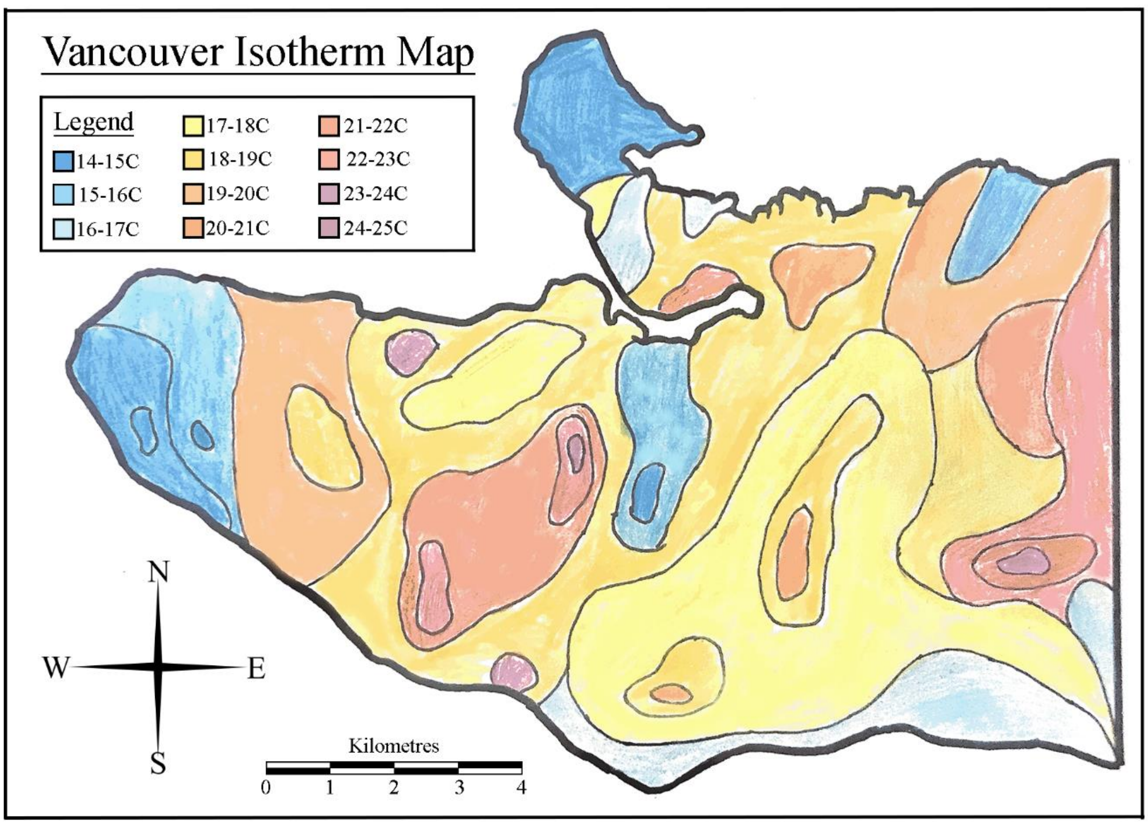


Albedo is the primary factor linked to my hypothesis as it has the single highest effect on urban temperature. Two of the recorded factors for each location included building density and vegetation density. Both common building materials such as brick, tiles and concrete and trees/heavy vegetation both have very low albedo values on average (ranging from 0.1-0.4 for building materials and 0.15-0.18 for trees). Lower albedo values simply means that the area reflects less solar radiation and thus absorbs and stores and radiates it off as heat.

For the purpose of proving my hypothesis that there is a positive correlation between building density and temperature in the city of Vancouver. I attempted to use Spearman’s rank correlation coefficient to find evidence of the relationship. The full data table is attached to the appendix, but the calculated values of Spearman's Coefficient are 0.82061 and 0.852412. For vegetation density’s relation to temperature and building density with temperature respectively.

Spearman's coefficient values for both vegetation and building density when in relation to temperature do not range between -0.7 and +0.7 and are also both positive. It is determined that both have a significant positive correlation with temperature. Meaning that areas with denser buildings or vegetation have a higher temperature when compared to areas with lower densities. As Spearman's coefficient for building density is slightly higher, it can be assumed that there are other variable(s) in effect. One such variable can be the disruption of wind flow as large buildings and skyscrapers greatly reduce the speed of wind. Thus, keeping heat trapped in one place for longer.

