Decomposition and sensitivity analysis of bus travel times

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Motivation

- Reliable travel time is important for transit passenger satisfaction and agency operations

- Better understand travel conditions

- Identify issues causing travel time variations

- Choose the right improvement strategy for a given location

- Develop more precise schedules

Literature Review

- (Paper 1) Traffic lights + Ridership variations -> Mixture travel time distributions -> Harder for scheduling + operations

- (Paper 2) Travel times / speeds are much easier to model without dwell times and signals.

- Traffic light studies mostly simulation based with equal cycle lengths

- Travel Times aggregated by hours whereas lights can change by minutes

Idea / Question

- Decompose travel times with more detailed information

- Analyze the sensitivity of travel times according to each trip steps (departure time, inter-stop speed, dwell time, traffic lights…)

- Where does the travel time variations come from?

- How much travel time variations can be attributed to each step?

Decompose travel time

Sensitivity analysis of bus travel times
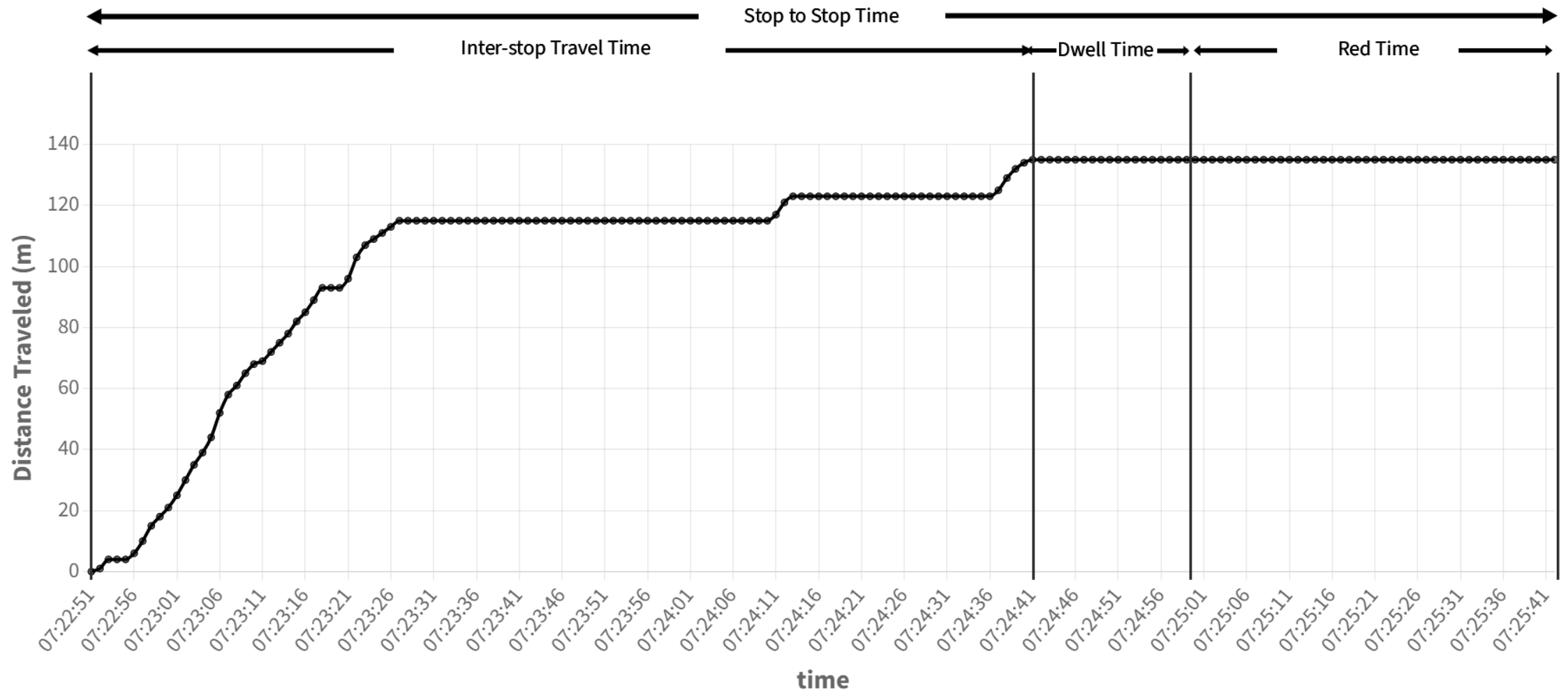
Example: 27-O 06:30

Arrêt / Feu	Action	Heure	Feu
Laurier / Jeanne-d'Arc	Depart	06:30:00	-
Laurier / Pie-IX	Check Light	06:30:15	🟢 16
	Depart	06:30:15	🟢 16
Pie-IX / Saint-Joseph	Dwell	06:30:50	-
	Check Light	06:30:57	🔴 13
	Depart	06:31:10	🟢 59
Saint-Joseph / Bourbonnière	Dwell	06:32:09	-
	Check Light	06:32:35	🔴 5
	Depart	06:32:40	🟢 57
Saint-Joseph / 18e Avenue	Check	06:32:53	🟢 65
	Depart	06:32:53	🟢 65
Saint-Joseph / No 3600	Dwell	06:33:20	-
	Check Light	06:33:29	🟢 33
	Depart	06:33:29	🟢 33
Saint-Joseph / 13e Ave	Dwell	06:33:53	-
	Depart	06:34:01	-
Saint-Joseph / Saint-Michel	Dwell	06:34:24	-
	Check Light	06:34:39	🔴 18
	Depart	06:34:57	🟢 44

