Measures of Public Transit Accessibility

A Case Study on Cultural and Art Amenities in Metro Vancouver

Luka Vukovic
Rain Shen
Yuxuan Cui
Graham Kerford
Statistics Canada

Our Team

THE UNIVERSITY OF BRITISH COLUMBIA

Graham Kerford

Rain Shen

Yuxuan Cui

Luka Vukovic

Our Client

The agency of the Government of Canada commissioned with producing statistics to help better understand Canada, its population, resources, economy, society, and culture.

Joseph Kuchar

Bjenk Ellefsen

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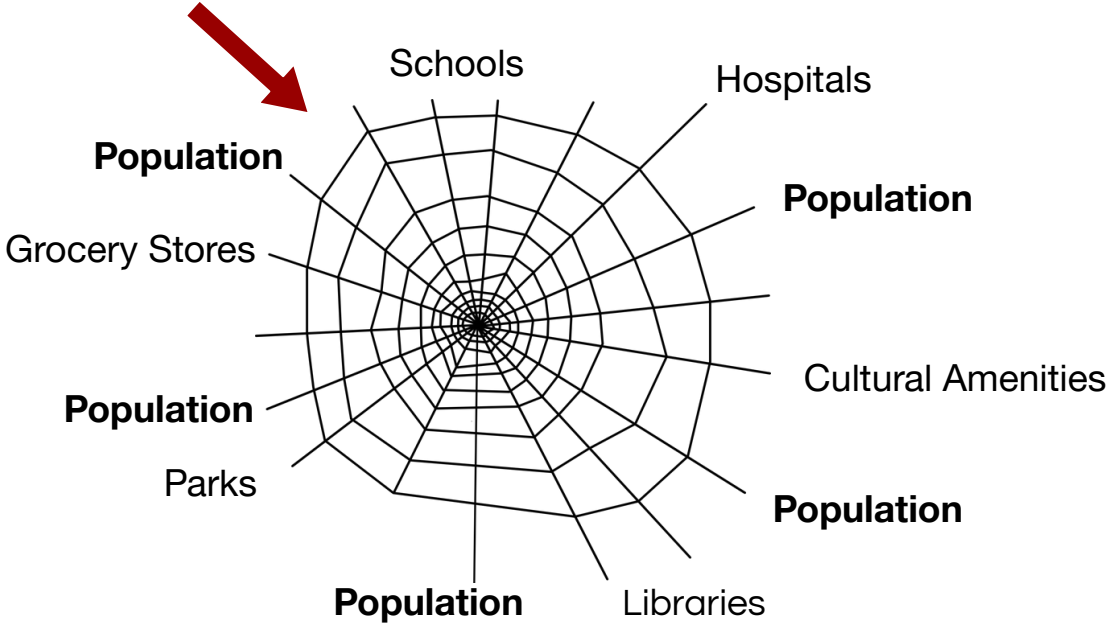
1. Background & Motivation

It’s all about resource distribution.

The Transportation Network



Measures of Accessibility

	Mode	Measure based on:
Last year:	**Driving/Walking**	**Distance**

[1] Statistics Canada, 2021

What about public transit?

- **Multi-modal complexity**
  = bussing + walking + biking
- **Transit network complexity**
  = many possible travel solutions

It's difficult to compute.

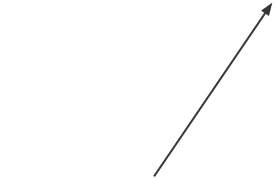
What about public transit?

- Canadians depending on public transit:
  - Large Cities: **1 in 5** [2] Statistics Canada, 2017
  - All Cities: **1 in 6** [2] Statistics Canada, 2017

- If transit accessibility **isn't measured**,
  we **under-represent** a large segment of the population.

What about public transit?

… which can inevitably **worsen pre-existing inequalities** in the urban landscape. [3] Lubitow, 2017



Core problem

Measures of Accessibility

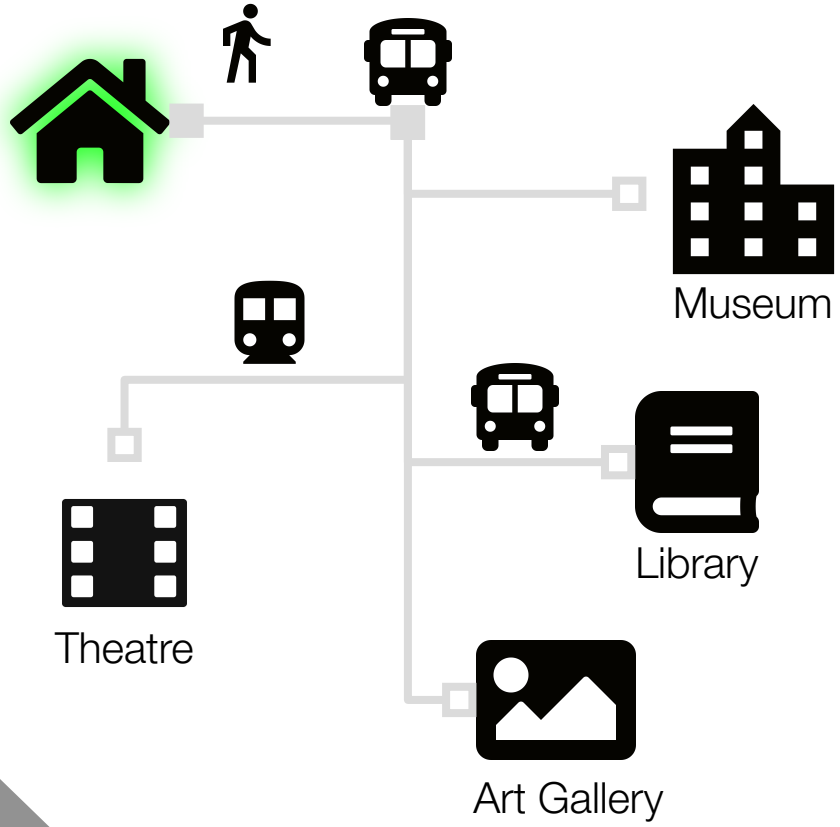
	Mode	Measure based on:
Last year:	**Driving/Walking**	**Distance**
This year:	**Public transit**	**Travel time**

To Cultural and Art Amenities

Large indicator of **Quality of Life** and **Community Appeal**

Origin

Cultural Amenities



Time to the **nearest** amenity of each type (minutes)		Accessibility Score
Museum:	20	0.050
Library:	40	0.025
Art Gallery:	30	0.033
Theatre:	10	0.100
Average:	25	0.040

2. Problem Statement

The client needs a **scalable** and **efficient** framework to compute transit measures of accessibility across Canadian metropolitan areas.

3. Aims & Objectives

Aims and Objectives

Efficiently compute Vancouver's transit time from each city block to all cultural amenities.

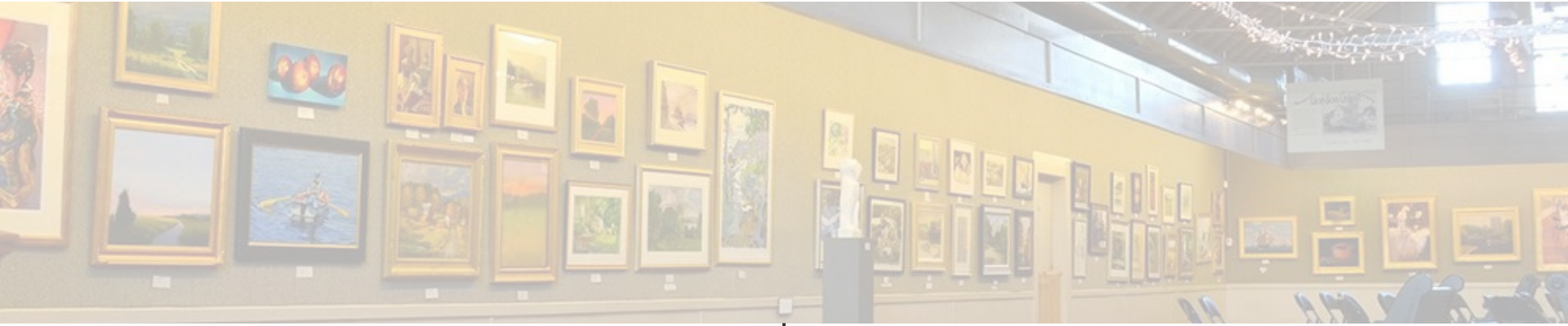
15197 * 353

Develop various accessibility measures using these travel times.