Below is an isothermal map of Vancouver created by hand and later digitally modified in adobe photoshop with the same data as was used for calculating spearman's rank.



From the map, there is evidence of an urban heat island in Vancouver as certain areas are definitely warmer than others. However, it differs from my hypothesis as it does not center around the central business district (the area directly under the northmost blue area (Stanley Park)). This may be due to the coastal winds blowing cool air through the downtown area. The increase in cooler winds may be enough to negate the urban canyon effect caused by the tall buildings and thus keep temperatures lower than previously predicted.

With the visual aid of the isotherm map, two high temperature anomalies can instantly be seen. One near the bottom by SW Marine Dr & Camosun St and another near the center at West 3rd Avenue & Dunbar Street. Going into google map's street view for a closer look yields a few possible reasons as to why temperatures are so much higher. The first location mentioned seems to be quite a busy intersection with many cars, commercial trucks and public buses. Released emissions lower the albedo in the surrounding air and when compounded with the raw heat emitted from the vehicles, it may be a key reason as to why the anomaly exists. The second location of interest seems to have patches of new asphalt on the road. The albedo values of asphalt can greatly vary from 0.05 (dark and fresh) all the way to 0.20 (older and paler). Again, this increase in albedo may be a primary reason for the existence of this anomaly.

There are also two low temperature anomalies on the map. One in the center of the map by W 15th Ave & Birch St and another all around the Hastings Sunrise neighborhood. Many buildings in the first location are made with lightly colored materials. Such as wood painted white and maroon bricks. Furthermore, the area is quite open with few trees and a small field of grass. The second anomaly affects a far larger area, spanning over a full neighborhood and exactly three data points. After being unable to find any factors that may contribute to the abnormally low temperatures, it can only be determined that perhaps there were disparities in either the methodology or equipment of the group in charge of the three locations.

These four locations were singled out as anomalies because they could not be explained by the urban heat island effect with the hottest temperatures being close to the central business district (CBD) and further areas cooling down gradually. Additionally, the areas surrounding the anomalies do not display a gradual rise or decline in temperatures. For example, the high temperature anomaly at the bottom of the map is higher than 24°C, while the immediate surrounding area is only a mere 17°C. Ultimately, they likely are a result of some form of error as the disparity in temperature from the surrounding locations is simply too high but for the purpose of analysis in this section, reasoning was applied. However, potential sources of error will be included in the evaluation section of this IA.

Conclusion

I was able to conclude that Vancouver has a defined urban heat island. However, it does not reside within the central business district as I originally hypothesized. Due to factors such as coastal winds and being surrounded by water on nearly three fronts. The urban heat island instead forms around the geographical center of the city (as can be seen in my isothermal map). Furthermore, both vegetation and building density had a positive correlation with temperature due to the albedo of different materials. Evidence for this lies in Spearman's coefficient values when analyzing all three sets of data with 87 entries each. Between temperature and vegetation density, a value of 0.82061 was conceived and 0.852412 for temperature and building density.

Additionally, it was important that the number for building density had a higher value as it shows the effect of wind flow being hindered by urban buildings and thus further increasing the average temperature (in relation to vegetation dense areas). Most anomalies found on the map can be related directly to albedo values in the area.

Evaluation

One of the largest strengths of the methodology of data collection used to answer the fieldwork question would be the number of students available to collect data. Over the course of under half an hour, three sets of 87 points of data in a region of 115 km^2. Being able to quickly and effectively collect data during the evening is likely the biggest factor in contributing to the success of any IA’s produced from it. This is due to the evening being the most optimal time to collect data that would be used for determining the presence and/or location of an urban heat island as the temperature differences are the largest as it is when winds are the weakest. However, this can also be seen as a downside to collecting data in the evening as temperatures fall quickly across the entire city due to the sun setting. This is counter swayed by the fact that the sheer size of the class allows for data collection in the evening to be possible.

A suggestion on how the fieldwork methodology could be improved would be in how data was collected for building and vegetation density. Throughout the process of analyzing data, I felt the scope and range of data collected for the two aforementioned data points was lacking and it was hard to come to accurate and meaningful conclusions with only a range from 1-5. However, Spearman’s rank correlation greatly helped in alleviating this issue as data points were all ranked without regard to the range of the data.

