Math 208W Project - Expo line Extension

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1 Introduction

An efficient transit system that is effective and sustainable is not only important but also complex. Public transit is a must for maintaining a sustainable transportation system that provides travelers greater opportunity, choice, and access to a variety of economic and social activities. The system should be accessible and available for everyone to stay connected to activity centres. One of the most imperative features for evaluating a city's public transit is accessibility. It is a measure of peoples' ease and convenience in reaching transit services. Another measure of it's effectiveness is the location of Sky Train Stations. The system is efficient if these locations are optimized by taking in different constraints.

A report in 2017, Translink stated an increase of 5.7 in the "boardings" from the year 2016 – 2017 [1]. A follow-up report in 2018, Translink recorded an increase of 7.1 in passengers stated as their "biggest annual increase" [2]. Kevin Desmond, the CEO of Translink said that the "demand for Translink is still running high..." and that they should keep investments high for a more reliable and an accessible system for the community [1].

These findings indicate the need for an efficient transit system is only growing, which means that there will be upcoming projects for the expansion of the current Sky Train model. In this project, we will be specifically talk about the Expo Line extension connecting cities of Surrey and Langley.

The first step to solving a problem is by stating it. To find the most effective station placement, we believe that placing too many stations will result in some stations not being used to optimal capacity which results in costs exceeding any profits made. Alternatively, having fewer stations than required will hamper accessibility resulting in fewer people using transit making the system counter-productive.

To tackle these concerns, our goal is to find the optimal number and the placement of stations between start and the terminus station.

