# SampaNoShape

## São Paulo Bus Movement Model

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# São Paulo [bus system]

São Paulo Bus System:

- Number of vehicles : ~ 14.400
- Number of bus routes: ~2.271
- Contractual value: R$ 66 billion (20 years)
- Passengers transported per workday: 6 million
- Passengers transported in 2017: 2.86 billion

Processed data:

- Number of monitored vehicles: 14.139
- Number of monitored bus routes: 2.183
- Monitored period: 1 week + 1 atypical day

Imagem: Marcelo Camargo - Agência Brasil

# Simulation [bridging planning-reality gap]

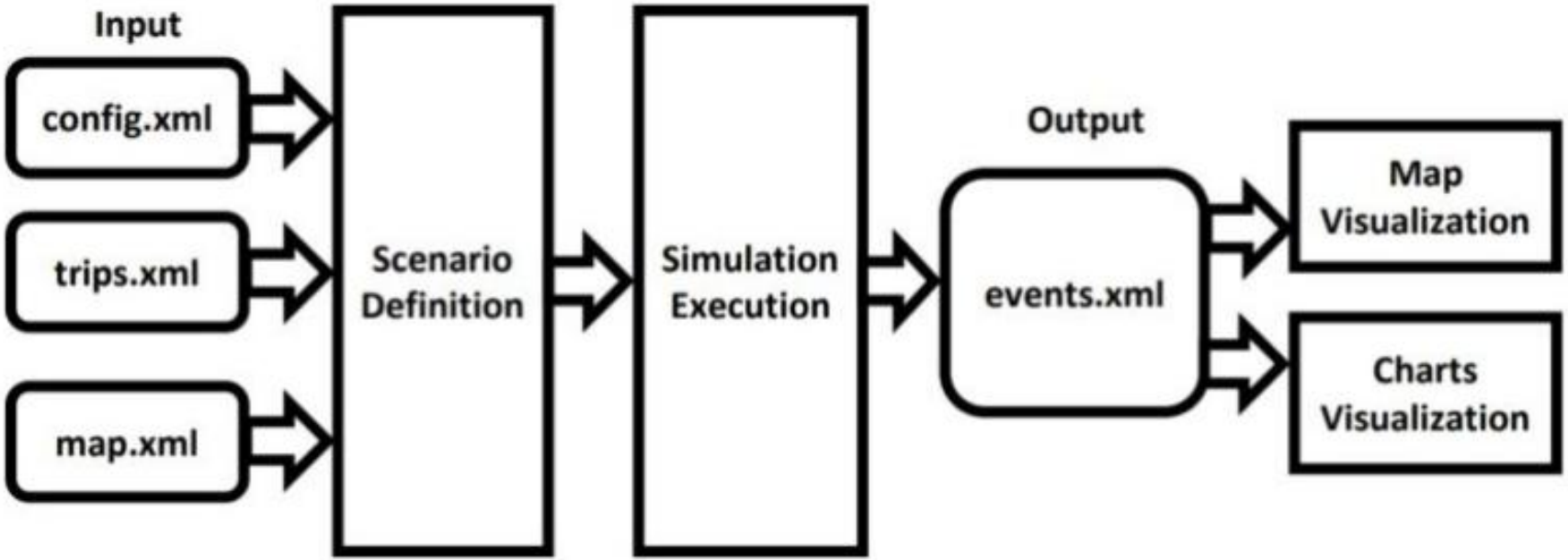
*“A simulation can show to city planners the behaviour and dynamics of the city in different hypothetical scenarios.” [Santana et al.]*

Models based on real bus service data recreating mobility aspects of São Paulo

- Simulating bus movement patterns of each week day
- Evaluating impacts of seasonal bursty period
- Helping government agencies to plan changes in the bus infrastructure

# InterSCSimulator

## [traffic simulator for smart cities]




Documentation: http://interscity.org/software/interscsimulator/

# Data Source


**Innovation startup, focused on smart cities and particularly on urban mobility issues**

Develop products for:

- Government
- Citizens (passenger)
- Bus operators
- Companies


**SPTrans**

São Paulo bus transit authority

**GTFS**

[General Transit Feed Specification] Specification that defines a format for exchanging static transport information (GTFS, 2018).