Framework
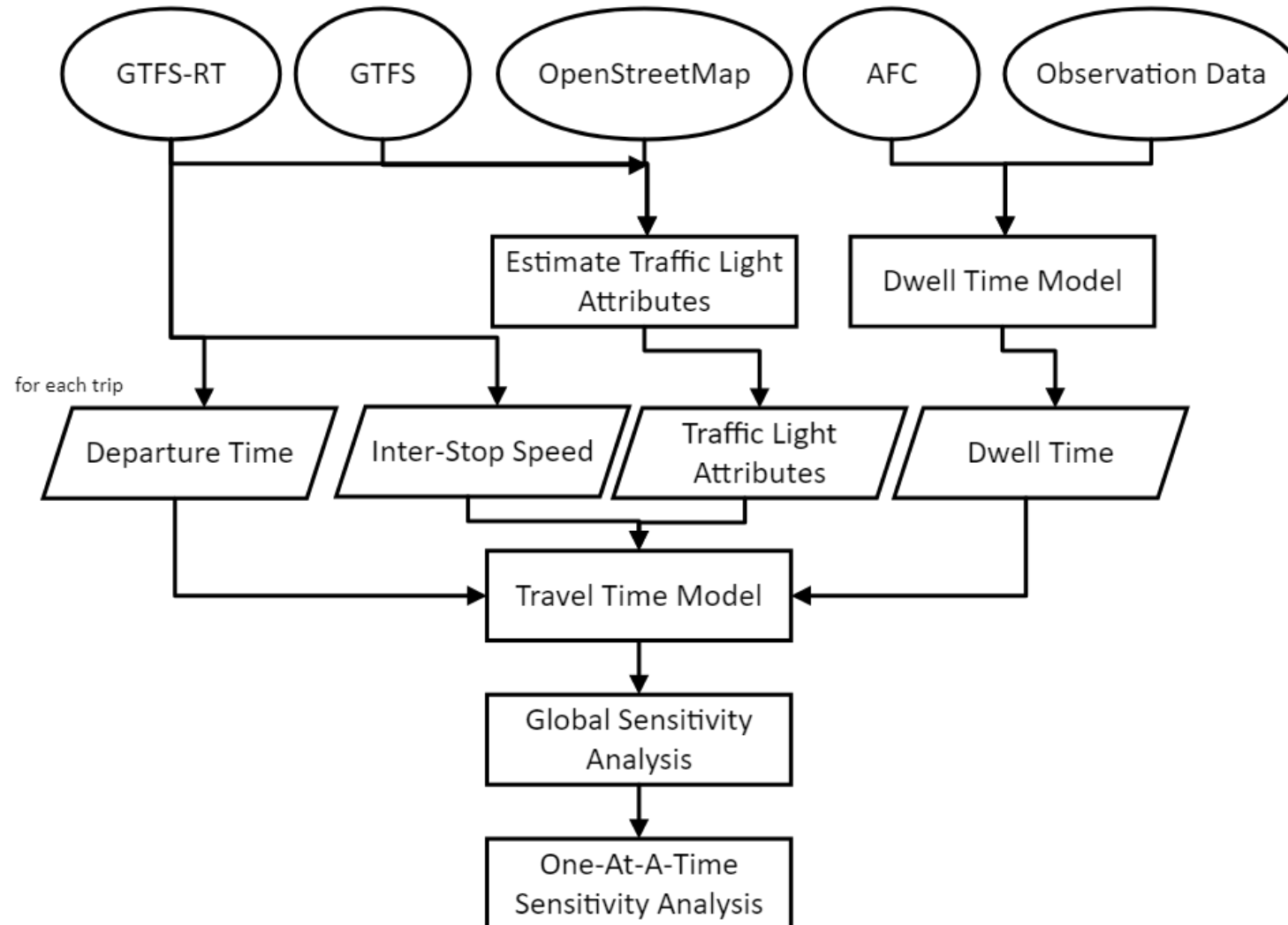
Global Sensitivity Analysis

- Based on variance decomposition (Sobol Method)

- Deals with interactions, non-linearity

- Allows to rank the importance of each variable

- First order index
  - Percent variations of result Y attributed to a given variable X without interaction effects

- Total order index
  - Percent variations of result Y attributed to a given variable X with interaction effects
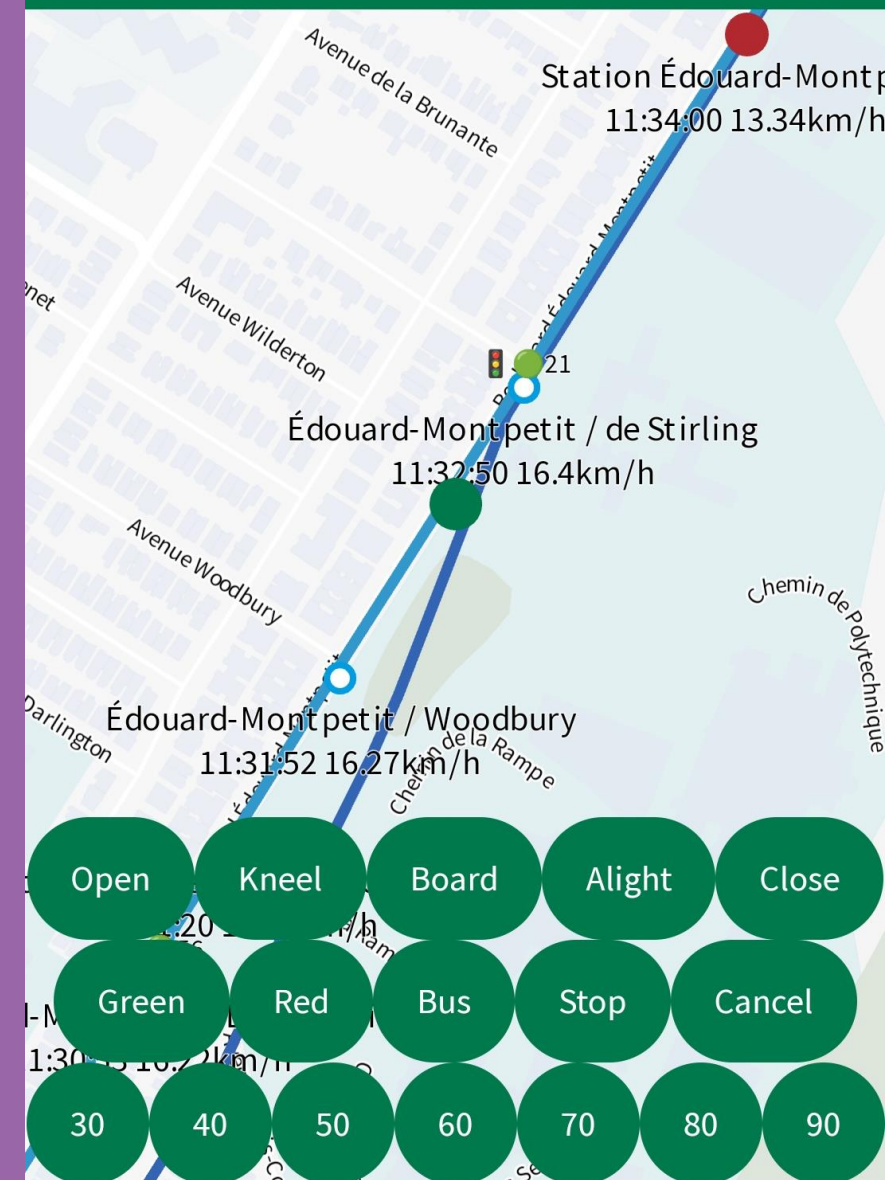
Case Study: STM

