CASA0003 - Group Mini Project: Digital Visualisation

Project Title: What has the city of Toronto done to improve the urban cycling experience?

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Project Output	Output Description
Project Output Files	https://github.com/fang-zeqiang/Digital-Viz-City-Transformations
Project Website	http://zeqiang.fun/Digital-Viz-City-Transformations/Website/
Presentation Slides	Google Slides: https://docs.google.com/presentation/d/16NHbO3nTWZxb4Ngn3Iml_55S58I21zF9-_rZNnfiK7w/edit?usp=sharing Github: https://github.com/fang-zeqiang/Digital-Viz-City-Transformations/blob/main/CASA0003-Group9-Pre.pptx
Presentattion Video	Stream: https://web.microsoftstream.com/video/56de5776-0db6-49bc-94ee-775f182de0bf Github: https://github.com/fang-zeqiang/Digital-Viz-City-Transformations/blob/main/Video/Group9-Pre-for-Stream.mkv

Task Name	Major Contributors	Additional Contributors	Relevant Chapters in Report
Concept Development	All team members		1
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Data process: Bicycle Racks	Yujie Lyu		3.1
Data process: Bike Sharing	Junkai Ding		4.1
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1 Introduction

1.1 Background

Public transport in Toronto can make 154 trips per stop per day, which rank 22th among the main cities as mentioned. Toronto's Public transport has a wider reach because of the Improved cycling infrastructure in Toronto. The average distance cycled to Toronto public can be much greater than the average distance walked (Toronto Urban Mobility Index, 2021).

There are about 1.4 bikes per 1000 people in the city of Toronto, which rank the sixteenth among the main big cities in the world. Bikes have become more and more important in the city of Toronto (ibid, 2021).

Toronto can be divided into 140 neighbourhoods as shown in figure 1. Toronto is a big city where many people ride their bike for commuting from different neighbourhoods.

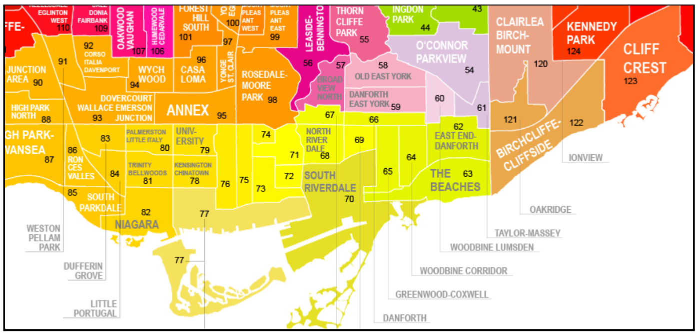


Figure 1 City of Toronto Neighbourhoods (Open Toronto, 2021)

As presented on the official website "Between 2005 and 2013, the City of Toronto identified 13 Priority Areas (also called Priority Neighbourhoods and Priority Improvement Neighbourhoods) through the Neighbourhood Action Plan." But there is little material for neighbourhoods' policies after 2014, especially for bicycles. This project will find urban cycling trends and insights behind the dataset via multiple visualisations.

This visualisation project aims to tell a story about how Toronto faced challenges and improved the cycling experience in the next few years? The topics include bicycle theft problems, parking racks solution and future mobility bike sharing.

1.2 Storyline Design

Here is our storyline: The first part is the serious problem of bicycle theft in Toronto. Then, to solve this problem, parking infrastructures are supposed to be established. At last, bike share is a more flexible and safer cycling style for future mobility.

2 Bicycle Theft

This visualisation section will contain two interactive maps (Toronto bike theft frequency map and bicycle theft characters map).
The former aims to show the frequency of the bicycle theft cases of Toronto in temporal and spatial dimensions on the map and observe the trend of bike theft from 2014 to 2020 on the line chart.
The latter will tell a story about three theft happening patterns (or categories), which can help government and individuals tell the differences among neighbourhoods. This can provide evidence for them to take effect bicycle theft prevention policies or actions.

2.1 Data

This bicycle thefts dataset is from Toronto Police Service Public Safety Data Portal (data source link: https://data.torontopolice.on.ca/datasets/bicycle-thefts). And Toronto Neighbourhoods' boundaries dataset is from City of Toronto Open Data Portal (data source link: https://open.toronto.ca/dataset/neighbourhoods).

Data preprocessing will be divided into two sections --- neighbourhoods frequency change and cluster analysis. The former focus on the temporal change in the frequency of theft happening but the later aim to find the spatial characters from the theft data after cluster analysis.

2.1.1 Frequency calculation

The primary GeoJSON data file is reported by Toronto Police Service which contains Bicycle Thefts occurrences in 140 neighbourhoods of Toronto from 2014-2020.

At first, use Python to clean the data including missing data processing and error value dropping and select the needed columns which are 'Hood_ID', 'Occurrence_Year', and 'event_unique_id'.

Then group each case by 'Hood_ID' and 'Occurrence_Year' attributes and output the counts of groups.

According to the 'Occurrence_Year', create an array of length 140 for each year and allocate these counts to the corresponding arrays with the position decided by their 'Hood_ID'. From this, the numbers of bike theft cases per year in all neighbourhoods have been obtained.

The next step is to combine this output with boundaries of City of Toronto neighbourhoods. Merge the two datasets with the same columns which are 'Hood_ID' in the bike theft frequency dataset and 'AREA_SHORT_CODE' in the boundary dataset, then output the final data to a new GeoJSON file.

2.1.2 Clustering analysis

Firstly, data clean working is applied in the raw data source including missing data processing and error value dropping. For example, the record row which contains 'NSA' in the Hood ID column will be dropped. In the next step, some data preparation is conducted. This process first identifies the hoods to which theft data belongs. Then it performs a data aggregation operation (similar to the "Group by" in SQL) before averaging the theft data in each hood to obtain the average level of frequency and cost of the bike which can represent corresponding neighbourhoods.

For drawing the clusters boundaries, it is of importance to merge theft data with geometry elements. After importing the neighbourhoods boundaries dataset, it can join the processed neighbourhoods theft data. Before applying cluster analysis, normalising the merged theft data is executed to obtain the standard scale for these two dimension attributes (frequency and cost of theft bikes). The optimal number of clusters (k=3) is chosen by applying the elbow method. Then k-means cluster analysis is utilised to fit this normalised data and its silhouette score is almost 0.5 which means the effectiveness of clustering result is good.

Lastly, this previously processed data is labeled with the cluster result labels. After averaging the theft data of each cluster (including the cost and frequency of bicycles) the characteristics and location of each cluster (category) can be recognised and described in the natural language sentences as given in the table below. The cost of bikes between 1000 dollar and 1030 dollar is defined as the low price level (cheap bike) and the cost above 1050 dollar can be categorised into high price level (expensive bike) although the differences of price among these three clusters are not obvious. Simultaneously, the cluster in blue on the map can be defined as low risk level area because of low bicycle theft frequency (about 40 cases) but that in yellow can be considered as the high risk level neighbourhoods due to the high frequency (above 1200 cases)

Table 1 Neighbourhoods bicycle theft characters and details

Category	**Area Colour**	**Cost of Bike**	**Theft Frequenc**	**Count**
Low Risk level Cheap Bike	Blue	1003	43	120
Medium Risk level Expensive Bike	Purple	1050	346	16
High Risk level Medium-Price Bike	Yellow	1037	1287	3

2.2 Design

2.2.1 Theft Frequency Visualisation

To show the density of the bicycle thefts occurrences of Toronto in temporal and spatial dimensions, a standard choropleth map based on color shading is designed to display the frequency. Multiple colour intensities are used to show the different values. The main functions on the map are shown in the below table.

Table 2 Frequency map feature

Feature	Description
Legend	Display the value range for each color. The unit is the number of bike theft cases per year.
Pop-up Window with Hover Effect	Highlight the boundary of the target neighbourhood and display a pop-up window to show the detailed information of ‘neighbourhood name’, ‘case number’, and ‘year’.
Slider with Autoplay Button	A fixed Side-bar in the top-left which contains a slider. The slider has an ‘autoplay’ button and also allows users to change it.
Total Number	A fixed text box in the bottom-left which displays the total number of bike theft cases of whole Toronto in a given year.

2.2.2 Theft Characters Visualisation

As shown in the below table, there are four main features in this visualisation work such as map elements, animation effect and information display section.