(scores and time measures)

Demonstrate how these measures can be used to **visualize** and **analyze** local and intercity **transit accessibility.**

Case Study



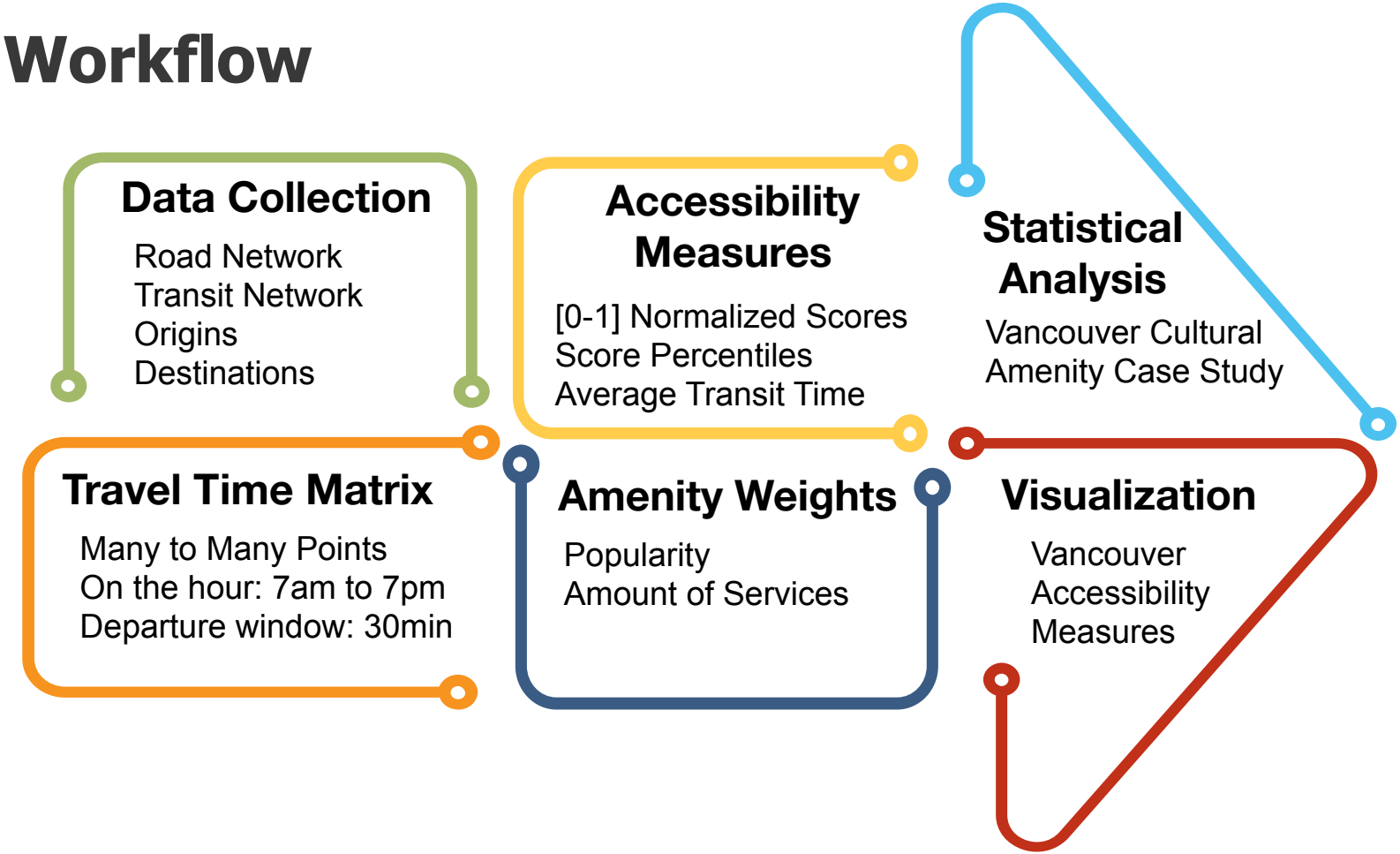
Cultural and Art Amenities

Libraries, Galleries, Museums, Theatres

Metro Vancouver

Our Starting Point

Workflow

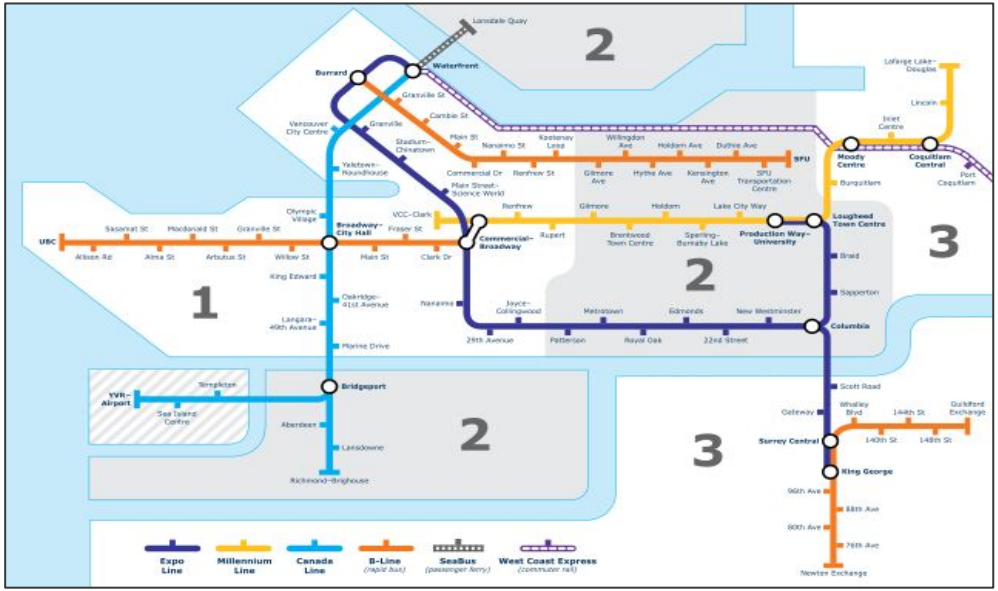

Data Collection
Road Network
Transit Network
Origins
Destinations
Accessibility Measures
[0-1] Normalized Scores
Score Percentiles
Average Transit Time
Statistical Analysis
Vancouver Cultural Amenity Case Study
Travel Time Matrix
Many to Many Points
On the hour: 7am to 7pm
Departure window: 30min
Amenity Weights
Popularity
Amount of Services
Visualization
Vancouver Accessibility Measures

4. Data & Methodology

Open-Source
Data, Tools, and Technologies

The Data We Used

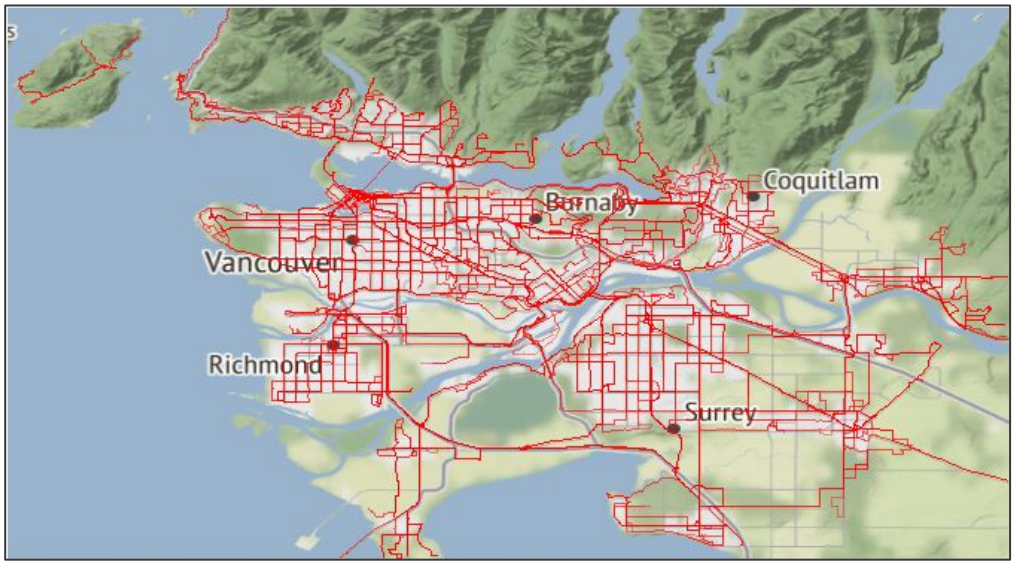
Skytrain Transit Network → General Transit Feed System (GTFS)



The Data We Used

Bus Transit Network

→ General Transit Feed System (GTFS)



*From the Open Database of Cultural and Art Facilities (ODCAF)

The Data We Used

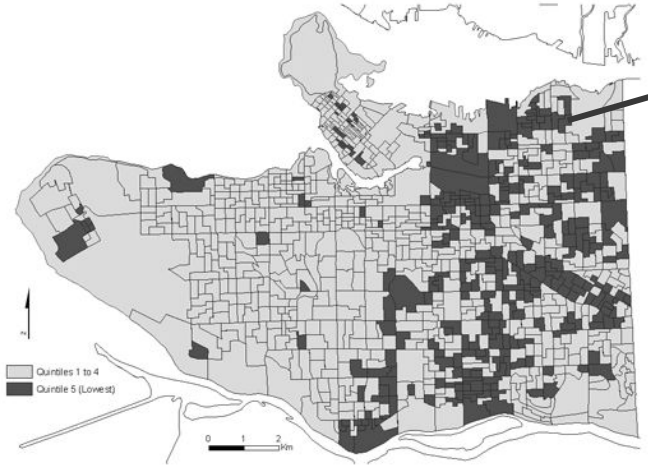
Destinations (amenities)

→ Unique ID, Latitude, Longitude, Type

ID: 10111
Latitude: -49.2
Longitude:127.3
Type: Museum

The Data We Used

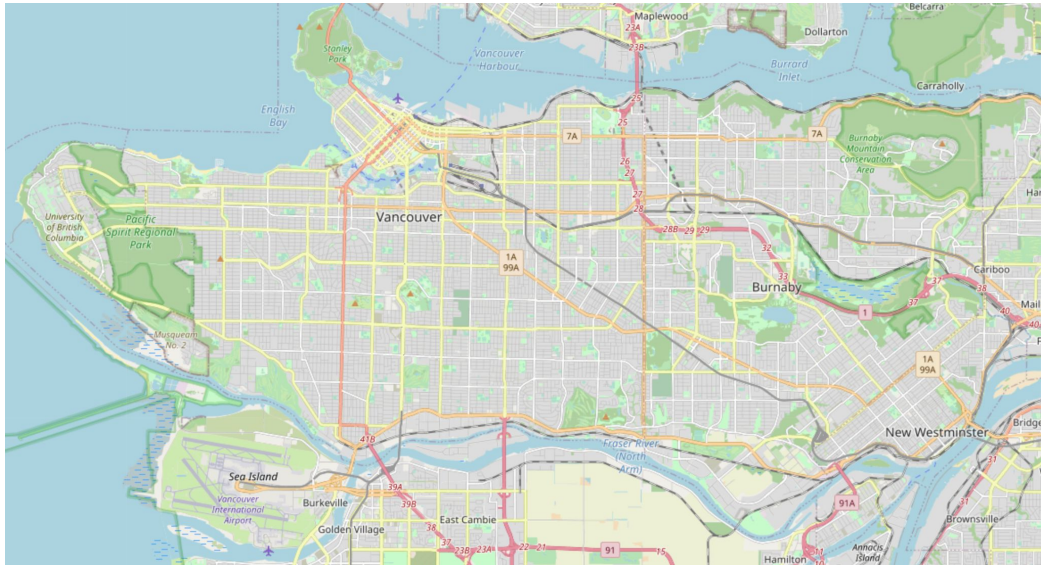
- **Dissemination Blocks**
  → Unique ID, Lat, Lon, Population
- **Polygon Data**
  → Geospatial Shapefiles