If the fieldwork question was modified to include identifying and explaining a location for the center/peak of the urban heat island (if it was to be found), discussions would have simply another layer of depth and allow the student to accomplish more within the IA.

Potential sources of error are most likely found as human errors due to the inherent nature of organizing so many students in an event like this will almost always result in human error of some kind. Evidence for this would be the three points of data near the top right sectors of the map all done by the same group. The data they collected was extremely low compared to both the nearby sectors and all the sectors in general. Such anomalies can only be attributed to faulty equipment or poorly applied methodology. However, even in the light of such blatant human error, I attempted to avoid using it as an excuse in my analysis as there is still a slim chance that human error was not the case for the discrepancies.

This study could be expended if urban city planners were to observe distinguishing traits of cooler areas and apply them in more places across the city. As global warming is such a major issue in today’s world, finding ways to increase albedo in sustainable and natural ways without major disruption to the city or neighborhood.

Appendix

Group	Location	Temperature (in C°)	Rank	Vegetation Density	Rank
1	a	14	82	5	4
	b	16	66	5	4
	c	18	35	1	85
2	a	17.5	45	4	16.5
	b	15.5	72.5	3	45
	c	16	66	2	73.5
3	a	20	15.5	1	85
	b	18.5	28.5	2	73.5
	c	17	54.5	4	16.5
4	a	18.5	28.5	2	73.5
	b	18.5	28.5	1	85
	c	17.5	45	1	85
5	a	11.5	86.5	3	45
	b	12.5	85	2	73.5
	c	11.5	86.5	2	73.5
6	a	20	15.5	3	45
	b	19	23	5	4
	c	21	8.5	2	73.5
7	a	21	8.5	3	45
	b	20.5	11.5	2	73.5
	c	19.5	18.5	2	73.5
8	a	22.5	4	2	73.5
	b	19.4	20	3	45
	c	21.2	6	4	16.5
9	a	20	15.5	1	85
	b	17.5	45	4	16.5
	c	16.5	60.5	4	16.5
10	a	18	35	3	45
	b	18.5	28.5	4	16.5
	c	17.5	45	3	45
11	a	19.5	18.5	3	45
	b	18	35	3	45
	c	17	54.5	3	45
12	a	18.5	28.5	3	45
	b	17.5	45	2	73.5
	c	19	23	2	73.5
13	a	16.5	60.5	3	45
	b	17.5	45	4	16.5
	c	15	77.5	3	45
14	a	13.5	84	3	45
	b	15.5	72.5	3	45
	c	14.5	79.5	2	73.5
15	a	16.5	60.5	3	45
	b	17.5	45	4	16.5
	c	16.5	60.5	3	45
16	a	23	3	3	45

	b	22.2	5	3	45
	c	20.2	13	4	16.5
17	a	25	1	3	45
	b	19	23	5	4
	c	15.5	72.5	4	16.5
18	a	17.5	45	2	73.5
	b	18	35	3	45
	c	15.5	72.5	4	16.5
19	a	14.5	79.5	3	45
	b	15	77.5	3	45
	c	15.5	72.5	4	16.5
20	a	21	8.5	3	45
	b	20	15.5	2	73.5
	c	18.5	28.5	5	4
21	a	19	23	4	16.5
	b	21	8.5	3	45
	c	24	2	3	45
22	a	17.5	45	4	16.5
	b	18	35	3	45
	c	20.5	11.5	4	16.5
23	a	17.5	45	3	45
	b	16.5	60.5	3	45
	c	16	66	3	45
24	a	15.5	72.5	3	45
	b	16.5	60.5	4	16.5
	c	17.5	45	3	45
25	a	19	23	4	16.5
	b	18	35	3	45
	c	17	54.5	2	73.5
26	a	15.5	72.5	3	45
	b	18	35	3	45
	c	17.5	45	2	73.5
27	a	17	54.5	3	45
	b	16	66	4	16.5
	c	16	66	3	45
28	a	14	82	3	45
	b	15.5	72.5	5	4
	c	14	82	5	4
29	a	17.5	45	2	73.5
	b	17	54.5	2	73.5
	c	17	54.5	3	45

