Urban Fabrics and Transit Ridership: Comparing Public Transit Use Rate Spatial Distribution between Montreal, Vancouver, and Calgary

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Abstract

It is known that Canadian cities have tried to address per capita greenhouse gas emissions through transit-oriented development and improving accessibility to public transit options. However, there is a knowledge gap with regards to how urban form and socioeconomic factors may affect the spatial distribution of public transit ridership. In my GIS analysis, I have produced three separate maps of Montreal, Calgary, and Metro Vancouver which compare transit ridership rates between the cities. This is done with 2016 census data because of its comprehensive nature despite sources of error and uncertainty such as spatial generalization and data suppression. I produced the 3 maps by filtering data, data layer joins, calculating transit ridership rates, and visualizing those rates through manual classification. My discussion of the maps in reference to planning literature illustrates how long-distance travel corridors and dense urban cores are associated with certain patterns of public transit ridership. However, it is also evident that these associations are muddled by the diversity of factors at play in public transit ridership and unforeseen consequences such as gentrification.

Introduction

According to Natural Resources Canada's data from 2016, Canada's transportation sector accounts for 21% of total energy use and final energy demand (Natural Resources Canada, 2019). Public transit systems play a key role in reducing this sector's carbon footprint in addition to connecting city dwellers to jobs and services while mitigating traffic congestion on roads (Giuliano, Chakrabarti, & Rhoads, 2015). It is also reported that the expansion of light rail projects also have a causational relationship with increased levels of physical activity per capita (Macdonald, Stokes, Cohen, Kofner, & Ridgeway, 2010). With respect to global cities, it is known that increased length of transit lines in conjunction with more even station distribution can reduce reliance on single-occupancy vehicles (McIntosh, Trubka, Kenworthy, & Newman, 2014). However, after sharp increases in public transit ridership throughout the 1990s, many Canadian cities (such as Halifax, Montreal, Ottawa, Toronto, Calgary, and Vancouver) have experienced stagnant or declining public transit use rates since the 2010s (Curry, 2016).

While Montreal, Calgary, and Vancouver have not reached the same population or economic thresholds as global cities such as New York, Tokyo, or London, they are the 2nd, 3rd, and 8th most populous municipalities in Canada (Statistics Canada, 2017a). Vancouver has recently been noted as a leader in public transit ridership amongst North American cities (Normandin, 2018). However, at the time of Statistics Canada's census in 2016, Translink's system was not as highly regarded. After a series of agency-related scandals and management departures, approval ratings of Translink had sunk down to 29% in 2015 (Normandin, 2018, para. 8). While statistics may have changed recently, the 2016 census data is the most comprehensive data available to calculate the statistics necessary for this study.

In contrast to Vancouver, Calgary is known to be more reliant on motorway transportation and single-occupancy vehicles due to neoliberal cuts to infrastructure resources and public funding (Wood, McGrath, & Young, 2012). Nonetheless, Calgary Transit has made efforts to respond to public feedback which criticized bus service frequency, the connectivity between Downtown Calgary and northeastern commercial centers, and bus to CTrain (light rail) transfers (Calgary Transit, 2017, p. 9). While financial crunches in city spending have been noted across Canada over the last 20 years (Vander Ploeg, 2008), Calgary is noteworthy for its fragmentation in urban form and thus warrants comparison to other metropolitan areas and cities (e.g. Vancouver and Montreal). In light of their significantly large populations, sizable greenhouse emissions impact, and recent initiatives to increase public transit options, I have conducted GIS analyses in order to investigate the relationship between their urban form and their spatial distribution of public transit use rates.

Methodology

Utilizing Newman, Kosonen, and Kenworthy's (2016) framework for analysis in my discussion/results section, I will interpret how the cities' urban form, public policies, and socioeconomic factors may affect public transit use. I produced 3 manually-classified maps using ESRI's ArcGIS to visualize public transit ridership across the census tracts (CT's) in Montreal, Metro Vancouver, and Calgary. My process for generating these maps is described below and in my flowcharts on pages 18 to 20 of this report:

1. Acquire

    I downloaded census cartographic data from 2016 from Statistics Canada in order to have a geographical framework for visualizing public transit use distribution. In order to promote readability at scales which could capture the entire metro area of these cities, I opted to download census tract boundary data rather than dissemination area data. I proceeded to also download shapefiles for oceans plus large interior lakes, rivers, and smaller interior lakes. I aimed to incorporate these shapefiles into the maps in order to reduce the amount of blank space on each map. I downloaded the ZIP files for these shapefiles from Statistics Canada and unzipped them into my project folder. After that, I imported the shapefiles themselves into my final project geodatabase.

    After acquiring the necessary cartographic boundary files for spatial analysis, I went to the University of Toronto Computing in the Humanities and Social Sciences (CHASS) page to download census database files (DBF). I requested database files for total question respondents per census tract for each city in addition to public transit use respondents per census tract. Specifically, I downloaded total sex data from the "journey to work" catagory of the 2016 census, acquiring respondent quantities for "mode of commuting for the employed labour force aged 15 years and over in private households with a usual place of work or no fixed workplace address." In total, 6 tables were downloaded to my project folder and eventually imported into my geodatabase.