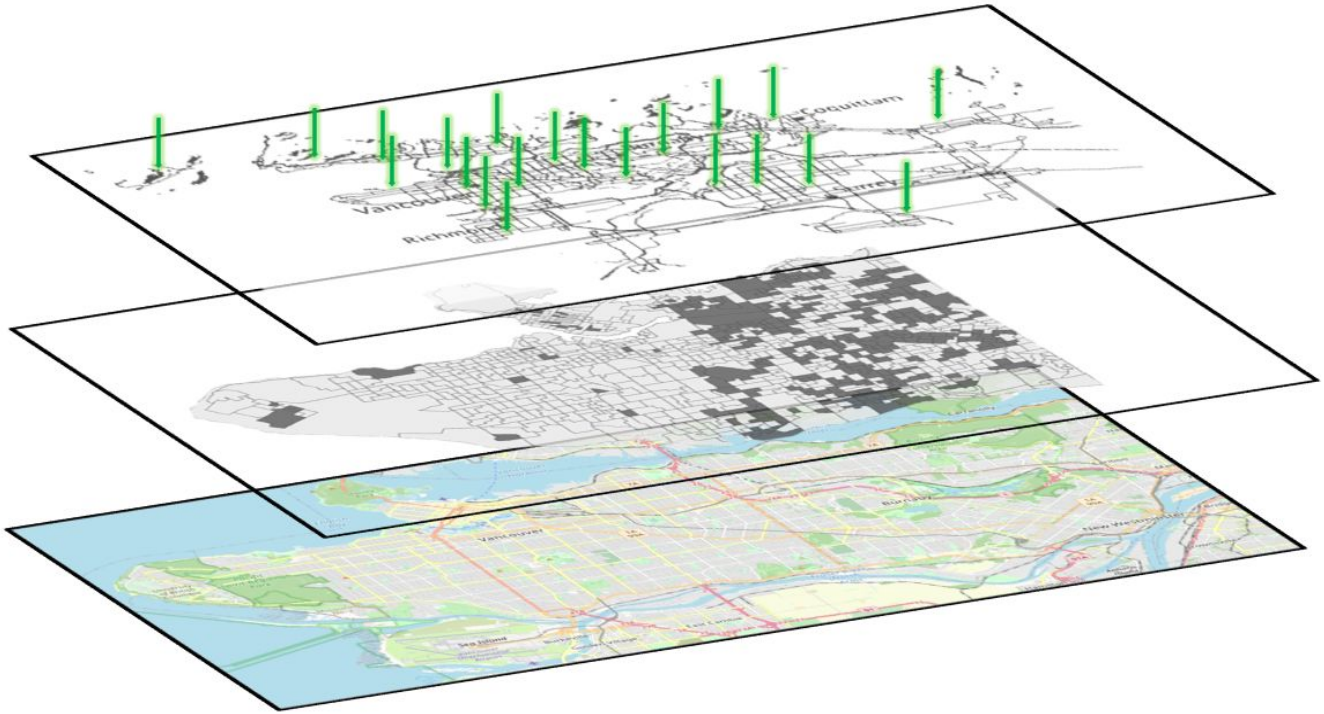
DBUID: 923910111
CDNAME: BURNABY
Latitude: -49.2
Longitude: 127.3
Population: 468

The Data We Used

- **Street Network**
  → Open Street Map (OSM)



Welcome Our Data Sandwich

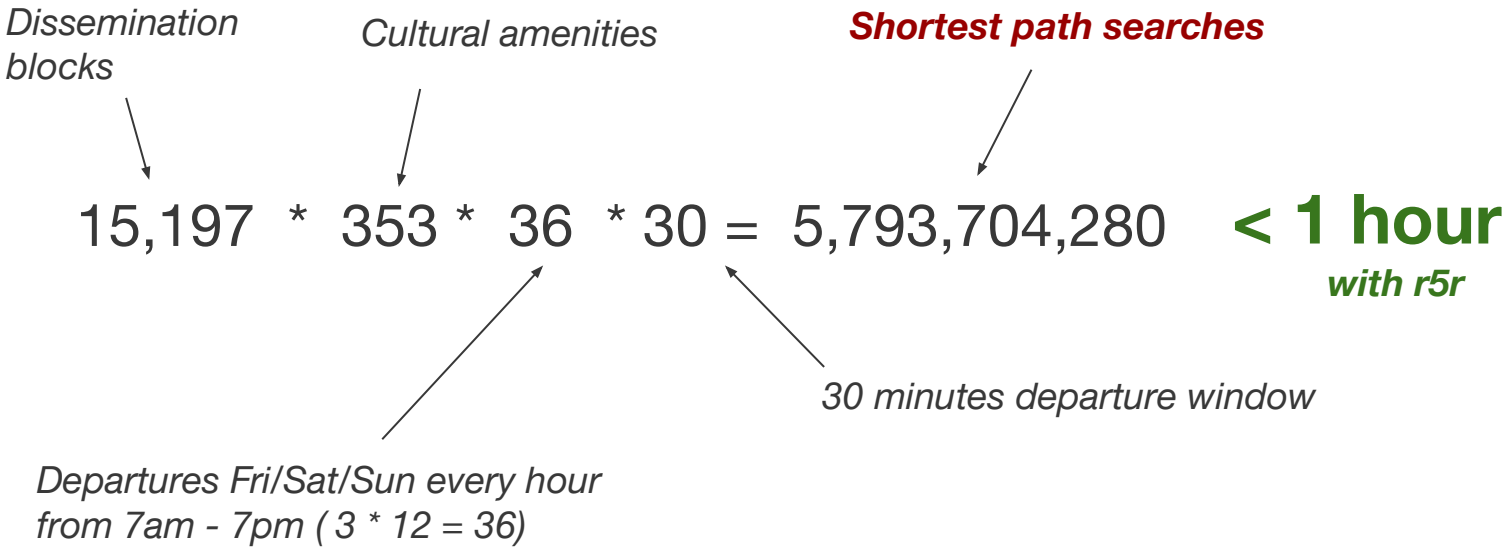


Computation

1. **Travel Time Matrix**
   - Conveyal's R5 (Rapid Realistic Routing on Real-world and Reimagined networks) → r5r Library

   - Steps:
     i. ***Build network****: layer street and transit network*
     ii. ***Set constraints****: mode = bus+walk, max walk = 1km, max time = 2h*
     iii. ***Compute****: shortest path transit times from each origin to each amenity*

Computation



Travel Time Matrix

O	D	$\mu_{O,D}$	$\sigma_{O,D}$
fromId <chr>	toId <chr>	avg_unique_time <dbl>	sd_unique_time <dbl>
59150004004	10	99.76316	5.364721
59150004004	15	72.48718	3.401794
59150004004	157	96.69231	3.001349
59150004004	1759	106.82051	4.388213
59150004004	1760	46.58974	2.642944
59150004004	1822	76.64103	3.990035
59150004004	1839	76.15385	2.680715
59150004004	1840	75.15385	2.680715
59150004004	1916	99.07692	3.571706
59150004004	1930	86.97436	4.923024

o_i → 59150004004 (row)

d_j → 15 (column)

μ_{o_i,d_j} → 72.48718

σ_{o_i,d_j} → 3.401794

Score Measure

Unique trip score:
(from origin ***i*** to destination ***j***)

$$s_{o_i,d_j} = \frac{1}{\mu_{o_i,d_j} + 2\sigma_{o_i,d_j}}$$

Mean trip time

Std. Dev of trip time

Final Block Score:
(from origin ***i*** to ***n*** destinations)

n = 1 : closest destination
n = 2 : closest 2 destinations
...
n = N : all destinations

$$s_{o_i} = \sum_{j=1}^{\{1,2,3,n\}} s_{o_i,d_j}$$

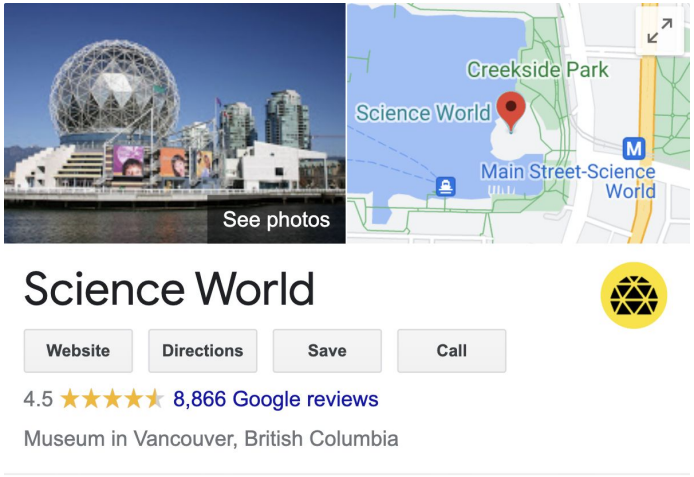
Amenity Weight (Mass)

