Selecting Station Locations for a Public Bike-Share Program: A Case Study for the City of Vancouver, B.C.

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Abstract

More than 600 cities around the globe have implemented public bike-share programs (PBSPs) and these numbers are continuing to grow. Following the successes of these PBSPs, the city of Vancouver is investigating the possibility of implementing its own system. Since the majority of PBSPs address the last mile problem (i.e. the idea that the last leg of a trip is generally the least efficient), we focus our model on the downtown Vancouver area. The PBSP station location problem is formulated as a deterministic integer programming model, and is solved using CPLEX. Our objective is to maximize the value of a PBSP by optimizing the placement of bike stations. More specifically, our model uses data that provides pedestrian and bike traffic volumes along with popular arrival and departure destinations, such as public transit facilities and tourist attractions, in order to quantify the utility of placing stations in certain locations. In order to strike a balance between convenience for the user and the economic feasibility of the PBSP, this paper also examines the effects of varying the total number of stations to be placed in the system.

1 Introduction

As a result of the ever-increasing value that modern society places on health and sustainability [5], bicycling has experienced a renaissance as a popular method of both transportation and leisure. Following the successes of public bike-share programs (PBSPs) around the world, the city of Vancouver is investigating the possibility of implementing its own system [7].

It can be argued that one of the main contributors to the success of a PBSP is station placement [6]; as a result, the goal of this paper is to determine a selection of bike-share station locations that will maximize the value of a public bike-share system. Physical, financial, and political restrictions create limitations to both the potential locations of stations and the number of stations that can be constructed.

A deterministic integer-programming model is used to determine a good selection of station placements for a PBSP. The model considers several factors including station size and station density, along with added values for station locations in areas with greater accessibility and convenience as determined by collected data.

2 Literature Review

As PBSPs are a relatively new phenomenon, the number of studies conducted on finding optimal station locations for a PBSP is limited. Bryant (2013) focused on optimal locations for a PBSP in the city of Richmond, Virginia by applying heuristic spatial analysis techniques to an adapted version of the set covering problem (known as the maximum covering location problem) [2]. The heuristic served to locate the bike stations that would cover the most demand points along a transportation network within a specified distance.

Bryant's model identified all existing bus stops as potential station locations and then used an origin-destination analysis (based on Dijkstra's algorithm) to determine a reasonable walking distance between stations. A distance of approximately 400 metres was ultimately chosen.

Although Bryant's model had the most similarity to ours, other studies have been conducted on PBSP station locations. Croci et al. (2014) and Ma et al. (2014) focused on the relationship between existing stations located by places of interest and their effects on PBSP usage. Ma et al. focused more on the economic impacts of the PBSP based on station locations in Washington, D.C. [3], while Croci et al. studied the optimal re-location of current PBSP stations in Milan based on the results of a regression analysis [4].

For all three studies, modelling the optimal station location problem for a PBSP was done in one of two ways: either (a) the distribution of parameters such as population and public transport density was used to look at which areas were the most suitable; or (b) optimization analysis such as set or maximal covering problems were used to create a suitability map for identifying the best locations.

3 Stakeholders

The stakeholders associated with implementing a PBSP in Vancouver include:

- **The City of Vancouver**

  Since the PBSP is a public program and will be implemented within the City of Vancouver, the impact of the program will have its highest effects on the city. The city will have one of the greatest influences on the project as they will have to invest time, money and resources into the program. Another important consideration is the reputation the City will hold should the project succeed or fail. For these reasons, the success of the project will be imperative.

- **Companies associated with building and installing the bike stations as well as providing the bikes**

  Companies associated with manufacturing and supplying parts for the PBSP will also have a large influence on the project. Similar to the city, they will also be investing ample time and resources into the project and as such, the outcome of the project will be of high importance to them.

- **Future users of the PBSP**

  The Vancouver community as well as the future PBSP users will rely on it as a way to promote efficient and environmentally friendly methods of transportation within the city.

- **Sponsors (i.e. banks, local universities, etc)**

  The effect on sponsors is again, similar to the effects on the city and the companies associated with implementing the PBSP. As it is likely their company logos will be advertised on the system, their reputation is also at stake.

- **Translink**

  Since the PBSP is intended to solve the last-mile problem, it should encourage people to opt for public transit more frequently than motorized vehicle. This should result in a higher usage of Translink system. At the same time, it also allows users to opt for cycling at rush hour periods, should buses be over-capacity. This also alleviates over-capacity issues.

