Metro Vancouver: Housing Market Crisis

Divyadarshan Punjabi: 22673263

Nirvaan Rohira: 43994755

University of British Columbia

MATH 340 101

Matthieu Heitz

December 4, 2022

AIM

This project aims to address the housing market crisis in Metro Vancouver (particularly for UBC students). We attempt to test and find the best possible housing option, in terms of magnitude of price, location and, value of the house in the current market scenario.

BACKGROUND INFORMATION

This project is going to be based on the current housing market crisis in Vancouver. The current housing market crisis is not unknown to any individual presently residing in or planning on moving to Metro Vancouver, BC. At present, the rental rates in Vancouver and its surrounding areas have risen by over 20 percent in the last 6 months. We are witnessing students currently combat the skyrocketing price in the rental market, coupled with the diminishing availability of housing supply in Vancouver. To give context to understand the gravity of the situation, there even have been cases of students having to re-locate once, if not twice, every year in the movement period in September.[1]

Through this project, we are considering potential solutions to the current housing market crisis that is plaguing Vancouver and its surrounding areas. This issue in our collective opinion has become quite dire and the necessity of a solution is urgent. We decided to model and address the issue in the form of a linear optimisation problem. We first scoured through rental websites like 'Craigslist,' 'Zumper,' using a web scraping Python script (Python library to be used:

[1] https://www.cbc.ca/news/canada/british-columbia/priced-out-rental-crisis-victoria-1.6390095

BeautifulSoup) to create a data set of potential housing options on a .csv file. The locations to be considered are the city of Vancouver, Richmond, Burnaby, and Surrey. We then formulate a LP problem with three decision variables: price of the house, opportunity cost of travelling (to account for location parameters), and the value of the house (i.e., price per sq. ft area) using our datasets. The expectation is to come up with an optimal solution which gives us a pretty good understanding of how to tackle the current market scenario.

OVERVIEW OF THE PROJECT

We have chosen 3 decision variables, x1, x2, and x3, as price of a house/rental, opportunity cost of travelling per day, and value of the house/rental respectively.

What is opportunity cost, and why are we considering it? Opportunity cost is the cost of choosing an activity by giving up the opportunity to do an alternate activity. In this case, if a student is travelling to campus from another city (for example: a commute time of an hour), the student is choosing to travel for an hour by giving up the opportunity to study for that hour. For simplicity's sake, we consider that a student is not benefitting or gaining any value during their commute. Nor do we consider if a student is engaged into paid work too. This scenario then just results in loss of study time. To quantify this loss of study time, we evaluate a student's cost of studying (i.e., tuition fee paid to university) in terms of per hour costs. To simplify our analysis, we only consider our model for international students. We find the per hour cost of studying for a UBC international student in the following way:

▪ Calculation:

- Y1: Science Average Tuition Fees = 43,000 CAD a year
- Y2: Engineering Average Tuition Fees = 55,000 CAD a year
- Y3: Sauder School of Business Tuition Fees = 55,500 CAD a year
- Y4: Arts Average Tuition Fees = 42,000 CAD a year
- Y5: Other Faculty Average Tuition Fees = 42,000 CAD a year
- Average fees = $\frac{(Y1+Y2+Y3+Y4+Y5)}{5} = \frac{(43000+55000+55500+42000+42000)}{5}$
- Average Fees = 47,500 CAD a year[2]

Therefore, the opportunity cost is $\frac{47500}{(365 \times 24)}$ per hour = 5.4 CAD/hour ~ 6 CAD/hour (to account for any price fluctuations). This calculation can surely be replicated for a domestic student, and thus, the LP model as well. Thus, opportunity cost helps to quantify time and distance in terms of monetary value.

To further simplify our rationale, we've considered the actual cost of travelling to be zero with the assumption that each UBC student has UPASS for public transport, and the cost of UPASS itself is already considered as a part of tuition fees. We are not including the possibility of the use of private transport like cars, as it goes beyond the scope of this LP problem. The coefficient of x2 in the objective function will be set to 20 (5 days of class × 4 weeks) to account for total travel time in a month.