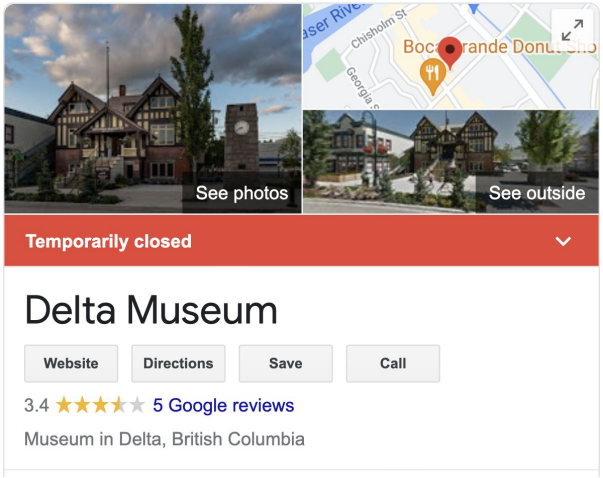
- **How can we consider amenity mass in the scoring?**

Amenity Weight (Mass)

- Considering two places

Amenity Weight (Mass)





Amenity Weight (Mass)

Equal weight =

Higher weight >

lower weight <

Amenity Weight (Mass)

Objective features for measuring amenity mass :

- Annual visitors
- Annual revenues of amenity
- Capacity of amenity

...

HOWEVER

However, really hard to find the data due to confidentiality

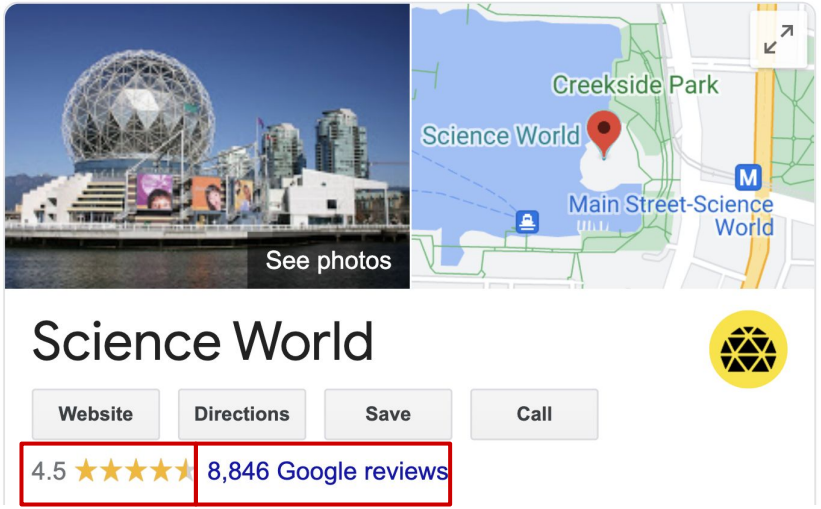
INSTEAD

Amenity Weight (Mass)

Google Place API

Amenity Weight (Mass)

Using Google Place data as proxy of objective data



Hours:	Sunday	10a.m.–5p.m.
	Monday	10a.m.–5p.m.
	Tuesday	10a.m.–5p.m.
	Wednesday	10a.m.–5p.m.
	Thursday	10a.m.–5p.m.
	Friday	10a.m.–5p.m.
	Saturday	10a.m.–5p.m.

Amenity Weights (Mass)

For galleries, theatres, and museums:

$$weights_{index} = (n(hour) + n(days) + n(rating) + n(reviews))/N_i$$

Amenity Weight (Mass)

For libraries:

$$weights_{index} = (n(hour) + n(days) + n(rating) + n(reviews) + \underbrace{n(space) + n(volume)}_{\text{Additional features:}})/N_i$$

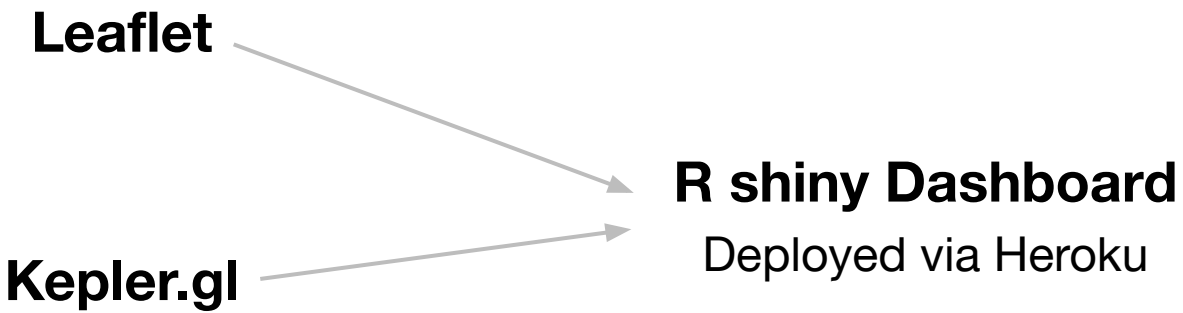
Additional features:
BC Public Libraries Systems

Amenity Weight (Mass)

Unique trip score with weights:
(from origin ***i***, o_i , to destination ***j***, d_j ,with Weights index ***i***,***j***)

$$S_{o_i,d_j} = \frac{(1 + weights_{index_j})}{\mu_{o_i,d_j} + 2\sigma_{o_i,d_j}}$$

Visualization



5. Results & Discussions

A Scalable Framework

Given that...

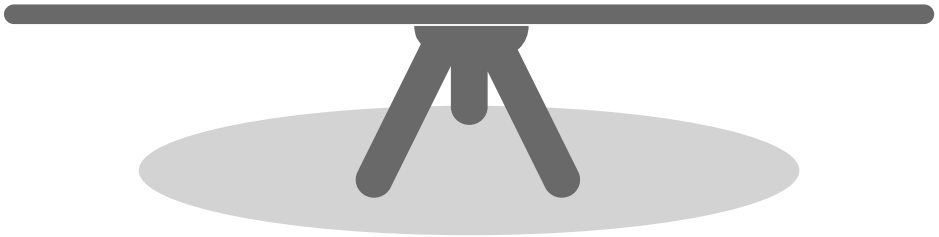
Home > Vancouver News

Vancouver ranks #3 in the world for quality of life

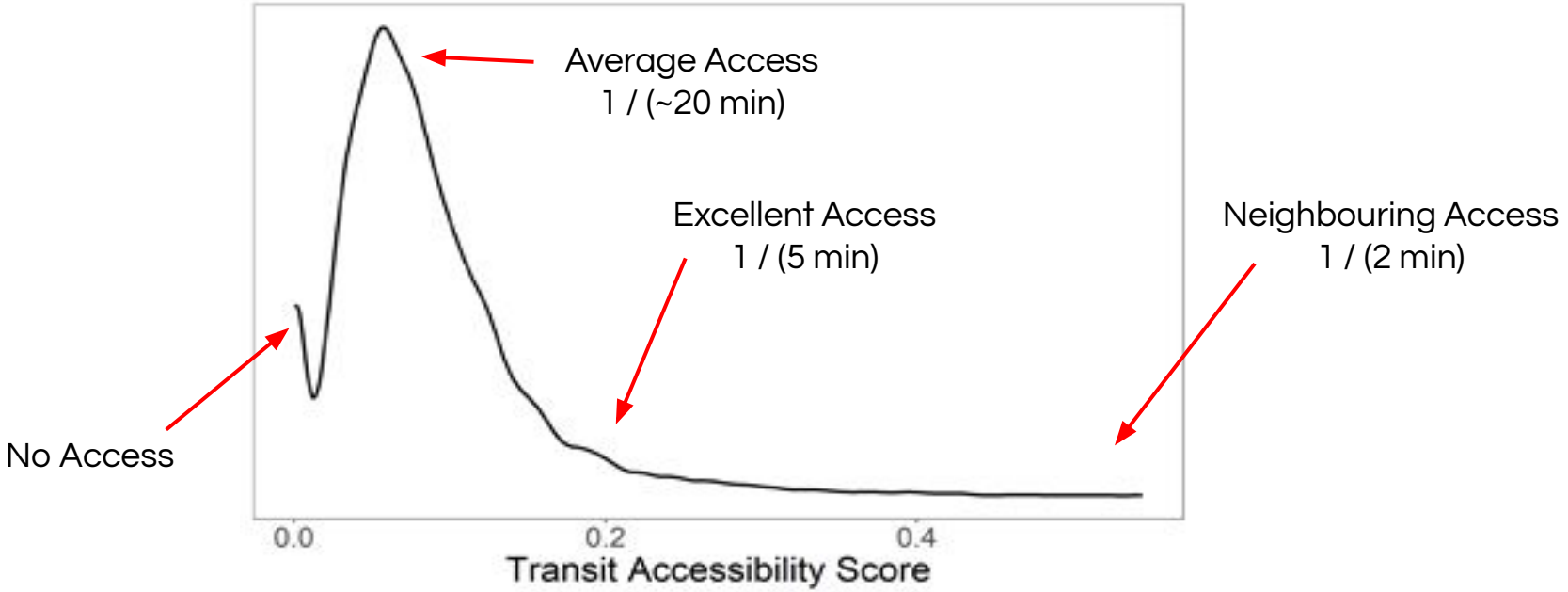
A recent survey has named Vancouver third in the world for quality of life in a three way tie with Auckland, New Zealand and Munich, Germany.

Mar 13, 2019 10:28 AM By: Elana Shepert

How does it fare regarding transit access to cultural amenities?