# Data Source

Scipopulis

Bus trips metadata
- Initial bus stop
- Start time of a trip
- Reference date

Edges metadata
- Stop From and To
- Edge length
- Shapes

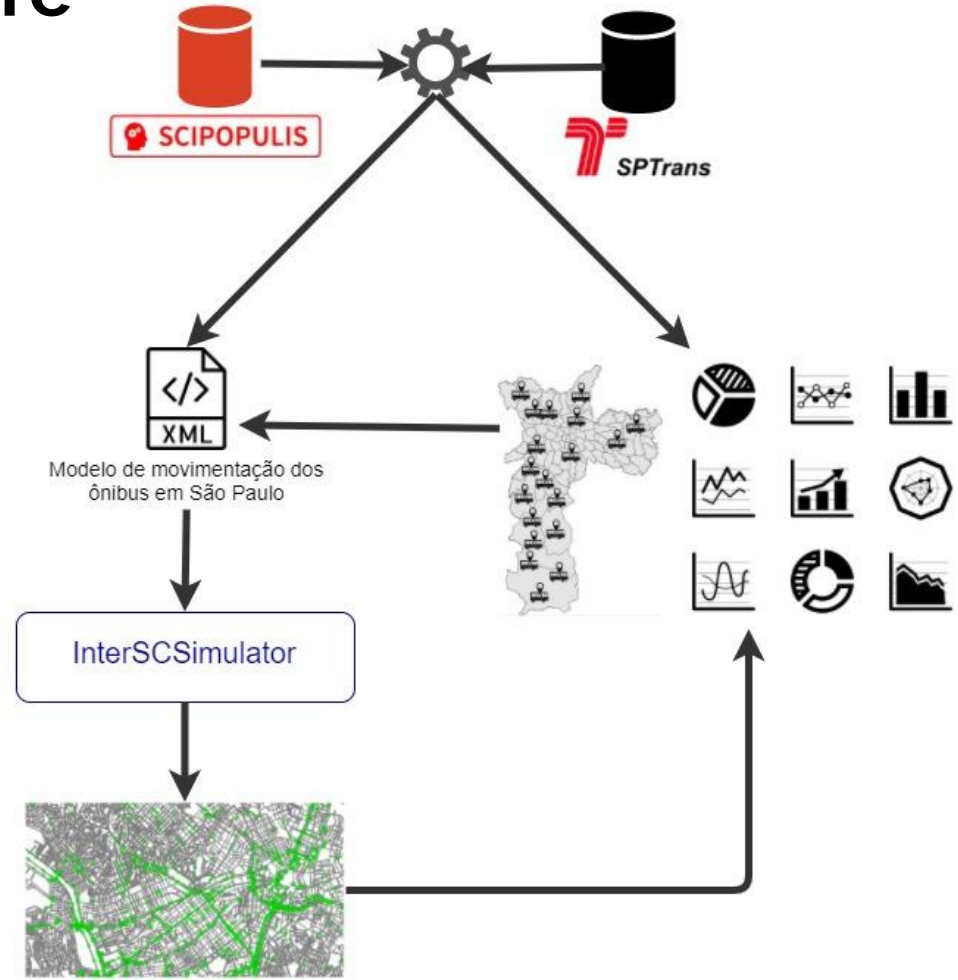
Log edges speed
- Bus average speed for each edge per hour

SPTrans

Bus trips metadata
- Stops sequence
- Bus schedule

Stops metadata
- Coordinates of location

# Architecture



# Main Challenges [of model construction]

- Matching Scipopulis and SPTrans data
- High data processing demand
- Elaborate strategies to deal with missing data
- Select relevant characteristics to be included in the model
- Make a good visualization to illustrate the insights

# Data Analysis [bus schedule]

2017, Oct 26th (Thursday)

**Goal**

To investigate differences between real and planned schedule

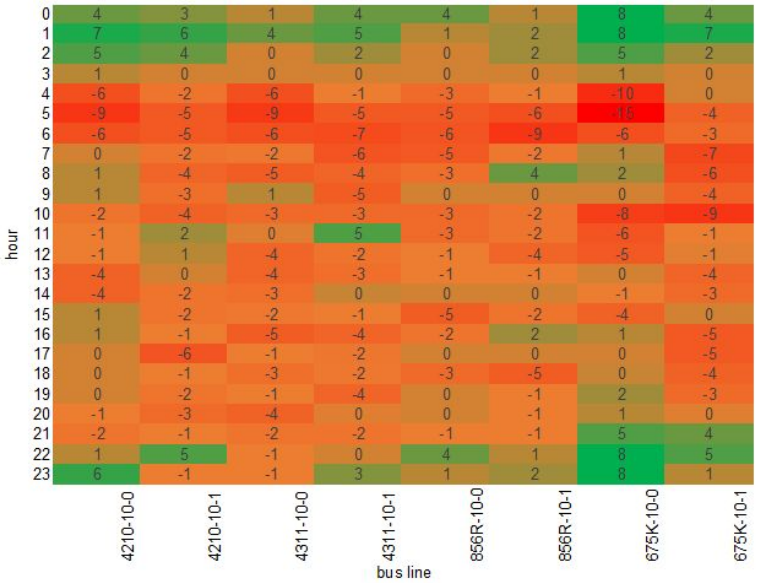
**Case study**

**1_**Line 675K-10
[Term.Jd.Ângela > Metrô Sta. Cruz)

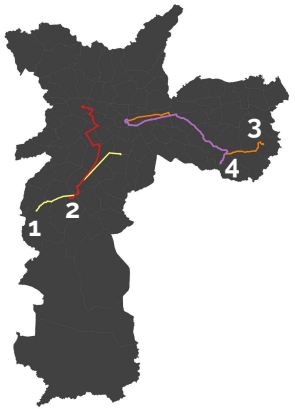
**2_**856R-10
[Socorro > Lapa]