- **Existing bike rental shops**

As existing bike rental shops will consider it a threat to their business regardless of where the stations are placed, the success of the program will also be of importance to them.

- **Pedestrians**

  The PBSP will serve as a cost to current sidewalk space, which could be an issue for pedestrians if it inhibits pedestrian traffic.

- **Other individuals, businesses or institutions interested in the program**

  Since this is a project that will require ample time and effort in terms of the planning and implementing stages, all the stakeholders will be affected to some degree. Some notable stakeholders who would also be impacted to a slightly lesser degree by such a program includes: the Vancouver Police Department (VPD) and Tourism Vancouver. The VPD are responsible for the safety and security of the citizens of Vancouver and as such, a PBSP could pose as a risk to cyclists, pedestrians and drivers should the program not be implemented properly. As the PBSP is also aimed to serve less frequent users, Tourism Vancouver could also benefit from the program. As a result, the interest in the project should be quite high for all the stakeholders.

4 Model Considerations

Ultimately, the placement of stations should be dependable and result in a fair total riding time [6]. Users do not want to have to walk a great distance to drop off or pick up their bikes, but having too many stations in close proximity may cause the cost of building another station to outweigh the benefit of having that additional station. In order to determine useful station locations, we employ a measure based off of station densities in previously successful PBSPs such as New York City and Paris. This follows an industry density standard of at least one station per 300 meters and at most one station per 100 meters [6]. In Vancouver, this translates to about one station per 2-3 blocks.

Arriving at a station with no available bikes or no available docks is of vital concern to PBSP implementers. Therefore, different station sizes will be incorporated into the model. The combination of station size as well as the set maximum distance between stations alleviates the problem of having no available bikes or docks at a station.

Ahillen et al. (2015) state that a frequent argument made in favour of PBSPs is that they help solve the common last-mile problem commuters face when limited strictly to public transit. Commuters who face this dilemma often opt for motorized vehicle for the entire trip [1]. Nair et al. (2011) explains that Paris Velib docking stations are placed next to the Paris Metro stations. They found that the most highly used docking stations are located next to transit stops and services [8].

From these findings, it was decided that, for the purposes of frequent PBSP users, stations should be situated within the vicinity of major transit facilities, which in Vancouver would consist of Skytrain stations, bus routes and ferry docks as well as major business centres. To satisfy the intermittent user, stations near major cultural locations, tourist attractions, parks, beaches and public spaces were also determined to be of value.

As bike stations are usually placed on sidewalks, they are subject to the same regulations as any other item built on a sidewalk [6]. Hence, it is essential that enough space be allocated for the station as to not impede pedestrian traffic or violate safety regulations.

5 Additional Considerations

Initiating a PBSP can be hectic as there are numerous aspects related to it that must be solved simultaneously. Equipment design and installation is one of the major considerations. Once the number of bike-share stations and their sizes have been determined, the next step is to design and build stations along with helmet vending machines at each location. Further, there has to be a certain procedure of transporting bikes and helmets from manufacturing company to stations and from one station to the other in case of over/under-capacity at the stations. The stakeholders will have to plan to cover (and hopefully minimize) installation and transportation costs. These issues are different from selecting potential station locations and have not been solved in the model.

Another aspect to be considered is bike-share equipment repair and maintenance. Maintenance includes bike replacements and helmet recycle/reuse. The authorities will have to set budget that will contribute towards such expenses. They will have to set rules to regulate PBSP usage and prevent theft and vandalism. How to check if a bike was returned and in what condition? Who is to be blamed for any damage? All such questions will have to be considered while setting rules. The procedures of repair and maintenance have not been considered in the prescribed model.

Moreover, PBSP implementers will also have to decide on bike rental fares and methods of payment. For the former, they will have to determine short-term user fee and long-term membership. The rental fares should be set such that the program is cheap and convenient to public and is considerate of other privately owned bike rental shops. For latter, it is very likely that stations will be run electronically, as in similar programs worldwide. The authorities will have to invest a huge amount of money to hire software developer companies to design and test the model. Such decision making problems will have to be implemented step-by-step and separately from selecting station locations.

For successful implementation of PBSP, the sponsors will have to notify people about the new program and promote them to ride bikes. This can be done through advertisements and promotional campaigns. Furthermore, the sponsors will have to educate pedestrians, cyclists and drivers and make them aware of each-other on road. They will also need mobile phone app and online

Figure 1: City of Vancouver's proposed target area

interface to further assist the public. The program implementers will have to set an additional advertising budget and work on this aspect separately.