Overall Accessibility Distributions



Overall Accessibility Distributions

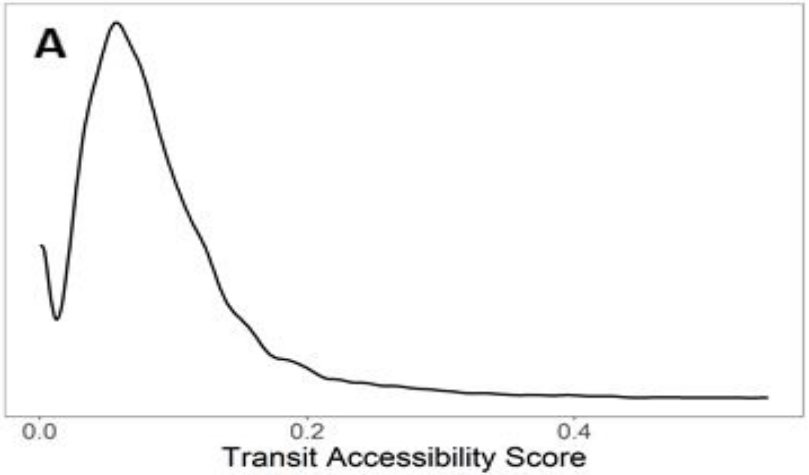
Scores:

Advantage:

- Account for **uncertainty**
- **Incorporates amenity weights** (& other non-time variables)
- **Standardized**

Disadvantage:

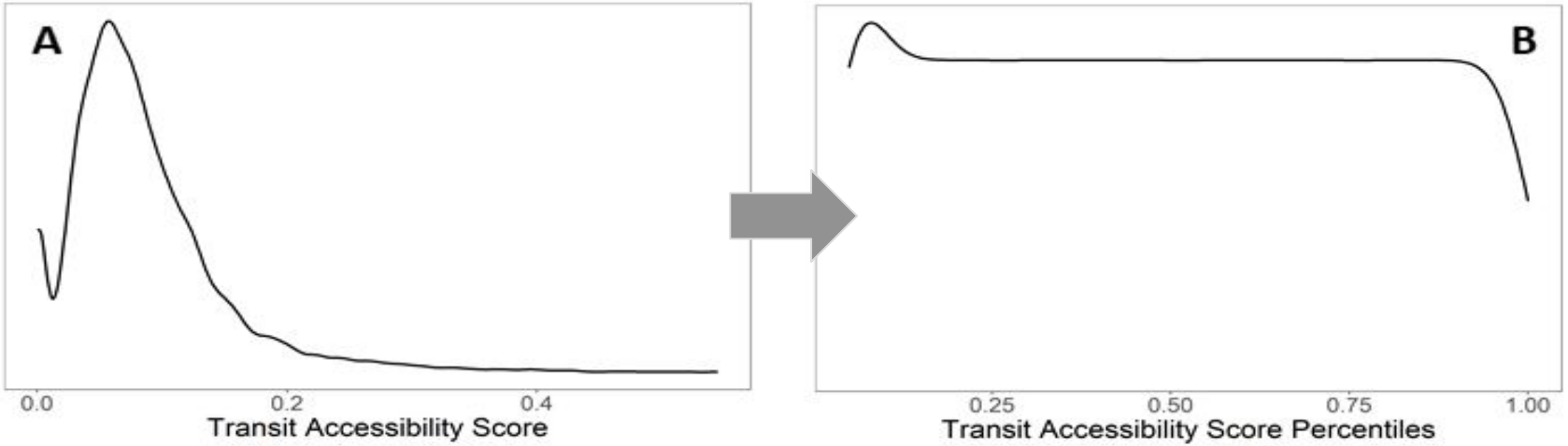
- Interpretability is non-existent



So what about interpretability?

Part I

Overall Accessibility Distributions

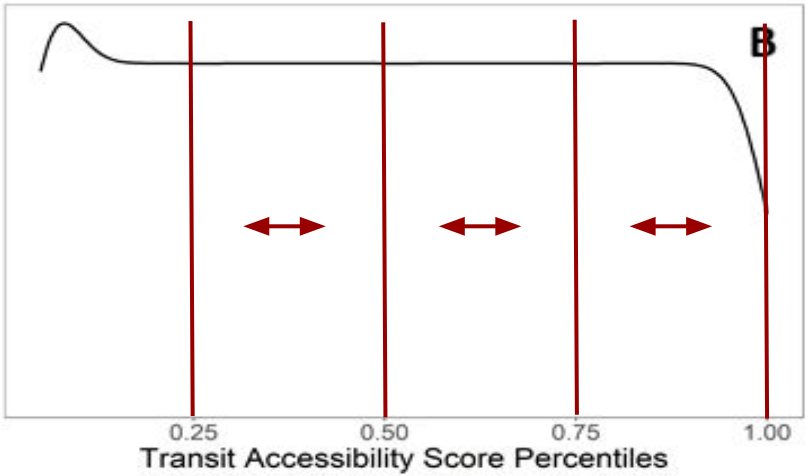


Overall Accessibility Distributions

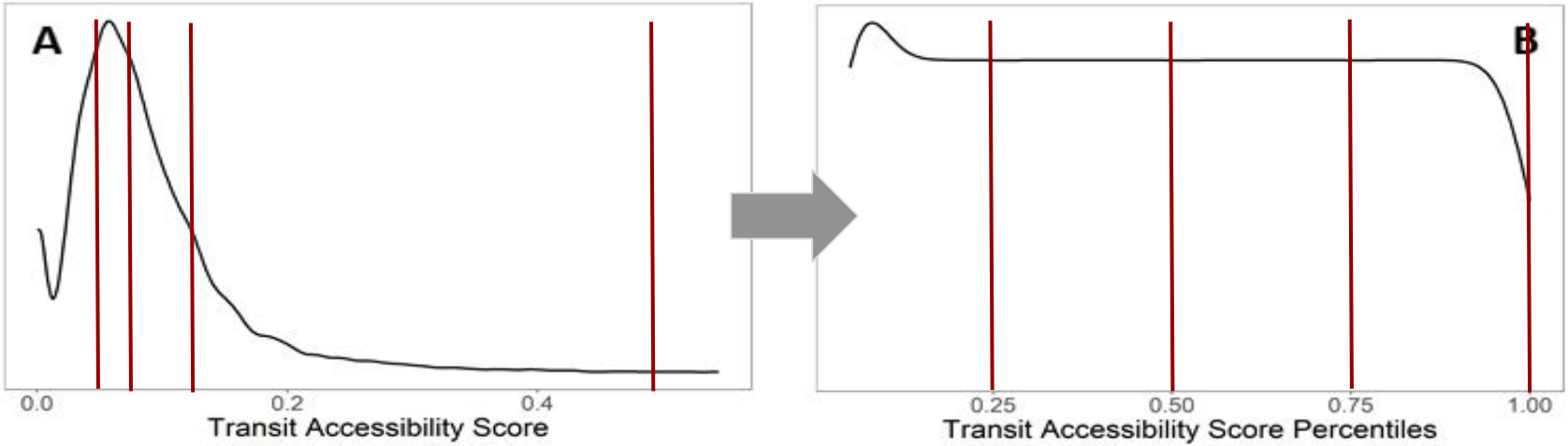
Percentiles:

Advantage:
- Interpretability of relative local access
- Uniformity

Disadvantage:
- Information loss on true access
- Information loss on true differences



Overall Accessibility Distributions

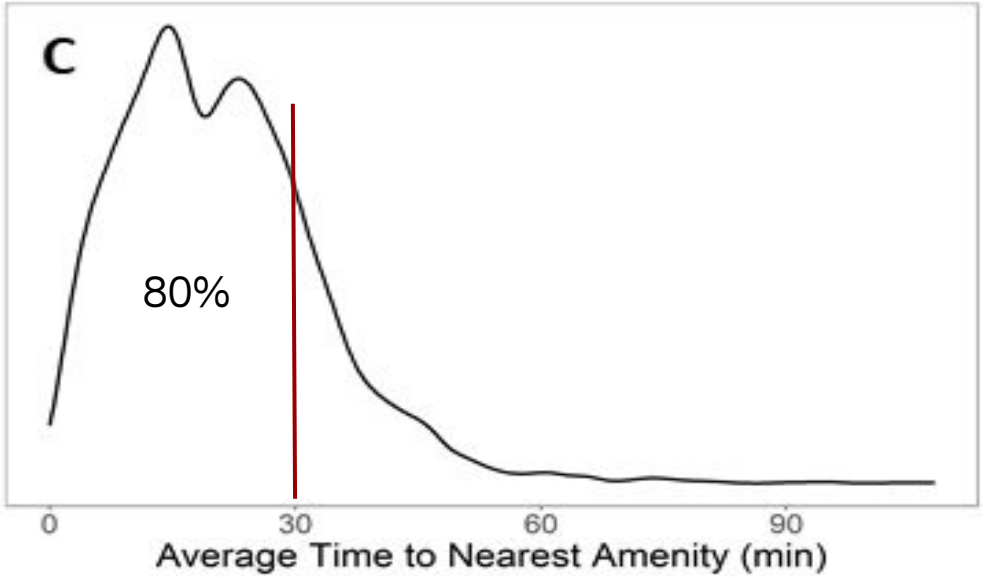


So what about interpretability?