2 Proposed Expansion

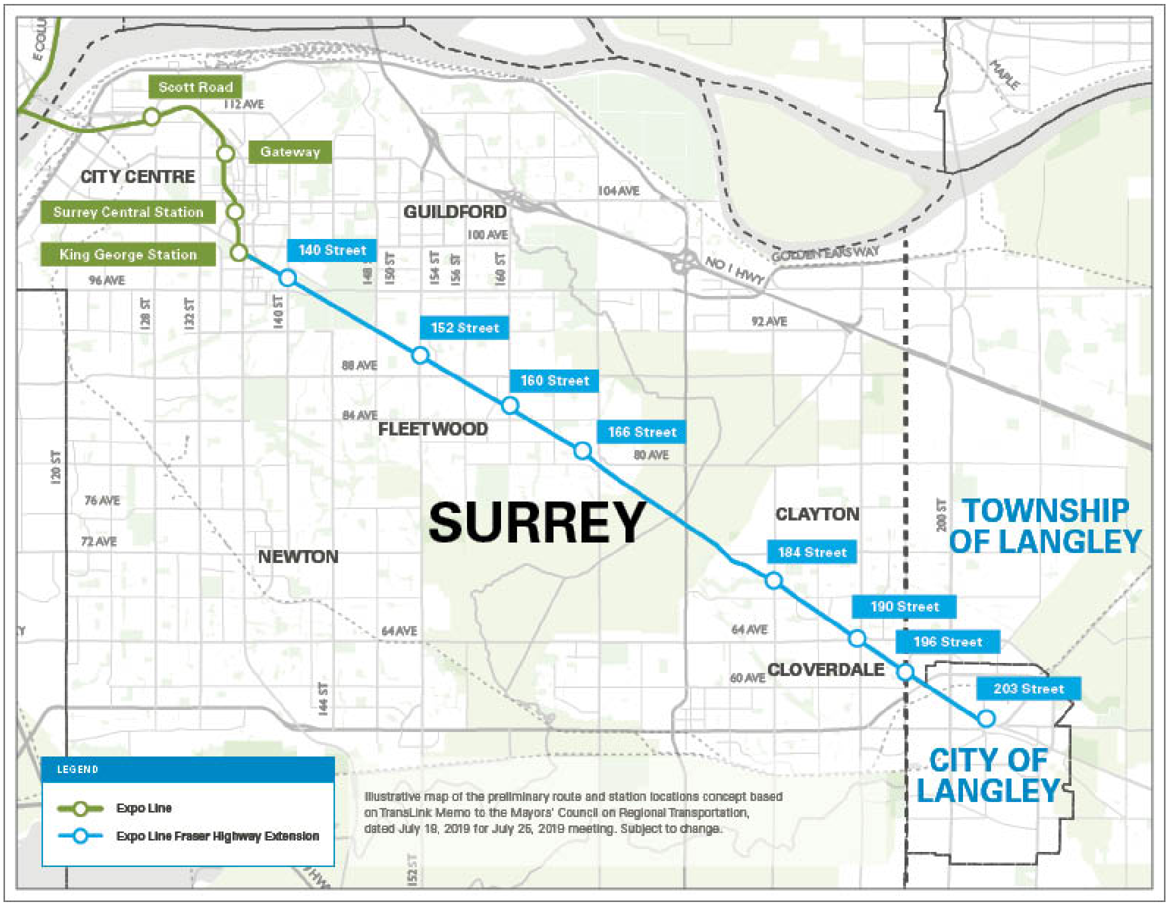

Figure 1: Skytrain stations Mapped from Surrey to Langley

The area south of the Fraser river is growing rapidly and it is projected that by 2050, the city of Surrey and Langley will house 420,000 new residents [3]. As a result of this, there will be 147,000 new jobs created. A growing population means a higher demand for public transit, and so to meet this demand, the Mayor's council decided to proactively work on the expansion project and on January 30, 2020, "Surrey Langley Skytrain Project" has been endorsed and is expected to start running by 2025 [4]. It will be a 16-km-Long Skytrain project connecting Surrey and Langley built over the Fraser highway. According to this plan, this project is estimated at 3.1 Billion.

The council has already allocated half of it and construction WAS expected to start later this year, however, due to the recent outbreak of the novel coronavirus the construction has been temporarily suspended until conditions become better. This plan offers socio-economic as well as environmental benefits. These include a reduction in the greenhouse emission along with an estimated reduction of cars on the road reducing congestion.

3 Methodology

Conventionally, Optimizing the stations for transit vehicles is done using a Mixed Integer Linear Programming. In a study done by Mahadikar et al in the Department of civil engineering at the Indian Institute of Science worked on optimising the bus allocation to the respective depot using the "dead kilometre minimization" technique [5]. They coupled this technique with Heuristic algorithms to provide optimal solutions of their model.

Another approach to the similar problem can be done using a Continuum model [6]. Researchers at the Northeastern University, Boston solved this by coupling dynamic programming with a discrete model.

Working with a time and resources constraint due to the current circumstances in the world, we approached this problem in a more simplistic way using a binary model.

4 Constraints

4.1 Population Density

This is an important constraint in our model because essentially, we would want our stations to be in high populated areas. Since accessibility is one of the key features of our model, We calculate population in a 600m radius by using a website called census mapper[7] which gives population in specific areas. However, the website gives population in 2016. Thus, our population value is undervalue by roughly 12 percent because population increase annually by 3 percent.

There has been existing debate regarding the land use and transit. Some believe that high population density would mean a higher use of cars, however Bertaud and Richardson found that there is indeed evidence of a positive correlation between low-density settlement patterns and a high reliance on automobiles as well as an association between high-density environments and more transit use is firmly established [8]. This further solidified our rational for including density in our model.