Our model is concerned with selecting potential station locations and their approximate sizes. The above mentioned additional problems of PBSP are not considered in our model: designing and building bike-share stations and helmet vending machines, transporting bikes and helmets, setting budget for various purposes, deciding rental fares and methods of payment, and creating user-interface.

6 The Data

In the initial stages of formulating the PBSP station location problem, the original target area we aimed to cover was the area that the City of Vancouver had originally proposed for their PBSP (see Figure 1).

Upon commencing data collection, it was discovered that there was not enough data available to cover certain regions within the initial target area, hence we narrowed our target area down to encapsulate as much of the data we had available, while still covering a reasonable area to implement a PBSP (see Figure 2).

Figure 2: Our final target area

6.1 Collected Data

As part of the data collection process, possible station locations must be identified. This was done using Google Maps Street View feature to virtually walk through the target area and manually classify the locations that could accommodate a bike-share station. The potential station locations were kept on a separate map in order to keep track of the collected data.

The red numbers next to each location in Figure 3 represent the maximum number of bikes that could fit in a station at that location. The bounds of the station sizes were determined based on the availability of space in the area. A red 'L' represents a location that is large enough to be build a very large station (60+ bikes). Note that these red values are indeed just bounds, ultimately, the model will be deciding the final station size (i.e. small, medium, large).

6.2 Existing Datasets

In order to add value to station locations in our model, real pedestrian and bike volume data collected by the City of Vancouver was used. Since the model is focused on placing stations throughout the core of downtown Vancouver (i.e. from Chilco Street to Columbia Street), the data focuses on covering as much of that area as possible. As a result, information on designated cycling lanes implemented by the City, major tourism sites, popular locations, and key transit stations were incorporated to better assess the value each street in Vancouver holds to a potential PBSP

Figure 3: Map of potential locations with maximum station sizes

user.

The bike volume dataset includes the number of bike trips made each month through nine streets from 2009 to 2015. Using 2015 data, these values range from 12,000 to 70,000 trips per month. The 2008 pedestrian volume data provides a count of the number of pedestrians seen on certain streets between 10am and 6pm. There are six levels of volume counts ranging from 0 to 26,000 (see Section B).

The purpose of the bike route data (see Section C) is to add value to stations based on convenience and safety. There are 5 cycling routes, ranging from AAA Network (Vancouver's safest and most comfortable cycling route), to Shared Use Lanes (painted markings on relatively busy streets). A station located on a AAA Network route would add greater value for safety and ease of transportation than a station located on a shared use lane.

The benefits of incorporating this data into the model are that it allows for a more objective value allocation to potential station locations. As such, it also provides a more practical solution. Unfortunately, despite extensive data gathering and collection, the datasets do not cover all the streets in Vancouver, so there may be cases where some streets were under-valued.

7 The Model

7.1 Overview

The fundamental idea behind our model is that each potential station location has an associated value. Given some constraints regarding where stations must be placed or cannot be placed, the model places a limited number of stations so that the sum of their values is maximized

7.2 Variables, Sets, and Parameters

Type	Name	Explanation
Binary Variables		
	x_i	Indicates whether or not a small-sized station is placed at location i
	y_i	Indicates whether or not a medium-sized station is placed at location i
	z_i	Indicates whether or not a large-sized station is placed at location i
Sets		
	P	Set of all potential locations
	F	Set of features that add value to locations
	L_f	List of potential locations near feature f
	R	The target area is partitioned into a set of regions R
	L_r	List of potential locations in region r
	S	Set of bike shops in target area
	L_s	List of potential locations near bike shop s
	C_i	List of potential locations within 100 metres of potential location i
	D_i	List of potential locations within 300 metres of potential location i
Parameters		
	N	Total number of stations to be placed
	Y	Maximum number of medium stations
	Z	Maximum number of large stations
	M	Minimum number of stations per region
	V_f	Value associated with feature f
	α	Factor by which the value of a small-sized stations is multiplied
	β	Factor by which the value of a medium-sized stations is multiplied
	γ	Factor by which the value of large-sized stations is multiplied

7.3 Adding Value to Stations

We assign location values by identifying the high-traffic and otherwise important parts of the target area. The following is a full list F of the features that we considered to add value to potential station locations:

1. Pedestrian volume
2. Bike volume
3. Bike lanes
   (a) AAA Network: The safest and most comfortable bike lanes.
   (b) Separated Bikeways: Bike lanes that are separated from other vehicles by a physical barrier
   (c) Local Street Bikeways: Bike lanes on relatively quiet streets.
   (d) Painted Bikeways: Painted bike lanes located between the sidewalk and the main street.
   (e) Shared Use Bikeways: Painted bike lanes in busy streets.
4. Skytrain stations
5. False Creek Ferry stations
6. Schools
7. Community centres
8. Waterfront property
9. Other important locations:
   (a) Vancouver Art Gallery
   (b) Harbor Centre
   (c) Vancouver Convention Centre
   (d) Canada Place

Each feature $f \in F$ has a value v_f and is associated to a set of potential locations L_f that are considered to be "close enough" to f. Thus, our objective function is:

$$\text{Maximize} \sum_{f \in F} \left(v_f \sum_{i \in L_f} x_i \right) \tag{1}$$

For now, we assume there is only one possible station size and each x_i is a binary variable representing whether or not a station is placed at potential location i. See Section A for a full table of features and the corresponding values.

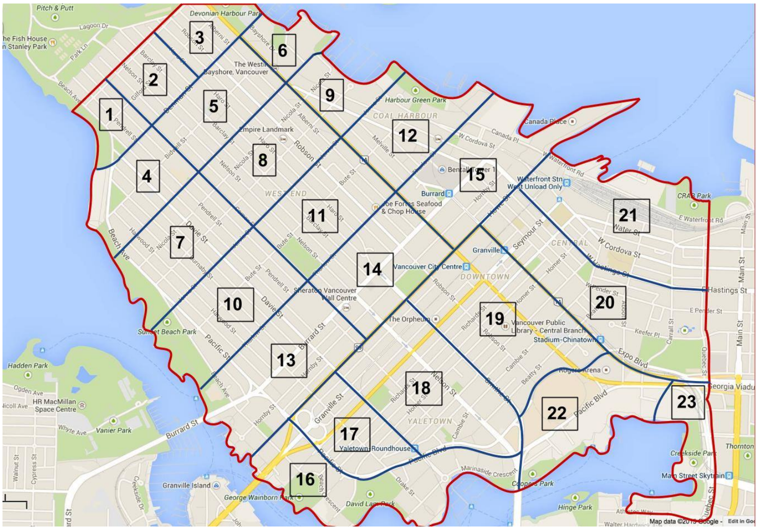


Figure 4: Target area partitioned in regions

7.4 Constraints on Station Placement

There are five main types of constraints:

1. Maximum Number of Stations:

$$\sum_{i \in P} x_i \leq N, \tag{2}$$

where P is the set of potential locations and N is the maximum number of stations that can be placed.

Naturally, the most convenient solution for the bike-share users would be if there was a bike station installed at every potential location. However, this is not economically feasible, thus the total number of stations to be placed is limited.

2. Minimum Number of Stations per Region:

$$\sum_{i \in L_r} x_i \geq M \qquad \forall r \in R, \tag{3}$$

In an attempt to ensure that the placed stations adequately cover the entire target area, we partition the target area into smaller regions (see Figure 4 on next page) and require that each region r has at least M bike stations.

Throughout our trials with the model, we have noticed that most of the region restrictions are implicitly satisfied. That is, even if we completely remove the region restrictions, the distribution of valuable locations across the target region causes the model to pick station locations that would still satisfy these eliminated constraints. Therefore, we run our model without region restrictions and we introduce restrictions as needed. For example, using $N = 80$, only regions 2, 8, and 10 would be relatively uncovered. Thus, we only add those three corresponding constraints.

3. Maximum Distance Between Stations

$$\sum_{i \in D_j} x_i \geq x_j \qquad \forall j \in P, \tag{4}$$

Each potential location j has a list of neighbours D_j that includes all potential station locations within 300 metres of j. This constraint ensures that if a station is indeed placed at location j, then at least one potential location from L_j is also used as a station location. Therefore, we are certain that the maximum distance from any station to its nearest neighbour is at most 300 metres.

4. Minimum Distance Between Stations

$$\sum_{i \in C_j} x_i \leq N(1 - x_j) \qquad \forall j \in P, \tag{5}$$

Similarly, each potential location j has a list of neighbours C_j that are “too-close" (roughly within 100 metres). That is, if a station is placed at location j, we do not want to place another station right next to it. This effectively simulates the fact that clustering many stations in a small area will not compound value for the bike-share customers.