**3_**4210-10
[Cid Tiradentes > Pqe.Dom Pedro]

**4_**4311-10
[Term S. Mateus > Pqe.Dom Pedro]



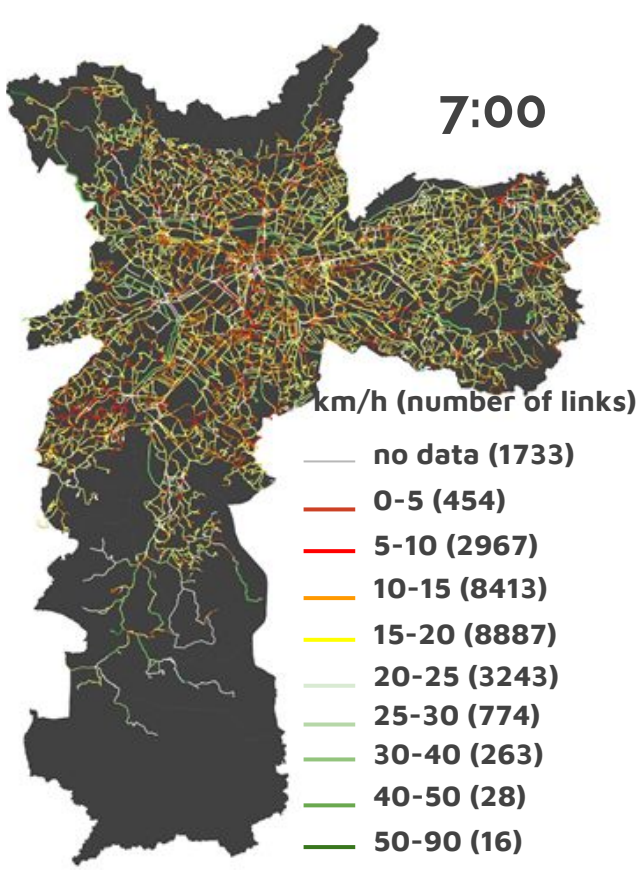

**Difference between real and planned frequency**

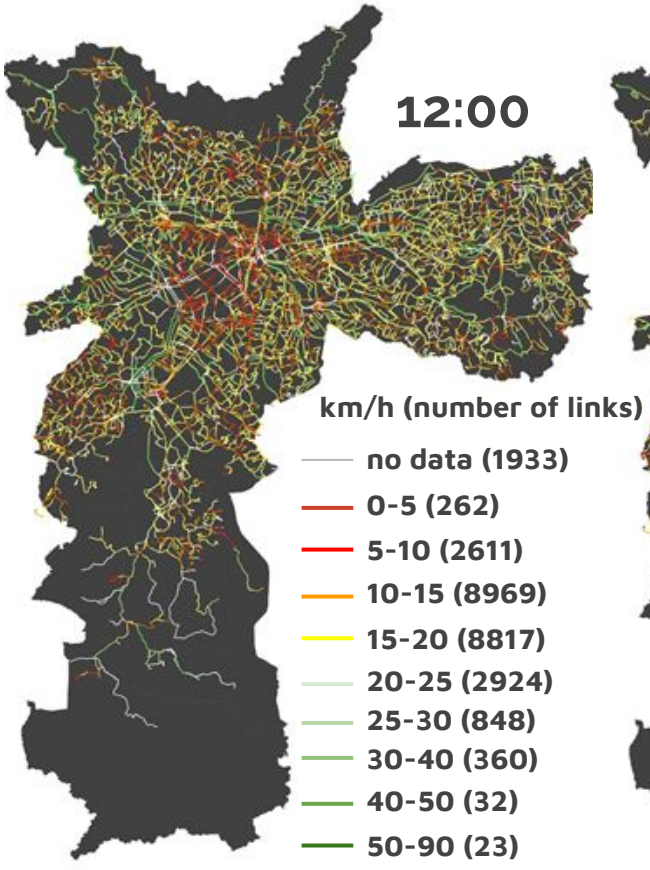


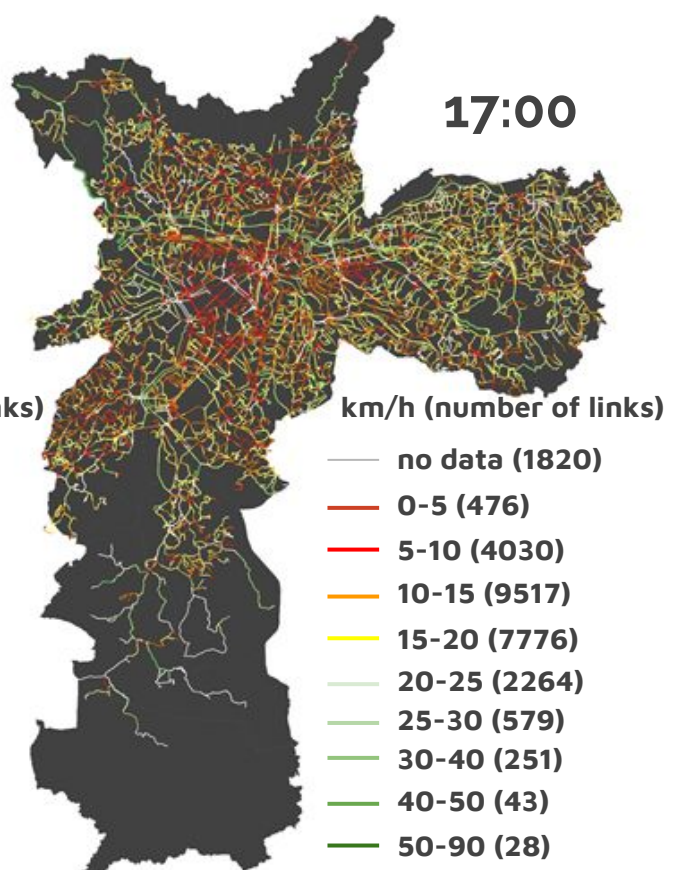
# Data Analysis [average speeds between stops]