2. Parse

Looking at the census cartographic boundaries, I filtered out census tracts which were not being used in this study. I also wanted 3 separate data layers for each of the cities' census tracts in order to create 3 separate maps. In order to do this, I first selected the census tracts I needed by attribute (whichever city I wanted) and exported the selected data into a new layer. Once I had new layers for the census tracts of each city, I reprojected each of them to the appropriate NAD 1984 UTM zones for each city (Vancouver = 10N, Calgary = 12N, and Montreal = 18N). I chose the mercator projection in order to remove the "tilt" from areas like Vancouver and preserve angles plus direction. Minor distortion with respect to area and distance was acceptable in this scenario because I wasn't looking at any variables related to area (e.g. population density). For the water shapefiles, I exported data and excluded areas outside of the data view for each city's census tract. I subsequently reprojected these files to the same projection and datum as their respective city census tract data layers. In the end, I had 3 different data frames for each city with appropriately scaled and projected data layers. I also imported the relevant transit census database files to each data frame, leaving 2 tables per city to mine for percentages. I joined the total transit user count database files to the public transit user count tables, preparing for subsequent analysis.

3. Mine

In order to make the table easier to read, I renamed the alias of the columns with public transit users and total respondent quantities to "P_Transit" and "T_Transit" respectively. With the joined tables, I had to create a new field which represented the percentage of public transit users among transit survey census results. I did this by entering a new field in the joined database file titled "PubPercent" with "double" number formatting, the same as the other fields. In order to prevent a system error for dividing by zero, I "selected by attribute" for '"P_Transit" <> 0 AND "T_Transit" <> 0' to exclude non-zero quantities from the calculation. I then started editor mode in data view and opened the field calculator for the "PubPercent" column. I entered the expression "[P_Transit] / [T_Transit]" to calculate the ridership rate. The calculator produced decimals which I then converted to percentages by manipulating the fields' properties. I left the uncalculated fields as <null> so that they could appear as blank areas which represent areas of data suppression. I did this for each city then joined the tables to the census tract boundary data layers for each respective data frame. With the joined spatial data layers, I reclassified each with 5 breaks, adopting a manual scheme with the same break points between each data frame in order to establish a more consistent metric for comparison.

4. Represent

Once I had the reclassified data layers based on public transit use rates, I turned on the appropriate water layers for each city data frame (e.g. Vancouver's ocean files and Montreal's interior lakes/river water layers). For each data frame, I aimed to capture as much of the metropolitan area as possible at a scale of 1:150,000 in order to make the maps more comparable to one another. Once the data frame was depicted at an appropriate scale, I viewed it in layout view and assembled my map with a title, relevant subheadings (e.g. datum and projection used), kilometer-based scale, legend (with data layer and heading labels removed in order to promote readability for a wider audience), north arrow, and name plus date of production.

Table of dataset:

Layer/Datafile Name	Source	Uses	Entity/data model	Attributes	Modifications
Canada_CT	Statistics Canada	To provide spatial framework for visualizing ridership	Vector polygon	CTUID, CTname, Province, City ID, geometric data, CMAtype	Select by attribute -> export to 3 new layers, remove Canada_CT, new layers reprojected, joined with joined transit tables
Water_Ocean	Statistics Canada	To reduce blank areas on map	Vector polygon	Hydrouid, Name, geometric data	Export data only in view, reprojection
Water_Lakes	Statistics Canada	To reduce blank areas on map	Vector polygon	Hydrouid, Name, geometric data	Export data only in view, reprojection

CalTransitTotal	UofT CHASS	Denominator for ridership calculation	Database file /tabular data	OID, CTUID, Total_T	Joined into CalTransitPub, removed
CalTransitPub	UofT CHASS	Numerator for ridership calculation	Database file /tabular data	OID, CTUID, Public_T	Joined with CalTransitTotal, rename column aliases, new field, calculate PercentPub field, joined with CT city layers
VanTransitTotal	UofT CHASS	Denominator for ridership calculation	Database file /tabular data	OID, CTUID, Total_T	Joined into VanTransitPub, removed
VanTransitPub	UofT CHASS	Numerator for ridership calculation	Database file /tabular data	OID, CTUID, Public_T	Joined with VanTransitTotal, rename column aliases, new field, calculate PercentPub field, joined with CT city layers
MontTransitTotal	UofT CHASS	Denominator for ridership calculation	Database file /tabular data	OID, CTUID, Total_T	Joined into MontTransit Pub, removed
MontTransitPub	UofT CHASS	Numerator for ridership calculation	Database file /tabular data	OID, CTUID, Public_T	Joined w/ MontTransit Total, rename column aliases, new field, calculate