[2] https://students.ubc.ca/enrolment/finances/tuition-fees/undergraduate-tuition-fees

The third decision variable, x3, is the value of a house calculated by dividing the price of the house with its square footage. We do so to have a rough estimate of the value of the house, in terms of size and demand. For example, let's consider a rental with a price of $2,000 and 700 sq. ft in downtown Vancouver, as compared to a rental with price $1,500 and 700 sq. ft in Kitsilano. With this information, we can definitely conclude that rentals in downtown Vancouver have more demand as compared to rentals in Kitsilano, since the price of rental per sq. ft in downtown Vancouver is more. We also see that in terms of size, the Kitsilano rental offers more value for money since you pay $2.14 per sq ft instead of $2.86 per sq ft.

We first devised and developed a web scrapping script to pull data from rental websites and formulate our own datasets. We resorted to web scrapping as opposed to relying on API's provided by rental search websites to access their data, as getting hold of any API was becoming logistically difficult. Below is the python algorithm that we used to scrape data. We used Python's BeautifulSoup library to do so. This particular version is for Vancouver but the same script (with some minor URL changes) was used for all the other locations.

```
from bs4 import BeautifulSoup
import requests
import time
import pandas as pd
from csv import writer

url =
"https://vancouver.craigslist.org/search/apa?query=Vancouver&min_price=&max_price=&availa
bilityMode=0&sale_date=all+dates"
page = requests.get(url)

soup1 = BeautifulSoup(page.content, 'html.parser')
soup2 = BeautifulSoup(soup1.prettify(), "html.parser")
lists = soup2.find_all('li', class_="result-row")

with open('RentalDataSet.csv', 'w', encoding='utf8', newline='') as f:
    thewriter = writer(f)
    header = ['Title', 'Location', 'Price', 'Area']
    thewriter.writerow(header)

    for list in lists:
        try:
            title = list.find('a', class_="result-title hdrlnk").text.replace('\n', '')
```

```
        except AttributeError:
            title = None

        try:
            location = list.find('span', class_="result-hood").text.replace('\n', '')
        except AttributeError:
            location = None

        try:
            price = list.find('span', class_="result-price").text.replace('\n', '')
        except AttributeError:
            price = None

        try:
            area = list.find('span', class_="housing").text.replace('\n', '')
        except AttributeError:
            area = None

        info = [title, location, price, area]
        thewriter.writerow(info)

    import csv

    df = pd.read_csv(r"C:\Users\Darshan Punjabi\PycharmProjects\340 -
Vancouver\RentalDataSet.csv")
    print(df)
```

The script scrapes URL's and saves the data onto .csv files. After scraping, we accumulated a total of 600 data points of raw data for all the four cities. Here, each data point corresponds to a rental listing. Since the data provided on each listing does not have a consistent pattern of information, we had to first clean the datasets we gathered. We cleaned the data on Excel. After cleaning the scrapped data, we now have 466 data points for all 4 cities. And the data points look something like this:

	A	B	C	D	E	F	G	H	I	J
1	Title	Location	Price	No. of bedrooms	Price per bedroom	Area	Area	Value of the rental ($/ft2)	Value 2.0	Per bedroom sq ft
2	Peaceful lovely Family House in Calverhall	(North Vancouver- Calverhall)	$5,390	5	$1,078.00	5br-2574ft2-	2574	2.1	$2.09	514.8
3	2BED+FLEX/2BATH One Burrard Biggest Balcony C	(Vancouver)	$3,900	2	$1,950.00	2br-810ft2-	810	4.82	$4.81	405
4	BEST ADDRESS IN TOWN deluxe ONE BED ONE BA	(667 Howe Street near Hotel Georgia)	$4,900	2	$2,450.00	2br-1011ft2-	1011	4.85	$4.85	505.5
5	Gorgeous 4 bedrooms + Den for Rent NOW	(Vancouver /west Dunbar)	$8,600	5	$1,720.00	5br-5600ft2-	5600	1.54	$1.54	1120
6	LOCATION 2 bed and Den in Park Royal West Van	(West Vancouver)	$5,350	2	$2,675.00	2br-1210ft2-	1210	4.42	$4.42	605