Table 3 Cluster map feature

Feature	Description
Legends Section	A style box at the bottom-right contains the cluster/character name and the corresponding geographic information colour block, which is convenient for users to quickly locate the area on the map
Hover Effect	A effect can darken the colour of the corresponding area when the user's mouse hovers in the target area which can highlight the neighborhood information that the user is currently looking at
Tooltip-Like Console	A fixed Side-bar in the bottom-left which can display further details when users’ mouse move on the target neighbourhood
Hiding Label	The label of hoods’ name will disappear when users zoom out to see the overall cluster map but appear when users zoom in to see several neighbourhoods

The main colours will be adjusted to the website theme such as white and blue. According to the above cluster analysis section the yellow will be applied in the high risk cluster and blue will be used to represent the low risk cluster. Yellow and blue are contrasting colours and purple will be an appropriate supplement for this colour theme to represent the medium risk neighbourhoods, which might draw user’s attention and increase their reading interest.

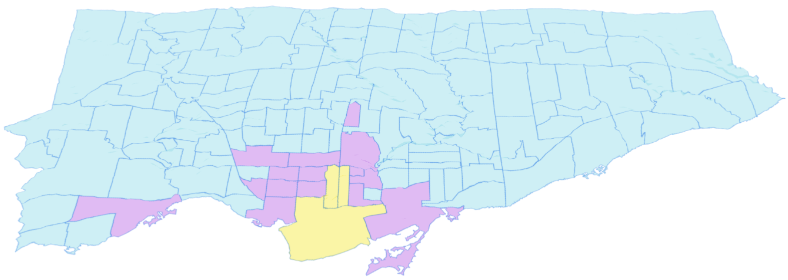


Figure 2 Colour matching schemes for different regions

2.3 Development

2.3.1 Bike Theft Frequency Visualisation

The overall organisation of bike theft frequency visualisation has been shown in the below figure.

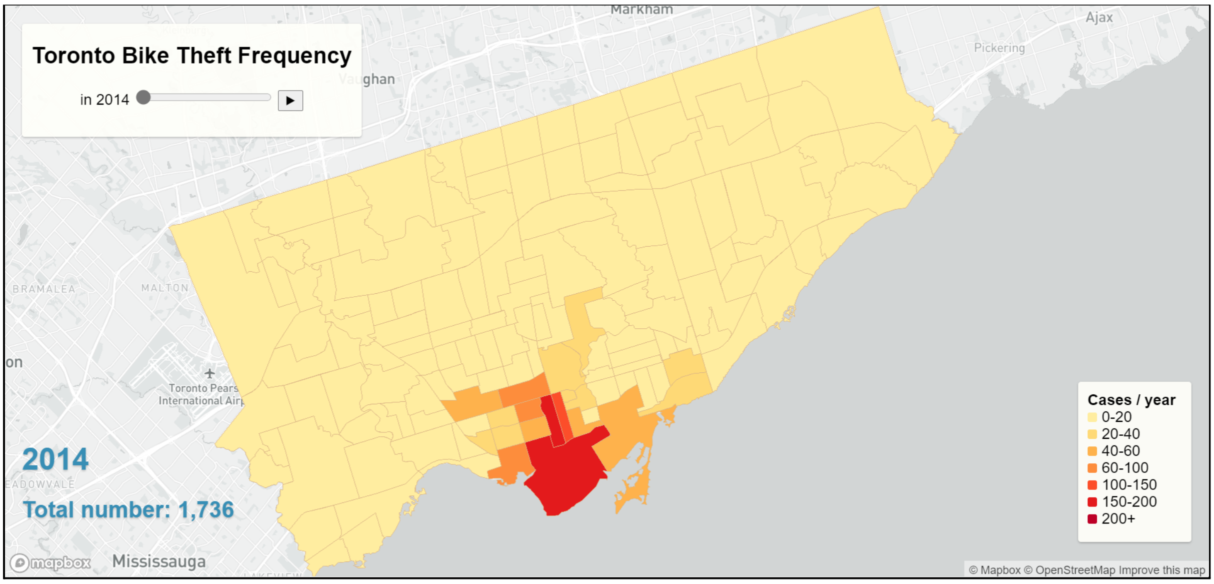


Figure 3 Bike theft frequency map organisation and layout

There is a slider that supports the "autoplay" function at the top left with a play button. If the button is clicked, the pointer of the slider will be moved automatically and change one year per second. If clicked again, the "autoplay" function will be stopped. Once the pointer reaches the end, it will return to the starting point and start again. The slider also allows users to change the year by themselves. With the change of year, the appearance of the choropleth map is also changed to the corresponding year.

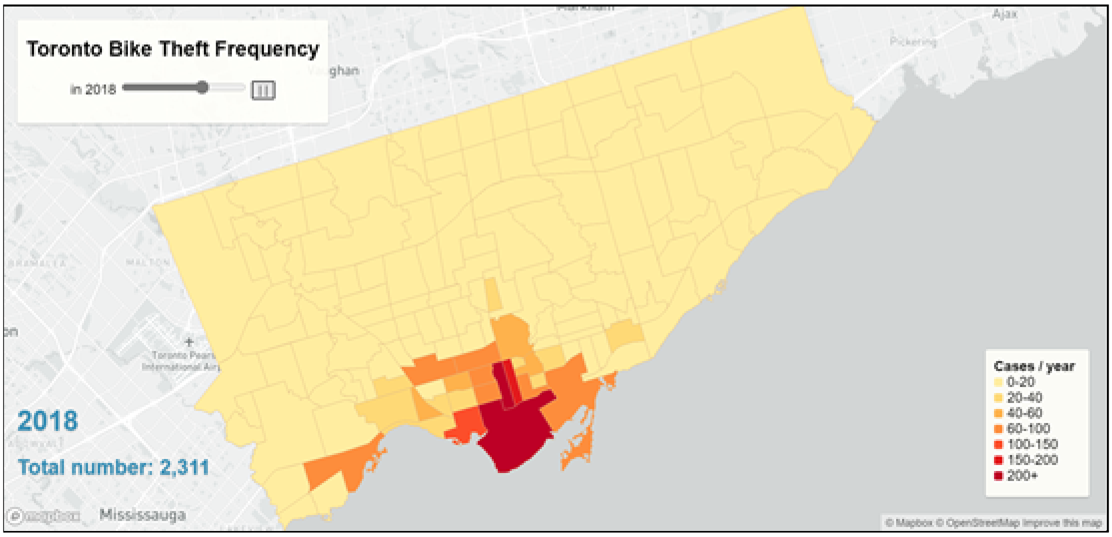


Figure 4 The year slider with the autoplay button

```
if (clicked == 0){
    clicked = 1;
    document.getElementById('auto').value = "|  |"
    cnt = self.setInterval(function() {
        var now = parseInt(document.getElementById('slider').value);
        var t = now + 1;
        if (t > 6) {
            t = 0;
        }
        document.getElementById('slider').value = t;
        filterBy(t);
    }, 1000);
}else{
    cnt=window.clearInterval(cnt);
    clicked = 0;
    document.getElementById('auto').value = "▶"
}
```

To show more detailed information like specific value and neighbourhood name, a pop-up window is applied with hover effect. When the mouse hovers over a neighbourhood area, its boundary will be highlighted and a pop-up window will be displayed following the mouse movement. As shown in the below figure, the pop-up window contains the information of ‘neighbourhood name’, ‘case number’, and ‘year’. It should be noticed that when the year slider is changed, the information in the pop-up window will also be changed to the current year.