					PercentPub field, joined with CT city layers

Results and Discussion

With respect to the Metro Vancouver, it is not particularly surprising to see elevated ridership levels closer to Skytrain stations. As discussed by Newman, Kosonen, and Kenworthy in their article on historical pathways of urban transit development, long-distance transit “can go out much further than the old tram and metro networks or basic bus lines and the fabric is based mainly on corridors of stations and dense sub-centres” (2016, p. 433). Looking at the public transit use rate map, the layout of these corridors and sub-centres seems to correlate with ridership. There are pockets of elevated public transit use rates in sub-centres with stations such as New Westminster, Marine Drive/Cambie, and Metrotown. According to Miller, Shalaby, Diab, & Kasraian’s Canada-wide ridership trends study, other built environment and transit service factors which may affect transit use rates include local business opportunities, land use mix, population density, highway/freeway networks, and urban land areas types (2018). When it comes to these sub-centres in Vancouver, elevated income levels associated with gentrification can also explain higher ridership rates in these areas. Regional sustainability policy which incentivizes high density condominium development, mixed use zoning (e.g. malls next to stations), and upzoning policy from Burnaby’s municipal council are indicative of how transit-oriented development policy initiatives can also have socially-exclusive implications (Jones & Ley, 2016). While mixed land use present in areas such as Metrotown and New Westminster are found to have a positive impact on public transit usage (Newman, Kosonen, & Kenworthy, 2016), displacement from gentrification may offset the benefits of transit-oriented development. Individuals who move further into the suburbs and away from transit sub-centres may instead use cars for long-distance commuting, especially when suburban street networks are less walkable and more suitable to cars. While my Metro Vancouver transit use map indicates higher use rates amongst dwellers in census tracts at the corridor sub-centres, there are numerous other factors at play which undermine the linearity of this analysis. In contrast to Vancouver’s corridor-oriented transit network, my map of Montreal visualizes the impact of a well-connected inner city urban fabric on ridership rates.

The heat map of Montreal’s transit ridership indicates high rates across much of the downtown island. However, the rates begin to quickly fall off in a spatially even manner beyond the urban core. This is in contrast to the corridor pattern of Metro Vancouver and can be associated with a variety of factors. For one, the geographical barriers of the Prairies River and St. Lawrence River eliminate non-metro pathways for transit between suburban regions plus hubs and the downtown core. Moreover, the younger, urban population of Montreal's core in combination with student socioeconomic conditions have been shown to positively impact public transit use within the core (Eluru, Chakour, & El-geneidy, 2012). This in combination with McGill University's location in the city core in contrast with UBC and SFU's remote locations may also contribute to higher population density and more student populations in those census tracts. These factors are known to interact with and may compound socioeconomic elements such as the share of college students in the urban core, poverty rates, the proportion of recent immigrants, and ethnic makeup which are known to be the most significant non-transit/built environment factors (Chakraborty & Mishra, 2013; Wang & Woo, 2017). It is known that Montreal's urban core is also generally more affordable than that of Vancouver. Gentrification in downtown areas can push low-income individuals such as students and minorities away from the core, provoking discussions about housing affordability and social exclusion (Chiang, 2017). With students being a significant population in both cities, socioeconomic pressures can be a pivotal factor in whether or not ridership is concentrated within the core or along outer corridors.

In contrast to the heat maps of Vancouver and Montreal, Calgary presents lower rates of public transit use across the board. One major reason for this could be the road network system of Calgary's suburbs which often feature loops and lollipops rather than grid-iron patterns. These are known to have the lowest level of connectivity and have a significant negative impact on city walkability and thus public transit ridership (Pasha, Rifaat, Tay, & De Barros, 2016). However, it is also interesting to note that public transit use rates are more even across Calgary's metro area than both Vancouver and Montreal. This may be due to the core and corridor-oriented structures of Montreal and Vancouver respectively, but it may also be connected to Calgary's light rail system. Similar to Vancouver, Calgary features slightly elevated transit ridership near the red and blue lines of the CTrain (refer to images 3 and 4 in the appendix). However, the increase in transit use rate is not as substantial as Vancouver. According to Pasha et al. (2016), Calgary is regarded as the oil and gas capital of Canada and features a very high carbon footprint per capita. According to the city's transportation committee chair, increased vehicle use rates in the core have been caused by high home vacancy rates in the downtown area. This in combination with reduced revenues at Calgary transit have exacerbated public transit accessibility challenges for both the city's core and outer reaches (Neufeld, 2017). All in all, a variety of socioeconomic, historical, and political factors are associated with low levels of ridership across Calgary save for CTrain corridors.

One element that is apparent from the visualization is that there is a correlation between the corridors and sub-centres of long-distance, outer transit lines and public transit ridership. This is not to say that shorter-distance transit methods are less associated with higher public transit ridership. In fact, it seems to be quite contextual based on municipal planning priorities, the urban fabric of the city, socioeconomic factors, weather, and service accessibility and consistency. This contrast is evident between Montreal's dense urban centre and the sub-centres of Metro Vancouver as shaped by transit-oriented development. However, as shown by both maps, the dominance of a certain transit style in a city is not mutually exclusive to the efficacy of other options. Public transit use rates across Vancouver are generally higher than Calgary which can be explained by Vancouver's interconnected bus system.