- Observation
  - Jan 2024
  - 20 Routes

- Planned service: GTFS

- Delivered service: GTFS-RT

- Ridership + Dwell Time
  - Observation on board vehicles
  - AFC

- Traffic Lights:
  - OpenStreetMap
  - Infer phases and cycles from GTFS-RT
 - Verification on board + at intersections

11:32:52 Delay: +00:24 Speed: 48.57 km/h

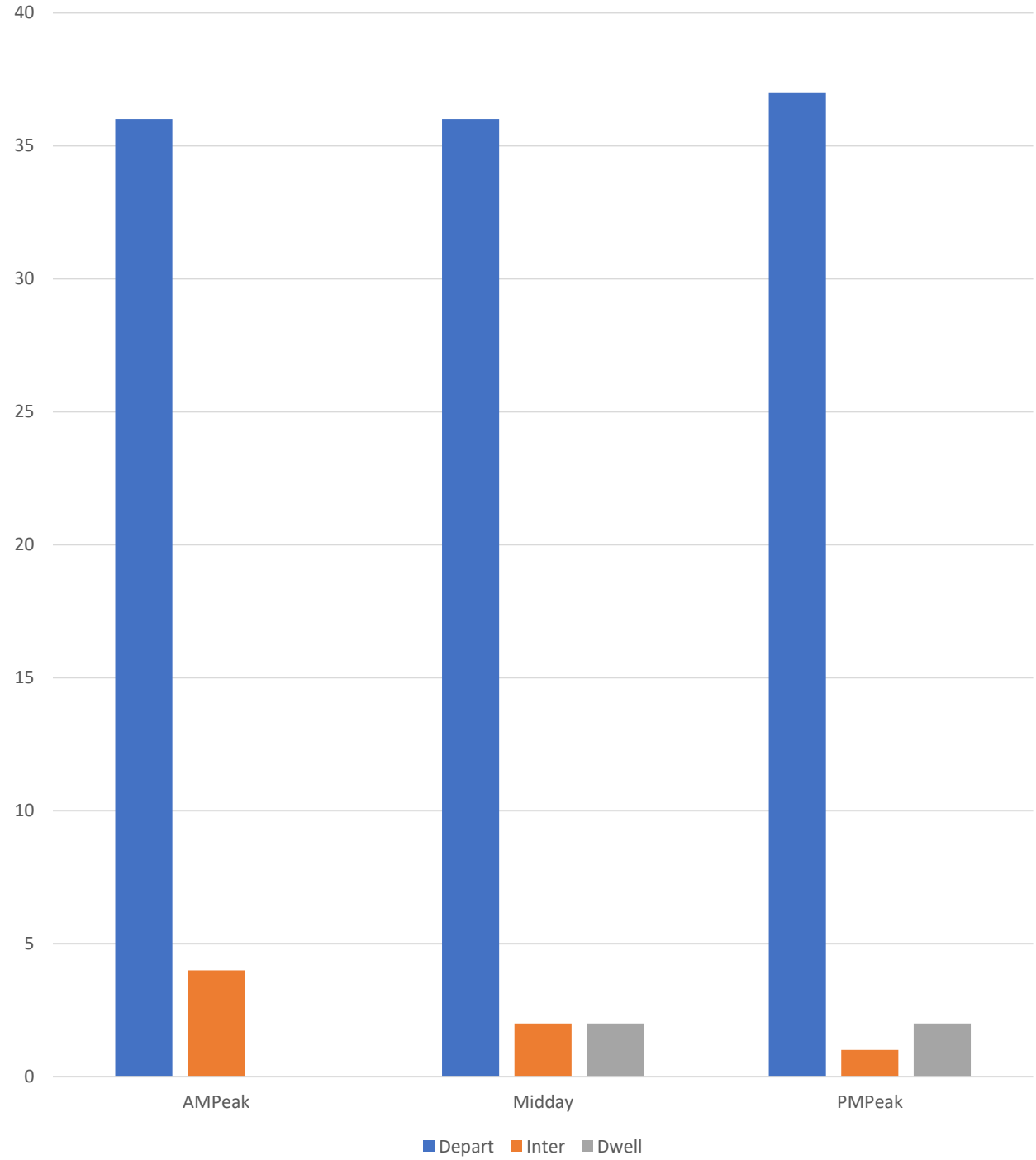To: Édouard-Montpetit / de Stirling

Station Édouard-Montp
11:34:00 13.34km/h

Édouard-Montpetit / de Stirling
11:32:50 16.4km/h

Édouard-Montpetit / Woodbury
11:31:52 16.27km/h

Open	Kneel	Board	Alight	Close
Green	Red	Bus	Stop	Cancel
30	40	50	60	70	80	90

Travel Time Sensitivity

- First Order Most Important
  - Departure: 25%
  - Dwell: 25%
  - Inter stop: 50%