5. Minimum Distance From Bike Shops

$$\sum_{i \in L_s} x_i = 0 \qquad \forall s \in S, \tag{6}$$

In order to minimize the damages done to existing bike shops, we will create a buffer zone (of roughly 200 metres) around these existing shops where we cannot place bike-share stations. That is, each bike shop s has a list L_s of potential locations where stations cannot be placed. This mirrors the compromise that the city of Vancouver offered to the bike shop owners as a part of their bike-share proposal.

7.5 Constraints on Station Sizes

In order to add another element of realism and practicality, we allow the model to place different size stations at each potential location. We consider three sizes: small (station can hold 1 - 14 bikes), medium (station can hold 15 - 29 bikes), and large (station can hold at least 30 bikes). We shall use 3 binary decision variables: x_i for small stations, y_i for medium stations, and z_i for large stations.

Naturally, we add constraints that ensure that the potential location is large enough for each station type by setting $z_i = 0$ and $y_i = 0$ appropriately. In addition, we ensure that at most one kind of station is placed at each potential location and that the total number of stations (of all types) is below the limit.

$$x_i + y_i + z_i \leq 1 \qquad \forall \text{ potential locations } i \tag{7}$$

$$\sum_{i \in P} (x_i + y_i + z_i) \leq N \tag{8}$$

In order to give the model an incentive to place larger stations near high-value features, we multiply the value of a potential station location by α if a small station is used, by β if a medium station is used, and by γ if a large station is used, where $\alpha < \beta < \gamma$.

Therefore, our objective function is:

$$\text{Maximize} \sum_{f \in F} \left(v_f \sum_{i \in L_f} (\alpha x_i + \beta y_i + \gamma z_i) \right) \tag{9}$$

We set these parametrs to $\alpha = 1$, $\beta = 2$, and $\gamma = 4$.

We also need to limit the number of medium and large stations, or else the model would simply place these larger stations wherever possible. We set two parameters, Y and Z and enforce the following constraints:

$$\sum_{i \in P} y_i \leq Y \tag{10}$$

$$\sum_{i \in P} z_i \leq Z \tag{11}$$

That is, the total number of medium stations is at most Y and the total number of large stations is at most Z. We set $Y = \lfloor N/5 \rfloor$ and $Z = \lfloor N/10 \rfloor$.

However, since there are several particularly highly valued areas (for example, the Waterfront area) it is likely that the model will simply cluster all the allowable medium and large stations at these choice locations. Therefore, we impose another constraint that enforces a minimum distance of 300 metres between consecutive medium/large stations:

$$\sum_{i \in D_j} y_i \leq N(1 - y_j) \qquad \forall j \in P \tag{12}$$

$$\sum_{i \in D_j} z_i \leq N(1 - z_j) \qquad \forall j \in P \tag{13}$$

This will both stop the model from greedily placing medium/large stations wherever possible as well as simulate the effect of diminishing returns associated with having multiple larger stations in a small area.

8 Computational Results

8.1 Sample Solution

Varying the total number of stations to be placed is an interesting problem by itself. However, we first present a final solution for a set value of N. The city of Vancouver proposes to build 125 stations [7] across their target area. However, since our target area is smaller, we use $N = 80$.

We solved the model using CPLEX 12.6.1 [9] on a 2012 MacBook Pro Retina with a 2.6Ghz Intel Core i7 processor and 16GB of RAM. Our model, which contains 1128 binary variables and 1704 constraints, was solved in 0.10 seconds. Figure 5 illustrates the solution obtained.

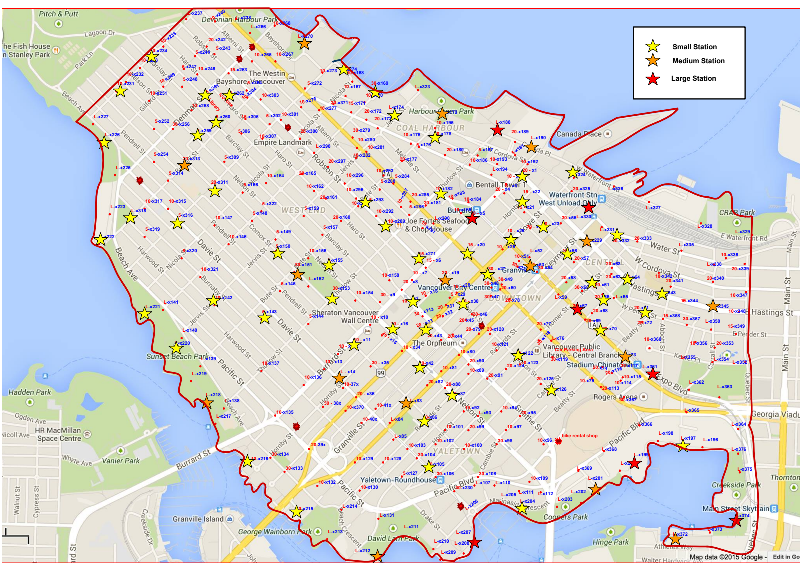


Figure 5: Solution at $N = 80$ overlayed over map of potential locations.