Part II

Overall Accessibility Distributions

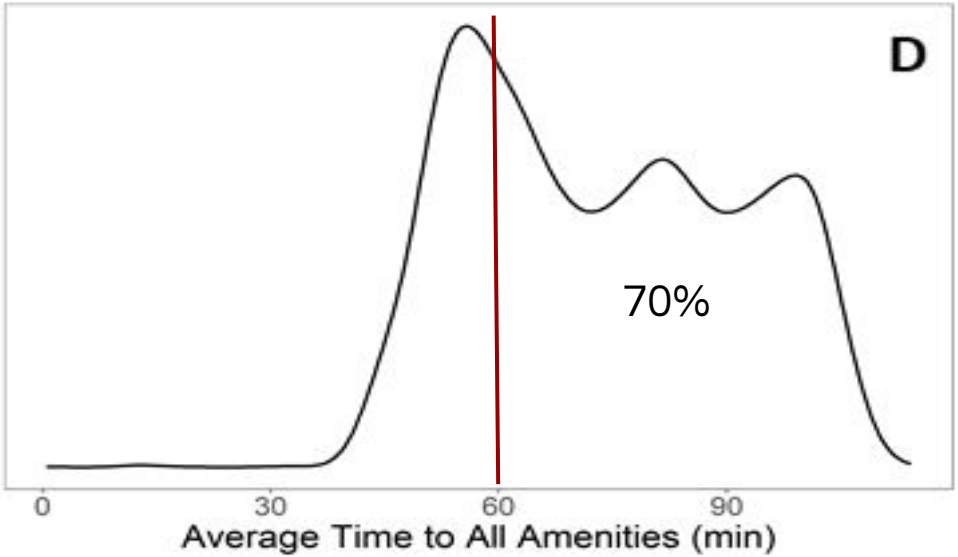
Nearest Cultural Amenities are not far!
(< 30 min for 80% of people)



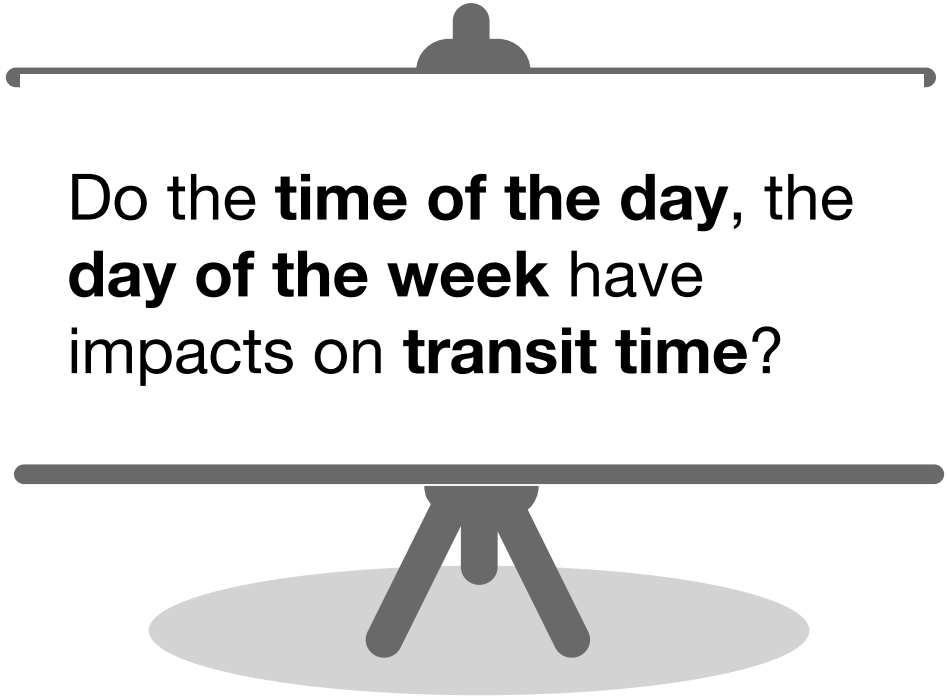
**Assumes average traffic, no delays, missed busses, etc...*

Overall Accessibility Distributions

All Cultural Amenities… are quite far.
(> 1 hour for 70% of people)

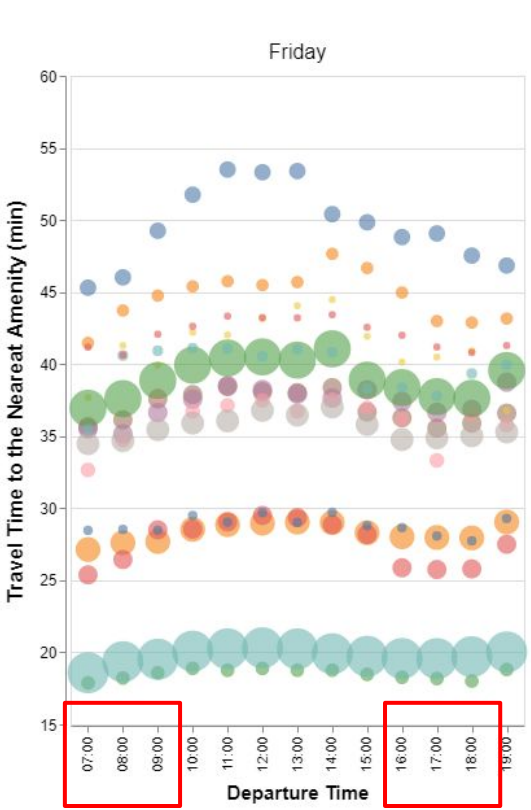


**Assumes average traffic, no delays, missed busses, etc…*



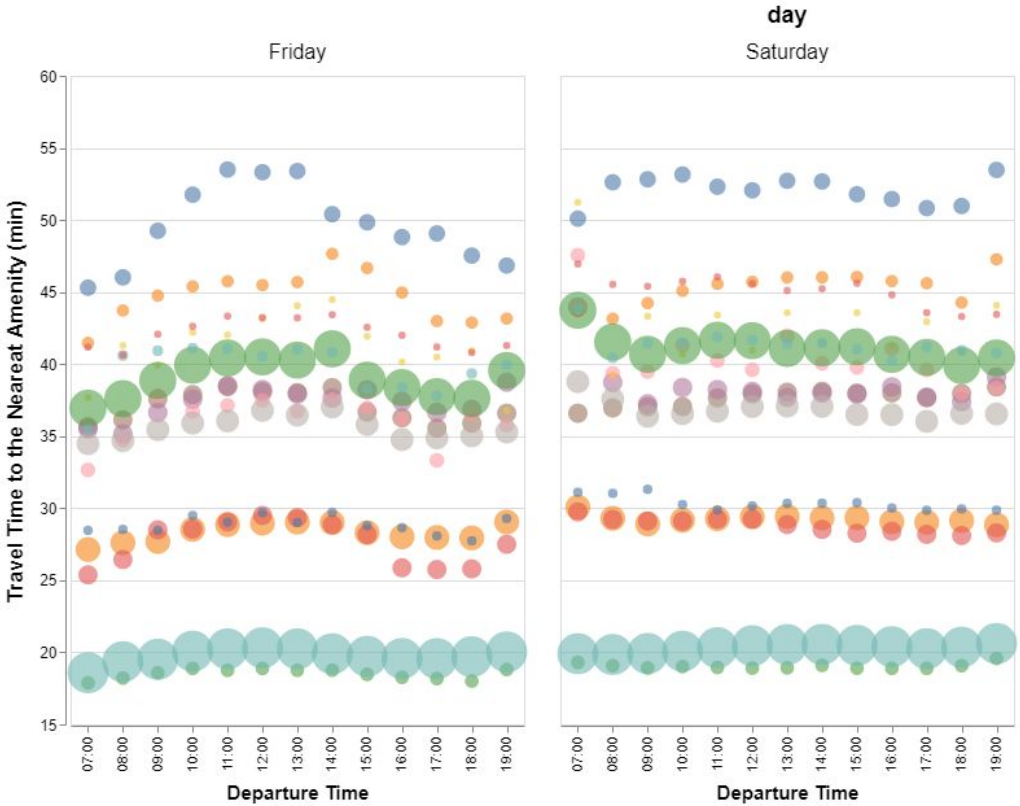
Do the **time of the day**, the **day of the week** have impacts on **transit time**?