- Total Order Most Important
  - Departure: 50%
  - Dwell: 12,5%
  - Inter stop: 37,5%

- Temporal changes during the day
  - Departure time less important later in the day
  - Inter-stop speeds become more important later in the day

- Red times vary the most
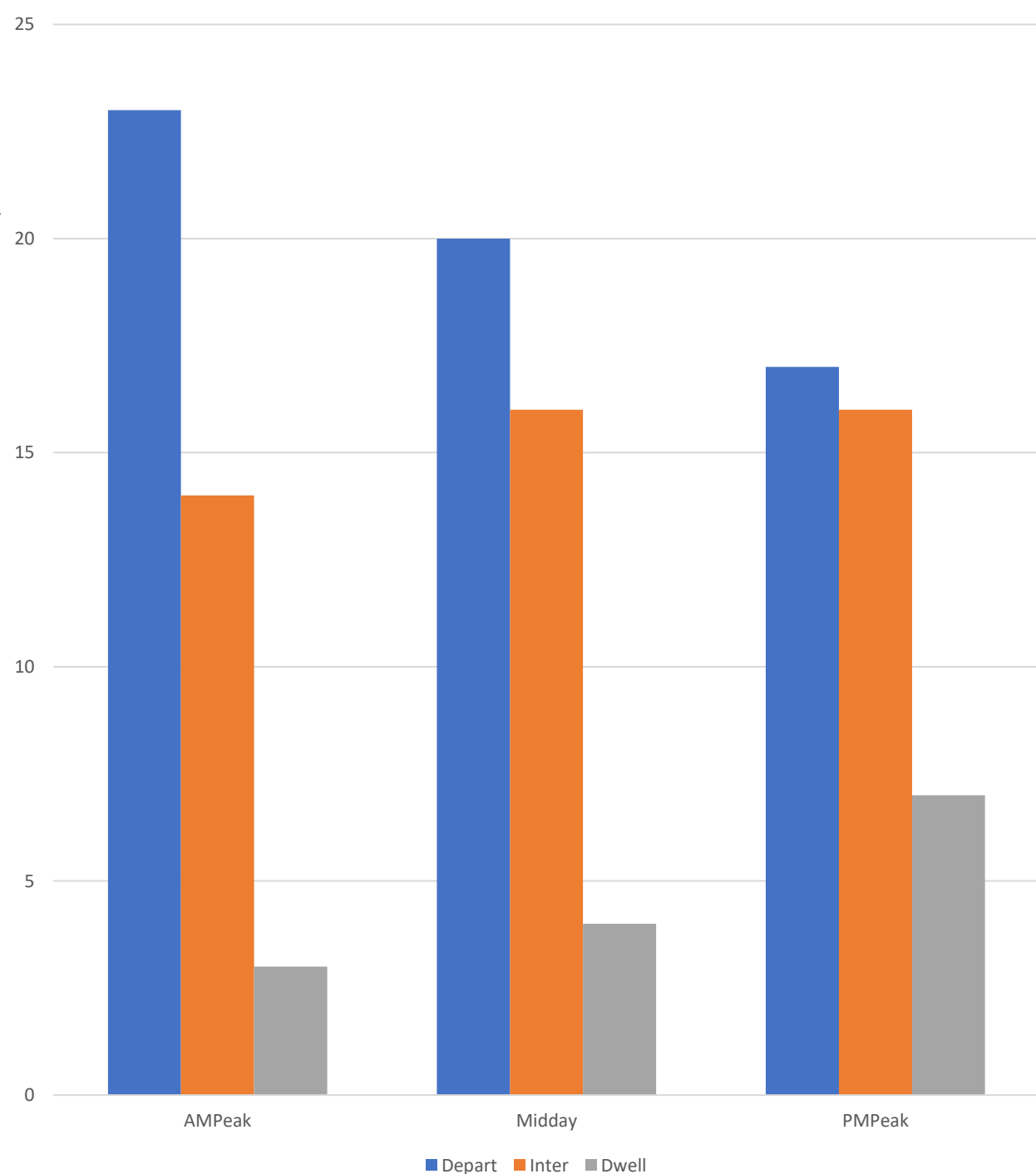
Red Time Sensitivity

- 20 ~ 25% Travel Time
- First Order Most Important
  - Departure: 62,5%
  - Dwell: 18,75%
  - Inter stop: 18,75%
- Total Order Most Important
  - Departure: 92,5%
  - Inter stop: 7,5%
- Really important to choose the right moment to depart
- Need to consider red time variations for scheduling

Visualization

Shows temporal variations

Easier for planners to prioritize resources and utilise their local knowledge.