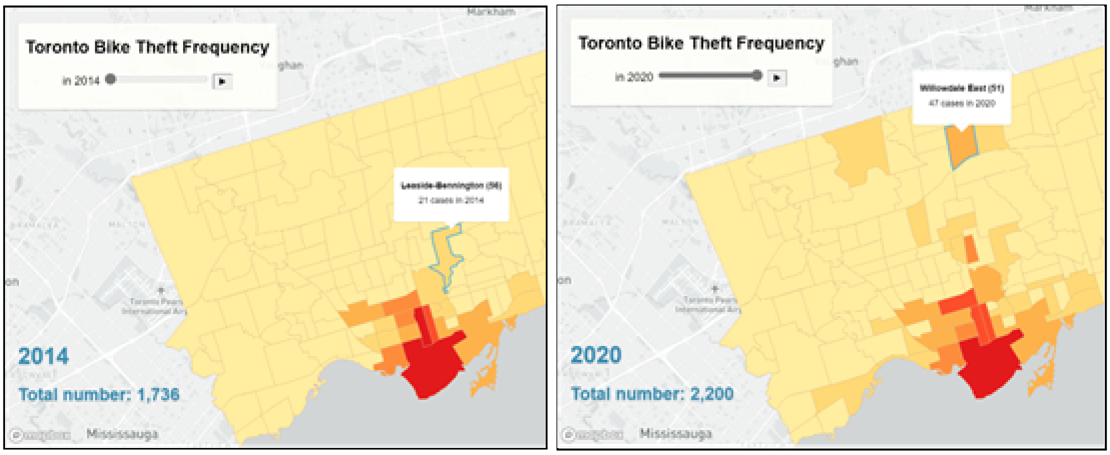


Figure 5 Pop-up window with hover effect and the total number

In addition, there is also a text box at the bottom left to show the total number of bike theft cases of the whole City of Toronto in a given year. It should be noticed that when the year slider is changed, the information in the pop-up window will be also changed to the current year.

As for the legend, it has been displayed at the bottom right to show the value range for each color. The unit is the number of bike theft cases per year.

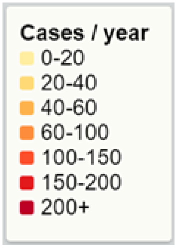


Figure 6 Legend of the bike theft frequency map

2.3.2 Theft Cluster Visualisation

The overall organisation of clustering visualisation can be found in the below figure. The complex layers of the map (including road traffic, physical geography, etc.) are deliberately removed. This is to prevent complex information from affecting readers' visual interaction and information exploratory experience.

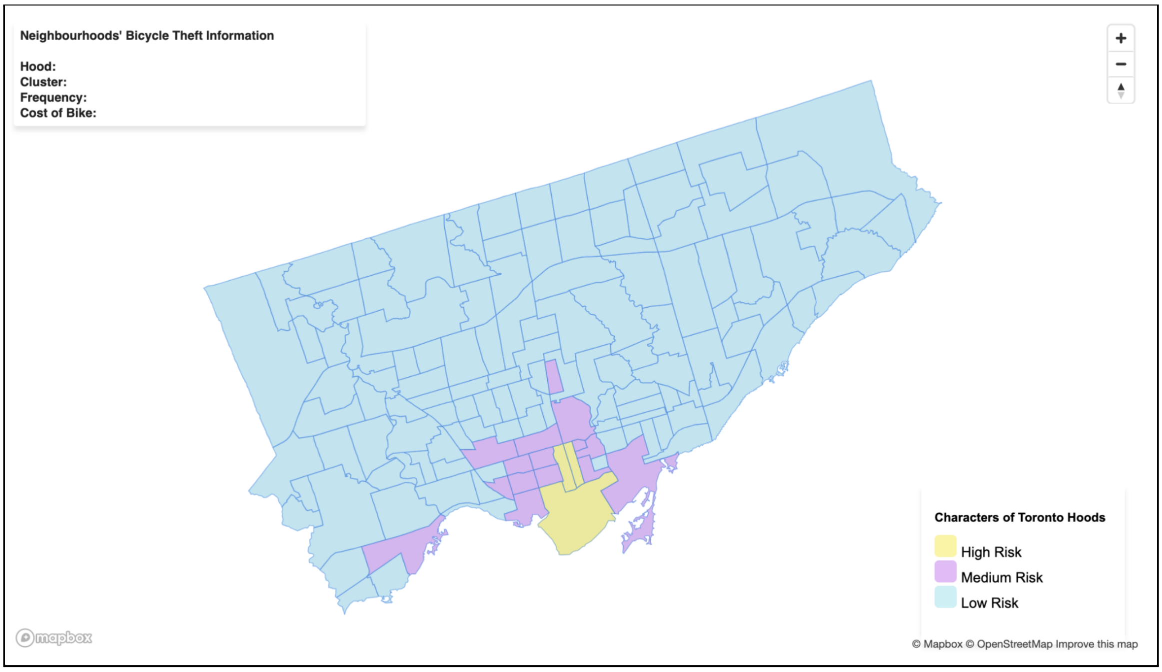
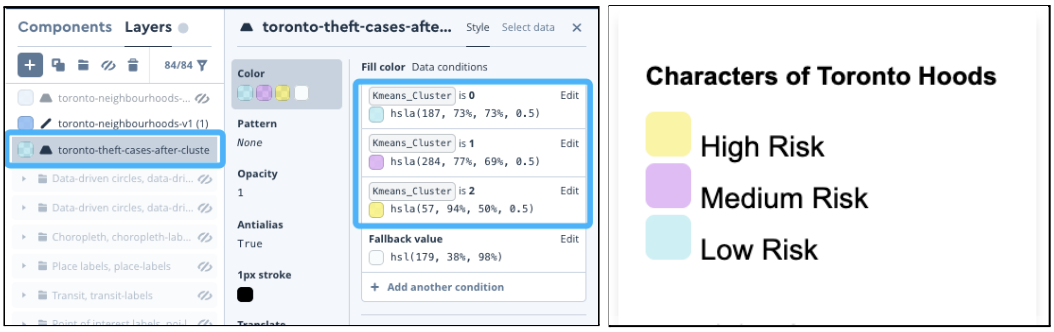


Figure 7 Cluster map organisation and layout

In order to maintain the unity of the color of the legend and the color blocks of the map, the hsla colour standard is utilised for quantitative drawing as shown in figure (a) below. In the specific programming implementation, the work uses JavaScript loop statements to print text and corresponding colour blocks in the legend box as shown in the codes below. This output result can be seen in the figure 8 (b) below.

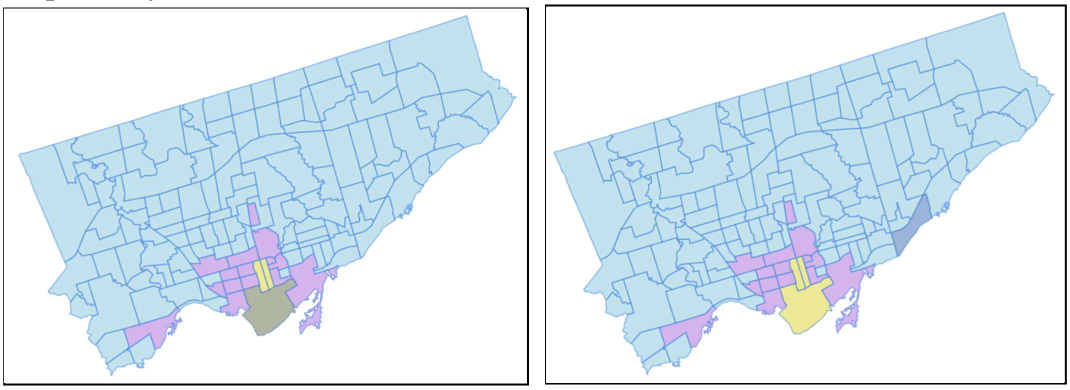
```
for (i = 0; i < layers.length; i++) {
  var layer = layers[i]; var color = colors[i];
  var item = document.createElement('div');
  var key = document.createElement('span');
  ...
  var value = document.createElement('span');
  value.innerHTML = layer;
  item.appendChild(key);
  item.appendChild(value);
  legend.appendChild(item);}
```



(a) (b)

Figure 8 Map coloured legends and colour matching method

Hover effect is applied to highlight the selected neighbourhood area. If users' mouse is hovering in one of 140 neighbourhoods, the target area will change its fill colour into a deeper and darker one as shown in the figure 9. This interactive effect is designed to increase user's exploratory interest.



(a) (b)

Figure 9 Hover effect and fill colour change feature

When the users' mouse is in the corresponding neighbourhoods, the further details will display and reflect in the top-ft sidebar. As shown in the below figure 10, the mouse is hovering on the No.77 hood. Simultaneously, the further details about N0.77 hood (waterfront communities) include the average frequency and cost of bikes as mentioned in the above cluster analysis section can be found in the top-left sidebar. The cluster name is also included in this information dashboard.