2017, Oct 26th (Thursday)

**Maximum speed at** a) local streets [30 km/h] / b) bus corridors [50 km/h]

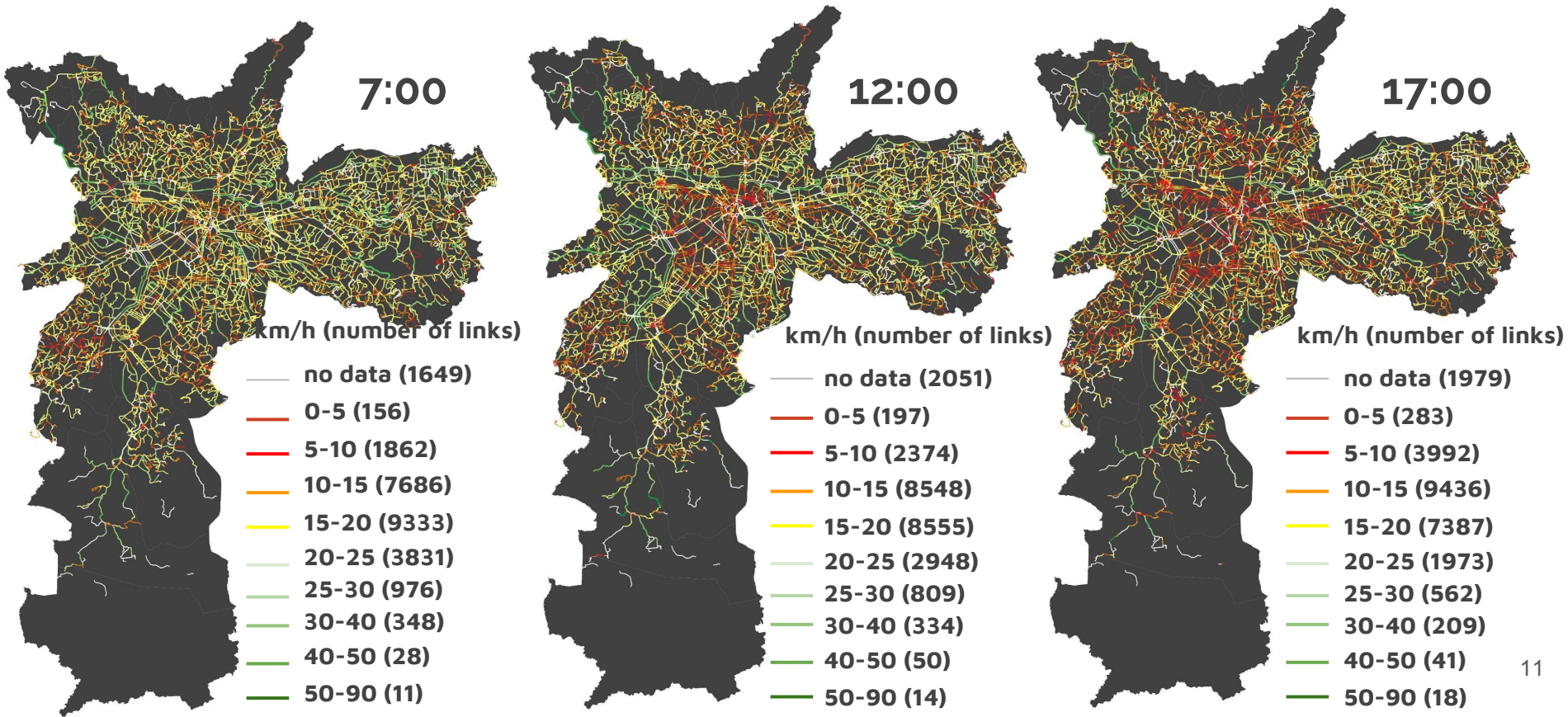


# Data Analysis [average speeds between stops]

2017, Apr 13rd, (Thursday, Atypical day: Easter eve)

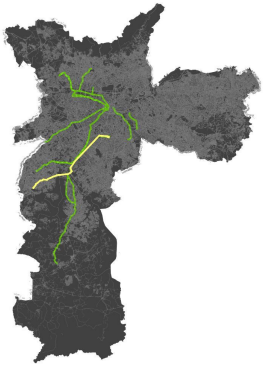


# Data Analysis [travel times]

2017, Oct 26th (Thursday)

**Goal**

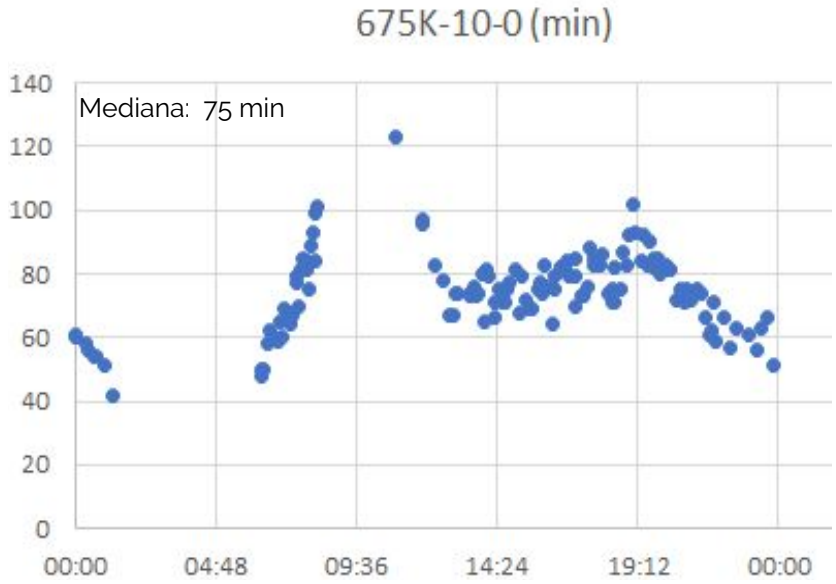
To investigate how travel times vary through the day for lines which connects peripheral to central areas