Sensitivity analysis of bus travel times

AM

Midday

PM

Departure Time Changes

- Impose the same interstop speed, dwell, and light settings

- Travel + Red times changes 4 minutes within 10 minute

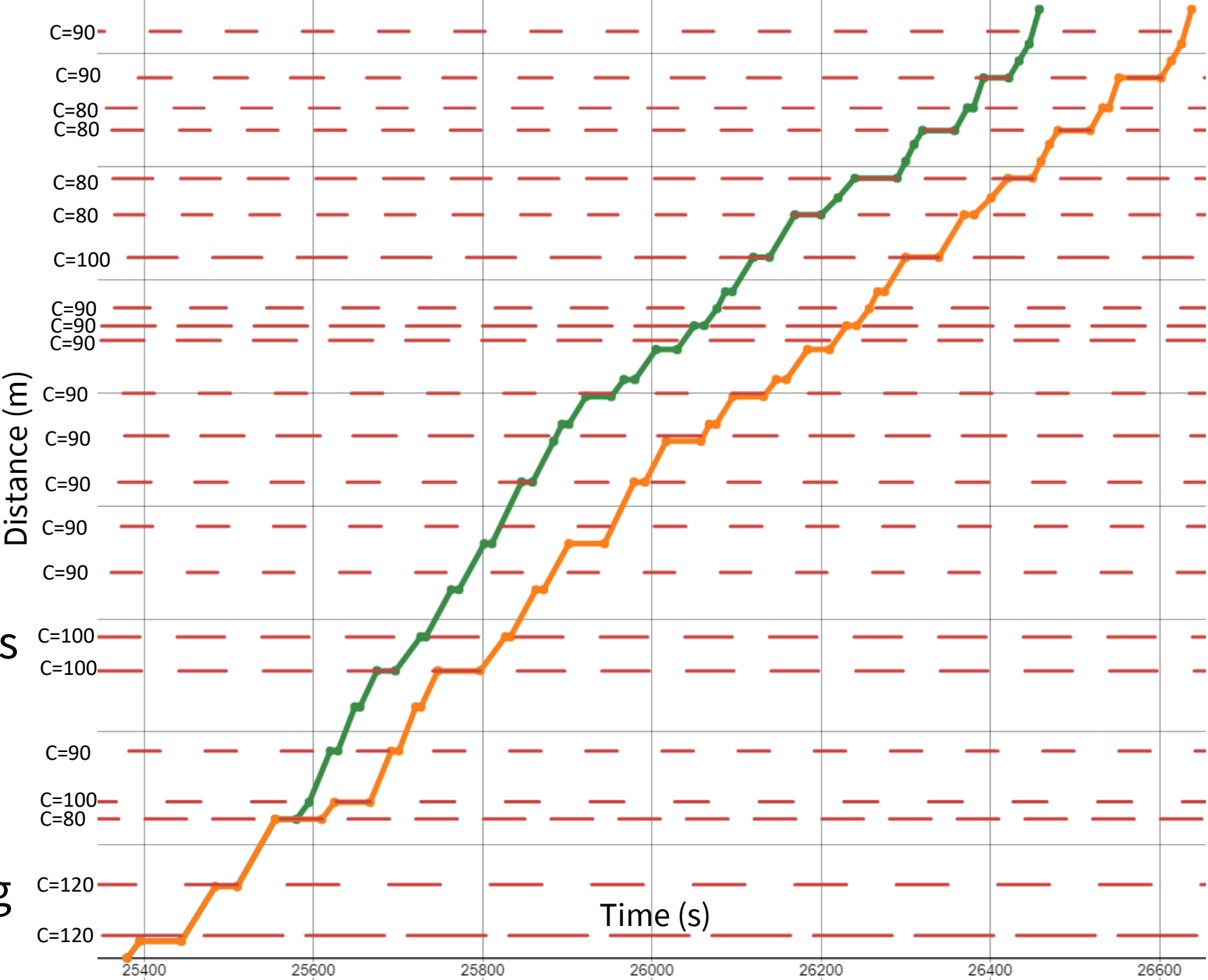- Real-Time observations are CONDITIONAL averages
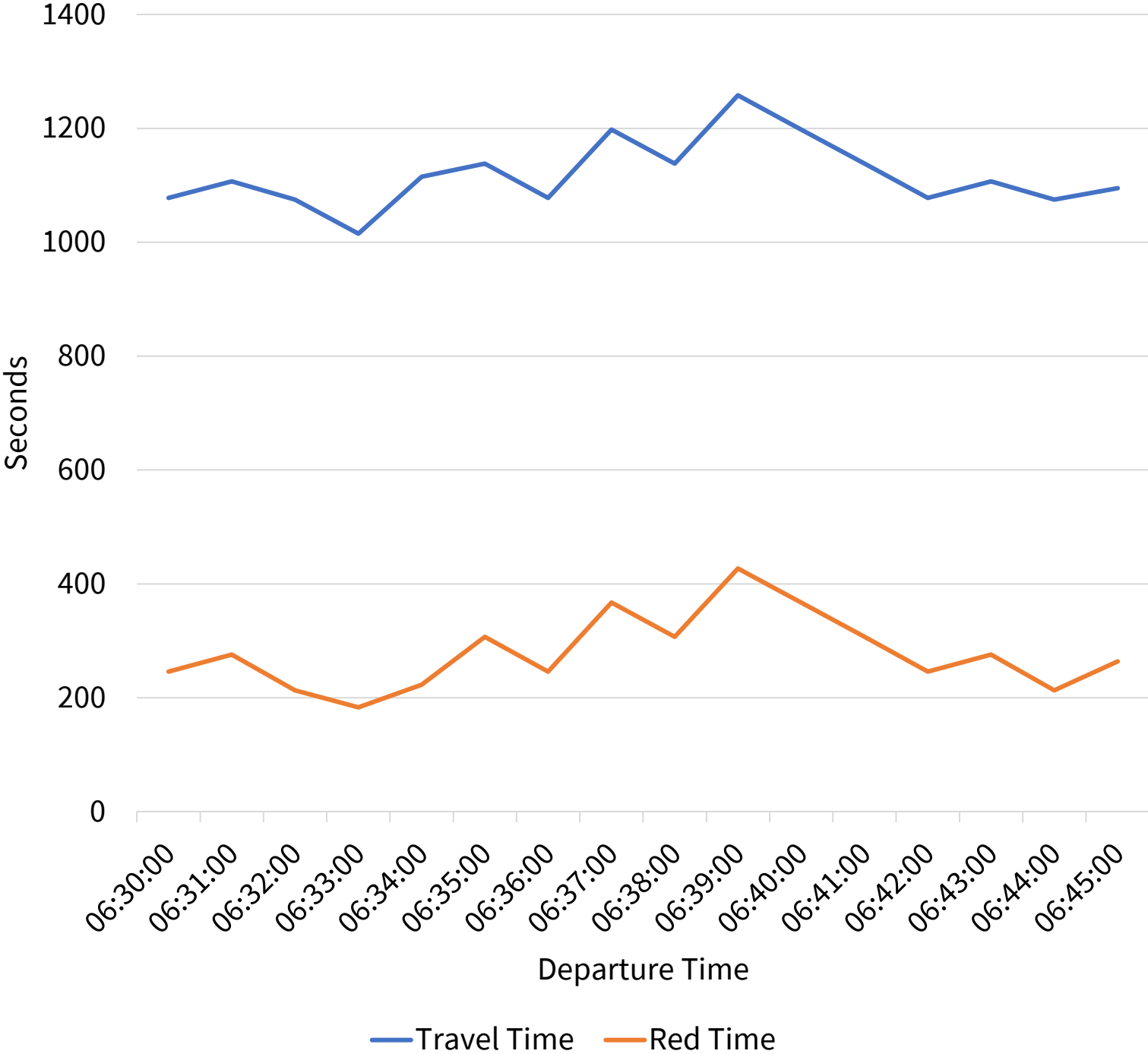
Ridership Changes

