Evaluating Transit Reliability: Comparing Travel Time and Travel Speed Approaches

Yuxuan Wang, Catherine Morency, Martin Trépanier

Polytechnique Montréal

Motivation

- Reliability is important for transit passenger satisfaction and agency operations.
- Need to improve reliability
- Better understand travel conditions
- Identify causes of delays
- Choose the right improvement strategy for a given location
- Develop more precise schedules

Literature Review

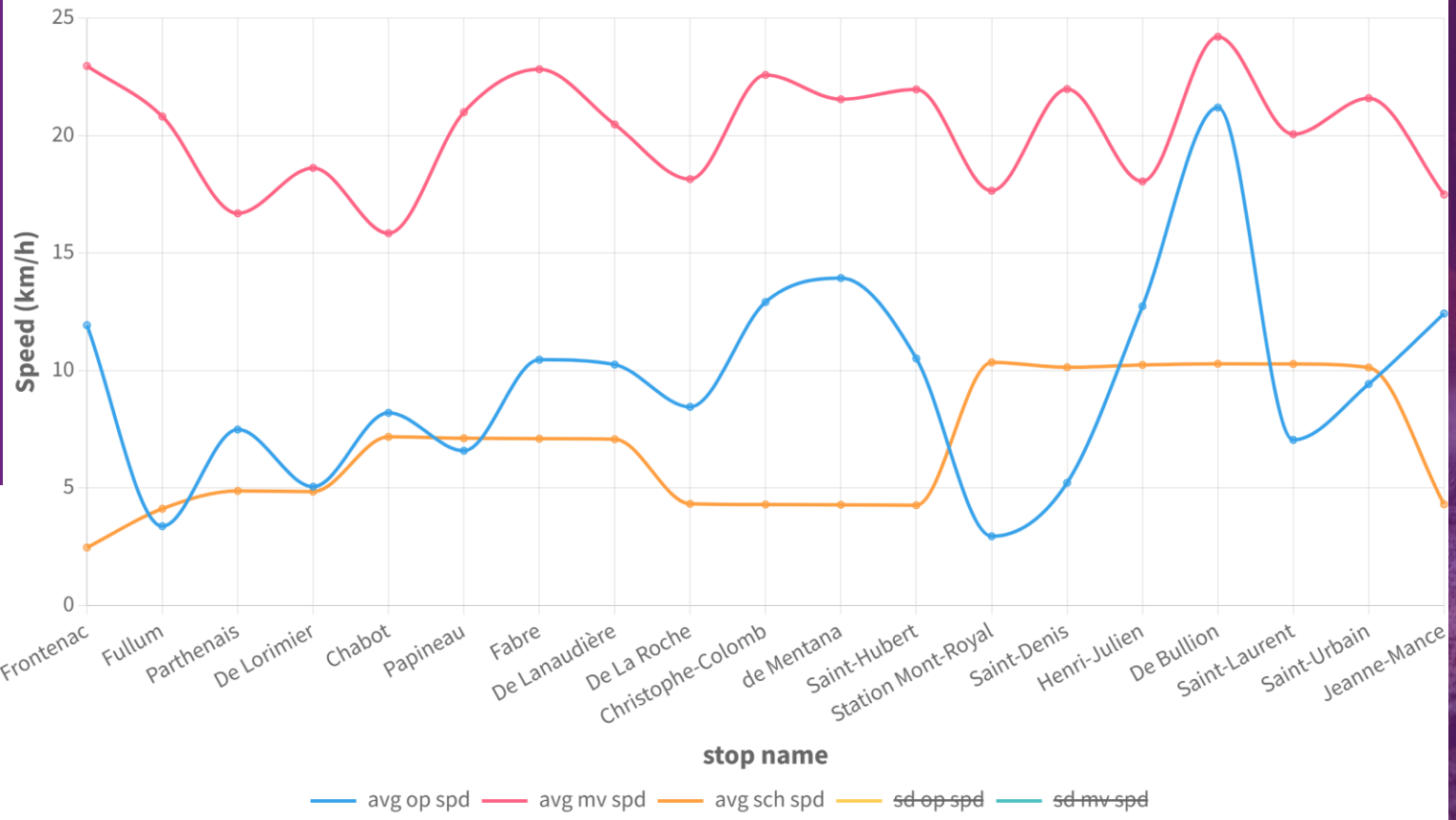
- Mainly focuses on travel time, comparison with planned schedules
- Indicators: on-time performance, timepoint to timepoint time, operation speed
- Diagnostic: classify services based on TCQSM or agency standards, then find issues causing low performance
- Factors affecting reliability: congestion, ridership variation, neighbourhoods, peak hours, service date, street design…
- Need: more detailed indicators to pin point causes of unreliability

Delay Example 1: Slow Travel Conditions

Delay Example 2: Crowding + Long Red Lights

Delay Example 3: Slow Travel Conditions + Crowding + Long Red Lights

Idea: Travel Speed?