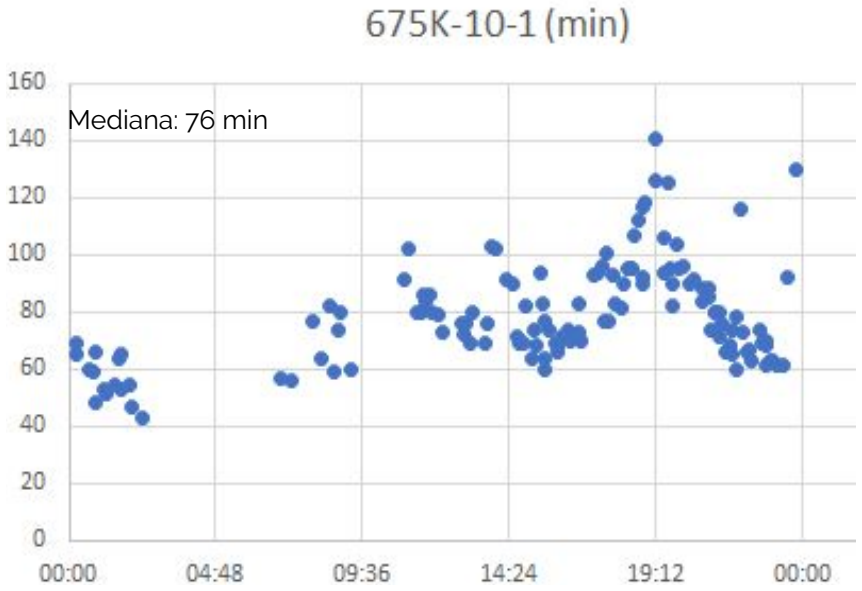


**Case study**

Line 675K-10

[Term.Jd.Ângela > Metrô Sta. Cruz)



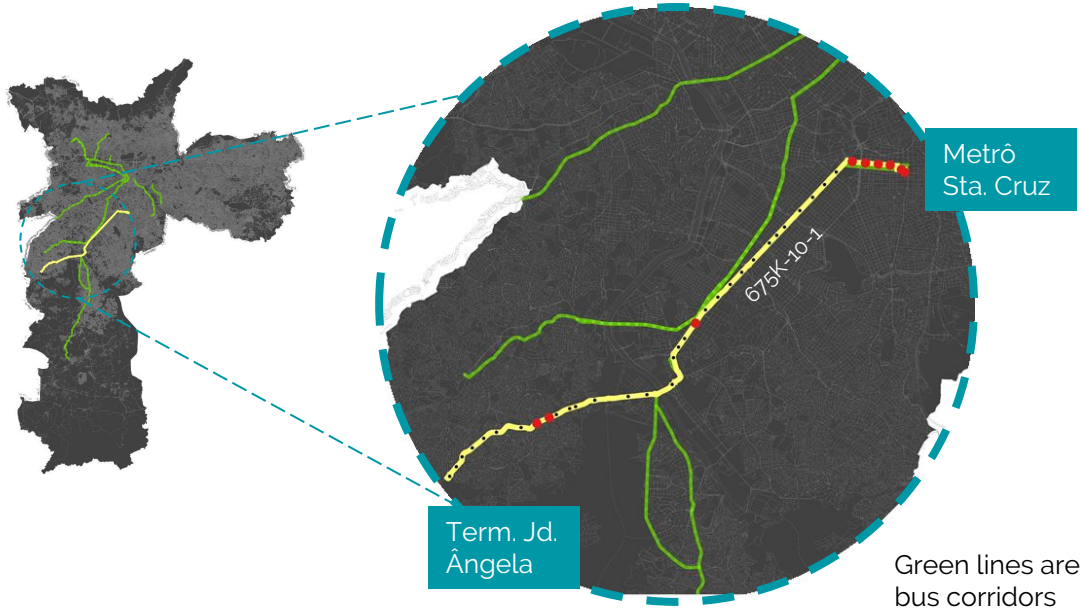



# Data Analysis [headway regularity]

2017, Oct 26th, 7:00 am (Thursday, morning peak)

**Case study**
Line 675K-10
[Term.Jd.Ângela > Metrô Sta. Cruz)

**Goal**
Investigating headway patterns (bunching x delays)




**Line 675K-10 [Term. Jd. Ângela > Metrô Sta. Cruz)**

# Data Analysis [headway regularity]

2017, Oct 26th, 7:00 am (Thursday, morning peak)