After initial analysis on the datasets, we found the average price per bedroom (or to say, per person; considering a person lives in a bedroom and does not share) and the average price per sq ft for each city. We also calculated the opportunity cost of travelling to UBC from each city manually. The algorithm to do so was to find the total time of travelling (i.e., 2 – way) in a day (in hours), and then multiplying it with the per hour opportunity cost we found above (i.e., $6 per hour). For Surrey, we found the average time to come to UBC from Surrey Central Station. Similarly, for Richmond, it was from Richmond Canada Line station. And for Burnaby, it was from Burnaby Sky Train station. We added 10 minutes to the travel time for each of these location to account for walking, transit switching etc. For Vancouver, we took the arithmetic mean of the average time it takes to come to UBC from Kitsilano, Oakridge, Granville Island, and Vancouver City Centre. The following is the summary of this data:

City	Price of Rental (Per Person)	Opportunity Cost	Value of the Rental (Price per sq. ft)
Vancouver	$2048.84	$8.65	$3.77
Richmond	$1491	$15	$3.09
Burnaby	$1743	$16	$3.54
Surrey	$1251.59	$18.6	$2.76

From the table, we can intuitively notice that as we go farther away from UBC; we get more value for our buck in terms of price per sq. ft. In terms of price per rental, Vancouver is the most expensive. An important note to keep in mind is that this price of rental for each city is not an average of 1-bedroom apartments, but rather an average price an individual pays to acquire their own bedroom in any type of rental suite. Evidently, we also see the opportunity cost of travelling increase as we go farther away from UBC.

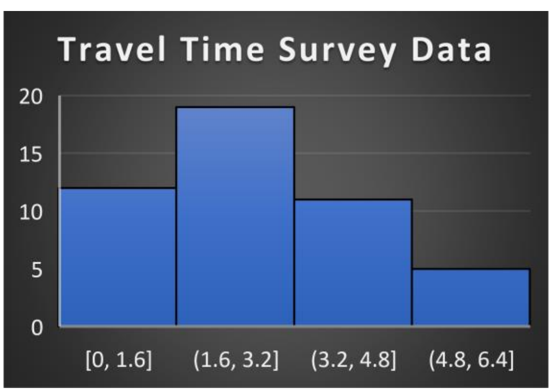
The idea, now, is to develop an LP problem and its constraints from observing various trends in our datasets and in the current market scenario. We then run the LP to get optimal values for price per rental (x1), opportunity cost (x2), and value of a rental (x3). After running the algorithm, we compare the optimal values to the values we have for each city in the summary table above. We do so to understand which city is more optimal to live in.

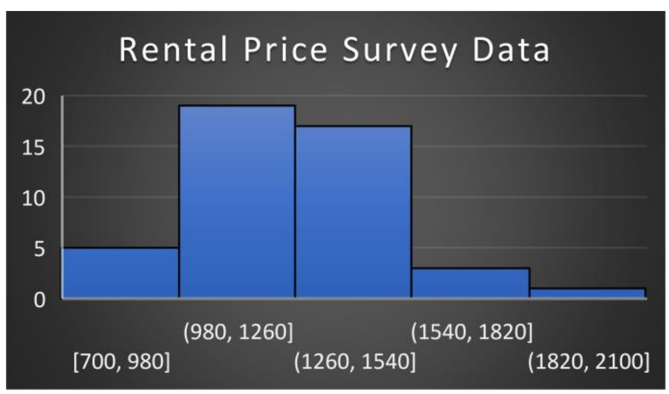
In order to devise our LP problem, we conducted a formal survey using the Qualtrics system to gauge the current market sentiment among our peers. We performed sentiment analysis on the received survey data and compiled the results in the following manner:

A summary statistic table has been shown Below:

No. of Survey Takers	**Weighted Average of Maximum Time travelled (in a day)**	**Weighted Average of Maximum Rental Price willing to be paid (per month)**
47	2hr 42mins.	$1287.234

Graphical Analysis:





We devised the LP problem in the following manner:

Objective function(z): $z = \min x1 + 20x2 + 100x3$

Subject to the following constraints:

1. $8 \leq x2 \leq \mathbf{16.2}$
2. $\mathbf{1287.234} \leq x1 + 20x2$
3. $x1 - 400x3 \geq 0$
4. $700 \leq x1 \leq \mathbf{1287.234}$
5. $x2 + 8x3 \geq 40$
6. $1.88 \leq x3$

Guide for User – Input: The numbers in bold depict price of rental constraint (constraint 2 and 4) and opportunity cost (constraint 1). Change the numbers based on your specific need.