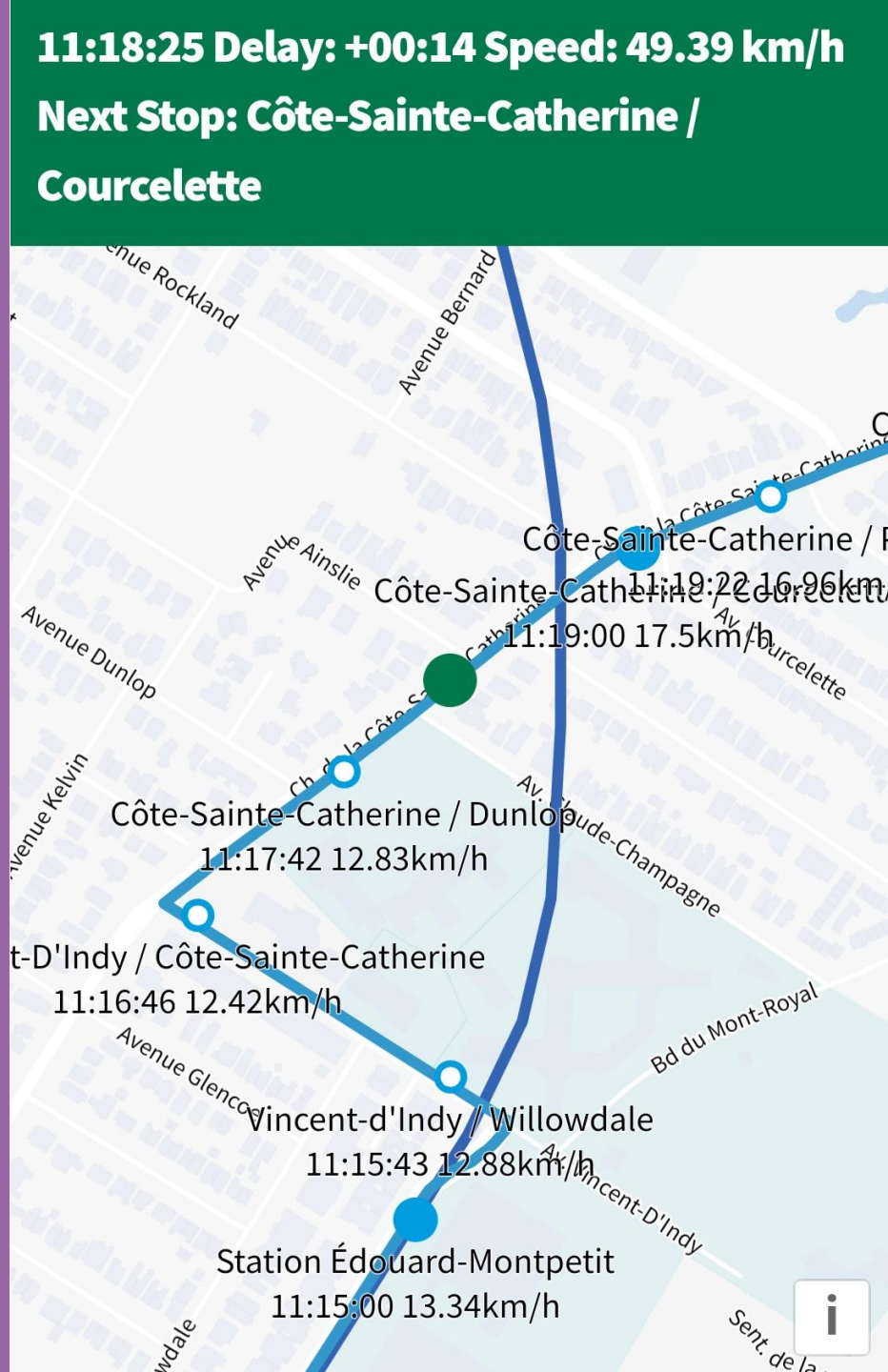
Idea: Travel Speed?