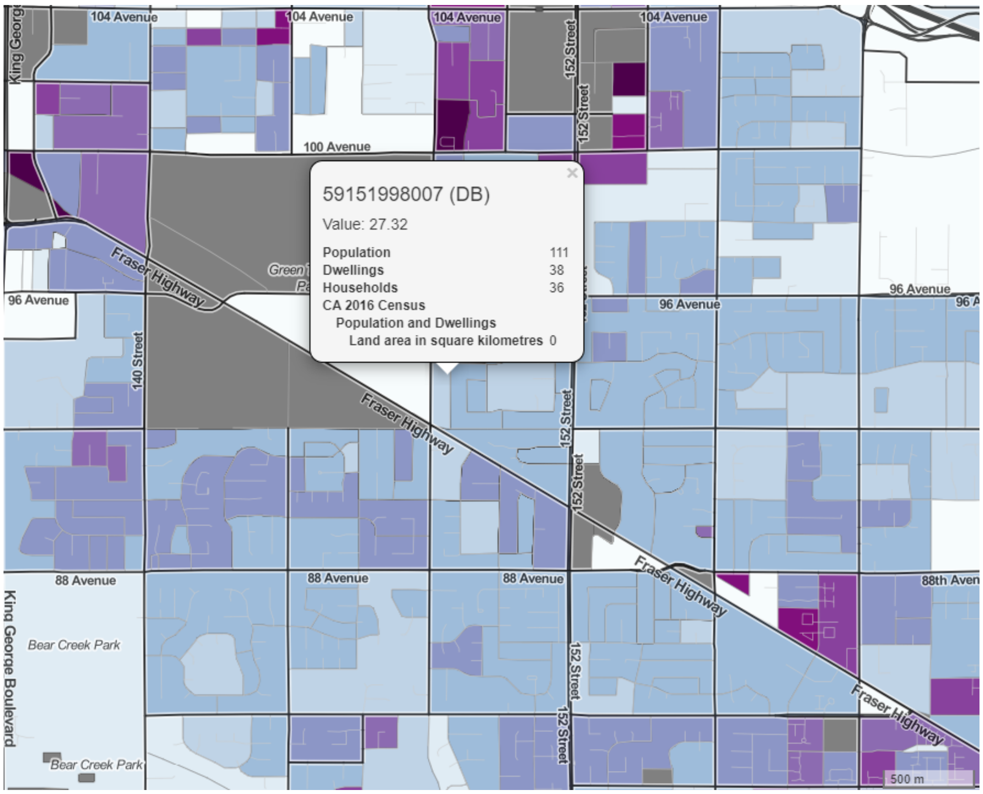

Figure 2: Population Density of area south of Fraser river

4.2 Zoning

Zoning was found by using a website called cosmos[9]. This website indicates which areas have specific zoning restrictions. However, it does not indicate which zoning areas have malls or any other high traffic areas. Zoning also creates problem because there are some areas where we cannot make a Skytrain station due to protective land. We can not make a Skytrain station on 144st, 148st and 176st.
$X_{144st}+X_{148st}+X_{176st} = 0$

4.3 limit of Skytrain stations

Every municipalities has a limit of how many Skytrain station will be allocated in that area. This was determine of how many stations Translink was willing to allocate for there actually expansion. Surrey will have 4 station, Fleet-wood will have 3 and Langley will have 1. The following is a equation to hold the constraint true.

$X_{140st}+X_{144st}+X_{148st}+X_{152st}+X_{156st}+X_{160st}+X_{164st}+X_{168st} = 4$