Error and Uncertainty

A degree of data suppression and error always comes into play with census data due to Statistics Canada's data exclusion rules and how census tracts are generalized. For instance, they have rules which exclude standard areas under a population size of 40 or below. Moreover, as shown in my data acquisition process, the tabular transit data files only account for populations in private households for the employed labor force aged 15 and older. Certain populations such as homeless individuals who use transit and Indigenous groups who often move between urban centres and outer city areas. In light of such suppression, some Indigenous healthcare advocacy groups have opted to execute their own censuses in order to focus on issues such as healthcare, poverty, and unemployment (CBC News, 2018). Underreporting of certain populations by Statistics Canada may produce underrepresentation of public transit usage rates amongst poorer individuals in urban centres. It is known that lower-income individuals are more likely to use public transit (Pasha et al., 2016), thus that underrepresentation may be more significant than one might expect. Moreover, undercounting can produce census tracts which have no reported data as shown in the blank areas present on all of the maps. While Statistics Canada's data is

Another aspect of census data which can lead to a degree of error is generalization of CT zones. While Statistics Canada tries to make tracts as socioeconomically homogenous as possible, the modifiable area unit problem can come into play when data is aggregated into select statistics. This is visible in census tracts which have disproportionately high public transit rates such as Stanley Park in the Metro Vancouver map. One can read the polygon as stating that the entirety of the area (including the park itself) features high ridership rates among residents, but that isn't really the case since most housing development is concentrated within the southwest corner of the census tract.

Future Research and Recommendations

A statistical analysis and further resident studies should be done to analyze if proximity to public transit is a substantial, independent cause for urban dwellers to opt for using public transit. These studies should be contextual and executed within these specific locales since different cities feature different cultures of public transit ridership and urban fabrics (e.g. the contrast between Calgary and Metro Vancouver). As previously discussed, there are numerous factors which affect public transit ridership rates. Investigating the statistical relationship between urban fabric layout and ridership rates is a complex process muddled by the diversity and overlapping of factors at play. Moreover, these respective cities are undergoing constant transformation which may impact the ridership spatial distributions. The City of Vancouver is planning to construct a Skytrain extension which will extend from the Millenium Line to Arbutus and eventually UBC (TransLink, n.d.) For the future, it is clear that urban development patterns, socioeconomic factors, and transit accessibility can impact the distribution of public transit ridership across cities. These are evident in how corridors and mosaics of transit use rates are formed in correlation to transit-oriented development (this is especially clear in Metro Vancouver and Calgary). However, as discussed in my review of literature, causation between development initiatives and elevated public transit ridership is muddled by the diversity of factors at play and possible unforeseen consequences (e.g. gentrification).

Moreover, as discussed previously, Indigenous and homeless populations in urban centres have been underrepresented in federal census results. Indigneous initiatives to execute censuses on their own terms may be more effective at tracking public transit use rate for the population in question. The idea behind the “Our Health Counts” Indigenous census project can also be applied to transit surveys in order to provide more insight on a traditionally underrepresented population. This can have significant policy implications with respect to the social welfare and transit development (such as how social assistance to low-income or homeless individuals in urban centres may or may not affect transit use rates).

All in all, it is evident that transit development initiatives require holistic lenses of analysis which consider socioeconomic factors, the built environment, and local city culture. As shown in the gentrification of Skytrain sub-centres in Vancouver, transit-oriented development may have unforeseen negative consequences on ridership because of displacement. However, this specific interaction (and whether or not it is present) has not yet been subject to statistical and geospatial analysis and thus qualifies as a knowledge gap.