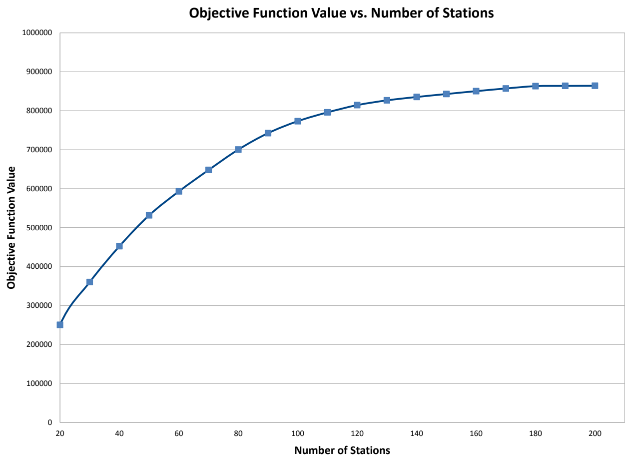


Figure 6: Objective function value levels off for large number of stations (N)

8.2 Selecting Number of Stations (N)

The more stations we are allowed to place, the higher our objective function value will be. However, given that certain locations are more valuable than others, we expect that there will be diminishing returns.

That is, if N is small, then it is likely that there is another highly valued location that can still be used and thus placing $N + 1$ will provide a large increase in the objective function value. On the other hand, if N is large, it is likely that there are no more highly valued locations to be chosen and thus placing $N + 1$ stations will result in only a marginally better objective function value. Here we detail this trade-off.

Using CPLEX, we solve our model for gradually increasing values of N. Plotting the objective function value versus N, we get the graph in Figure 6.

As expected, Figure 6 shows a diminishing rate of increase that almost flattens completely. We also plot the rate of increase in Figure 7 (i.e. the difference in the objective function value between $N - 10$ and N).

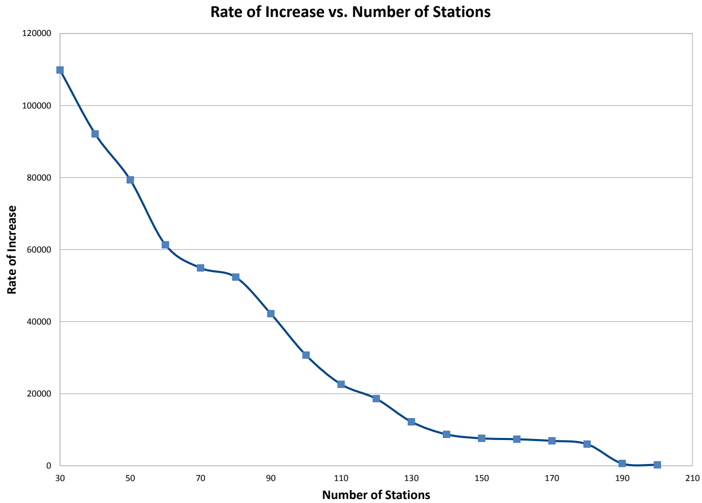


Figure 7: Graph of diminishing returns

Notice that both of the above graphs do not consider low values of N (i.e. $N \leq 20$) because the as-needed region restrictions (in this case, five regions were required to have at least two stations each) mean that low values of N are either infeasible or result in station placements that do not add much value to the objective function. That is, the model must focus on satisfying the constraints before looking to optimize the objective function.

This analysis supports the idea that $N = 80$ is indeed a good choice if sufficient resources are available.

9 Discussion and Future Work

For the city of Vancouver, our model found a good set of bike station placements (illustrated again in Figure 8). The main stakeholders should be satisfied because the entire target area is covered, there are no isolated clusters of stations that would be inconvenient to reach or leave, and the most popular or otherwise valuable parts of the city are easily accessible. The following sections provide ideas for possible future work.