**Case study**
Line 675K-10
[Term.Jd.Ângela > Metrô Sta. Cruz)

**Schedule *per* stop**

| Term. Jd.Ângela 420013604 | 420013203 | 420013197 | 420013383 | 4200946 |
|---|---|---|---|---|
| 06:59 | 07:04 | 07:05 | 07:07 | 07:08 |
| 07:05 | 07:07 | 07:08 | 07:09 | 07:10 |
| 07:09 | 07:13 | 07:14 | 07:16 | 07:17 |
| 07:16 | 07:16 | 07:19 | 07:21 | 07:22 |
| 07:20 | 07:22 | 07:24 | 07:25 | 07:26 |
| 07:23 | 07:26 | 07:28 | 07:30 | 07:30 |
| 07:26 | 07:29 | 07:31 | 07:33 | 07:34 |
| 07:32 | 07:35 | 07:36 | 07:40 | 07:41 |
| 07:35 | 07:37 | 07:39 | 07:41 | 07:43 |
| 07:38 | 07:42 | 07:43 | 07:45 | 07:46 |
| 07:43 | 07:47 | 07:49 | 07:52 | 07:53 |
| 07:45 | 07:50 | 07:52 | 07:54 | 07:55 |
| 07:55 | 07:57 | 07:59 | 08:00 | 08:02 |
| 07:59 | 08:01 | 08:03 | 08:04 | 08:05 |
| 08:01 | 08:06 | 08:06 | 08:08 | 08:09 |
| 08:05 | 08:09 | 08:10 | 08:12 | 08:14 |

**Headway *per* stop**

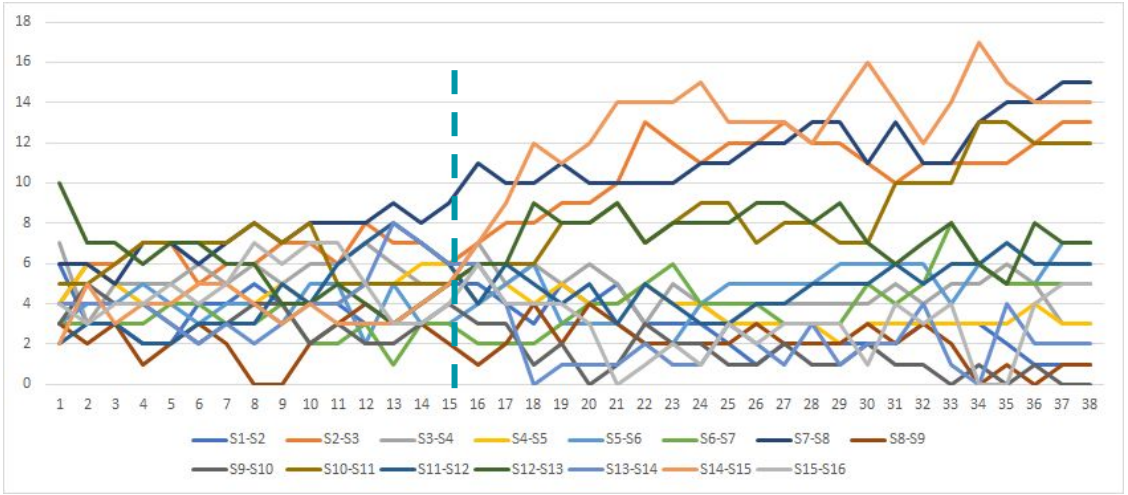
| Schedule - bus starting a trip | Sequence | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 420013604 (First headway at bus terminal) | 420013203 | 420013197 | 420013383 | 4200946 | 420013265 | 420011609 | 450011613 | 450011987 | 4203717 | 450011990 | 450011981 | 450011991 | 810011977 | 810011973 | 7206842 | 7206861 | 7206906 | 7206864 | 7206780 | 720015652 | 720015654 | 720015656 | 720015658 | 1506163 | 150015661 | 150015663 | 150015665 | 530015317 | 530015318 | 530015319 | 530015320 | 530015173 | 920015203 | 920015204 | 920015205 | 920015225 | 920015230 |
| 6:59 | 1st | 6 | 3 | 3 | 2 | 2 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 | 4 | 3 | 5 | 4 | 5 | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 1 | 1 | 1 |
| 7:05 | S1-S2 | 4 | 6 | 6 | 7 | 7 | 5 | 6 | 6 | 7 | 7 | 6 | 8 | 7 | 7 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 13 | 12 | 11 | 12 | 12 | 13 | 12 | 12 | 11 | 10 | 11 | 11 | 11 | 11 | 12 | 13 | 13 |
| 7:09 | S2-S3 | 7 | 3 | 5 | 5 | 5 | 6 | 5 | 6 | 5 | 6 | 6 | 7 | 6 | 5 | 5 | 7 | 5 | 6 | 5 | 6 | 5 | 3 | 5 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 5 | 6 | 5 | 3 | 3 |
| 7:16 | S3-S4 | 4 | 6 | 5 | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 6 | 6 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 |
| 7:20 | S4-S5 | 3 | 4 | 4 | 5 | 5 | 3 | 4 | 4 | 3 | 5 | 5 | 2 | 5 | 3 | 3 | 4 | 5 | 6 | 3 | 3 | 3 | 2 | 2 | 4 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 4 | 6 | 5 | 5 | 7 | 7 |
| 7:23 | S5-S6 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 2 | 2 | 3 | 1 | 3 | 3 | 2 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 4 | 4 | 4 | 3 | 3 | 3 | 5 | 4 | 5 | 8 | 6 | 5 | 5 | 5 | 5 | 5 |
| 7:26 | S6-S7 | 6 | 6 | 5 | 7 | 7 | 6 | 7 | 8 | 7 | 8 | 8 | 8 | 9 | 8 | 9 | 11 | 10 | 10 | 11 | 10 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 11 | 13 | 11 | 11 | 13 | 14 | 14 | 15 | 15 |
| 7:32 | S7-S8 | 3 | 2 | 3 | 1 | 2 | 3 | 2 | 0 | 0 | 2 | 3 | 4 | 3 | 3 | 2 | 1 | 2 | 4 | 2 | 4 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 0 | 1 | 0 | 1 | 1 |
| 7:35 | S8-S9 | 3 | 5 | 4 | 4 | 3 | 2 | 3 | 4 | 4 | 2 | 3 | 2 | 2 | 3 | 4 | 3 | 3 | 1 | 2 | 0 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 7:38 | S9-S10 | 3 | 5 | 6 | 7 | 7 | 7 | 7 | 8 | 7 | 8 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 8 | 8 | 9 | 7 | 8 | 9 | 9 | 7 | 8 | 8 | 7 | 7 | 10 | 10 | 10 | 13 | 13 | 12 | 12 | 12 |
| 7:43 | S10-S11 | 5 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 5 | 4 | 6 | 7 | 8 | 7 | 6 | 4 | 6 | 5 | 4 | 5 | 3 | 5 | 4 | 3 | 3 | 4 | 4 | 5 | 5 | 5 | 6 | 5 | 6 | 6 | 7 | 6 | 6 | 6 |
| 7:45 | S11-S12 | 2 | 7 | 7 | 6 | 7 | 7 | 6 | 6 | 4 | 4 | 5 | 4 | 3 | 4 | 5 | 6 | 6 | 9 | 8 | 8 | 9 | 7 | 8 | 8 | 8 | 9 | 9 | 8 | 9 | 7 | 6 | 7 | 8 | 6 | 5 | 8 | 7 | 7 |
| 7:55 | S12-S13 | 10 | 4 | 4 | 4 | 3 | 2 | 3 | 2 | 3 | 4 | 4 | 5 | 8 | 7 | 6 | 6 | 4 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 2 | 1 | 3 | 1 | 2 | 2 | 4 | 1 | 0 | 4 | 2 | 2 | 2 |
| 7:59 | S13-S14 | 4 | 5 | 3 | 4 | 4 | 5 | 5 | 4 | 3 | 4 | 3 | 3 | 3 | 4 | 5 | 7 | 9 | 12 | 11 | 12 | 14 | 14 | 14 | 15 | 13 | 13 | 13 | 12 | 14 | 16 | 14 | 12 | 14 | 17 | 15 | 14 | 14 | 14 |
| 8:01 | S14-S15 | 2 | 3 | 4 | 4 | 5 | 4 | 5 | 7 | 6 | 7 | 7 | 5 | 3 | 3 | 4 | 6 | 4 | 4 | 4 | 3 | 0 | 1 | 2 | 1 | 3 | 2 | 3 | 3 | 3 | 1 | 4 | 3 | 4 | 0 | 0 | 4 | 5 | 5 |
| 8:05 | S15-S16 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