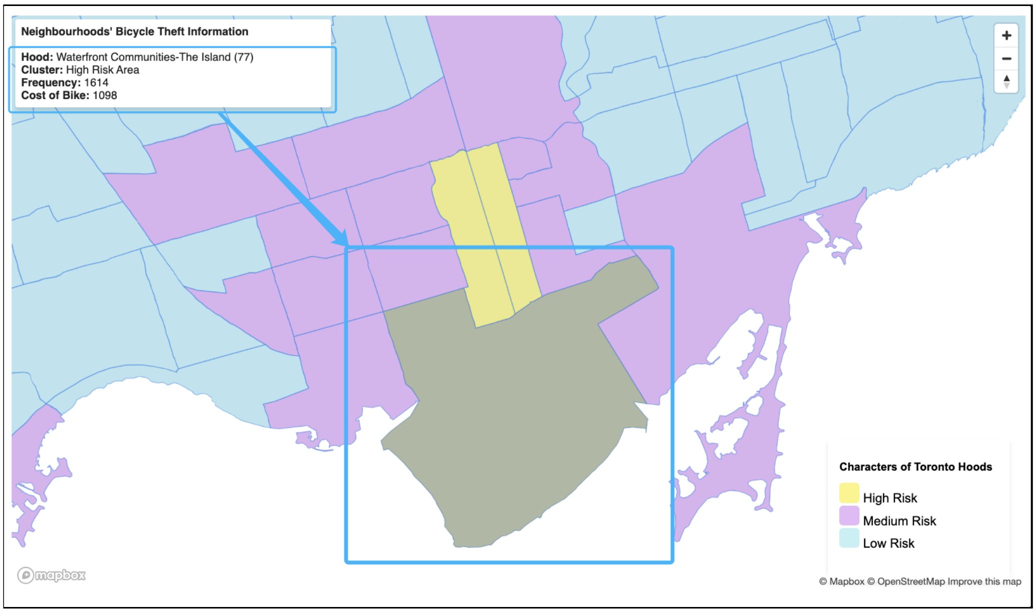


Figure 10 Neighbourhoods information display function

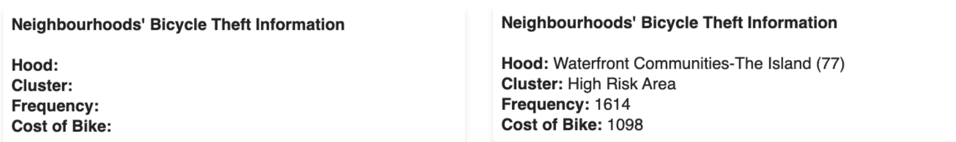
The above functions are implemented through getElementById of javascripts; first define the attributes to be displayed and the corresponding ID names in the label part of the sidebar; then in the Javascript, the information is captured and transmitted with the mouse action function as shown in the below codes;

```
map.on('mousemove','state-fills', function (e){
        var hood = e.features[0].properties.AREA_NAME;
        var cluster = e.features[0].properties.Kmeans_Cluster;
        var frequency = e.features[0].properties.Freq;
        var cost = e.features[0].properties.Cost_of_Bike;
...}
```

The Sidebar layout is implemented through html tags as presented in the following code for details. There are about 4 kinds of tags used here, and the tag contains “&” which means a placeholder tag used to optimise the organisation.

```
<div class="clusterInfo">
  <div><strong>Neighbourhoods' Bicycle Theft Information</strong></div>
  <div><strong> </strong></div>
  <div><strong>Hood:</strong> <span id="hoo"></span></div>
  <div><strong>Cluster:</strong> <span id="clu"></span></div>
  <div><strong>Frequency:</strong> <span id="fre"></span></div>
  <div><strong>Cost of Bike:</strong> <span id="cost"></span></div>
</div>
```

The output results can be seen in the figure 11 (a) below. Javascript can listen to the action of users in the map render process. When the status of users’ mouse is changing to the hover, the information will be catched and delivered to the sidebar text elements in the figure 11 (b).



(a) (b)

Figure 11 Tooltip-like sidebar

For other functions, mapbox’s scroll function of zoom in and out is banned to increase the experience of browsing the website by applying the “map.scrollZoom.disable()” function. To be more specific, users can scroll the website page but wrongly activate map’s zoom in and out function by unconsciously placing the mouse in the visualisation area.

2.4 Key Findings

The first choropleth map shows the number of Bicycle Thefts cases per year in Toronto by reported year and the Neighbourhood. As shown in the demonstration, it is clear that the cases are concentrated in the core areas in the South.

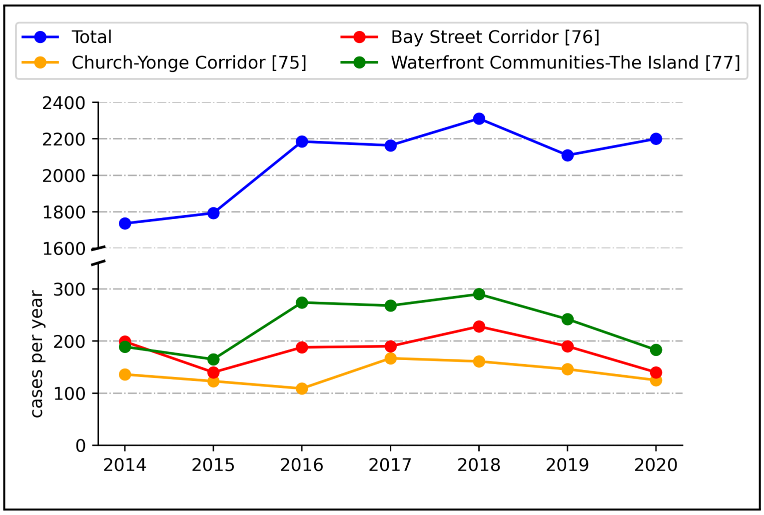


Figure 12 The trend of bicycle theft frequency in Toronto

As for the trend in the number of bicycle thefts, from this line chart, the blue line shows that the overall trend is upward and has peaked at over 2300 cases in 2018, because of rapidly increasing bike use and lack of locking stations for bikes.

It should be noted that there is a rebound in 2020. The reason for this is that COVID-19 has caused a bike boom (Pinkbike, 2021). As people turned away from public transport and towards cycling as a form of exercise during the lockdown periods of 2020, the number of bikes being sold spiked drastically. And new cyclists lack experience and awareness of bicycle theft prevention.

In addition, it is found that the frequencies in the core areas have decreased in the last two years. This is because of the government policies and suggestions (City of Toronto, 2021). The government recommended people to use good locks and locking techniques for Bike Theft Prevention and also released policies to help people in the recovery of a stolen bicycle.

According to the table and map comparison in the figure 13 below, three characteristics of bicycle theft can be identified. For example, the "blue" community of the first cluster is far from downtown Toronto. Its risk of theft and the cost of stolen bicycles is low. The purple area (the second cluster) is closer to the city center. Its risk of bicycle theft is medium, but the cost of stolen bicycles is the highest; Finally, the stolen bicycles that cover the "yellow" areas of the city center (the third category). Its average cost is moderate but the risk of theft is the highest.

Category	Area Colour
Low Risk level Cheap Bike	Blue
Medium Risk level Expensive Bike	Purple
High Risk level Medium-Price Bike	Yellow

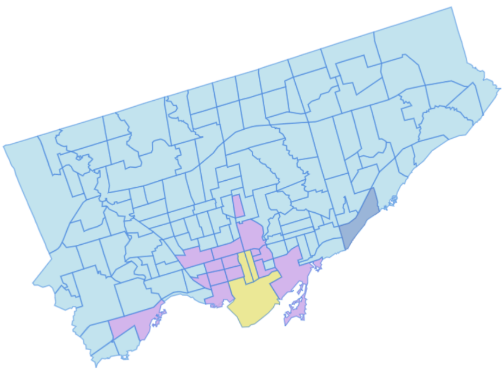


Figure 13 Bicycle theft portrait and coloured area

The government should pay more attention to the theft of bicycles in the purple cluster areas and pay attention to investment plans for the construction of bicycle infrastructures in these areas. For example, parking racks, lockers and other facilities can be used to protect bicycles. For the communities in the yellow cluster (city center), it is recommended to introduce more bicycle parking points in the limited space to protect as many and more expensive bicycles as possible.