- Delays: How fast can we go? How long are we going to get stuck?
- Remove distance (somewhat) from the equation
- More intuitive to understand travel conditions using travel speeds
- Easier to compare between segments using travel speeds
- Railway scheduling: Line speed, train speed (freight vs passenger), and dwell time profile required to schedule train positions, meeting, and passing events, then translate to arrival and departure times.

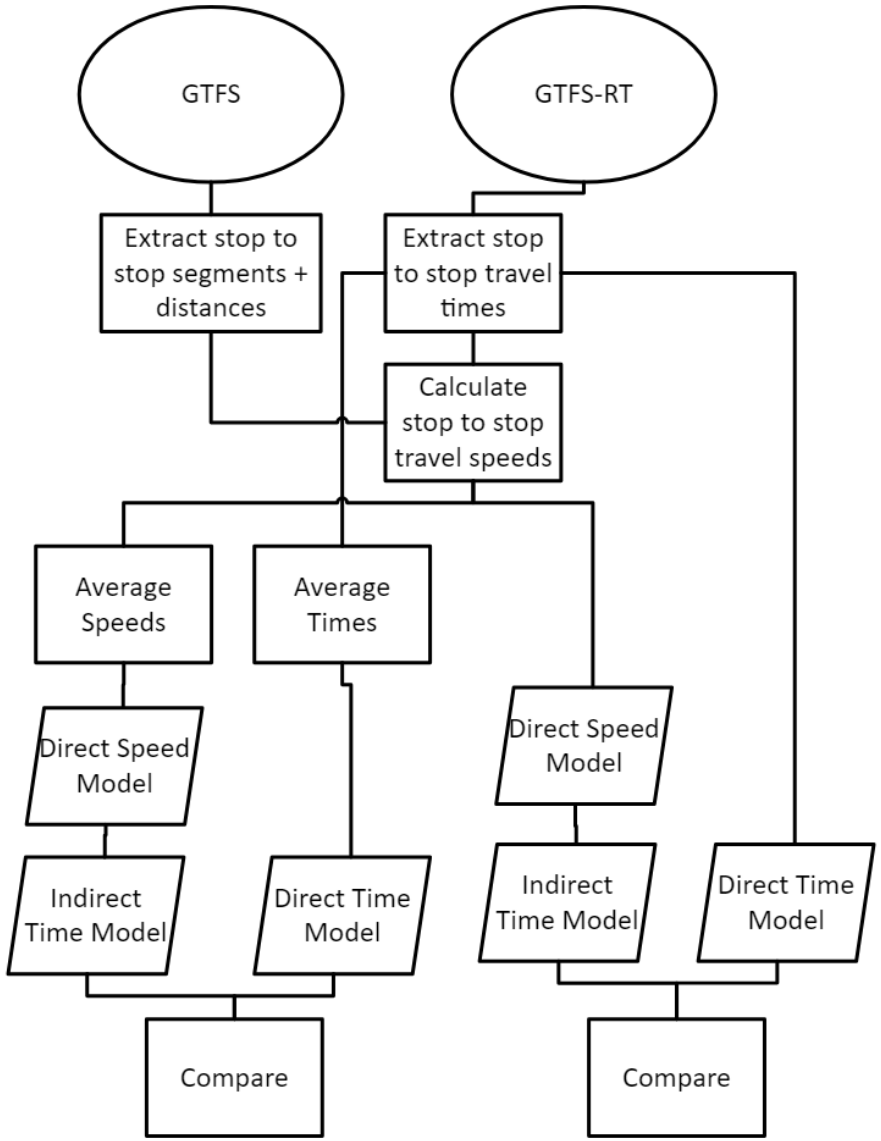
Research Data

- Data: STM GTFS + GTFS-RT
- Update: 5 ~ 20 seconds
- Date: May 1, 2021 -> Apr 1, 2023
- Validated by: High frequency GPS data collected by me!

