Montreal in 15 minutes

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Abstract

Urban planning and sustainability are essential in enhancing the liveability of cities, and the concept of the 15-minute city offers a promising framework. This research focuses on Montreal, Canada, to evaluate its adherence to the 15-minute city model, which aims to provide residents with access to essential amenities within a 15-minute journey using various transportation methods. We developed an interactive app that visually represents neighbourhood accessibility to different amenities via walking, cycling, and driving. Our methodology involves collecting data from OpenStreetMap, processing it to create choropleth maps and distance graphs, and presenting it through a user-friendly interface built with Streamlit. The app allows users to analyse amenity distribution and travel times, aiding in informed relocation decisions and urban planning. Our findings suggest that while Montreal shows potential as a 15-minute city, with some neighbourhoods like Ville Marie and Le Plateau-Mont-Royal offering excellent amenity access, peripheral neighbourhoods need improvements in accessibility. The research highlights the importance of reliable data and suggests future enhancements, including integrating real-time data and public transportation analysis, to provide a more comprehensive understanding of urban accessibility.

1 Prototype and code

- **Code repository:** https://github.com/emmastoklee/GDS_project
- **Application prototype:** https://gds-15minute-city-montreal.streamlit.app/Welcome
- *Please write the note to michel.poesze@gmail.com if the application is not running as expected. The resources allocated by free pricing tier of the Streamlit community cloud sometimes are exceeded by the app.*

2 Introduction: Towards more liveable cities

Urban planning and sustainability play a key role in the way citizens interact with a city and its amenities. Following the concept of the 15-minute city (Moreno, Allam, Chabaud, Gall, & Pratlong, 2021), we aim to provide a visual, interactive application that displays the accessibility within 15 minutes to different amenities using diverse transportation methods in the city of Montreal, Canada, neighbourhood by neighbourhood.

The motivation is to understand the accessibility differences in terms of **time** and **distance** to different key amenities within Montreal. To do so, the app provides a visual display of the amenities' distribution per neighbourhood, as well as the estimated time arrivals (ETAs) using different transportation methods: walking, cycling and driving.

We hope our work will serve not only users who want to move around the city, but also those who want to improve accessibility and mobility within Montreal and other cities.

3 Background

3.1 The concept: 15-minute city

The concept of the 15-minute city has increasing become part of the public consciousness, as urban planners implement the strategy across the globe. Carlos Moreno initial proposed in the concept in 2016, in part, as a response to the negative impacts that car-dependent urban planning has brought (Moreno et al., 2021).

To explore the nature and reality of applying the 15-minute city planning paradigm, choosing a specific city to study was a clear method to do so. Numerous cities were considered such as Paris and Madrid, however it was evident that many European cities have already successfully implemented 15-minute city, or are on their way to do so (Birkenfeld, Victoriano-Habit, Alousi-Jones, Soliz, & El-Geneidy, 2023). Thus, a North American city felt an interesting case to explore, due to the car-centric nature of these cities, as well as the larger scale of the city which allows for optimal neighbourhood specific analysis.

Montreal was chosen as the city to explore the 15-minute city in more depth. This is in part due to the 15-minute city being part of its urbanisation plans, and the fact that the 15-minute city planning paradigm is often seen as unreachable in North America due to its reliance on car travel (Birkenfeld et al., 2023). Further, exploratory analysis was conducted to gain a holistic overview of Montreal where 25,403 points of interest were found of 131 unique types. It was also established that Montreal consists of 18 districts/ neighbourhoods *(arrondissements in French)*. Moreover, Montreal being a large city with many neighbourhoods gives better scope to explore where in the city it is best to live, compared to a city of a small size. Montreal is the second-biggest city in Canada and 10th largest in North America (Wikipedia contributors, 2024), and as of 2021 the city had a population of 1,762,949 whilst growing by 3.4% between 2016 and 2021 (Statistics Canada, 2021). When balancing up these factors, we concluded that Montreal would be the best city to use in our research.

3.2 The solution: Enabling users to analyse with no code

The solution is to develop an app to explore to what extent Montreal is a 15-minute city, through walking, cycling and driving, as well as where one may like to live in the city based on which type of amenities are most reachable in that area.

The app takes inspiration from (Logan et al., 2022) paper where they explore whether neighbourhoods in New Zealand allow residents to reach amenities within a range of durations (5 min to 20+ min) and different modes of transport (walking, cycling or driving). Their method of calculating distance is adopted within the summary choropleth maps used to give an overview of the spread of different types of amenities within the city of Montreal. They calculate travel durations by finding the centroid of each neighbourhood block and calculating the distance to all amenities of interest. For example, the centroid of the neighbourhood is first calculated and then the distance to the nearest supermarket in that neighbourhood is calculated. This process the adapted in our app as average distance to all POIs of each category of amenity is calculated. However, since this does not account for the specific route an individual would travel to the amenity, neighbourhood specific maps are calculated with distance graphs to show which amenities are reachable within 15-minutes travel time by walking, cycling and driving. Thus, users will be able to have an overview of which neighbourhoods have most access to different types of amenities, whilst then exploring more deeply within each neighbourhood to find where it is optimal to live.

An app is used for this, as it allows for the easy access to numerous visualisations where users can choose the combinations of neighbourhood and amenity type. In contrast, to include this number of visualisations in a report would be excessive. An app can be dynamic, both providing an overview of the city as a whole, whilst also allowing users to focus on specific neighbourhoods and amenities they are particularly interested in. Therefore, we decided that an app would be the ideal way for users to explore the concept of a 15-minute city. It allows them to discover the most suitable neighbourhoods based on their preferences and needs.