3 Parking Capacity

In reducing the theft rates and providing a parking-friendly environment, Toronto's government establishes a number of existing city policies that support the development of high-quality bicycle parking infrastructure, promote a standard of "green" development and support bicycle use city-wide. The Toronto Bike Plan study conducted a survey in 1999, and the results showed approximately 49,000 cyclists in Toronto consider secure bicycle parking as their second most important need. Based on the survey results, the Bike Plan establishes a vision for cycling in Toronto which is reflected in the general policies of the Official Plan. Toronto's Official Plan encourages increased bicycle use through a number of policies. Among these policies are specific provisions for bicycle parking.

The visualisation of the distribution of permanent and seasonal multi-capacity bicycle parking racks will be conducted through an interactive map using Mapbox tools.

3.1 Data

The dataset including the geo-boundaries of 140 neighbourhoods in the City of Toronto was explored by the ESRI Canada Education and Research Team on June 6, 2014 (website: https://open.toronto.ca/dataset/neighbourhoods). In this section, the neighbourhoods are displayed on the interactive map as background.

The shapefile of permanent and seasonal multiple-capacity bicycle parking racks installed and managed by the Cycling Infrastructure and Programs Unit was extracted from the open data website of the City of Toronto published on 24 May 2021 by the transportation services team (website: https://open.toronto.ca/dataset/bicycle-parking-racks/). The dataset includes the geo-informations (longitude, latitude, ward names) of every parking racks, and most importantly, the parking capacities of them. The information of the dataset is shown below.

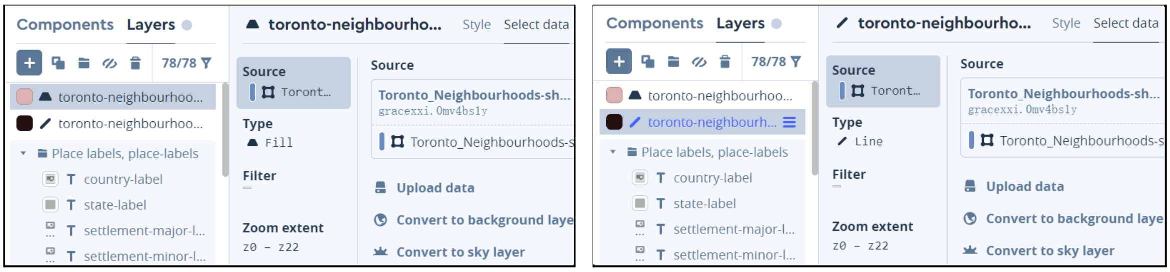
_id	ADDRE...	ADDRE...	LINEAR...	ADDRE...	POSTAL...	CITY	WARD_...	CAPACITY	geometry
6268	310564	150	Borough ...	150 Boro...	M1P 4N7	Toronto	Scarboro...	8	{"type": "Point", "coordinates": [-79.2572409577755, 43.772810595742]}
6269	367443	71	New For...	71 New ...	M1V 2Z6	Toronto	Scarboro...	8	{"type": "Point", "coordinates": [-79.3074473906934, 43.8230331061332]}
6270	379258	95	River Gr...	95 River ...	M1W 3T8	Toronto	Scarboro...	8	{"type": "Point", "coordinates": [-79.3173896510384, 43.8209470944401]}
6271	394585	24	Victoria ...	24 Victor...	M4E 3R9	Toronto	Beaches...	8	{"type": "Point", "coordinates": [-79.2810262938561, 43.6753630680448]}
6272	772775	315	Bloor St W	315 Bloo...	M5S 1A3	Toronto	Universit...	8	{"type": "Point", "coordinates": [-79.3985624500635, 43.6674469424306]}
6273	772800	398	Bloor St W	398 Bloo...	M5S 1X4	Toronto	Universit...	16	{"type": "Point", "coordinates": [-79.4073484623935, 43.6661256151956]}
6274	772833	481	Bloor St W	481 Bloo...	M5S 1X9	Toronto	Universit...	8	{"type": "Point", "coordinates": [-79.4071172092532, 43.6657537893633]}
6275	772852	509	Bloor St W	509 Bloo...	M5S 1Y2	Toronto	Universit...	8	{"type": "Point", "coordinates": [-79.4083859964734, 43.66546090160741]}
6276	772899	612	Bloor St W	612 Bloo...	M6G 1K7	Toronto	Universit...	8	{"type": "Point", "coordinates": [-79.4138388158142, 43.6647341700049]}

Figure 14 Bike Parking Capacity Data Overview

3.2 Feature Design

3.2.1 Neighbourhoods Visualisation

This interactive map uses the neighbourhood boundaries of Toronto as background and displays the parking rack capacities on the top layer as circles. In order to keep the clarity of street names and place labels, the opacity of the neighbourhood layer should be small, so it was set to 0.1 in this project. However, the boundaries of the neighbourhood became too transparent to be seen, so the same neighbourhood dataset was imported to the map as source type ‘line’ and the opacity of the boundary lines was set to 0.5.



(a) (b)

Figure 15 Neighbourhood layer settings

The draft of implementation on background mapping using Mapbox displays as below:

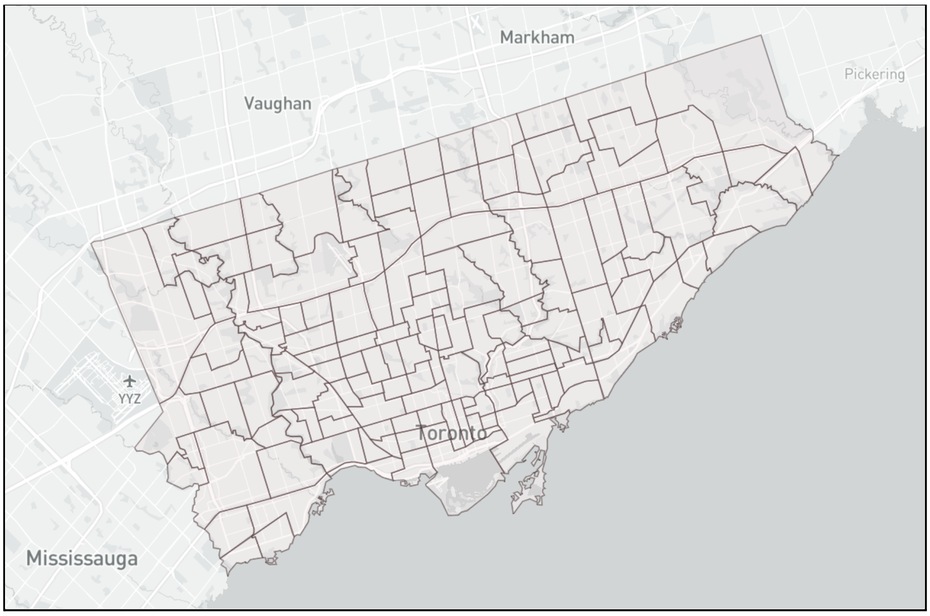


Figure 16 Neighbourhoods background visualisation

3.2.2 Bicycle Parking Racks Visualisation

The table below shows the main features which were illustrated in this interactive map.

Table 4 Parking Racks Capacity map feature

Feature	Description
Pop-up Window	Displays the addresses and capacities of parking racks of each single parking point. The information window pops up when the user puts their cursor over the rack's circle, meanwhile the cursor changes to a pointer. The pointer changes back to a cursor when it leaves and removes the pop-up window.
‘Zoom to’ Button	A fixed sidebar in the top-left contains two ‘zoom to’ links, city centre and total view. The zoom level and mapping centre changes in different views.
Legend	Demonstrates the value range for each color. The division is based on the capacity scales of bicycle parking racks.

Besides, it is worthy to mention that the circle appearance differs in different zoom levels. When you zoom in, the circle radius increases, color for both two ranges gets darker, and the opacity gets larger as well.

3.3 Development

This section will focus on the visualisation implementation of the features introduced in the previous section. The overall distribution of the bicycle parking racks is displayed in the below figure 17. The title and zoom-to links are located at the top-left while the legends are at the bottom-right.