- 217 lines
- 2022 buses
- 17000+ bus trips on weekdays
- 10322 stop to stop segments



Research Framework

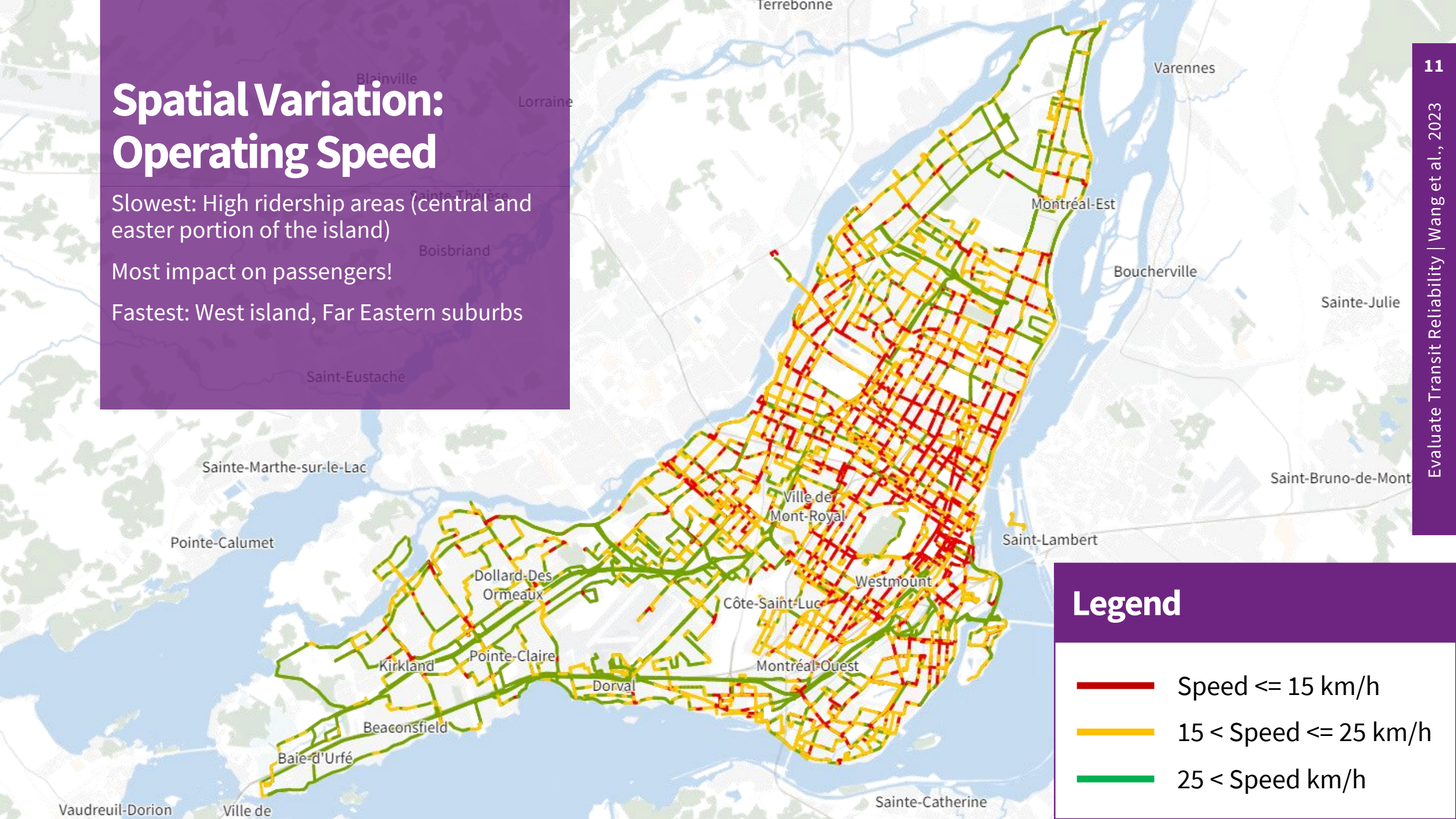


Spatial Variation: Operating Speed

Slowest: High ridership areas (central and easter portion of the island)

Most impact on passengers!