- Impose the same departure, inter-stop, and light settings
- Skip less used stops
  - 16:36, 6:46:36
- Make all stops
  - 17:53, 6:47:53
- Make all stops with extra crowding
  - 19:55, 6:49:55
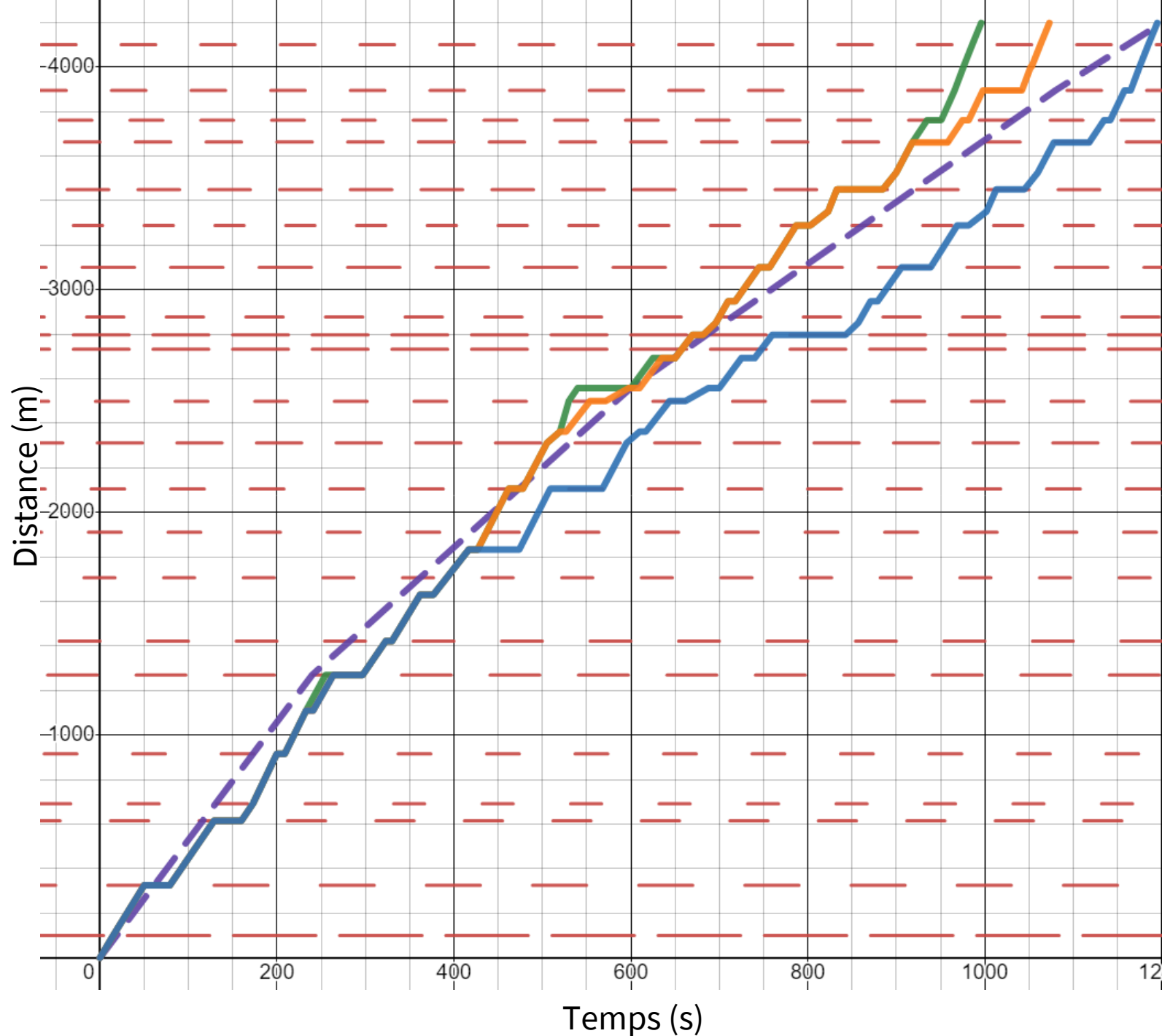
Traffic Light Changes

- Keeping same departure, interstop, dwell times

- Timing plan version Jan 2024 vs Sep 2023

- Travel + Red times increased by 3 minutes

- Because green waves don't line up

- Consider the impact for bus when changing timing plans

Conclusions

- We can better decompose the travel times by adding more details (lights, ridership)

- Observations are conditional, may need more thinking before applying the travel times to nearby departure times

- Better choose the right strategy to improve service and revise schedules

- Framework can be applied elsewhere, but results may differ

- For fixed signal timing plans:
  - Important choose the right time to depart
  - Be careful when changing traffic light synchronizations
  - Make priority light decisions earlier + more aggressive

Limitations + Future Works

- Need to consider interaction between buses (Same route, different routes, local vs limited routes)