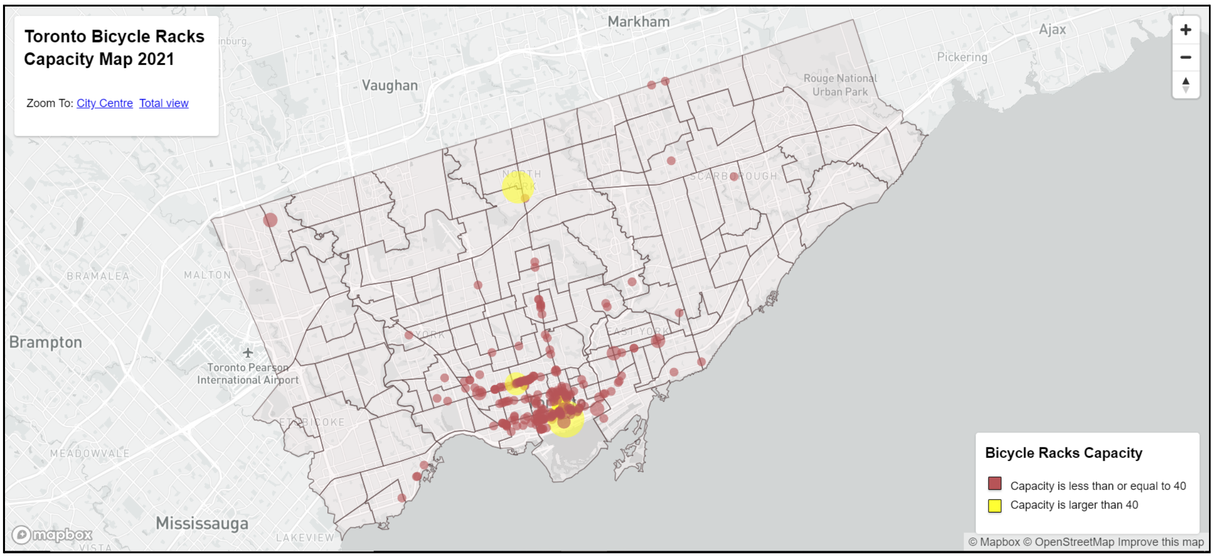


Figure 17 Bicycle Parking Racks distribution and layout

Firstly, the pop-up window is implemented by adding three event listeners, one is to display the pop-up window, one is to change the cursor to a pointer, the last one is to change it back to a cursor and removes the pop-up window. The key codes are shown as below:

```
map.on('mouseover','racks', function (e){
    mypopup
        .setLngLat(e.features[0].geometry.coordinates)
        .setHTML("<h3>" + e.features[0].properties.ADDRESS_FULL
                +"</h3>Capacity: " + e.features[0].properties.CAPACITY)
        .addTo(map);
});
map.on('mouseenter','racks', function (){
    map.getCanvas().style.cursor = 'pointer';
});
map.on('mouseleave','racks', function (){
    map.getCanvas().style.cursor = '';
    mypopup.remove();
});
```

The pop-up window displaying the exact addresses and capacity of each bicycle parking racks is visualised as below:

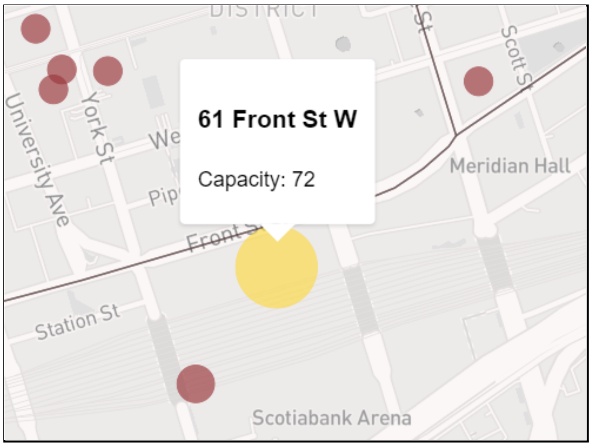


Figure 18 Pop-up window of parking racks

Secondly, the ‘Zoom to’ button on the top-left is achieved by adding the event listener based on the ‘fly to’ function. The zoom level and centre locations (latitudes and longitudes) switch in different views using a for loop and switch case statement. The key code below shows the settings of the ‘City Centre’ zoom link.

```
for (i = 0; i < x.length; i++) {
  x[i].addEventListener('click', function(e) {
      var lat,long;
      switch(e.target.id){
          case "centre":long=-79.386;lat=43.655;break}
      map.flyto ({
          center: [long,lat],
          zoom: 12.5,
```

```
            speed: 0.4 });
        });
    }
```

The visualisation of the city centre view is displayed as below:

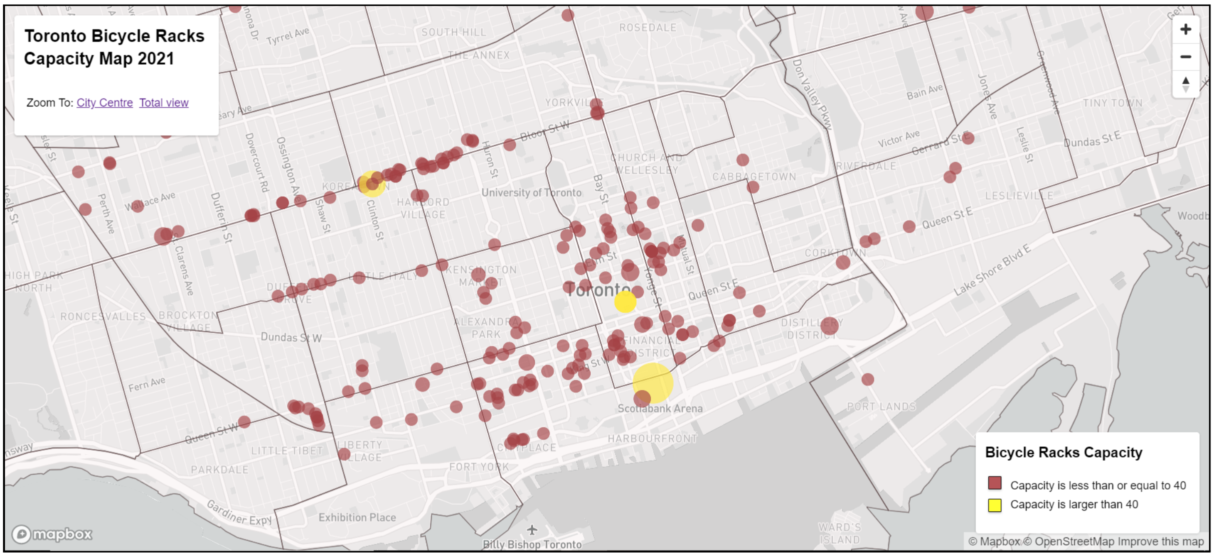
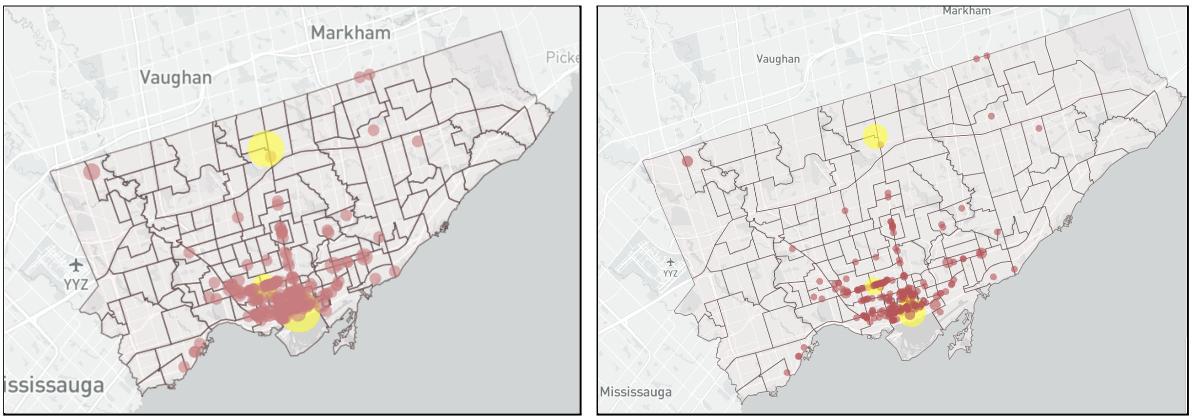


Figure 19 Bicycle Parking Racks distribution in the city centre

As for the legends, it is implemented by creating boxes and tables with grey background color and is located at the bottom-right as shown in the above figure. The implementation of changes in circle appearances when zooming in is based on the ‘stops’ function.

```
        stops:[
              [{zoom 7, value: 32}, ‘#eed8d9’],
              [{zoom 7, value: 40}, ‘#ffff4c’],
              [{zoom 10, value: 32}, ‘#b65457’],
              [{zoom 10, value: 40}, ‘#ffff33’],
              ...
        ],
```



(a) (b)

Figure 20 Capacity circles when (a)Zoom out (b)Zoom in

3.4 Key Findings

The map shows a positive correlation between the distribution of parking racks and the theft rates. It is clear that the city centre has the largest bike parking capacity. However, the installation of parking racks in places with high theft rates, such as the city centre, may cause a waste of the prime areas. To improve the cycling experience, the local authority popularised the bike share plan to make cycling travel/commute more flexible and safer.