$X_{176st}+X_{184st}+X_{188st}+X_{192st}+X_{196st} = 3$

$X_{200st}+X_{203st}+X_{204st}+X_{206st}+X_{208st} = 1$

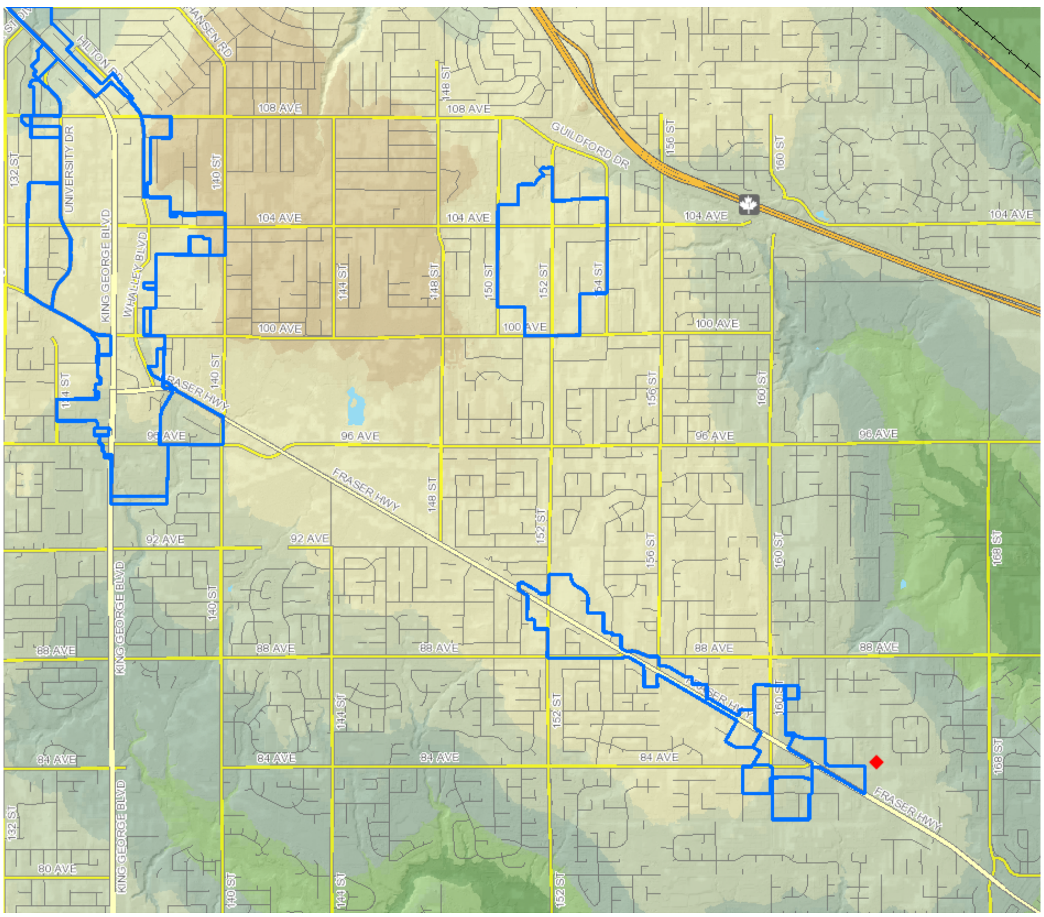

Figure 3: The blue areas indicate business improvement areas.

5 The model

Our decision variables are listed below

B_i = 1 if intersection i has a bus stop; 0 if not

Z_i = 1 if intersection i belongs to a commercial/industrial area or business improvement areas; 0 if not

P_i = sum of people per hectare within a 600m radius around the intersection

Y_i = (.5*B_i+Z_i+1)*P_i

Y_i is to calculate the value at each station for example, 160st has a bus stop and population of 3000 thus the value would be Y_{160st}= (1.5)*3000. If a sky train station is in zoning commercial/industrial area then that Skytrain station has a higher value. For example, 164st is in commercial zoning area with a population of 2000 then its value would be calculated as the following (.5*0+1+1)* 2000.

X_i = 1 if the station is chosen; 0 if not.

Objective function:

$$Z_{max} = \sum_{n=1}^{18} (\mathrm{X}_i{*}(Y_i\text{-}(Y_i{*}(X_{i-1} + X_{i+1}){*}.3)))$$

Our objective function is to maximize the told value. Also, there is constraint in our objective stating that if there is station before or after another station then lower the stations' value that was in question. For example, 164st station has a station before it then 164st station value would be lowered by 30 percent.

6 The Results

Using the excel solver we found that the optimal solution is having a station at 140st, 152st, 160st, 168st, 184st, 188st, 196st, and 203st. This seems to be a reasonable solution because the stations are spread so there is no cluster.Also, there is no decimals for the stations,for example .5 station which makes no sense you can not have half a station.There is some assumption that can play big factor in this solution. We assume that zoning areas will have the same amount of demand but some zoning areas could have malls and more places where people more are abundant. Hence, if we had proper data on this our solution might be different.

7 Comparison

The results above are in line with Translink's proposed plan. Our results are similar but not exact, however given our limited resources we came up with an effective working model taking in the population density and zoning areas as constraints. These results also compliment our hypothesis that a higher population density would result in greater transit use.

The differences between the two results can be highlighted in terms of the placement of the stations. The Translink model has a station in the midpoint of 188st and 192 st. Since our model only takes whole values, we can only place a station at one of the two street intersection. This is because these streets are conveniently located next to the Willowbrook Shopping Centre, and Wallmart. Our model recognised these areas to have a higher density than other areas and assigned a larger value.