4 Data

To create a useful app for users, up-to-date data with a high level of detail and accuracy in terms of mapping the city and the amenities available to the population, is required. This is, while the data should be free-to-access and with a low computational power as to not slow the function of the app.

4.1 Data acquisition

There are three main forms of data required for the building of the app: amenities data, graph data and neighbourhood data. These have been acquired from two sources: OpenStreetMap and Quebec's official website.

4.1.1 OpenStreetMap: Amenity and Graph data

OpenStreetMap is the main data source, particularly in terms of collecting amenities data. The Python package OSMnx is used to collected amenities/points of interest (POI) as well as graph networks (walking, cycling, and driving) from OpenStreetMap. OpenStreetMap is open source data which has been compiled by a community of contributors (OpenStreetMap, 2024). One key drawback of OpenStreetMap is its lack of completeness of POIs, as these are community reported, there may be some missing or inaccuracies in the data. Further, there is the potential that out-dated POIs remain in the dataset, such as restaurants that may have closed (Moradi, Roche, & Mostafavi, 2022).

In terms of graph data, a study of positional accuracy of OSM roads in Canada in 2017, showed that 77% of OSM roads are within a five-meter buffer of reference roads (Zhang, 2017). This is in contrast to a study from 2010 from the UK, where there was only 29% accuracy (Haklay, 2010). Thus showing that the OSM data quality in Canada is relatively high. However, a key disadvantage of graph data related to cycling graph as there are numerous different type of paths which can cause the data to be quite messy and unreliable (OpenStreetMap contributors, 2024).

4.1.2 Neighbourhood data

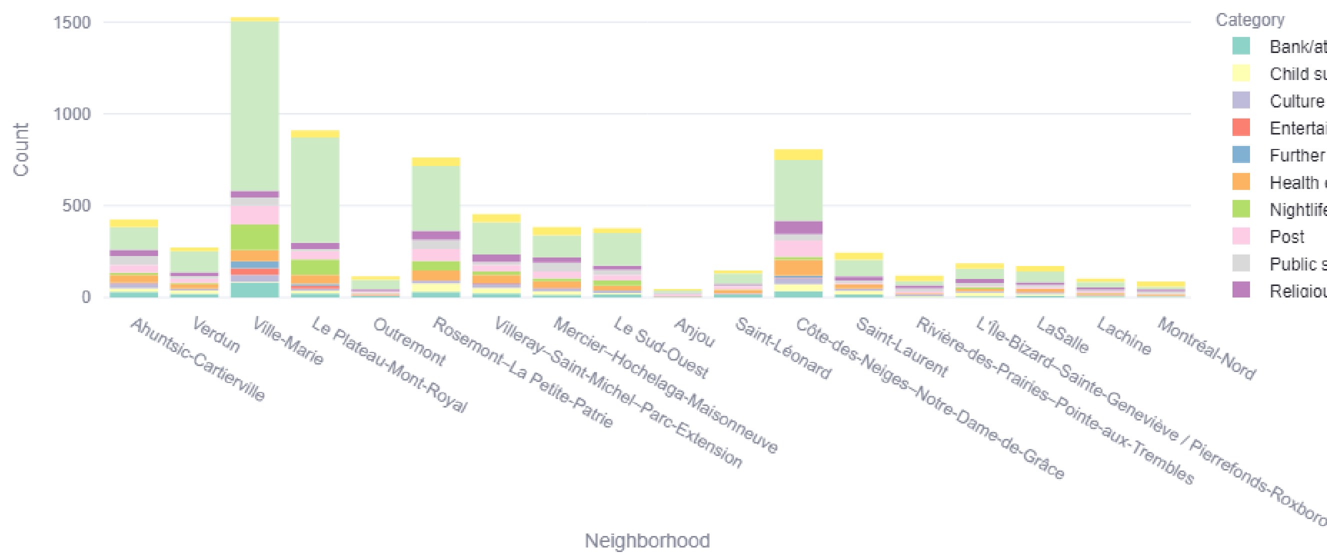


Figure 1: Amenity category count by neighbourhood

Defining the subdivision to focus on for the research was not an easy task. For example, the official boundaries do not often correspond to the sociological and cultural activities of the citizens, whereas unofficial division data is not often easy to find, nor reproducible.

In the case of Montreal, it was challenging to find a clear subdivision to focus on. *Quartiers* were initially considered as a feasible one, but discarded as they seemed too fine-grained and small for our purpose, which naturally has a more general scope. Districts, or *arrondissements*, on the other hand, comprised a larger, most commonly used subdivision that fit our purpose of understanding amenity distribution. As we are working with 15-minute distances, districts have a relevant size for this kind of analysis. In addition, as districts are defined due to administrative reasons, there are plenty of reliable, official data.

Because of this balance between the correct size for the analysis and the official, reliable data available, the official Montreal districts were the subdivision of choice for the project.

Detailed district mapping was downloaded directly from the open data from Quebec's webpage (Québec, 2024). The data is stored in the form of polygons in a geojson format, and contains geographic information about the eighteen main districts in the city of Montreal, listed in Table 1. A visual overview of the districts can be seen in Figure 2.