Standard Form:

Objective Function (z): $\max -x1 - 20x2 - 100x3$

Subject to the following constraints:

- $-x1 \leq -700$
- $x1 \leq 1287.234$
- $-x2 \leq -8$
- $x2 \leq 16.2$
- $-x3 \leq -1.88$
- $-x1 - 20x2 \leq -1287.234$
- $-x1 + 450x3 \leq 0$
- $-x2 - 8x3 \leq -40$ …… S.t. all three variables (x1, x2 and x3) are positive.

Where:
x1 is price of rental,
x2 is opportunity cost, and
x3 is the value of a rental (in terms of its price per sq. ft of the rental).

As mentioned above, these constraints are based on trends observed in our datasets, the current market scenario and sentiment analysis conducted on student survey. Constraint 1, 2, and 6 focus on bounding our decision variables. We noticed that students do not want to travel more than 2 hours 42 minutes a day commuting to-and-fro UBC. That set an upper bound of \$16.2 (\$6 x 2 hours 42 minutes) on x2. As far as the lower bound goes, Kitsilano was included in our Vancouver opportunity cost calculation and it took the least amount of time to come to campus from there. So, the lower bound was set to the opportunity cost of travelling from Kitsilano i.e., \$8. Similarly, no student wanted to pay more than \$1287.234 a month on rent (look at survey statistic table). A lower bound of \$700 offers surety against the risk of coming across rentals which do not meet general living standards. The lower bound on x3 in constraint 6 was observed in our datasets. We also observed that each student needs at least 400 sq ft[3], including personal and non-personal space, to themselves. Constraint 3 takes care of this factor. Constraint 5 is the result of the correlation we found between x2 and x3 from our datasets.

Below is the Python script we used to summarise and solve our LP problem. And we used Python's PuLP library to do so.

```
import pulp as pulp
z = pulp.LpProblem("question1", pulp.LpMinimize)
x1 = pulp.LpVariable('x1', lowBound=700, cat='Continuous')
x2 = pulp.LpVariable('x2', lowBound=8, cat='Continuous')
x3 = pulp.LpVariable('x3', lowBound=1.88, cat='Continuous')

z += 1*x1 + 20*x2 + 100*x3

z += x2 <= 16.2, "C1"
z += x1 + 20*x2 >= 1287.234, "C2"
z += x1 - 400*x3 >= 0, "C3"
z += x1 <= 1287.234, "C4"
z += x2 + 8*x3 >= 40, "C5"


print(z)
z.solve()
print("Objective value (Z):",pulp.value(z.objective))
print("x1 is", pulp.value(x1))
```

[3] https://www.youngandthrifty.ca/how-much-space-do-you-really-need/#:~:text=According%20to%20the%20engineering%20toolbox,feel%20comfortable%20in%20an%20apartment.

```
print("x2 is", pulp.value(x2))
print("x3 is", pulp.value(x3))
```

After running the LP algorithm, we get the following output/optimal solution.

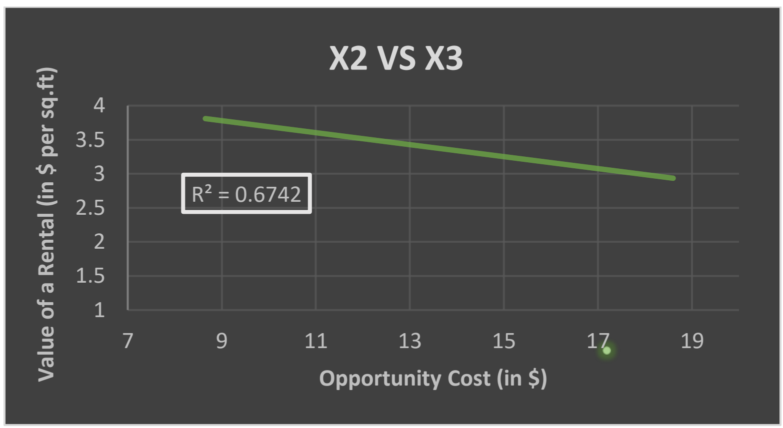
Objective value (Z): 1811.5
x1 is 1190
x2 is 16.2
x3 is 2.975