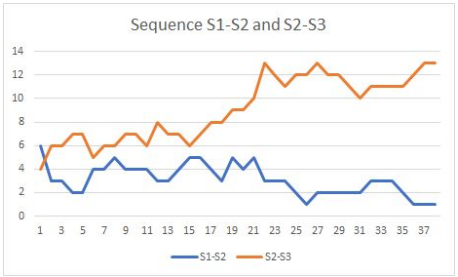
Headway at the stop is the same
Headway at the stop is higher
Headway at the stop is shorter
Bunching

# Data Analysis [headway regularity]

2017, Oct 26th, 7:00 am (Thursday, morning peak)

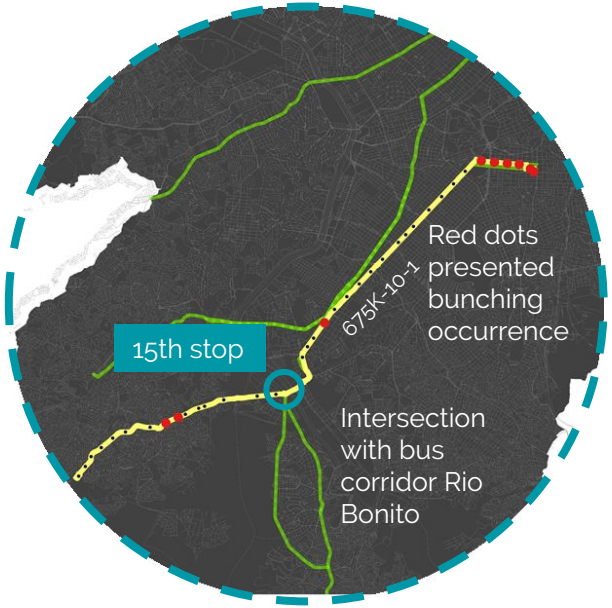
**Case study**
Line 675K-10
[Term.Jd.Ângela > Metrô Sta. Cruz)




Headway pattern - between the 15th and 38th stops, the headways show larger variations