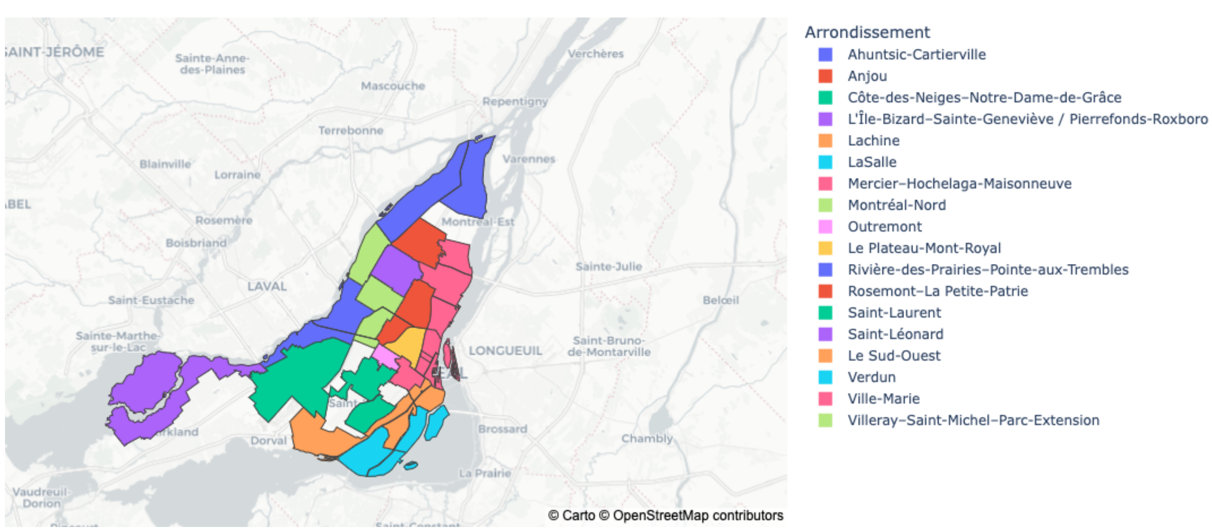


Figure 2: Montreal's district overview

Neighbourhoods
Ahuntsic-Cartierville
Anjou
Côte-des-Neiges–Notre-Dame-de-Grâce
L'Île-Bizard–Sainte-Geneviève / Pierrefonds-Roxboro
Lachine
LaSalle
Mercier–Hochelaga-Maisonneuve
Montréal-Nord
Outremont
Le Plateau-Mont-Royal
Rivière-des-Prairies–Pointe-aux-Trembles
Rosemont–La Petite-Patrie
Saint-Laurent
Saint-Léonard
Le Sud-Ouest
Verdun
Ville-Marie
Villeray–Saint-Michel–Parc-Extension

Table 1: List of neighbourhoods

4.2 Data processing

Once data was collected from OSMNX and from Quebec's webpage (Québec, 2024), it can now be processed to create visualising for use within the app. The use of data within the app is two-fold, with the first geospatial mapping being the creation of choropleth maps to summarise amenity accessibility in Montreal (see Figure 5). It is secondly used to create neighbourhood specific maps to show the distance to different types of amenity.

4.2.1 Choropleth Maps

The first application of the data is within choropleth maps. To create these maps, it was first required to clean the amenity data since it includes approximately 25000 POIs across 131 types of amenities, and this included around 5000 car parking spaces and 4000 benches which was not relevant for the app. Therefore, irrelevant POIs were removed. In addition, any amenity type with less than 10 POIs were removed. Following the cleaning of POI data, these are grouped into categories in Table 2.

Category	Includes	Sum of amenities
Restaurant/Cafe	restaurant, cafe, fast_food, ice_cream	3286
School	school	562
Further Education	university, college	81
Nightlife	bar, pub, nightclub	384
Health Care	pharmacy, dentist, clinic, hospital	532
Child support	kindergarten, childcare	263
Entertainment	theatre, cinema	81
Religious place	place_of_worship	453
Bank/ATM	bank, atm	336
Culture	community_centre, library, arts_centre, events_venue	215
Public services	social_facility, fire_station, police, recycling, social_center, public_building	406
Post	post_box, post_office	583

Table 2: Amenities data

Following, the creation of the these categories, a similar method is used as previously explain from Logan et al. (2022) paper. First, the centroid for each neighbourhood is calculated. Then, the average distance is calculated between every amenity category within each neighbourhood and the centroid of the neighbourhood. This allows for overview of the density and accessibility of different amenities in different neighbourhoods, and for users to choose an amenity they are interested in and to find which neighbourhood is best with regard to that amenity.

Additionally, a choropleth map outlining number of POIs per neighbourhood is created to show the density of amenities within each neighbourhood. The POIs included within this map are those in Table 2, however, it included to sum of all of these amenities rather than by category.

4.2.2 Distance Graphs

The second application of the data is through the use of distance graphs. To create these, the structure of the official neighbourhoods of Montreal was stored as NetworkX (Aric A. Hagberg and Swart (2008)) graphs using the available OSM data for walking, cycling, and driving lanes. The nodes represent intersections of lanes (as stored in OSM), and the edges, which represent the lanes themselves, are populated with speed data, manually specified based on the transportation type. Regarding this aspect, it is important to note as a limitation that OSM data is open-sourced, community reported, hence there could be certain inaccuracies in the location of the nodes. The manually entered speeds were set to 5, 15 and 50 kilometers per hour for the walking, cycling and driving graphs respectively. There is plenty of literature referring to walking and cycling speeds, hence we had difficulties reaching a particular agreement on it. Finally, we set the walking and cycling speeds to some average that seems reasonable based on both the existing literature and our own parameters. Driving was set to 50 km/h due to this being the speed limit in towns/cities in Quebec (Gouvernement du Québec, 2024).