ANALYSIS OF OPTIMALITY AND GENERAL DISCOURSE

Our optimal solution is x* = (1190, 16.2, 2.975). Interpreting the solution, our data suggests that a student is better off paying $1190 per month on rent, paying $16.2 in opportunity cost, and the value of the rental should be $2.975 per sq. ft. Opportunity cost of $18 also implies that a student spends 2 hours 42 minutes ($16.2 ÷ $6 per hour = 2.7 hours) traveling to – and – fro UBC campus in a day. This data clearly suggests that a student should not live in Vancouver but in a neighbouring city, presumably over an hour from UBC campus, to minimise their cost of living in the current market scenario. Comparing our optimal solution to the city-wise summary statistic above, we find that there is a higher chance of a student finding optimum housing in Surrey; which has an average rental price of $1251.59 per month, an opportunity cost of $18.6, and average value of $2.76 per sq. ft for a rental. We do so, by simply plugging – in Surrey's summary statistics in our objective function, to get 1899.59. This is the closet value we get to our optimal objective value – 1811.5. In our case, the significance of an objective value is nothing more than a mere rank. Through this we are able to deduce that Surrey is the optimal location for a student to find affordable housing.

A few trends were noticed in our formulated datasets. Namely, we noticed that our x2 and x3 variables, the opportunity cost and the value of a rental per sq. ft, are inversely related.

This means that as the distance from Metro Vancouver (the campus) increases, the value of rentals per sq. ft decreases. In order to test this, we made a summary statistic for all of our data points. We then took to excel and made a simple linear plot to test our hypothesis of the relation. We plotted opportunity cost against value of rental per sq. ft (as shown below). And, as hypothesised, we found a negative correlation between them. Understanding this, we notice that our optimal solution also follows this trend. To get a good value for our buck in this market, our solution recommends finding a place farther away from UBC campus.



This project on a first glance seems unconventional. When compared with other linear programming problems, this seems different due to the way our objective value and constraints are structured. To begin with, our objective value is nothing more than a mere rank that helps us compare solutions. This is unlike other conventional cost – minimisation problems, where the objective value holds significance value, not only in terms of rank but in terms of finding optimal cost/monetary value for the LP problem. Secondly, conventional cost – minimisation problems tend to find optimal 'quantities,' with a constant cost or dollar amount for each quantity in the objective function. Whereas, instead of finding optimal quantities, we are optimising dollar amounts in the objective function. This unconventional LP approach still works in our case since our objective value, even though it only serves as a rank, is still in dollar amounts (in terms of its unit) similar to conventional cost – minimisation problems.

Our project code does not have a direct user – input, but is surely user – centric. We say so because it can be tailored to each person's specific needs. For example, if a student is willing to pay $1,800 per month, they can simply change constraint 4 ($x1 \leq 1287.234$) to $x1 \leq 1800$, and run the LP problem to find the best price they should be paying and the location for it. This functionality also circles back to the unconventional nature of our project as it focusses on changing constraints for a user – input experience, rather than having a direct user – input. This also comes with an obvious caveat that the user should have a basic code understanding in Python. Hence, we made the code easy to read and understand.

Lastly, our project not only provides a solution to the current housing market crisis but also serves as a reference point for students to understand how to navigate through this said crisis. To elaborate, if a student does not know how much should they be paying for rent per month, our optimal x1 value of $1,190 solves the issue. Similarly, if a student thinks they should not be paying more than $1,000 per month, our solution provides a better understanding of the market to them. In conclusion, our project also succeeds in setting a benchmark in terms of rental price, location and value of a rental and establishes a ball park for a student to think – in with respect to the 'current' housing market.