Fastest: West island, Far Eastern suburbs



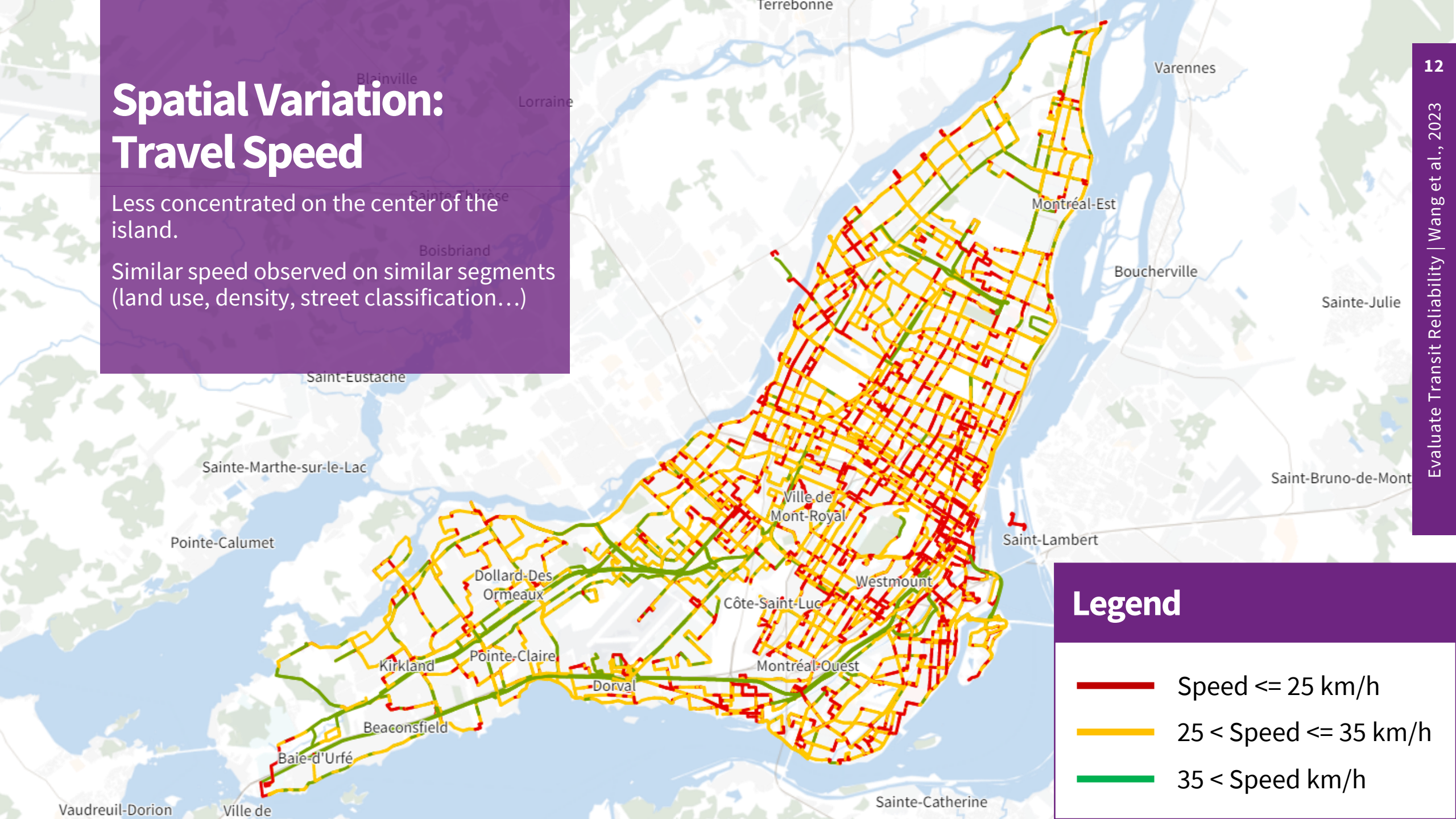
Legend

- Speed <= 15 km/h
- 15 < Speed <= 25 km/h
- 25 < Speed km/h

Spatial Variation: Travel Speed

Less concentrated on the center of the island.

Similar speed observed on similar segments (land use, density, street classification…)