4 Bike Sharing

4.1 Data

The bike-sharing data was collected from Toronto Open Data (data source link: https://open.toronto.ca/catalogue/?search=share%20bike%20station&sort=score%20desc).The origin data includes start and end station and time, ride duration, station id, bike id and trip id. An overview of the initial data is as follows:

	trip_id	trip_start_time	trip_stop_time	trip_duration_seconds	from_station_id	from_station_name	to_station_id	to_station_name	user_type
0	712382	1/1/2017 0:00	1/1/2017 0:03	223	7051	Wellesley St E / Yonge St Green P	7089	Church St / Wood St	Member
1	712383	1/1/2017 0:00	1/1/2017 0:05	279	7143	Kendal Ave / Bernard Ave	7154	Bathurst Subway Station	Member
2	712384	1/1/2017 0:05	1/1/2017 0:29	1394	7113	Parliament St / Aberdeen Ave	7199	College St W / Markham St	Member
3	712385	1/1/2017 0:07	1/1/2017 0:21	826	7077	College Park South	7010	King St W / Spadina Ave	Member
4	712386	1/1/2017 0:08	1/1/2017 0:12	279	7079	McGill St / Church St	7047	University Ave / Gerrard St W	Member

Figure 21 Overview of original data

The data records information about every time people rent a shared bike and is broken down into a number of tables by quarter.

The first thing this project did was to summarize each journey in Excel to get the total number of vehicles per station per quarter. After that, the Excel file was parsed in JavaScript language and then combined with the site latitude and longitude provided by the bike sharing site and the road information provided by Ckan to be stitched into geojson format (data source link: https://ckan0.cf.opendata.inter.prod-toronto.ca/ne/dataset/toronto-centreline-tcl).

4.2 Feature Design

The map focuses on visualizing how often people use bike-sharing. The dots on the map represent bike-sharing stations in Toronto. The shade of colour of each dot represents the magnitude of how often people use that bike-sharing station. The time period is from 2017 to 2019, and each year is divided into four quarters to see the changes in bike-sharing in Toronto.

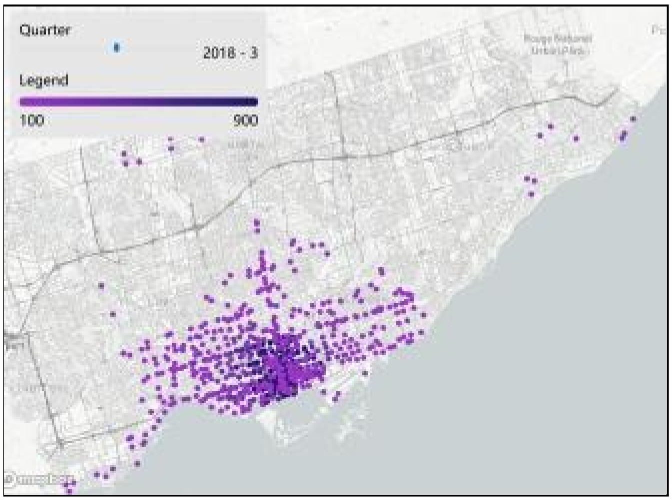


Figure 22 Share bike stations

It can be seen that the closer you are to the city centre, the more dense the bike-sharing stations are and the more frequently they are used. This is partly due to the fact that the traffic congestion caused by the dense population in the city centre makes people more inclined to use bicycles to travel. It is also due to the widespread separation of jobs and housing and spatial dislocation, which leads to a large demand for short distance travel in city centres.

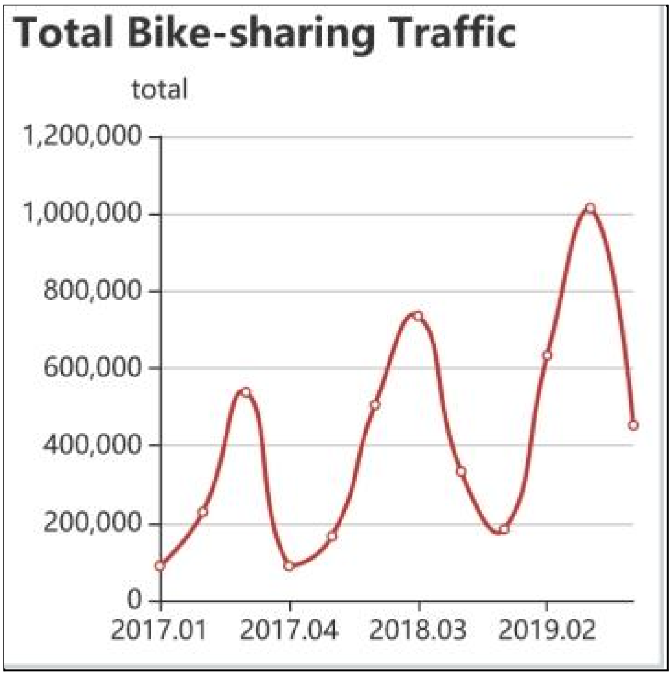


Figure 23 The trend of total bike-sharing traffic

This line graph shows the change in the frequency of total bike-sharing use in Toronto. We can see that frequency tends to peak in the third quarter of each year and fluctuates upwards from year to year.

4.3 Development

The data processing and development process for this visualisation is partly informed by this website: https://www.heywhale.com/mw/notebook/602f8376891f960015cfdb3f. Although it is python based, it validates the feasibility of my visualisation scheme and informs the final results. The main external plugins used by the code are ECharts and jQuery. The visualization is implemented based on some of the main code below.

Firstly, the App object is defined and the functions are defined in the App based on object-facing programming thinking, which is the main framework of the code.

```
const App = {
        init: function () {
          this.Year = "2017 - 1";
          this.bindEvents();
          this.initMap();
          this.initChart();
                 },
```

The init method defines the global variables for the year and the initMap, initChart charts that initialize the execution.

```
removeLayer: function () {
          if (this.map.getLayer(`data${this.Year}`)) {
            this.map.removeLayer(`data${this.Year}`);
          }
          if (this.map.getSource(`data${this.Year}`)) {
            this.map.removeSource(`data${this.Year}`);
          }
        },
        addLayer: function () {
          this.map.addSource(`data${this.Year}`, {
            type: "geojson",
            data: dataMappging[this.Year],
          });
          this.map.addLayer({
            id: `data${this.Year}`,
            source: `data${this.Year}`,
            type: "circle",
            paint: {....
```

In the initMap equation in order to implement a slider to change the time so as to show the usage of bike sharing in different quarters in Toronto, the removeLayer function needs to be called first to remove the last added layer and source, and then the addLayer function needs to be called to load the source and layer for the corresponding year (when the year is updated to the latest value). The colour of the dots is also defined by setting different ranges of num in the geojson to define the colour values of the corresponding interval.

4.4 Key Findings

Toronto's high latitude and temperate, humid continental climate make for very cold winters in Toronto. Therefore, It is understandable that bike-sharing traffic gradually rose in the first quarter and then fell rapidly after the third quarter. Cycling in the cold winter is never a good experience.