Building Density	Rank	Vegetation d	d^2
1	80	78	6084
1	80	62	3844
5	2.5	-50	2500
3	23.5	28.5	812.25
4	9.5	27.5	756.25
5	2.5	-7.5	56.25
5	2.5	-69.5	4830.25
5	2.5	-45	2025
4	9.5	38	1444
3	23.5	-45	2025
4	9.5	-56.5	3192.25
4	9.5	-40	1600
2	52.5	41.5	1722.25
3	23.5	11.5	132.25
3	23.5	13	169
1	80	-29.5	870.25
1	80	19	361
4	9.5	-65	4225
3	23.5	-36.5	1332.25
2	52.5	-62	3844
4	9.5	-55	3025
3	23.5	-69.5	4830.25
2	52.5	-25	625
1	80	-10.5	110.25
4	9.5	-69.5	4830.25
2	52.5	28.5	812.25
2	52.5	44	1936
3	23.5	-10	100
2	52.5	12	144
2	52.5	0	0
2	52.5	-26.5	702.25
2	52.5	-10	100
3	23.5	9.5	90.25
4	9.5	-16.5	272.25
2	52.5	-28.5	812.25
2	52.5	-50.5	2550.25
2	52.5	15.5	240.25
2	52.5	28.5	812.25
2	52.5	32.5	1056.25
2	52.5	39	1521
2	52.5	27.5	756.25
4	9.5	6	36
2	52.5	15.5	240.25
2	52.5	28.5	812.25
3	23.5	15.5	240.25
3	23.5	-42	1764

3	23.5	-40	1600
1	80	-3.5	12.25
2	52.5	-44	1936
1	80	19	361
1	80	56	3136
3	23.5	-28.5	812.25
1	80	-10	100
1	80	56	3136
3	23.5	34.5	1190.25
3	23.5	32.5	1056.25
4	9.5	56	3136
2	52.5	-36.5	1332.25
3	23.5	-58	3364
1	80	24.5	600.25
2	52.5	6.5	42.25
2	52.5	-36.5	1332.25
2	52.5	-43	1849
1	80	28.5	812.25
2	52.5	-10	100
2	52.5	-5	25
2	52.5	0	0
2	52.5	15.5	240.25
2	52.5	21	441
2	52.5	27.5	756.25
2	52.5	44	1936
2	52.5	0	0
2	52.5	6.5	42.25
2	52.5	-10	100
2	52.5	-19	361
2	52.5	27.5	756.25
2	52.5	-10	100
3	23.5	-28.5	812.25
2	52.5	9.5	90.25
1	80	49.5	2450.25
3	23.5	21	441
2	52.5	37	1369
2	52.5	68.5	4692.25
1	80	78	6084
3	23.5	-28.5	812.25
1	80	-19	361
2	52.5	9.5	90.25
		Total:	118113
		Spearman's Coefficient	0.820610374

Building d	d^2
2	4
-14	196
32.5	1056.25
21.5	462.25
63	3969
63.5	4032.25
13	169
26	676
45	2025
5	25
19	361
35.5	1260.25
34	1156
61.5	3782.25
63	3969
-64.5	4160.25
-57	3249
-1	1
-15	225
-41	1681
9	81
-19.5	380.25
-32.5	1056.25
-74	5476
6	36
-7.5	56.25
8	64
11.5	132.25
-24	576
-7.5	56.25
-34	1156
-17.5	306.25
31	961
19	361
-7.5	56.25
-29.5	870.25
8	64
-7.5	56.25
25	625
31.5	992.25
20	400
70	4900
8	64
-7.5	56.25
37	1369
-20.5	420.25

-18.5	342.25
-67	4489
-51.5	2652.25
-57	3249
-7.5	56.25
21.5	462.25
-45	2025
-7.5	56.25
56	3136
54	2916
63	3969
-44	1936
-8	64
-51.5	2652.25
-29.5	870.25
-44	1936
-50.5	2550.25
-35	1225
-17.5	306.25
-41	1681
-7.5	56.25
8	64
13.5	182.25
20	400
8	64
-7.5	56.25
-29.5	870.25
-17.5	306.25
2	4
20	400
-17.5	306.25
21.5	462.25
2	4
-14	196
42.5	1806.25
29.5	870.25
20	400
2	4
21.5	462.25
-25.5	650.25
2	4

Total:	97174.5
Spearman's Coefficient	0.852411697

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