After setting the amenities of interest, the previously built neighbourhood graphs were populated with amenity coordinates with the help of the Pandana (F. Foti (2012)) library. This was done by adding the relevant POIs in each neighbourhood and calculating the travel time in minutes based on the distance from each node to the closest relevant POI. The output of this process is a graph per neighbourhood containing distance information as well as travel time information per amenity. This was finally displayed as a map view for the users.

Two examples of the output can be seen in the results section: The walking travel times to pubs in the neighbourhood of Ville Marie (Figure 6a), and the driving distances to any public building in the neighbourhood of Ahuntsic (Figure 6b). Naturally, the driving travel times are, on average, shorter than the walking or cycling travel times, hence the heavily populated yellow or orange nodes in the second graph.

4.3 Analysis distribution: User application

An analysis of Montreal's neighbourhoods is interesting, and its results might already benefit individuals looking into relocating to or within the city. An even better approach from a user perspective is an application, which helps to identify the best addresses within the city based on interests and the mode of transportation used regularly. So, as mentioned before, we build an application like this in Streamlit, an open-source Python library that allowed us to create and share the app, hosted on the Streamlit community cloud. Streamlit is made for building interactive and visually appealing data science applications (Streamlit, 2024).

For higher performance, all calculations and geospatial analysis were conducted in Jupyter notebooks, as described in the section data acquisition. The main inputs for the application are the amenities within neighbourhoods (in geojson format), the distances from neighbourhood centres to the respective amenities (in parquet format), and the graphs for travel time calculation with each neighbourhood (in pickle format). On top of that we utilised Streamlit functionality and plotting libraries, such as matplotlib.pyplot and plotly in order to make the concept of the 15-minute-city in Montreal most easily accessible for the user. With the visualisations and our conclusions displayed, users now can do their own analysis of where they want to locate to within the city.

We structured the analysis into five different pages, to make the most user-friendly experience possible. Here are our key outputs:

1. a brief introduction to the application and its development context, displayed as seen in Figure 3,

2. a barplot distribution of the amenities of interest and their clustering categories by neighbourhood, so users can get a feeling of the distribution of amenities across the city and look into specific ones. This distribution is accessible as well in a dataframe format (See Fig 1),

3. a choropleth map of each individual neighbourhood of Montreal, representing their respective amenity density,

4. a second choropleth map representing the average distances to the amenity of interest per neighbourhood (See Fig 5a and Fig 5b as examples),

5. different graphs of the neighbourhoods, in which the nodes are coloured based on the time to reach a specific amenity using a specific transportation method. (See Fig 6b and Fig 6a as examples). This gives users a great indication of the best spots of living within a selected neighbourhood, and

6. a summary of the neighbourhoods' characteristics, where we explain our findings to give even more guidance for different interests and needs. (See Fig 4).

4.3.1 Technical pipeline: From raw data to user-friendly visualisations

Arranging the data and building the maps for the application was a long, complex process. Firstly, to build the appropriate choropleth maps (see file named *distance calculating choropleth* in repository for process):

- the centroids of the neighbourhoods' polygons were calculated,
- the POIs data was cleaned and arranged into categories,
- the average distance from each amenity category within each neighbourhood and the centroid of the neighbourhood was calculated. This was first in degrees, and then multiplied by 111,195 to convert to meter distance,
- the choropleth maps were built using these average distances per amenity and neighbourhood.

Secondly, to build the distance graphs (see file named *distance graphs final* in repository for process):

- we stored the structure of the neighbourhoods of Montreal as graphs for different transportation systems (walking, cycling and driving). This structure was retrieved from the publicly available OSM data (OpenStreetMap, 2024),
- we manually added speed data on the edges of the graphs based on the transportation type,
- the POIs in each neighbourhood were located in each graph based on their coordinates,
- the travel time was calculated based on the distance from each node of the graph to the selected POI.
- These travel times were stored in a dataframe and used to colour the different nodes based on their distance time to a specific amenity.