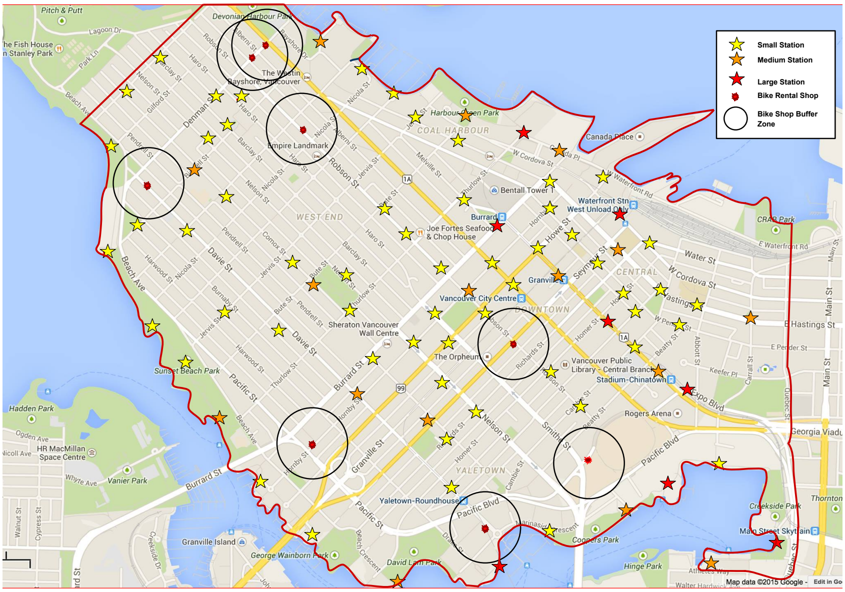


Figure 8: Solution at $N = 80$

9.1 Connectivity

One possible enhancement for our model is to consider the connectivity of the placed stations. That is, although we ensure that every station is at most 300 metres away from some other station, this does not mean that there will not be isolated clusters of stations away from the main set. In the case of a city where the most valuable features are very far away from each other, it is possible to have pairs of station spread out all over the target area such that the two stations within each pair are within 300 metres of each other, but any two pairs are completely separate.

9.2 Covering the Target Area

Currently, we partition the target area into smaller regions and force the model to place a certain number of stations in each region on an as-needed basis. Note that our model may be sensitive to the size of the regions. For example, if the regions are too large, it is possible that the model will only place stations in one corner and thus not adequately cover the entire region. Conversely, if the regions are too small, we may be removing a lot of the model's freedom to choose optimal locations.

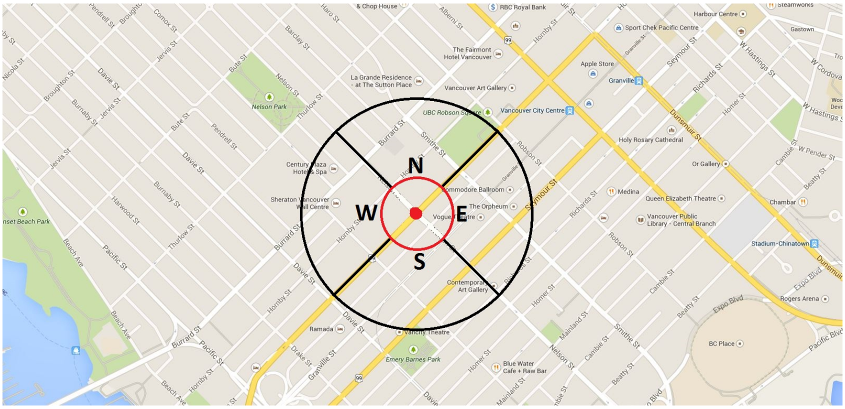


Figure 9: Visualization of Quadrant constraint.

9.3 Addressing Coverage and Connectivity

When our model resulted in a solution with some uncovered areas, these areas would usually be residential neighbourhoods. Therefore, we could improve the coverage of our target area by adding value to features (such as population density) that are generally associated with residential neighbourhoods.

If there is a need to explicitly address connectivity, one idea may be to change the Maximum Distance Between Stations constraints (4) to what we shall call Quadrant constraints. That is, instead of simply requiring that every station has a single neighbour within 300 metres, we will split the neighbourhood of each potential location into 4 quadrants as shown in Figure 9 on the next page.

We will still ensure that there is a minimum distance between any two stations (as indicated by the red circle), but we will also require that if a station is placed at location i, then at least one station is placed in each non-empty quadrant.