By subdivisions, times, days

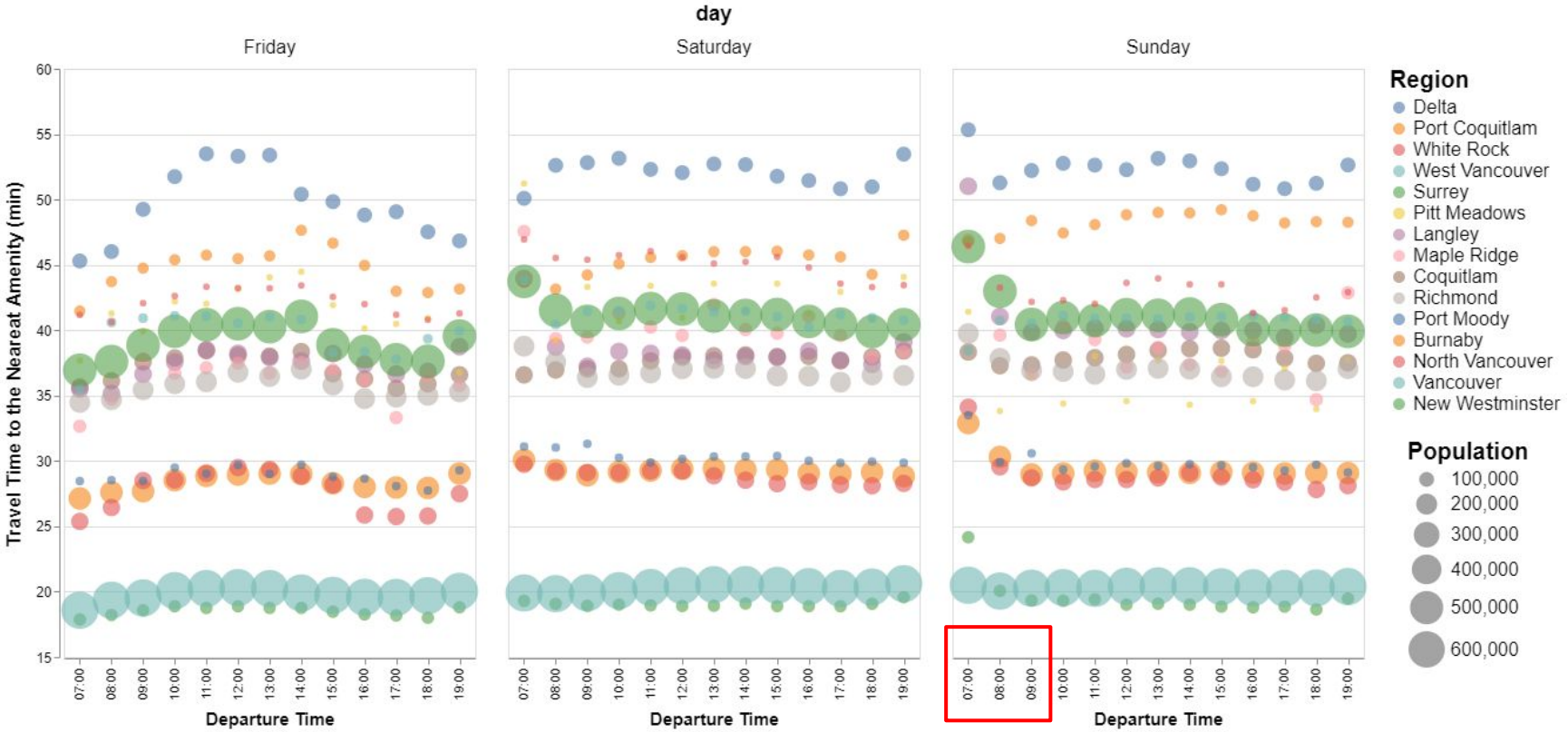


Peak hours

By subdivisions, times, days

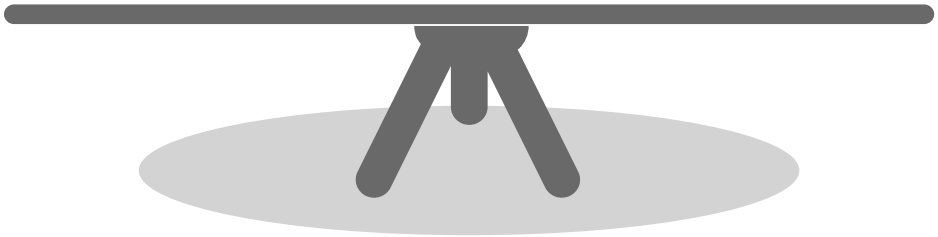


By subdivisions, times, days

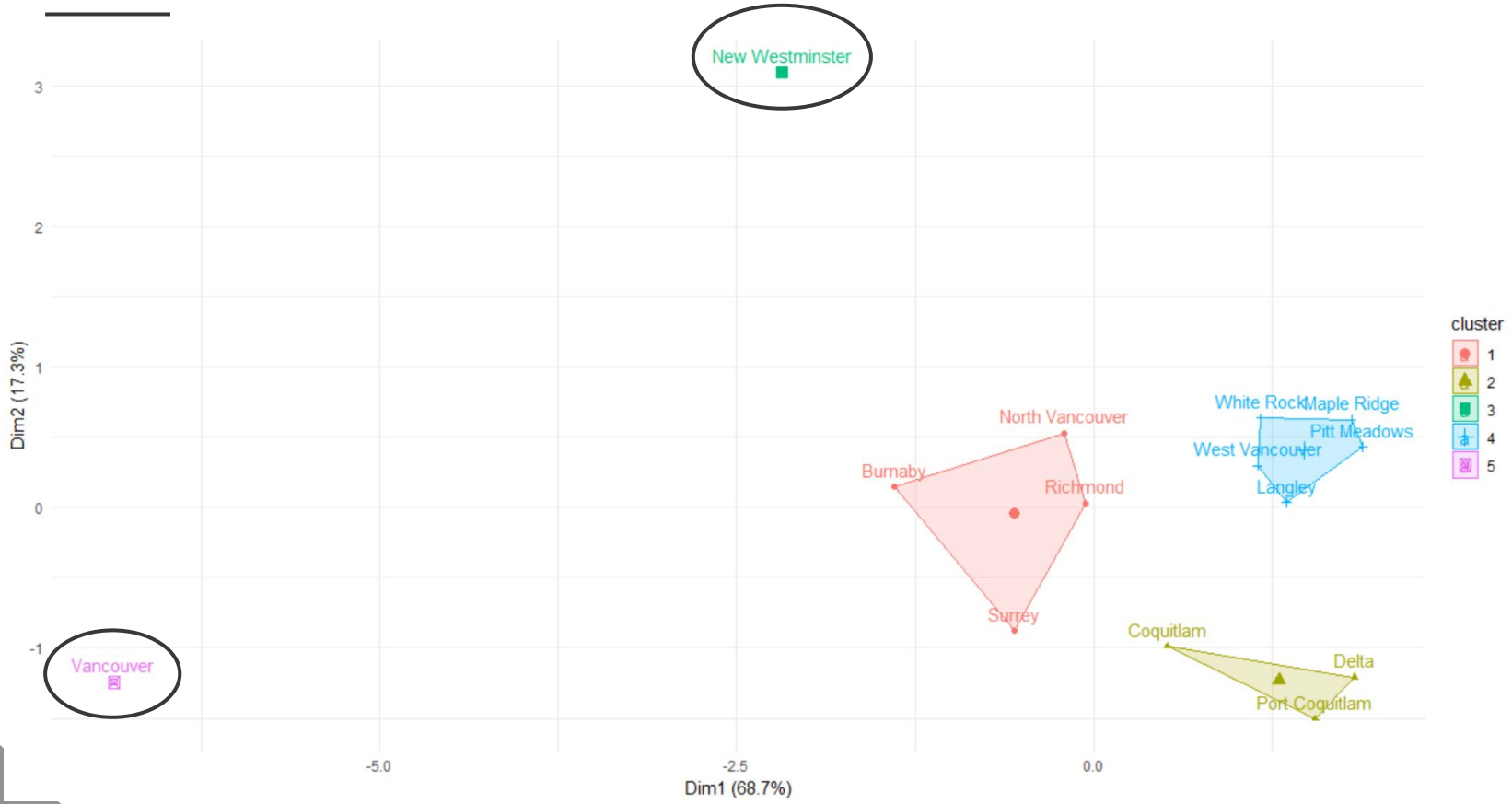


Service starts late

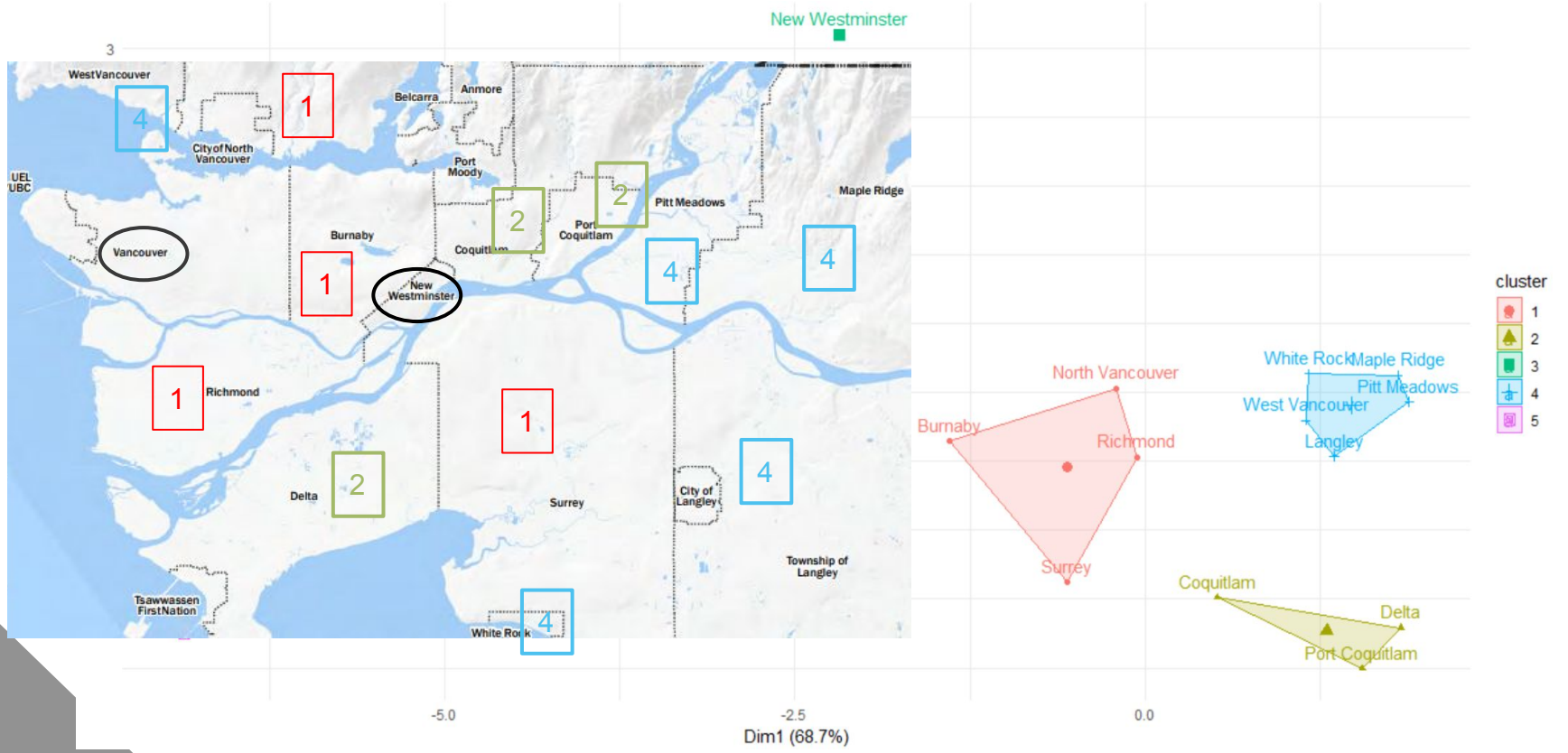
How do **subdivisions** differ regarding to **transit** and **amenities**?