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Image References

Image 1: Metro Vancouver Transit Distribution Map

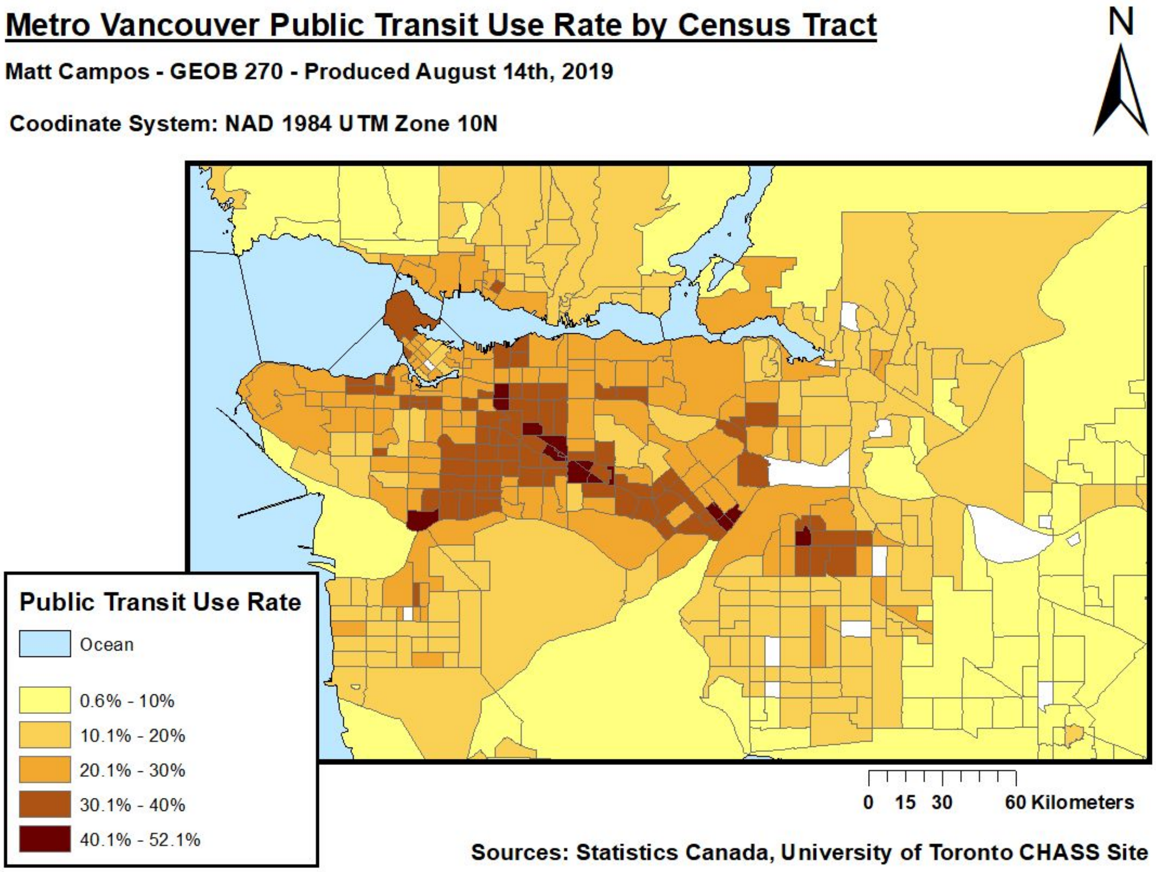


Image 2: Montreal Transit Distribution Map

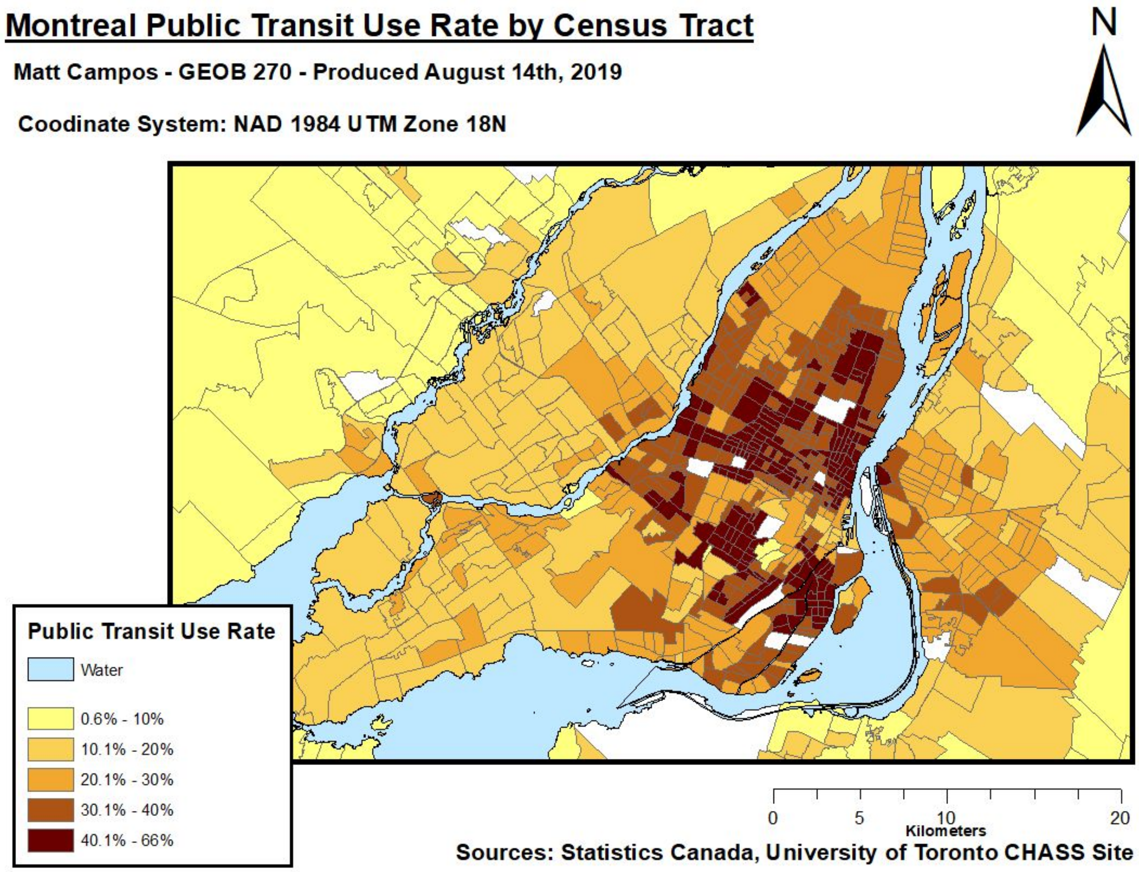


Image 3: Calgary Transit Distribution Map