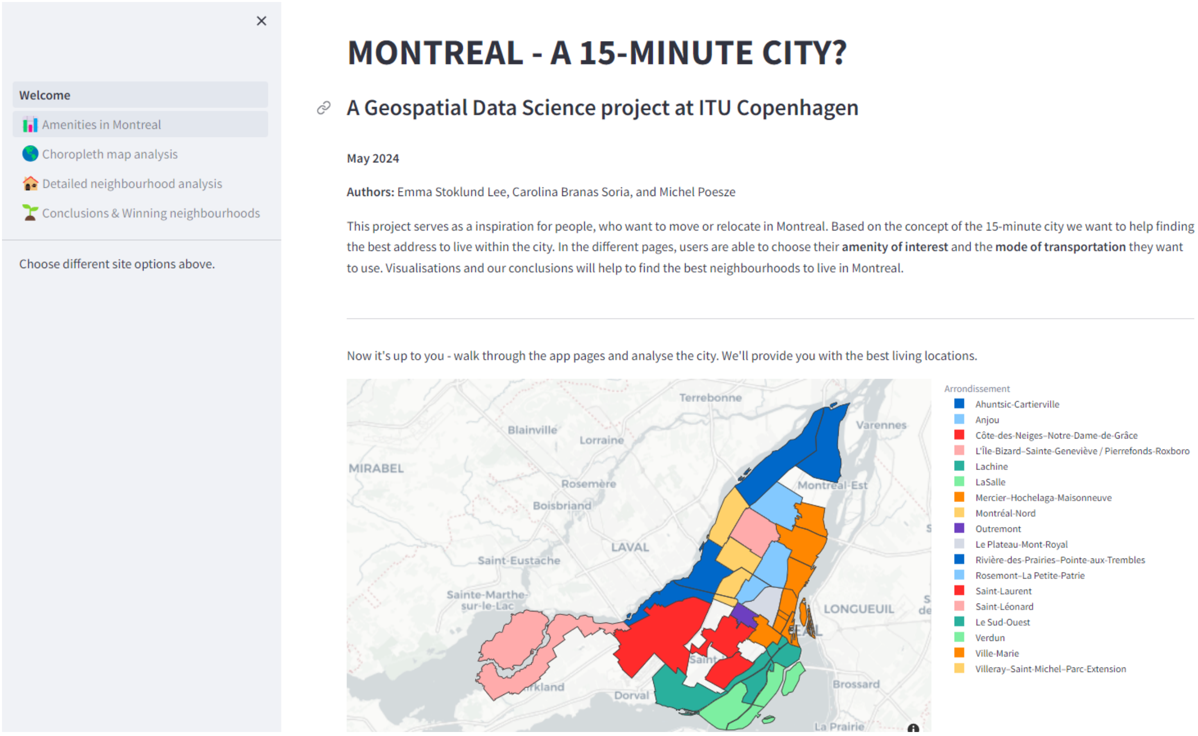


Figure 3: Application welcome page: Introducing the user to the purpose and context

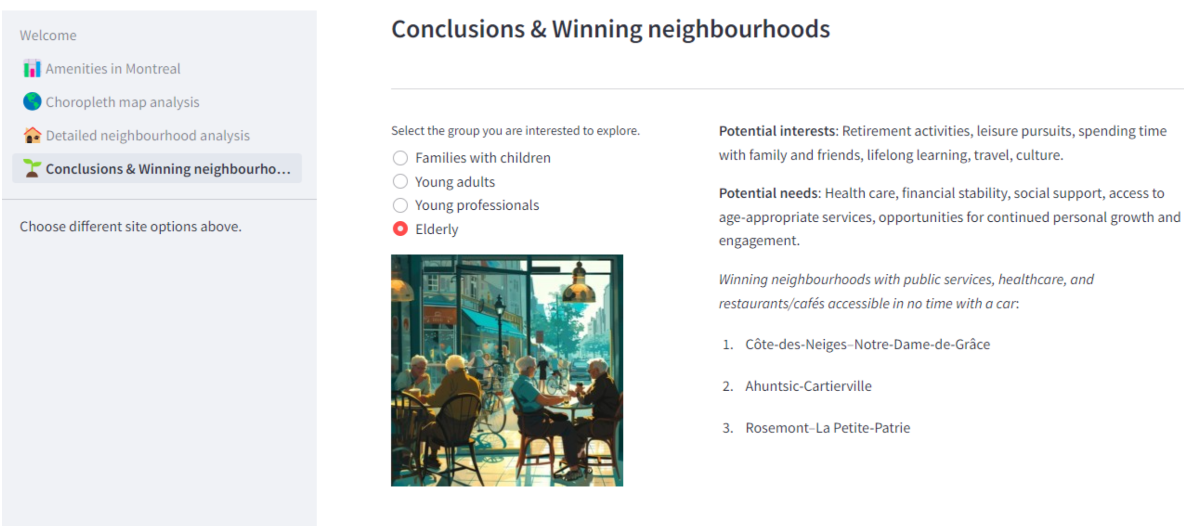
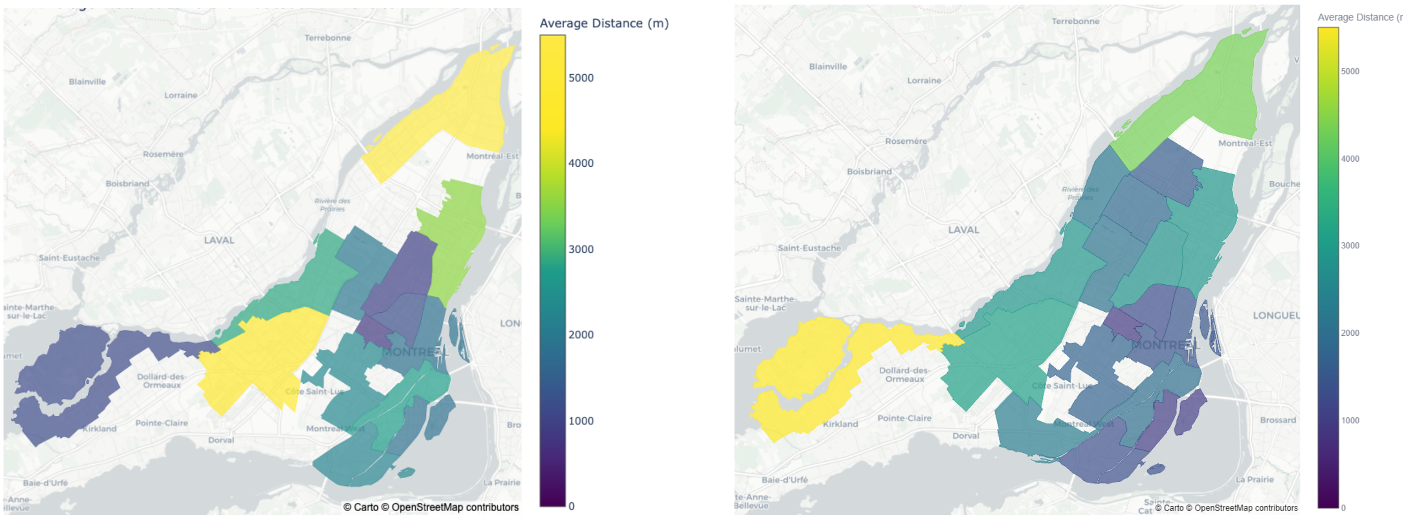