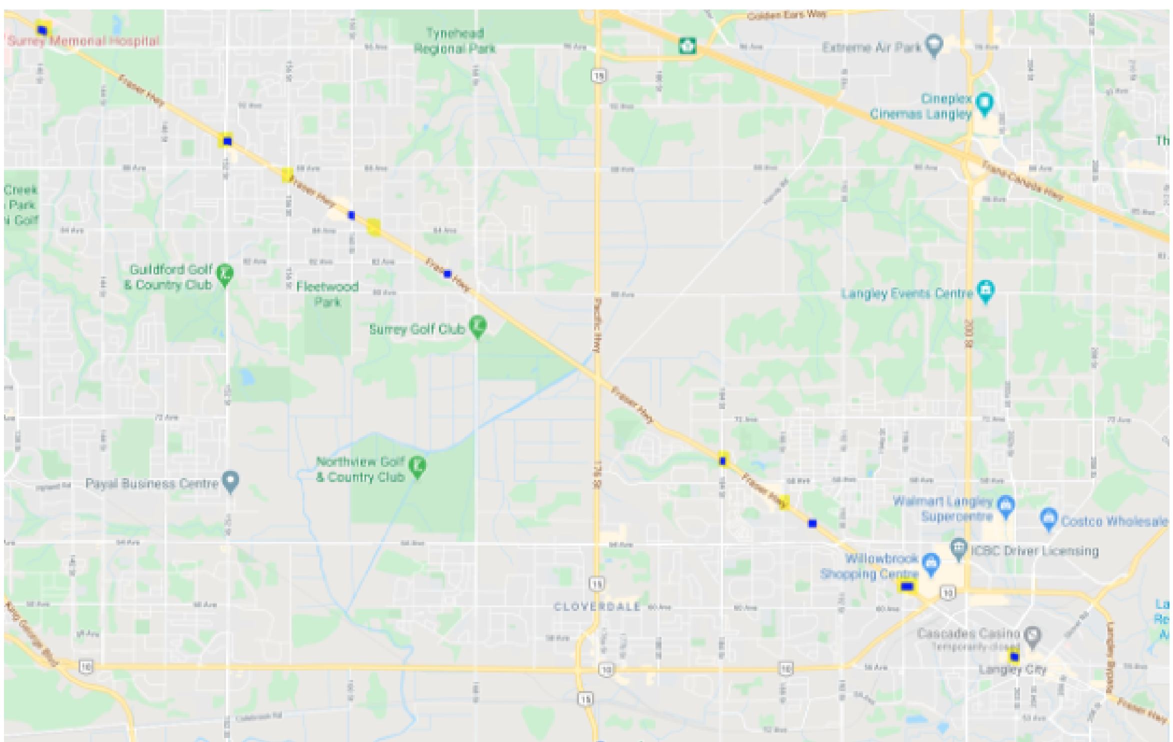

Figure 4: We overlayed and highlighted our solution onto the proposed plan

Another important aspect was the placement of the terminus station. We did not have a constraint that restricts the terminus station to be at one specific street, there the model could choose between 4 stations (203 st to 208 st). The final result was a station at 203 st. This is because of Langley Regional airport present next to 208 st. There are no neighborhoods within 2-3 blocks of it, hence the most populous between the 4 choices was 203 st.

TRANSLINK PROJECT	140 St	144 St	148 St	152 St	156 St	160 St	164 St	168 St	176 St	184 St	188 St	192 St	196 St	200 St
	1	0	0	1	0	1	0	1	0	1	0.5	0.5	1	
OUR MODEL	140 St	144 St	148 St	152 St	156 St	160 St	164 St	168 St	176 St	184 St	188 St	192 St	196 St	200 St
	1	0	0	1	0	1	0	1	0	1	1	0	1	

Figure 5: Side by Side comparison from the official plan and our solution

This project resembles the Surrey LRT Optimal Station Locations only in terms of the optimizing the transit stop location, however our constraints and objective function are different. They approached this problem from a cost perspective, whereas our model takes population density and effective use of the land [10].

Another imperative point to note is that the LRT project has been effectively been cancelled [11]. We just wanted to highlight that even though there are similarities between the LRT project and our Expo line extension, We did not add extra constraints that could further complicate our model and reached the same solution as the official Translink plan. Our model can be seen as an enhancement of the previous one because one of the reason it got cancelled was because of poor budgeting. The LRT allocated cost without looking at the geographical structure and did not take into account the zoning constrain which indicates that some areas are out of bounds.

8 Considerations

It was often stressed upon in class that no model is perfect, and to follow that fact our model has its own limitations and assumptions we had to make. These limitation include that the zoning areas were treated equally. Some zoning areas have malls and other facilities that a lot of people visit. Therefore, there would be more demand in those area, however our model does not consider that and this could change solution.

We did not take into consideration the change in traffic patterns in the future that could affect our solution.

We assumed the budget constraint. The proposed project is estimated at 3.1 Billion. Our model assumes that the costs and benefits are uniformly distributed between each station.

Another assumption is more into the future which we are not at the capacity to predict is the change in the population density of areas as well as the income of households. As more job opportunities come up, and new residents settle down, there might be some changes to urban planning due to transportation behaviour. Our model takes a uniform population percentage taking this particular route. There will be different results produced if there is an increase in cars.

9 References

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