Legend

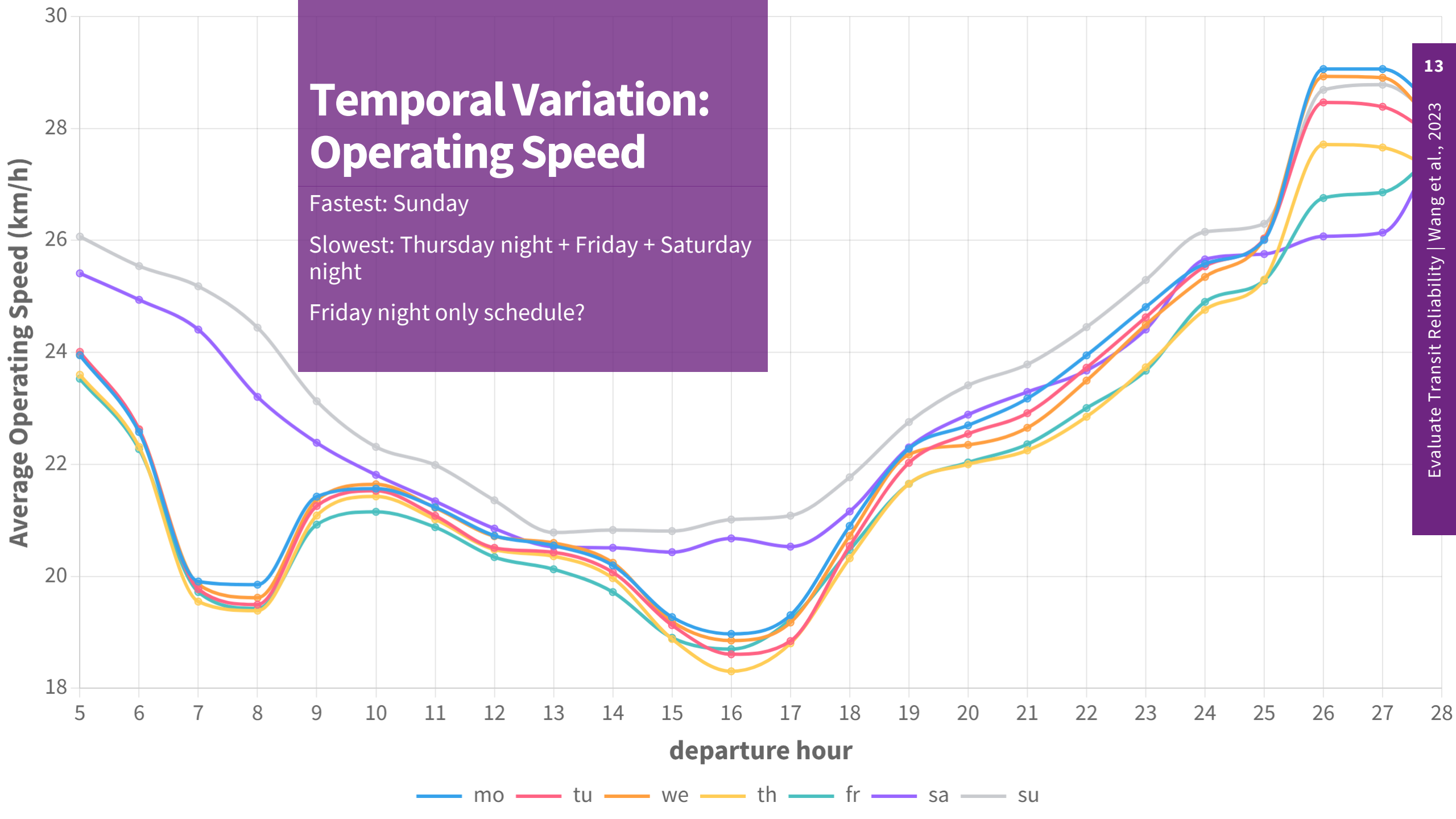
- Speed <= 25 km/h
- 25 < Speed <= 35 km/h
- 35 < Speed km/h

Temporal Variation: Operating Speed

Fastest: Sunday

Slowest: Thursday night + Friday + Saturday night

Friday night only schedule?