Figure 4: Application conclusions & winning neighbourhoods: Easy to understand conclusions from the overall analysis by population group

In conclusion, we empower individuals to make informed decisions about their relocation by providing them with valuable insights into the city's neighbourhoods and amenities. The user-friendly interface and comprehensive analysis make it easier for them to navigate and understand the data, enabling them to conduct their own analysis and find the most suitable neighbourhood for their needs. Overall, the research delivers a practical and accessible tool that enhances the relocation decision-making process and improves the user experience for individuals interested in moving to Montreal.

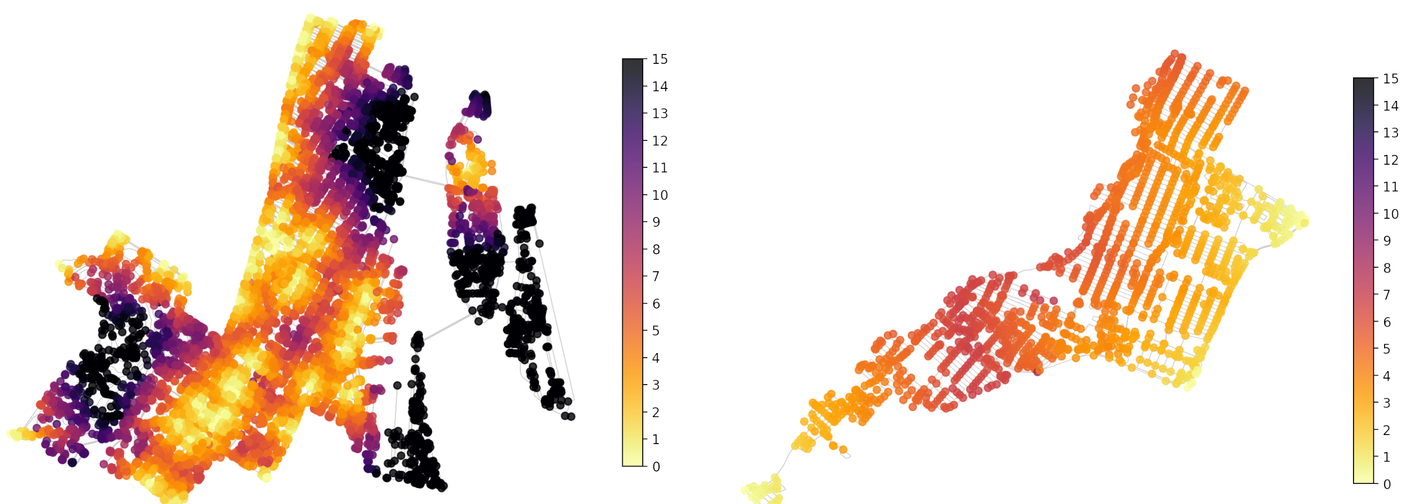
5 Results



(a) Average distance to further education

(b) Average distance to restaurant/café

Figure 5: Example of two choropleth maps



(a) Ville Marie - Walking - Pub

(b) Ahuntsic - Driving - Public building

Figure 6: Example of distance graphs

After analysing the amenities segmented by neighbourhood, choropleth and distance graphs, we observe that some districts like Ville Marie, Le Plateau Mont Royal or Rosemont La petite Patrie stand out in terms of access to amenities, particularly Ville Marie, with a total of 1551 amenities, almost 600 more than Le Platau Mont Royal. A plausible hypothesis for this high number of amenities would be that these three neighbourhoods are closely located in what is considered the most active and populated area of Montreal. In contrast, neighbourhoods like Anjou or Montreal Nord, located in a more suburban area of the city, count with way fewer amenities, 50 and 87 respectively.

To illustrate an example of these disparities, we plot the access to restaurants in both Ville Marie (Fig. 7a) and Anjou (Fig. 7b) by walking. It is possible to observe that Ville Marie is more heavily populated with yellow and orange nodes than Anjou, meaning that the walking time to the closest restaurant is lower in Ville Marie.

By having a close look at the calculated travel times per neighbourhood and amenity, we can get a better understanding on how the amenities are distributed. The results of the highest travel times are summarized in Table 3, Table 4 and Table 5.

Neighbourhood	Amenity	Travel Time
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	studio	8.877191
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	events venue	8.877191
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	nightclub	8.877191
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	university	8.877191
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	cinema	8.864752
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	bureau de change	8.669643
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	theatre	8.573234
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	social centre	8.573234
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	recycling	8.573234
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	college	8.380289

Table 3: Average driving travel times in minutes by neighbourhood

Neighbourhood	Amenity	Travel Time
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	hospital	14.182897
L'Île Bizard Sainte Genevieve, Montreal, Canada	hospital	13.397027
LaSalle, Montreal, Canada	hospital	13.074335
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	cafe	12.926578
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	pharmacy	12.845577
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	restaurant	12.625814
Ahuntsic-Cartierville, Montreal, Canada	hospital	12.187633
L'Île Bizard Sainte Genevieve, Montreal, Canada	cafe	11.997281
Saint-Laurent, Montreal, Canada	hospital	11.888874
Lachine, Montreal, Canada	hospital	11.144096