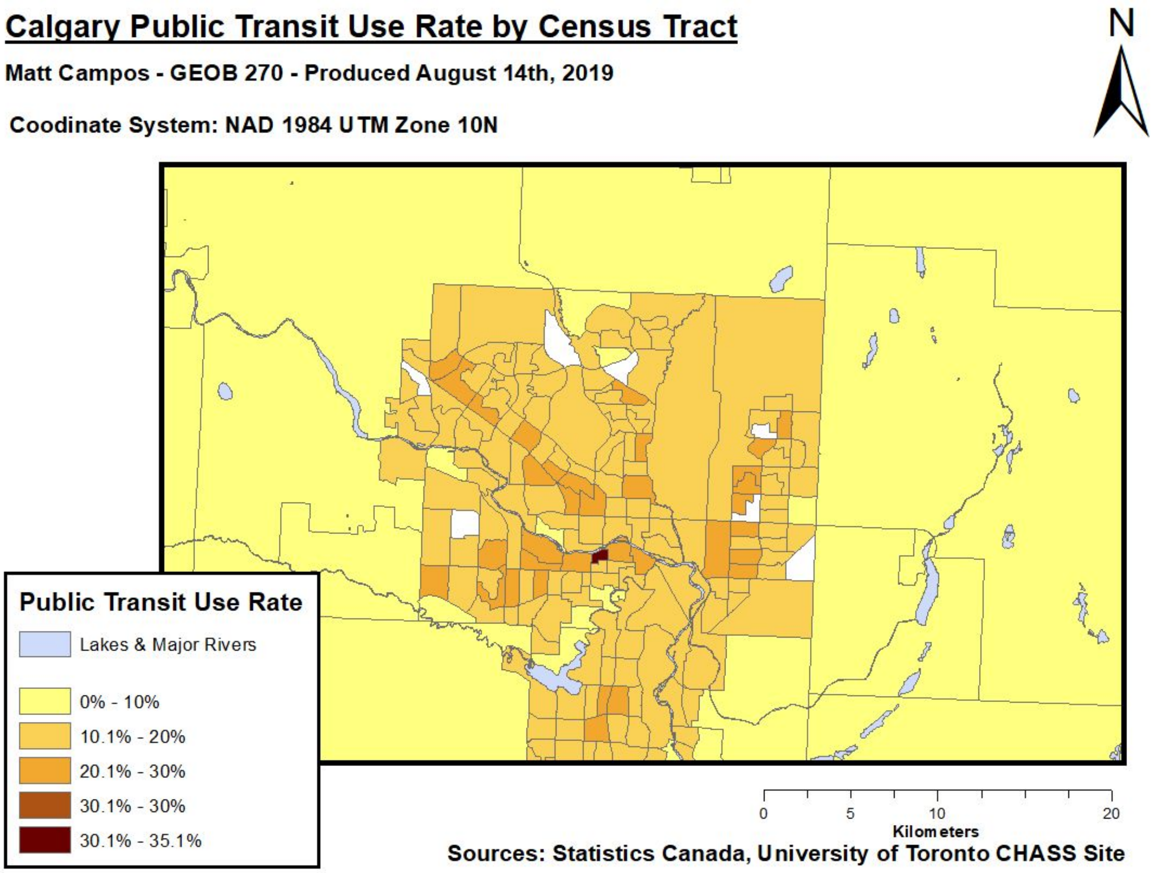
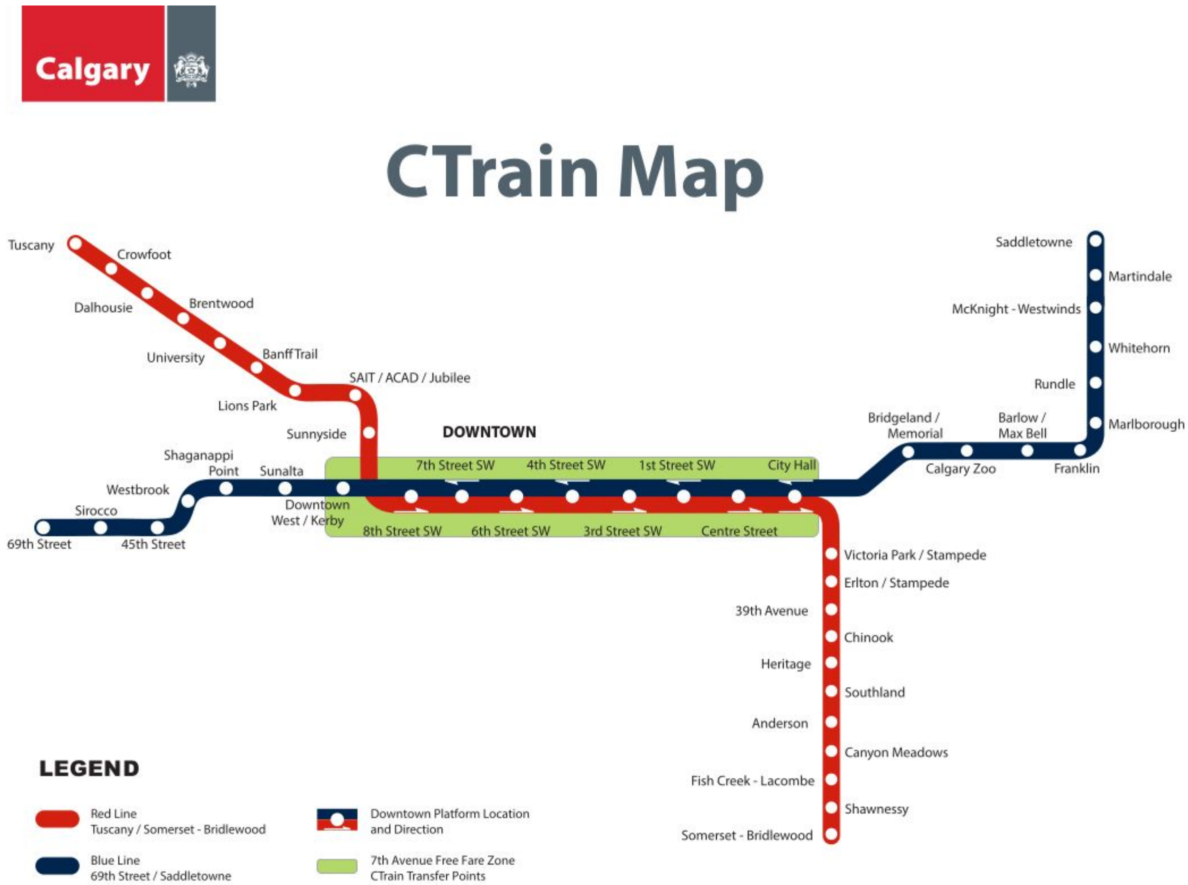
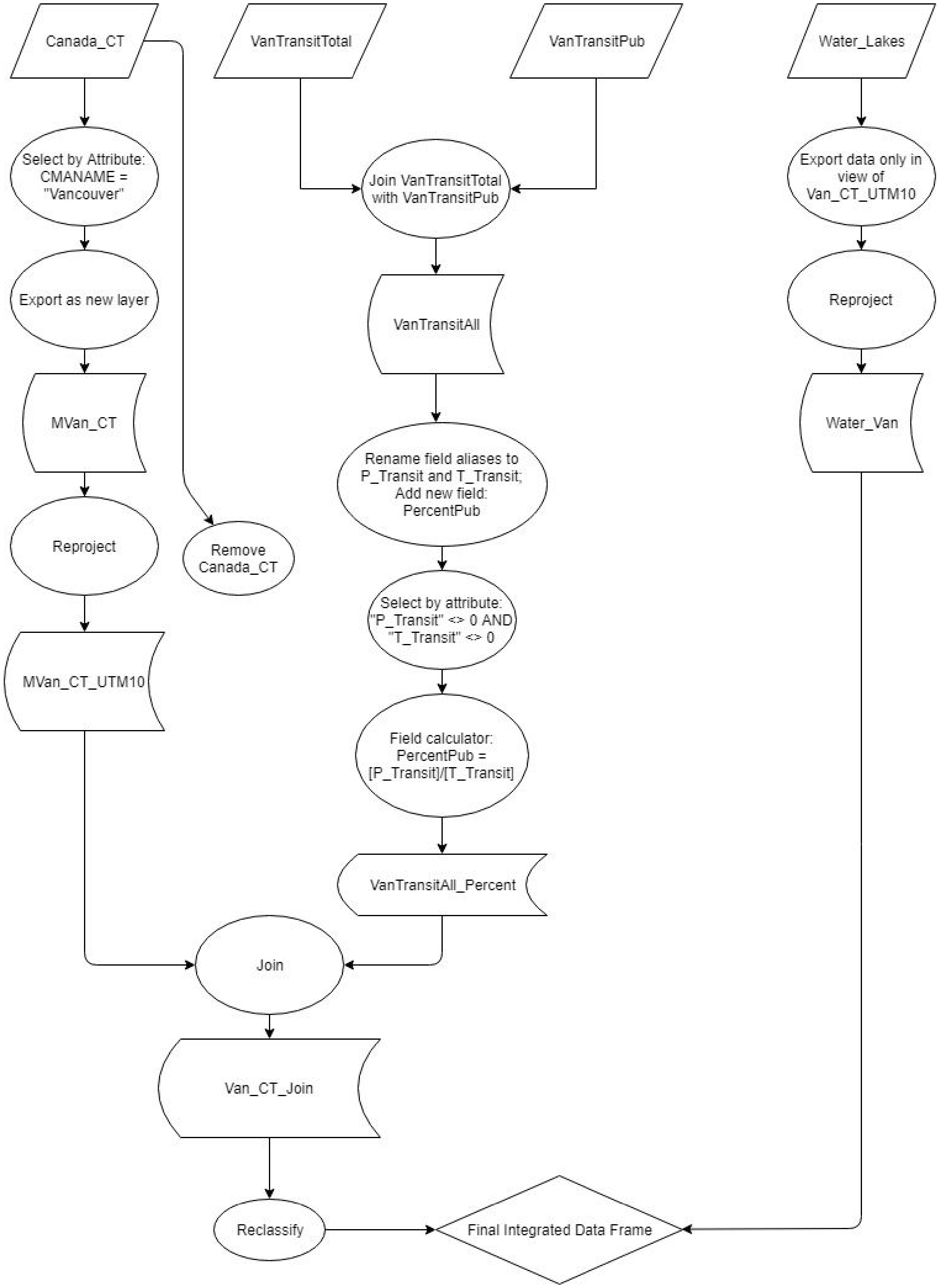