It is clearly impractical to change the climate of a city in order to enhance the cycling experience. According to Wikipedia, the government has been investing more and improving its facilities for bike-sharing from August 2017 to the end of 2019. On April 1, 2017, the daily operations of the Toronto bike share system was transferred to Shift Transit by TPA, which is a partner company of the PBSC, but the TPA maintains ownership of the system (Motivate, 2017). In August of the same year, the government invested $4 million in an expansion of Bike Share Toronto, bringing the system to 270 stations, 2,750 bikes and 4,700 docks (City of Toronto, 2017). Nearly 100 more stations, 100 bikes and 1,500 docks were added in August 2018 (Bike Share Toronto, 2018). At the end of 2019, the government made an additional investment to add 105 stations and 1,250 bicycles to the system (Bike Share Toronto, 2020). In recent years, the Toronto government has been working to expand the bike-sharing system, which explains the fluctuating rise in the frequency of total bike-sharing use from 2017 to 2019.

5 Web Development

This website will integrate the visual works of four of us, including Mengqing's frequency change visualisation, Zeqiang's theft pattern portrait, Yujie's parking capacity analysis and Junkai's bike-sharing stories. The storytelling elements will be reflected in the interactive effect and image and text content.

5.1 Webpage Design

For the website framework design, there are five sections in the main page including home page section, top navigation bar/menu, background block, digital visualization section and 'about us' module.

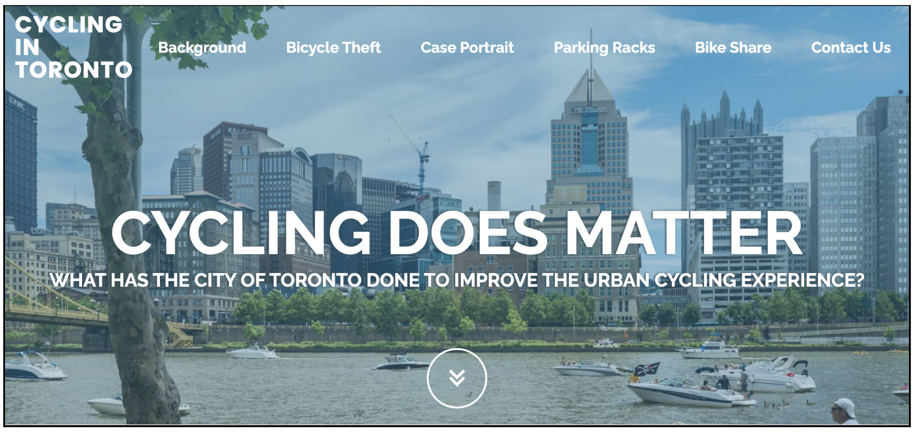


Figure 24 Home page and navigate bar layout

For content organisation design, there are several elements that we want to deliver for readers as shown in the below table. In addition to visualisation works, some animation effects and analysis sentences for works will be used to improve the cohesion between sub-stories works.

Table 5 Website content planning

Content Abstract	Description
Title	A phrase that can reflect the general content of the website story and the main research object
Background	The background content should convey why this project chooses the city of Toronto as the research object and presents the current situation and real world problems of urban bicycle policy
Bicycle Theft	There are two interactive maps and charts (including stories about theft frequency change and neighbourhood character portrait). The corresponding text sentences are given under these interactive elements to show trends and deliver insights
Parking Capacity	Toronto parking racks analysis serves as a solution to prevent the mentioned bicycle theft problem. The capacity analysis part can show how the government planned the cycling infrastructure
Bike Share	This webpage content will highlight the flexibility and convenience of shared bicycles; this module should incorporate geographic distribution and changes to show the Toronto government's emphasis on this mobility
About Us	Group member's profile will be presented in this section and project Github repository link will be placed here

5.2 Frontend Development

The whole website has a unified overall tone to make it clear, mature, simple and applicable. In order to enhance the beauty and interactivity of the website, some animation effects are also implemented, such as the appearances of key components, including the video, titles, and maps, with fade-in and fade-up effects. Hover effects are applied in the clickable parts with background and text color change.

In addition, to quickly import the video and maps made by the group members, <iframe> tag is used to embed the above four visualisation sections and a video within the current main HTML document. It should be noted that all widths of <iframe> tags are set to 100% to adapt these contents to the window size.

6 Conclusion

Overall, this visualisation project tells how the city of Toronto improved the urban cycling experience. Firstly, the project showed the changes in theft cases in Toronto and the neighbourhood distribution characteristics. The introduction of bicycle parking infrastructures shows the distribution of parking capacity in Toronto and the connection of theft problems; Finally, the project presents the development of bike share in the city of Toronto, which improved the theft problem and the limitations of parking racks.

6.1 Bike Thefts

The overall trend is upward and has peaked at over 2300 cases in 2018, because of rapidly increasing bike use and lack of locking stations for bikes. There is a rebound in 2020 due to COVID-19. Moreover, bike theft cases in the core areas have decreased in the last two years because of government policies and suggestions. After clustering analysis of bike theft data in 140 neighbourhoods, there are 3 characters for theft portraits but the differences of the theft bike cost are not extremely obvious. These three risk level areas share the similar spatial distribution of bicycle parking racks and these found patterns are conducive to bicycle policy formulation.

6.2 Bike Parking Racks

Based on the high demand of Toronto's cyclists on the secure bike parking environment shown in the Bike Plan survey, Toronto's government popularises and invests in the installation of parking racks. Places with high theft rates, therefore, own the largest parking capacity, such as the city centre.

Although the parking racks do help a lot in reducing the theft rates and offering a good choice of short journeys, there are still a couple of limitations. Firstly, the large-scale installation of parking racks in places with high theft rates, such as the city centre, may cause a waste of the use of prime areas. Secondly, the lo- quality parking racks may have negative influences on the city appearance. Last but not least, only the parking racks can't stop the theft cases. In conclusion, we may need a more flexible and safe cycling style. Therefore the government establishes the bike-sharing plan.

6.3 Bike Sharing

This visualisation encountered a number of challenges when visualising the data from Toronto Bike Share. The difficulty was the choice of visualization method and the corresponding data processing of the original data. The initial idea was to connect the start and end points based on each piece of travel information. Although this omitted many data processing steps, the source data was too large and resulted in a poor final image, so this approach was discarded and I thus opted for the current method.

This map visualisation of bicycle sharing still leaves much to be desired. Firstly, the time interval is set at quarterly intervals, which prevents us from observing more detailed changes. For example, changes in the frequency of bicycle sharing after the day a particular policy was enacted. In addition, adding temperature or weather to the map might give a better sense of the impact of weather on people's cycling experience.

Reference

Bike Share Toronto (2018). *Bike Share Toronto 2018 Expansion - More bikes and new stations*. [online] Available at: https://bikesharetoronto.com/news/bike-share-toronto-expands-to-new-neighbourhoods/ [Accessed 23 April 2021].

Bike Share Toronto 2019). *2019: Celebrating a Year of Milestones - Bike Share Toronto*. [online] Available at: https://bikesharetoronto.com/news/2019-milestones/ [Accessed 26 April 2021].

City of Toronto (2021). Bicycle Parking. [online] Available at: https://www.toronto.ca/services-payments/streets-parking-transportation/cycling-in-toronto/bicycle-parking/ [Accessed 26 April 2021].

City of Toronto (2021). *News item - Detail - News Releases & Media Advisories - Media Room | City of Toronto*. [online] Available at: https://web.archive.org/web/20170810011712/https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=af71df79b2df6410VgnVCM10000071d60f89RCRD&nrkey=25E652902FA78D588525817000509D99 [Accessed 26 April 2021].

City of Toronto (2021). *Bike Theft Prevention*. [online] Available at: https://www.toronto.ca/services-payments/streets-parking-transportation/cycling-in-toronto/safety-and-education/bike-theft-prevention/ [Accessed 26 April 2021].

Motivate (2017). *Motivate and Toronto Parking Authority Announce Transition of Bike Share Toronto Operations — Motivate*. [online] Available at: https://www.motivateco.com/motivate-and-toronto-parking-authority-announce-transition-of-bike-share-toronto-operations/ [Accessed 26 April 2021].

Pinkbike (2021). *Data Indicates that Bike Theft is on the Rise During the COVID 19 Pandemic*. [online] Available at: https://www.pinkbike.com/news/data-indicates-that-bike-theft-is-increasing-due-to-the-pandemic.html [Accessed 26 April 2021].

Toronto Government (2021). Neighbourhood Profiles. [online] City of Toronto. Available at: https://www.toronto.ca/city-government/data-research-maps/neighbourhoods-communities/neighbourhood-profiles/[Accessed 25 April 2021].