Table 4: Average walking travel times in minutes by neighbourhood

Neighbourhood	Amenity	Travel Time
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	hospital	10.378952
L'Île-Bizard–Sainte-Geneviève, Montreal, Canada	hospital	9.625549
Saint-Laurent, Montreal, Canada	hospital	8.238780
L'Île-Bizard–Sainte-Geneviève, Montreal, Canada	cafe	8.039454
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	restaurant	7.943757
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	cafe	7.650180
Rivière-des-Prairies–Pointe-aux-Trembles, Montreal, Canada	pharmacy	7.529681
L'Île-Bizard–Sainte-Geneviève, Montreal, Canada	restaurant	7.176562
L'Île-Bizard–Sainte-Geneviève, Montreal, Canada	pharmacy	6.583541
LaSalle, Montreal, Canada	hospital	5.661467

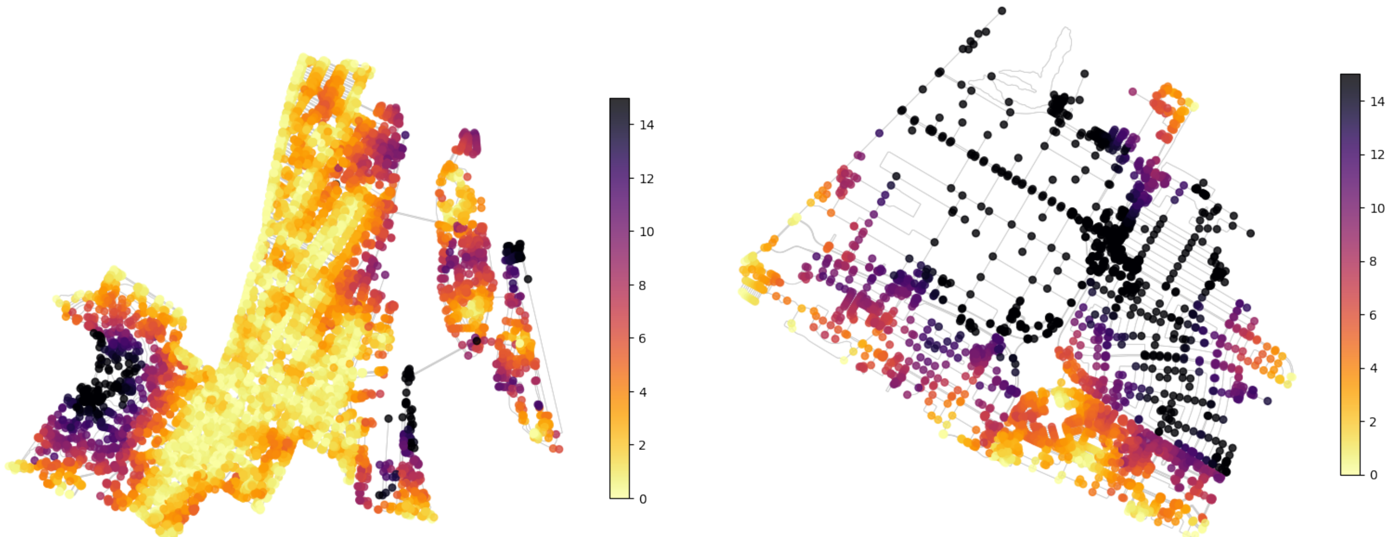
Table 5: Average biking travel times in minutes by neighbourhood

When **cycling**, the top three furthest amenities, on average, across neighbourhoods are hospitals, pharmacies and cafés, respectively. Rivière des Prairies Pointe aux Trembles is the neighbourhood with the highest travel times when cycling, but these do never surpass eleven minutes.

When **walking**, the top three furthest amenities, on average, across neighbourhoods are again hospitals, pharmacies and cafés, respectively. Rivière des Prairies Pointe aux Trembles is again the neighbourhood with the highest travel times when walking.

When it comes to **driving**, the travel times never go over nine minutes, and the furthest amenities to reach by this type of transportation are nightclubs, universities and studios. Again, Rivière des Prairies Pointe aux Trembles is the worst connected neighbourhood. It is important to consider that this particular neighbourhood is larger than the average, hence we hypothesize that its size could increase the resulting travel times. In addition, coming back to the point that nodes are retrieved from OSM data, it could be the case that certain neighbourhoods lack some nodes, increasing the distances from these to the amenities.

After all this analysis, we conclude that Montreal overall is a livable city with great access to amenities. One point of improvement would be to increase the number of amenities or reduce the commuting time to these on the peripheral neighbourhoods. Summarizing, and keeping in mind the previously mentioned limitations, the travel times in either transportation type never surpass the fifteen minutes, making Montreal, in theory, a successful 15-minute city.



(a) Ville Marie - Walking - Restaurant

(b) Anjou - Walking - Restaurant

Figure 7: Examples of contrasting centre and suburban distance graphs

6 Discussion: Points of possible improvement

In the discussion of our research, we recognize several limitations that provide opportunities for future exploration. Firstly, a significant aspect that could be considered in a subsequent project is the role of public transportation. As Montreal's public transit system is a crucial part of the city's urban landscape, its impact on neighbourhood dynamics is likely substantial for painting a complete picture. Incorporating public transport into future research could provide a more comprehensive understanding of the city's spatial structure and residents' mobility options.

A key limitation of our research is missing data, particularly concerning amenities. The unreliability of OSM data poses a challenge to accurately evaluating the availability and distribution of amenities across Montreal's neighbourhoods. This limitation may have affected our ability to fully comprehend the neighbourhoods' potential and the quality of amenity access. Future research could focus on utilizing more reliable data sources or implementing techniques to handle missing or unreliable data.