Different influences on subdivisions



Different influences on subdivisions



How well does transit **accessibility** meet the **needs** of the community?

Transit Efficiency

- *How optimized is the transit network for cultural amenities?*

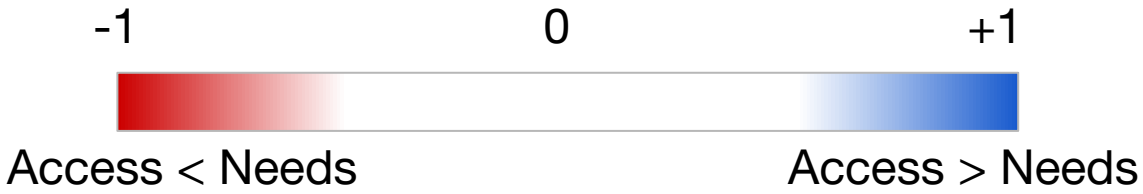
- Efficiency =

  how well **resources** for accessibility, match the **needs** for accessibility.

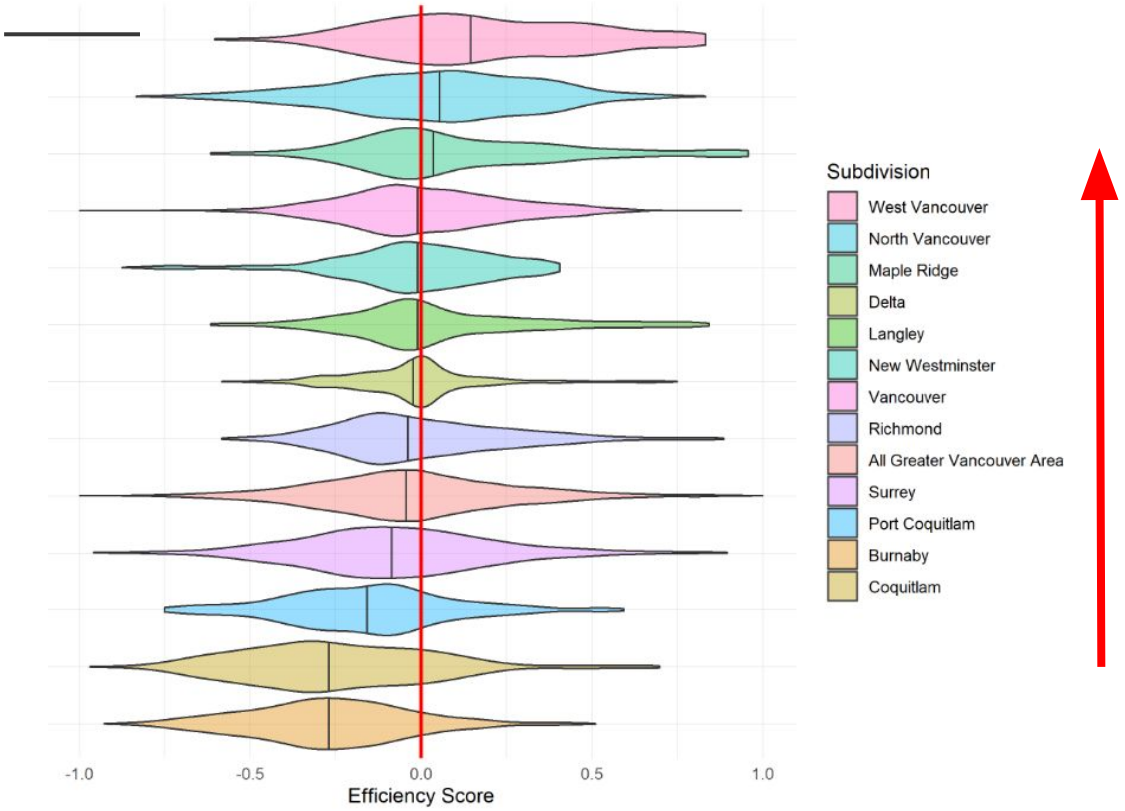
Transit Efficiency

Eff = norm$_{[-1, 1]}$ (%ile Accessibility Score - %ile Transit Network Needs)

This way we can visualize areas on both ends of the error spectrum:



Transit Efficiency



Increased Efficiency

6. Dashboard Demo

“See what no person has seen before”

7. Conclusions

Conclusions

Developed a **Scalable framework** for computing and visualizing transit accessibility measures.

Identified areas of high and low cultural-transit accessibility by **time**, **date**, and **amenity type** using our deployed dashboard.

8. Limitations & Future Work

8. Limitations & Future Work

Amenity Weights

Weights are too similar in value (0.4 - 0.6), thus do not alter the shape of score distributions

Need for more objective data sources

Estimated Transit Time

Does not consider: traffic, bus delays, max capacity busses, road construction, etc.

Traffic Data

Incorporate traffic congestion data into accessibility model

Account for pinch-points within the traffic network

Acknowledgements

We would like to acknowledge the time and effort of our advisors

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Bjenk Ellefsen

and to

All MDS faculty members

References

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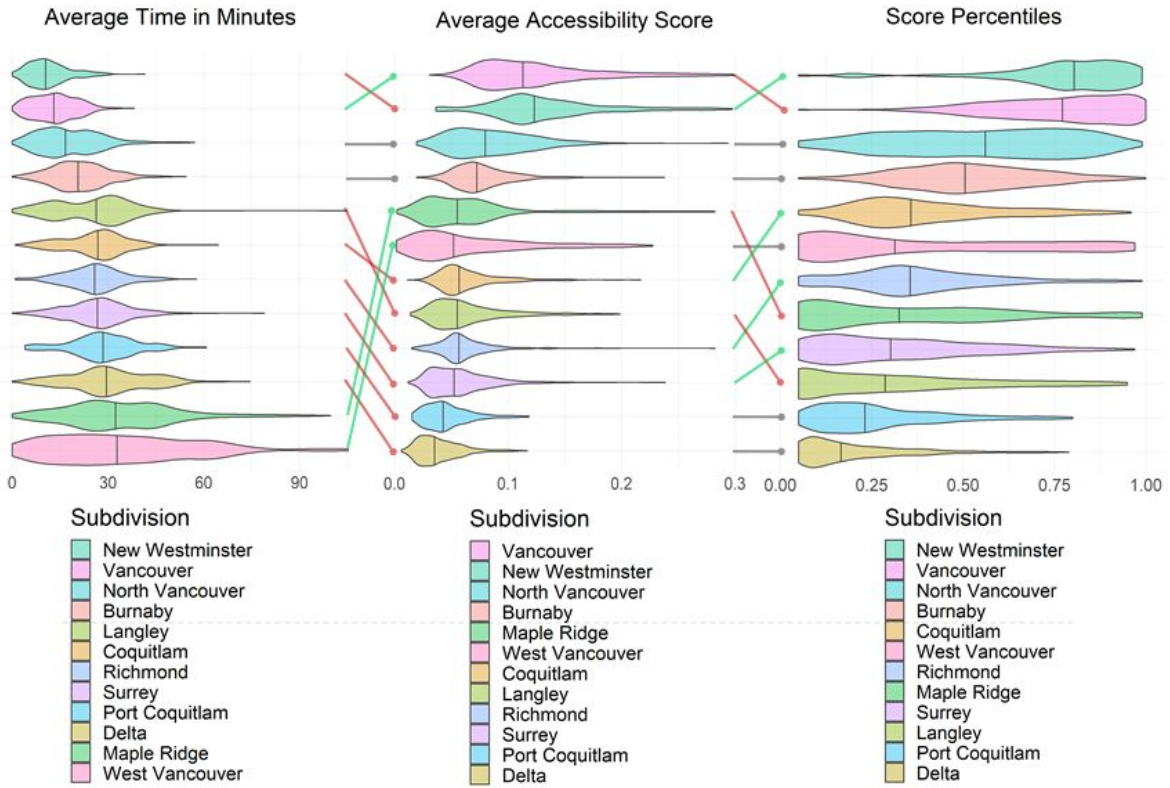
Thank You

Additional Slides

The Data We Used

Data	*Features*	*Source*
General Transit Feed Specification (GTFS)	All transit network data (stop coordinates, stop times, bus routes, etc.)	TransLink Open API
Dissemination Blocks (Origins)	Unique block ID, latitude, and longitude of the city block's centroid	Census of Population (Statistics Canada)
Amenities (Destinations)	Unique destination ID, types, latitude, and longitude	The Open Database of Cultural and Art Facilities (ODCAF)
OpenStreetMap (OSM)	Urban street network data	openstreetmap.org
Geospatial Shapefile	Dissemination block unique ID, longitude/latitude polygon data	Census Cartographic Boundary File (Statistics Canada)
'*Mass'* and Importance Features on Amenities	Operating Hours/Days, Visitors, Ratings, Reviews; Total space, total volume	Google API and BC Public Libraries Systems

Transit Measures Density by Subdivision



How Amenity Weights Affect the Score