More generally, the issue with simply requiring that every station has a certain number of neighbours w within some distance d is that the model may organize the stations into cliques of size $w+1$. That is, if all $w+1$ stations are within distance d of each other, then they shall satisfy (4) and they can feasibly exist as an isolated cluster.

The new idea is that, for every assigned station i, these Quadrant constraints will force the model to select additional stations in every possible direction away from i. Assuming that there are no major gaps in the target area where there are no potential locations, these constraints should enforce connectivity and coverage across the entire target area.

9.4 Flexibility of Model

All of the parameters in our model (refer to Section 7.2 for a full summary) are easily adjustable. We can change the total number of stations to be placed, which allowed us to perform the analysis in Section 8.2. We can also easily vary the maximum number of medium/large stations, which would allow us to perform a similar analysis to decide on the optimal proportion of small, medium, and large stations.

On the other hand, our model is not particularly flexible when it comes to altering the neighbour sets. In the ideal scenario, we would have a full distance matrix containing all the (location,location), (location,feature), and (feature,feature) pairs. We could then write a program that generates (for any given distance) the list of neighbours of every location and feature. However, finding the distances for every pair would take a quadratic number of manual measurements relative to the total number of locations and features $T = |P| + |F|$, which is simply not feasible for large T. One possible compromise is to have a reduced matrix that only contains the distances between relatively near neighbours and features.

10 Conclusion

As the number of PBSPs across the globe continues to increase, the issue of selecting good bike-share station locations is a problem of paramount importance. The city of Vancouver is a major city with a strong cycling culture that has not yet implemented its own PBSP. As such, it presents a particularly interesting opportunity for study.

Utilizing previous research and practical experiences with PBSPs in other cities, we form a model that attempts to optimize the placement of station locations in the downtown core of Vancouver. We use transit data to identify and add value to high-traffic streets that are most popular amongst pedestrians and cyclists. We also add value to important cultural, touristic, and recreational locations.

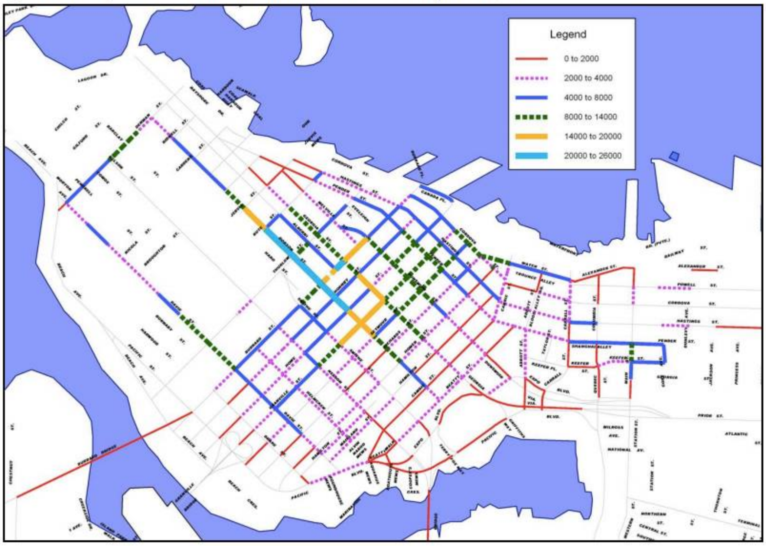
Solving our model with the analytically selected value of $N = 80$ yields an excellent solution for station placements in our target area. From the major transit hubs in the heart of the city to the beaches on the outskirts, the placed locations provide a thorough and well connected coverage of our entire target area. Furthermore, the fact that the model is solved in just 0.1 seconds means that we can safely add more layers of complexity in an effort to make the model even more flexible and realistic.

A Feature Values

Feature	Sub-feature	Value
Traffic Data		
	Pedestrian Volume	100 - 2,300
	Bike Volume	775 - 850
Skytrain Stations		6,000
False Creek Ferries		3,000
Bike lanes		
	AAA Network	2,000
	Separated Bikeways	1,500
	Local Street Bikeways	1,000
	Painted Bikeways	1,000
	Shared Use Bikeways	500
Schools		3,000
Community Centres		3,000
Waterfront Property		1,000
Other Important Locations		
	The Vancouver Art Gallery	5,000
	The Harbor Centre	5,000
	The Vancouver Convention Centre	5,000
	Canada Place	5,000

B Pedestrian Data [10]

Figure 4. Summary of 2008 Pedestrian Volumes on the Downtown Peninsula, 10am to 6pm.



C Map of Bike Lanes [12]

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