Particularly in relation to the distance graphs, some neighbourhoods are better connected than others. The OSM data, as mentioned, is open-sourced and not fully reliable. If we assume that the nodes are properly located, we for example observe that the walking graph of Ville Marie contains a higher number of nodes than the Anjou graph, meaning that Ville Marie is better connected for pedestrians than Anjou. This might explain the differences in the proximity to amenities in some cases. To add to these limitations, we point out that the speed times were manually added, without considering any stop signs, lights, traffic, or the different speeds allowed in each road.

Our analysis also bypassed the examination of access to employment, a critical component of 15-minute cities. The ability to reach employment opportunities within a short time significantly impacts a city's livability. By omitting this aspect, our research may not fully capture the lived realities of many Montreal residents. Future studies should consider including employment access as a key variable.

Another point of consideration: We must consider Montreal's identity as a 'car' city. Canada's car-centric infrastructure could influence our findings, especially regarding the potential of certain neighbourhoods and the lifestyle of different socio-economic groups. While our maps can illustrate broader spatial distributed amenities, they may fall short in capturing the nuances of navigating short routes with cars, especially neglecting parking opportunities for the vehicles. Car traffic and parking in general have a great influence on the livability of a neighbourhood and therefore, our visualizations may not deliver as much knowledge as desired about the lived realities of residents.

In addition, it is important to notice that the size of the neighbourhoods and their population are not normalized (e.g. by dividing by square kilometres of the neighbourhood), meaning that more research is needed to draw conclusions based on amenity accessibility. Despite needing further research, a plausible hypothesis would be that the neighbourhoods with the highest number of amenities are closely located in what is considered the most active and populated area of Montreal.

Lastly, in class exercise 10 it was shown that more complex methodology can be employed, wherein speed by mode of transportation was calculated more dynamically. The use of diverse calculation methods across studies can add complexities when comparing results, thereby potentially limiting the comprehensibility and implications of our findings. Moreover, our study also did not account for dynamic elements such as traffic conditions, traffic lights, and other real-time variables that can significantly influence travel times and accessibility. By not incorporating these dynamic elements, our research may offer a somewhat static and potentially misleading picture of mobility within Montreal.

While mentioning all the above limitations, our solution still delivers value in planning relocation within Montreal, which in essence was the main goal of the project.

7 Conclusion: Summing up

In our research, we aimed to develop an interactive application to illustrate the accessibility of various amenities within a 15-minute reach using different modes of transportation in Montreal. Our goal was to provide a tool not only for individuals considering relocating within the city, but also for urban planners and policymakers striving to enhance accessibility and mobility across Montreal.

We successfully created an app, which helps users visualise the accessibility of amenities in each neighbourhood of Montreal, which can be transferred to other cities with low effort as well, hence can be generalised well. This tool allows users to explore which neighbourhoods have better access to desired amenities and thereby assists in making informed decisions about where to relocate to. Our app incorporates visual display of amenities' distribution and estimated time arrivals by walking, cycling, and driving, offering a comprehensive view of Montreal's accessibility landscape.

From this project, we learned the importance of using reliable and dynamic data sources to enhance the accuracy and reliability of our application. Future research enhancements could include integrating real-time data using APIs, such as Google Maps, to account for traffic conditions, which would provide users with more accurate and practical information about travel times. Integrating live data into our analysis would enhance the applicability and reliability of our findings, making them more reflective of residents' daily experiences. Additionally, incorporating public transportation data and access to employment as key variables could offer a more holistic view of urban accessibility, making our app more robust and useful for a wider audience.

In conclusion, while our research provides valuable insights into Montreal's neighbourhoods, their amenities, and the accessibility in terms of the concept of the 15-minute-city, the solution is not comprehensive yet. The listed limitations highlight the complexity of urban analysis and the need for further, more comprehensive studies.

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Appendix A: Meta data tables

Table 6: Software Metadata

	Software metadata description	
S1	Current software version	gds_py:8.0, Python 3.9.16
S2	Permanent link to your code in your Github repository	https://github.com/emmastoklee/GDS_project
S3	Legal Software License	Creative Commons 4.0
S4	Computing platform / Operating System	macOS Monterey v. 12.5, Windows 11 Home
S5	Installation requirements and dependencies for software not used in class	plotly and streamlit which can be installed in python by using pip install and dependencies can be imported manually.
S6	If available Link to software documentation for special software	https://plotly.com/python/ and https://docs.streamlit.io/get-started
S6	Support email for questions	michel.poesze@gmail.com

Table 7: Data Metadata

	Data metadata description	
D1	Data License	OpenStreetMap: Open Data Commons Open Database License, Montreal Neighbourhood Data: Donnes Quebec Quartiers Sociologiques
D2	Dataset name / main properties	Data extracted from OpenStreetMap (OSM) using OSMnx to gather data on amenities and graph of travel by walking, cycling and driving - source: https://wiki.openstreetmap.org/wiki/Main_Page, Data downloaded from Quebec's Official website (Partenariat Données Québec) to gather the polygons for the official neighbourhood areas - source: https://donneesquebec.ca/recherche/dataset/vmtl-quartiers-sociologiques

Appendix B: Contribution statement

All group members equivalently contributed to all parts of the project.

Appendix C: Use of AI tools

The following AI tools have been utilized while developing code: Github Copilot (version 1.7.4421), ChatGPT-3.5. GPT-3.5 has been assisting in designing the LaTeX tables well.