Image 4: Calgary CTrain Network (Mapa Metro, 2010)

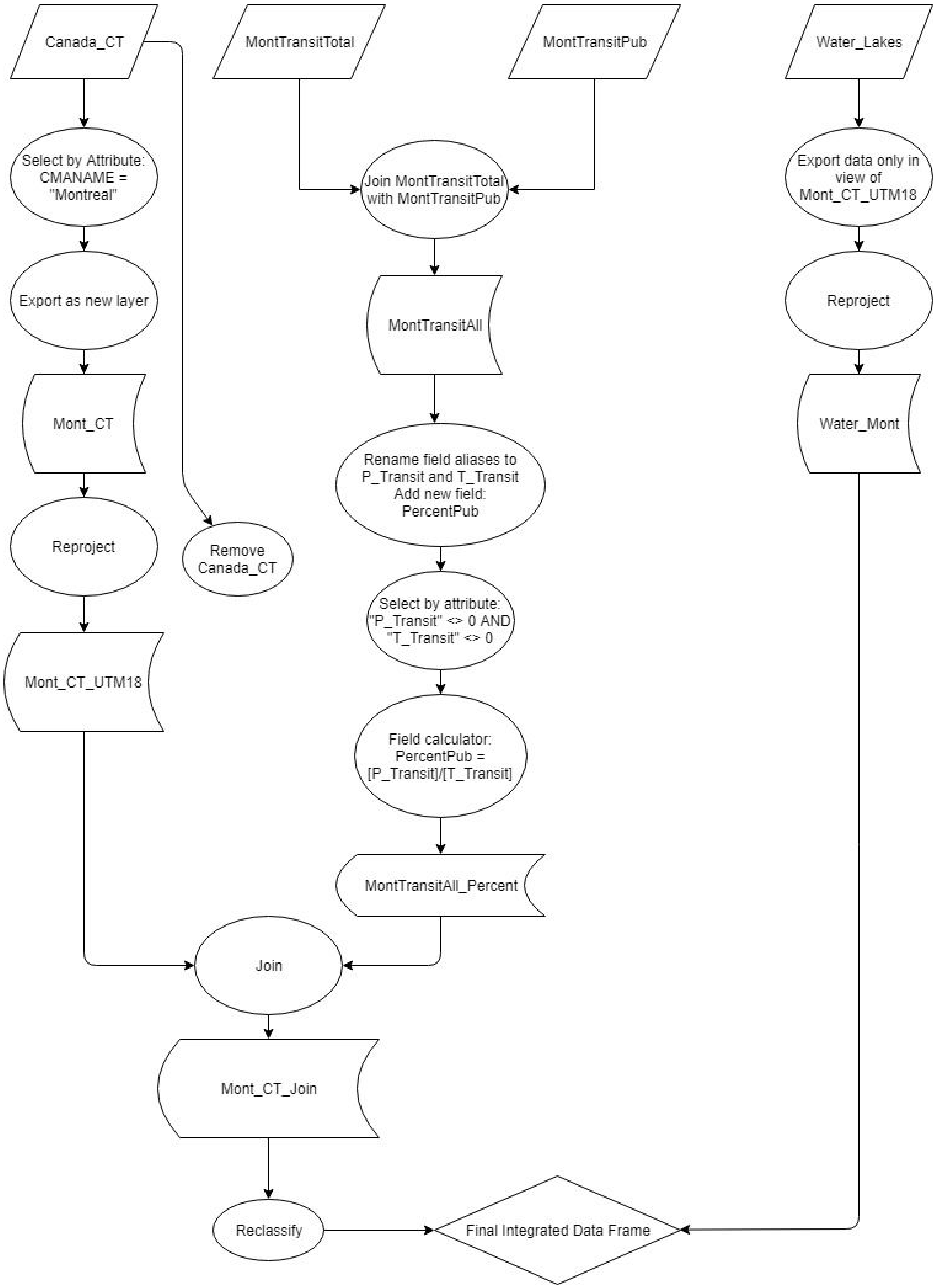


Flowcharts

Flowchart 1: Metro Vancouver Transit Distribution Map



Flowchart 2: Montreal Transit Distribution Map



Flowchart 3: Calgary Transit Distribution Map