Headway disequilibrium



# The Bus Movement Model [buses.xml]

```
<?xml version="1.0" ?>
<scsimulator_buses>

[...]

   <bus id="856R-10-0" interval="0,0,0,0,1200,...,1800" start_time="22150"
stops="4814577,4811359,...,810011966,810011968,810011969"/>
   <bus id="856R-10-1" interval="1800,0,0,0,3600,..,1200" start_time="23697"
stops="810011969,810011967,...,480014609,480014963,4814577"/>

[...]

</scsimulator_buses>
```

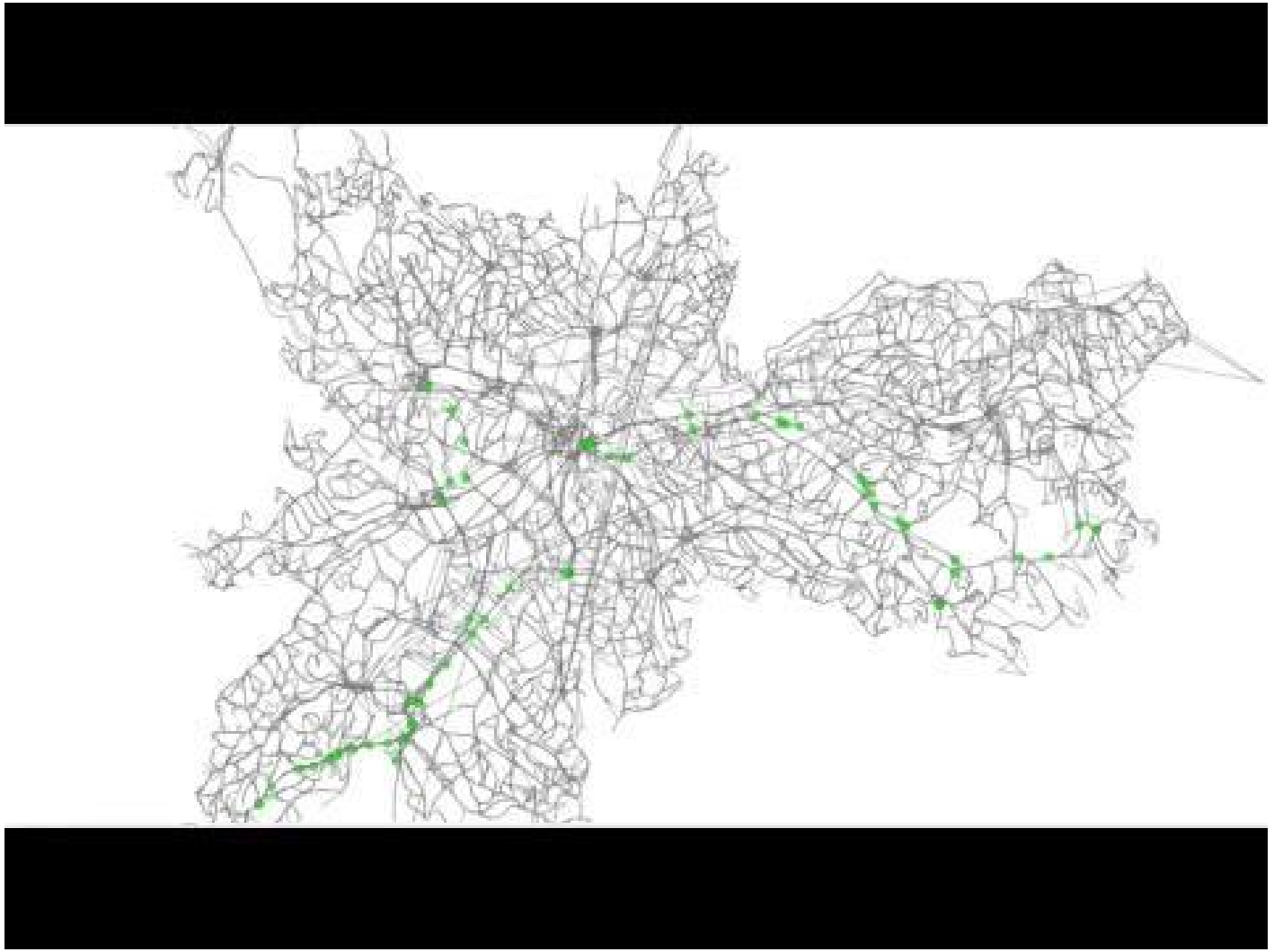
# The Bus Movement Model [map.xml]

```
<?xml version="1.0" ?>
<network>

 <nodes>
   [...]
   <node id="7906161" x="333228.6324660926" y="7386859.503655812"/>
   [...]
 </nodes>

 <!--================================================================-->

   <links capperiod="01:00:00" effectivecellsize="7.5" effectivelanewidth="3.75">
   [...]
   <link avgspeed="22.19, 21.42, ... , 12.88, 14.47, 18.27" from="790016357" to="790016218"
length="323" linkId="790016357-790016218" shapeLat="332442.8428304753, ... ,
332632.9512607706" shapeLng="7386061.151484802, ... , 7386274.432584263" />
   [...]
    </links>
</network>
```



# Conclusion [a future of possibilities]

**Future works**

Looking for better strategies to fill gaps in bus travel records, making analysis faster and more reliable

**Potentials**

The model we developed provides a more realistic input for simulating mobility planning, allowing better city traffic analysis, for example:

- Recreating the past, in order to analyse what happened
- Measuring the impact of changes in the city infrastructure
- Alternative routes analysis
- Comparison of potential interventions in the traffic