- Need longitudinal, temporal, and spatial analysis to discover the trend

- Better understand impacts of non-fixed timing traffic lights

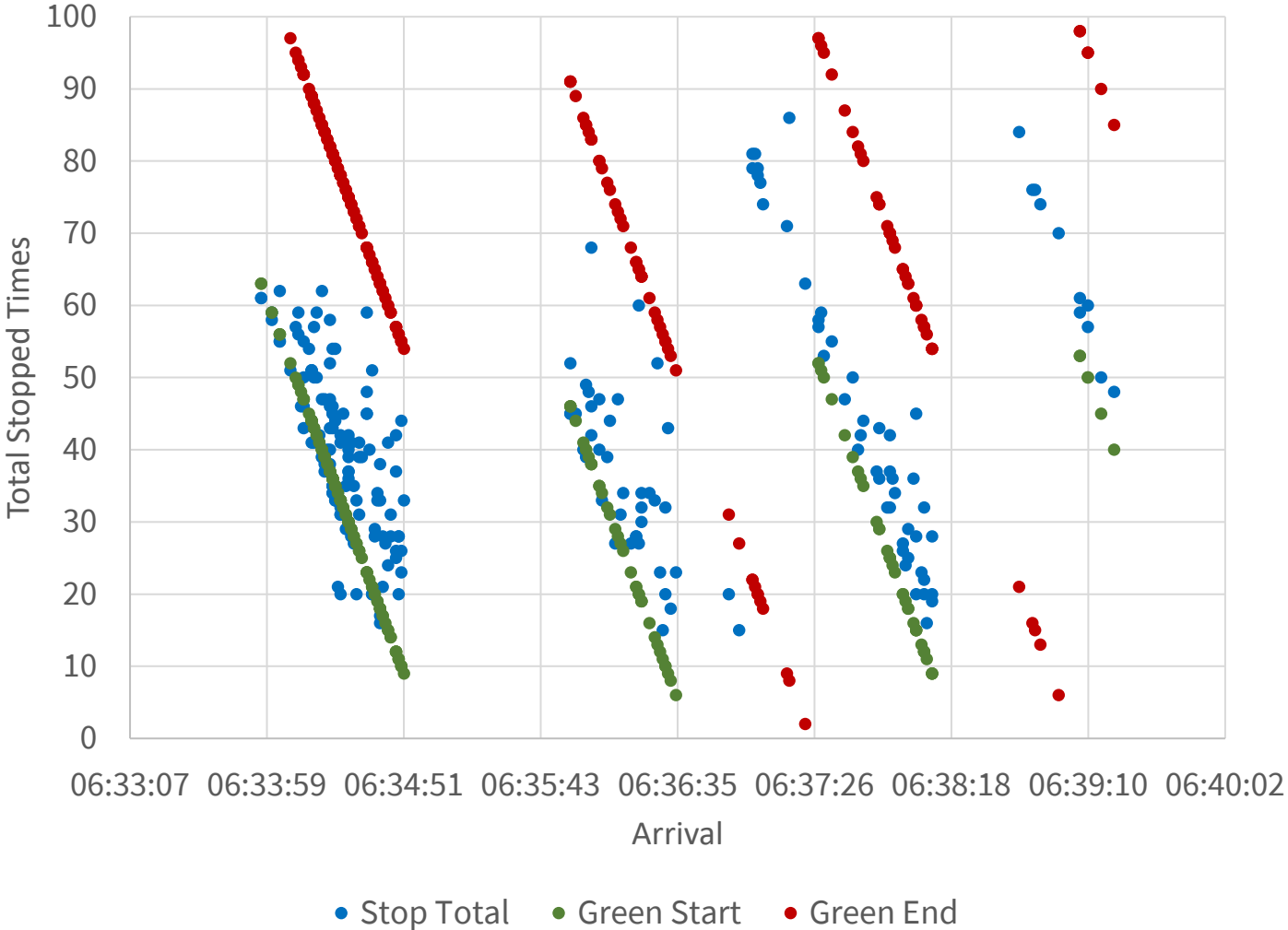- Compare between different systems
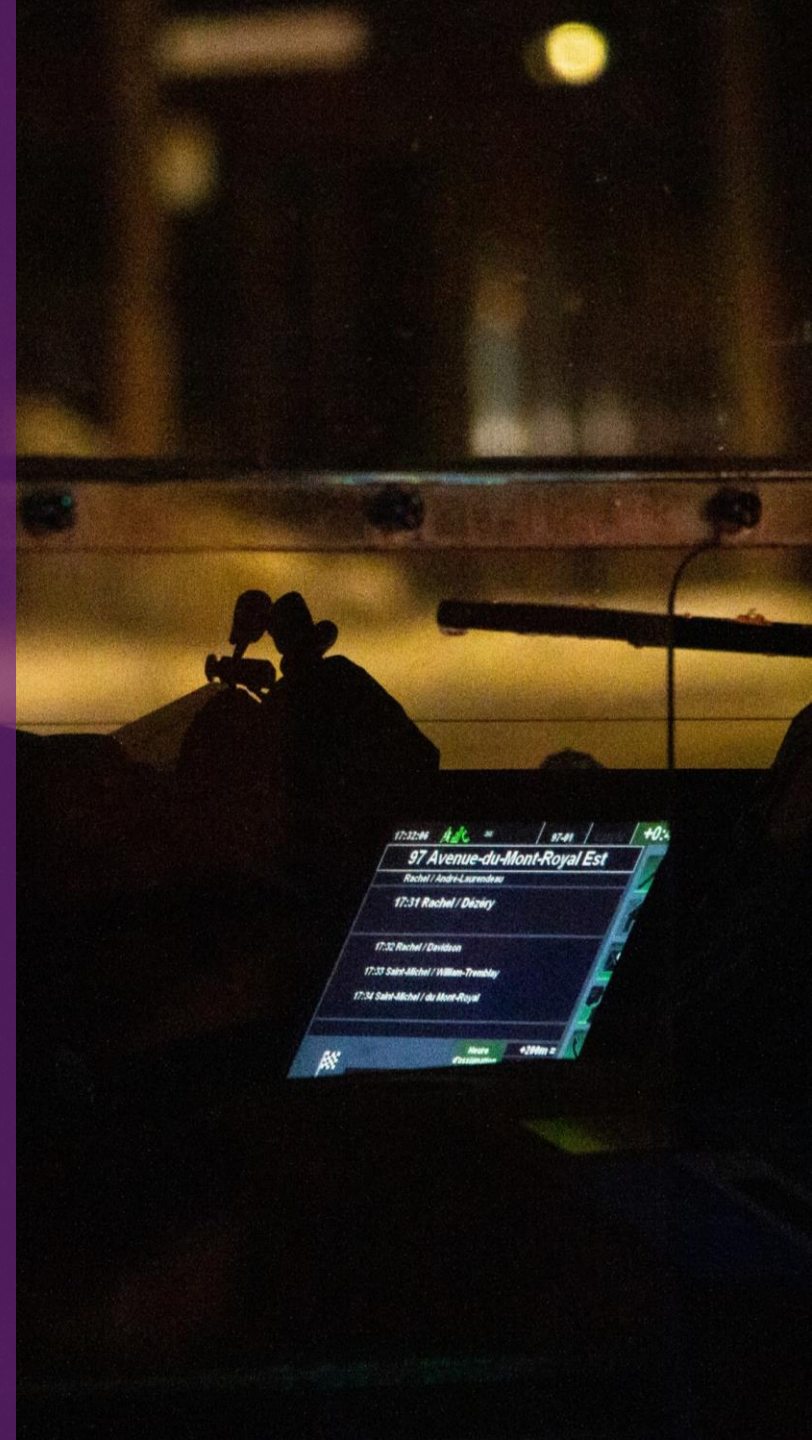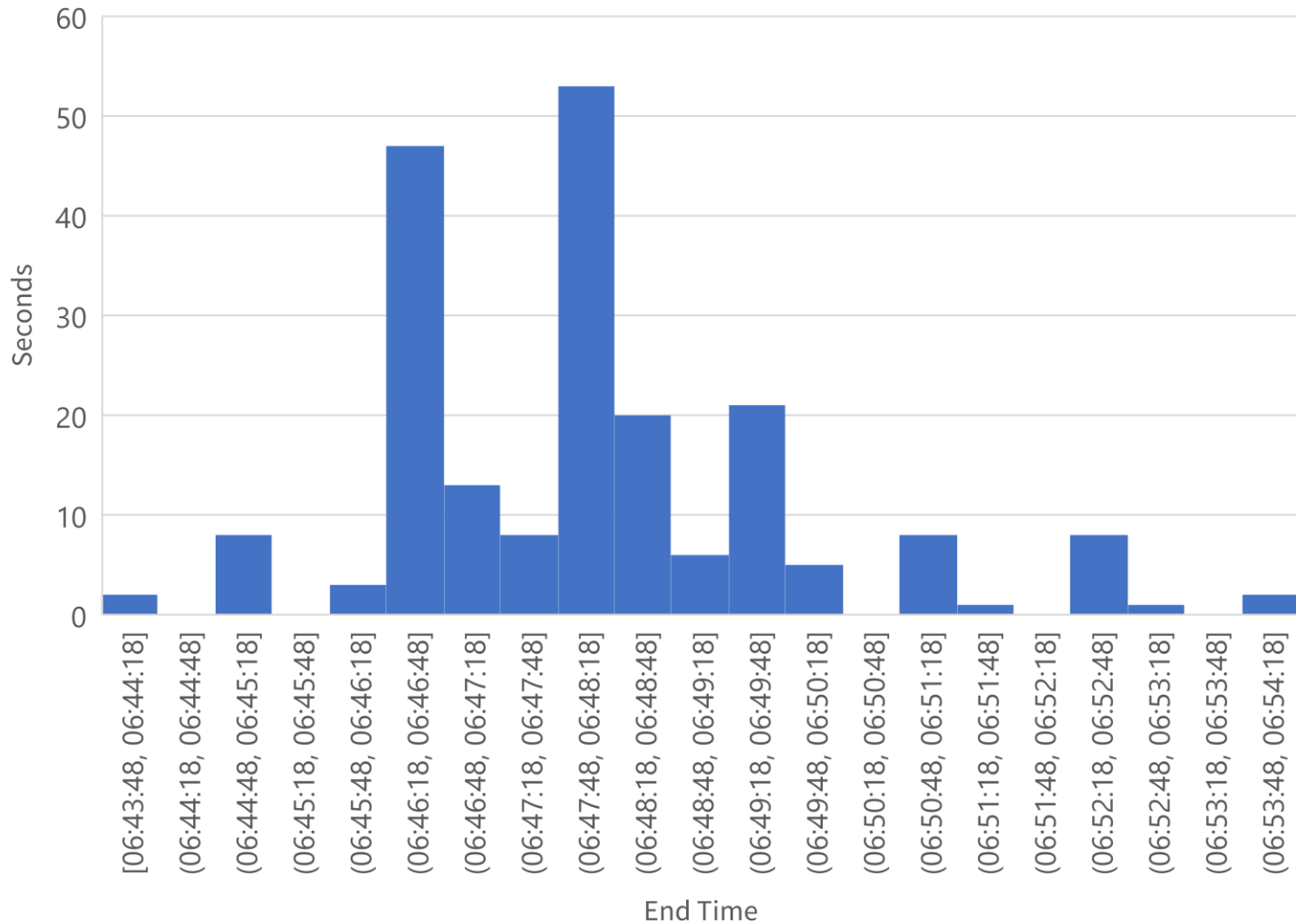
Thanks! Questions?

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Deduce Fixed Traffic Light Timings

- Stop Total
- Green Start
- Green End

Actual Observations 27-O 0630

Visualization System

In the course of improving the colors…