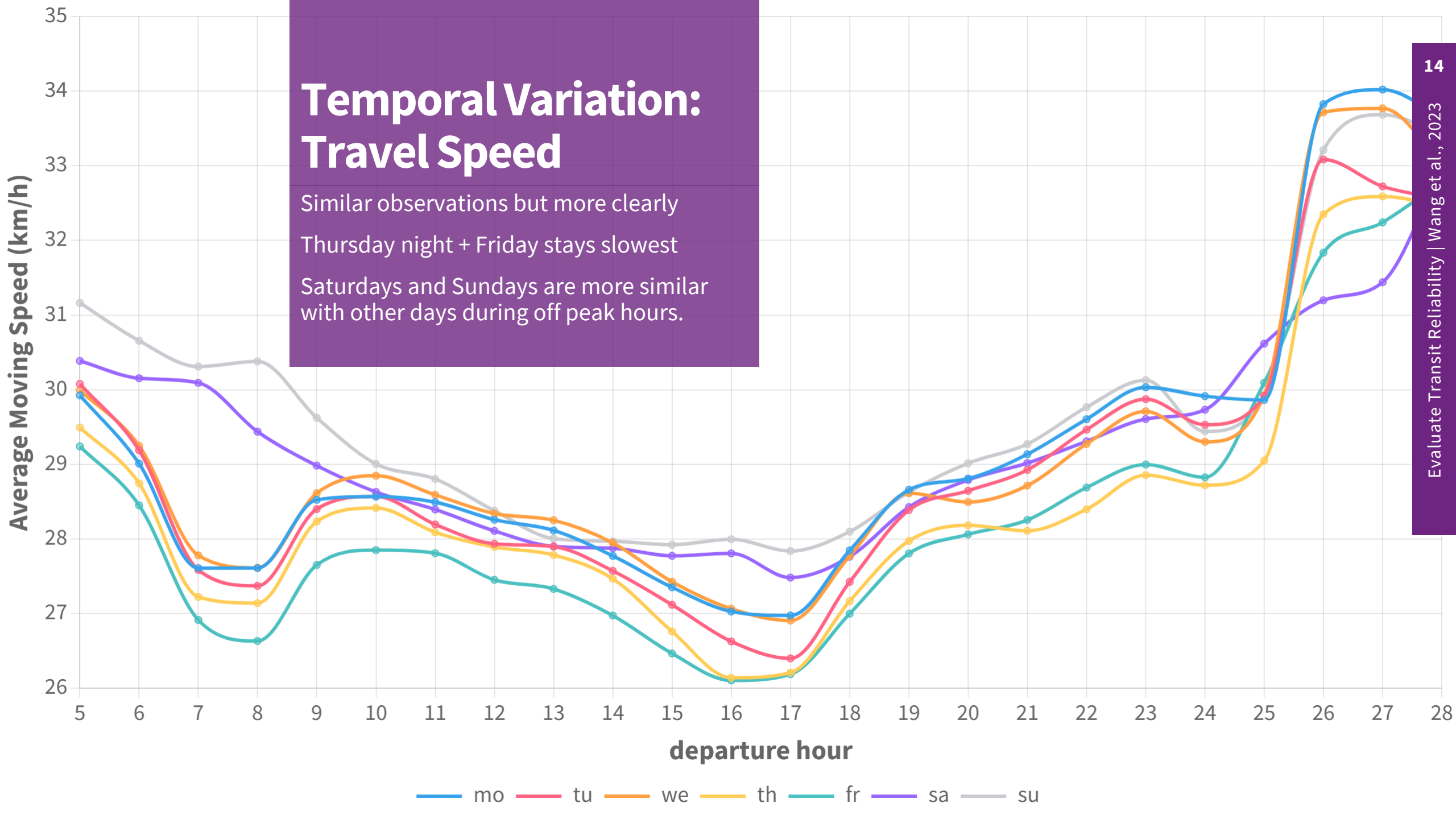


Temporal Variation: Travel Speed

Similar observations but more clearly

Thursday night + Friday stays slowest

Saturdays and Sundays are more similar with other days during off peak hours.



Modeling

- Models:
  - Ordinary Least Square (Simple linear)
  - Regression Tree (Simple non-linear)
  - Random Forest (Complex non-linear)
- Dependent Variables:
  - Average operating speeds (km/h)
  - Average travel speeds (km/h)
  - Individual operating speeds(km/h)
  - Individual travel speeds(km/h)
  - Average stop to stop times (sec)
  - Average travel times (sec)
  - Individual operating times (sec)
  - Individual travel times (sec)

Input Variables

- Temporal
  - Time of the day
  - Day of the week
  - Service changes (to come)
- Spatial
  - Segment length
  - Land use
  - Has bus lanes
  - Number of turns
  - Traffic lights
  - Stop signs
  - Neighbourhood (to come)
- Operational
  - Average passenger loads
  - Service frequency

Model Evaluation

- Absolute
  - R^2
  - RMSE
  - MSE
  - MAE
- Relative
  - MAPE

Preliminary Models

- More variables to come…
- Generally confirms previous observations
- In addition, number of turns, and number of traffic lights have a great impact on the speed

	Ind Travel Speed	Ind Operating Speed	Avg Travel Speed	Avg Operating Speed
Intercept	25,51	21,91	25,36	24,96
Sat	0,55	1,10	0,59	0,65
Sun	1,11	1,76	1,10	1,20
Early AM	1,89	3,35	1,75	2,58
AM Peak	0,16	0,13	0,86	1,15
PM Peak	-0,64	-0,85	-0,54	-0,49
Evening	0,47	1,13	0,31	0,97
Late Eve	1,47	2,89	2,23	3,62
Load	-0,03	-0,11	-0,11	-0,49
Delay	0,00	0,00	0,01	0,01
Service Freq	-0,07	-0,08	-0,07	-0,08
Num Turns	-3,39	-2,17	-3,27	-3,24
Traffic Lights	-0,92	-1,34	-0,86	-2,34
Avg Lanes	0,24	0,20	0,77	0,57
Speed Limit	0,02	0,08	0,19	0,13
has Bus Lane	-0,67	-0,27	-1,00	0,85
Oneway	-0,29	0,00	1,05	-1,63
Length	0,01	0,01	4,77	8,51
Mix	-0,01	-0,01	-0,75	-0,62
Downtown	0,00	0,00	-2,32	0,20
Industrial	0,00	0,00	-1,10	-1,02
Pop. Density	-0,31	-0,51	-0,42	-0,63

Model Comparisons - Average Speeds

		Operating			Travel		
		Linear	Forest	Tree	Linear	Forest	Tree
Speed Model	RMSE	6,171	2,620	2,834	5,524	1,924	2,110
	R2	0,432	0,898	0,881	0,401	0,927	0,913
	MSE	38,084	6,862	8,031	30,510	3,701	4,454
	MAE	4,868	1,881	1,840	4,277	1,265	1,271
	MAPE	0,265	0,098	0,092	0,173	0,048	0,047
Indirect Time Model	RMSE	43,089	15,496	14,525	37,817	11,243	10,664
	R2	0,510	0,931	0,939	0,537	0,959	0,963
	MSE	1856,662	240,116	210,975	1430,090	126,411	113,712
	MAE	11,234	8,432	7,866	9,800	4,349	4,208
	MAPE	0,256	0,145	0,143	0,183	0,093	0,093
Direct Time Model	RMSE	23,386	10,352	10,422	19,976	8,028	7,661
	R2	0,844	0,969	0,969	0,874	0,980	0,982
	MSE	546,904	107,172	108,608	399,045	64,442	58,695
	MAE	14,787	5,278	5,348	11,170	2,863	3,035
	MAPE	0,293	0,100	0,103	0,281	0,063	0,072

Model Comparisons - Actual Speeds

		Operating			Travel		
		Linear	Forest	Tree	Linear	Forest	Tree
Speed Model	RMSE	7,368	3,653	3,659	7,760	5,535	5,571
	R2	0,157	0,793	0,792	0,124	0,554	0,548
	MSE	54,286	13,344	13,388	60,213	30,632	31,032
	MAE	5,620	2,193	2,101	5,953	4,050	3,969
	MAPE	0,418	0,138	0,130	0,300	0,192	0,183
Indirect Time Model	RMSE	16,441	10,413	9,785	14,471	10,329	9,736
	R2	0,512	0,859	0,876	0,563	0,778	0,802
	MSE	270,307	108,421	95,739	209,400	106,679	94,781
	MAE	12,952	6,335	5,931	9,012	6,188	5,833
	MAPE	0,324	0,121	0,116	0,241	0,167	0,167
Direct Time Model	RMSE	22,971	9,551	9,139	13,769	9,301	8,765
	R2	0,321	0,883	0,892	0,607	0,821	0,841
	MSE	527,658	91,223	83,516	189,574	86,507	76,821
	MAE	17,259	6,133	5,682	9,581	6,032	5,506
	MAPE	0,417	0,130	0,120	0,296	0,188	0,172

Discussion

- Better communicate speeds to the drivers
- More important to improve slower sections
- Spatial temporal variables explains travel speeds better
- Improve operating time / speed models with additional variables (dwell, signals)
- Direct models have low RMSE but high MAPE
- Speed less affected by noise
- Need to determine which metric is more suitable for transit planning

Limitation + Next Steps

- Add additional datasets such as weather to the models
- Detours are not considered
- Distinguish passenger activity delays and traffic light delays
- Investigate more detailed passenger experiences and impacts
- Analyze passenger transfers

Thank you!
Questions?

Yuxuan Wang
Catherine Morency
Martin Trépanier

Polytechnique Montréal

Photo credits: Yuxuan Wang