Characterization of travel time variability in multimodal transport networks: new results from Santiago

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Travel time variability

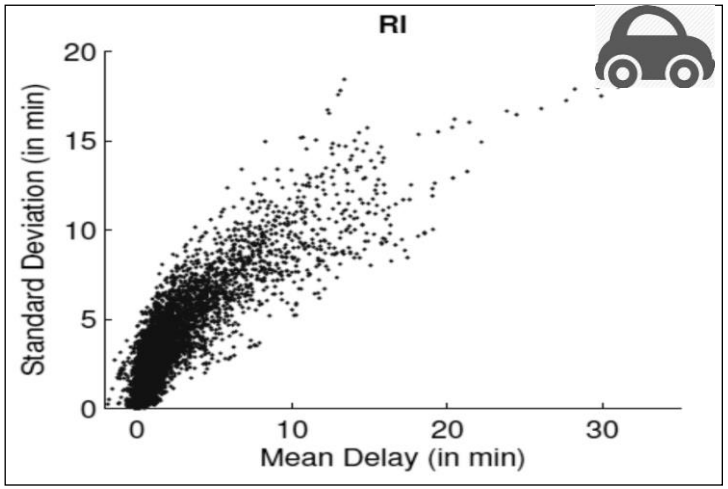
- People willing to pay to reduce mean travel time
  - **Value of travel time savings**: old friend

- People willing to pay to reduce travel time variability

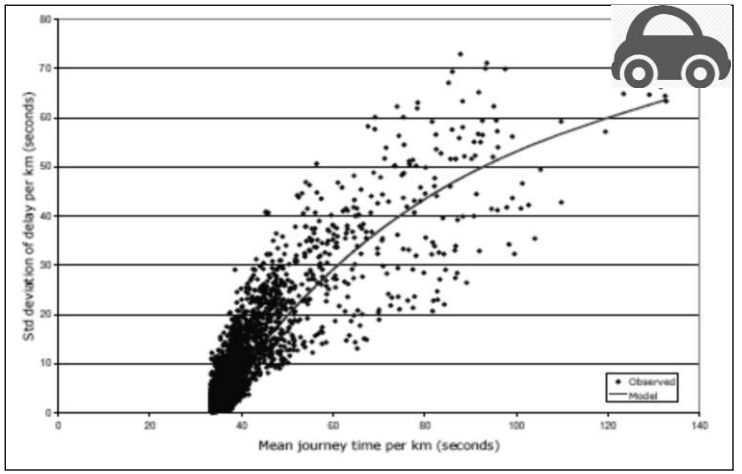
  (Jackson and Jucker 1982; Senna 1994, Small *et al* 1999; Lam and Small 2001, Bates *et al* 2001, Börjesson *et al* 2012)

  - **Value of reliability**

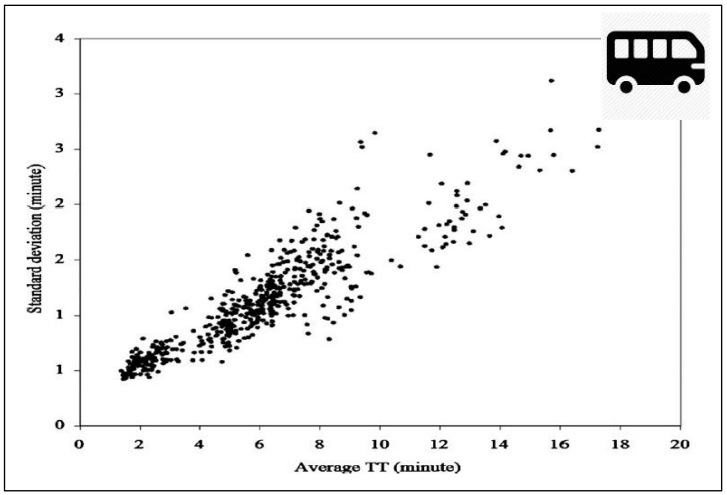
travel time variability?



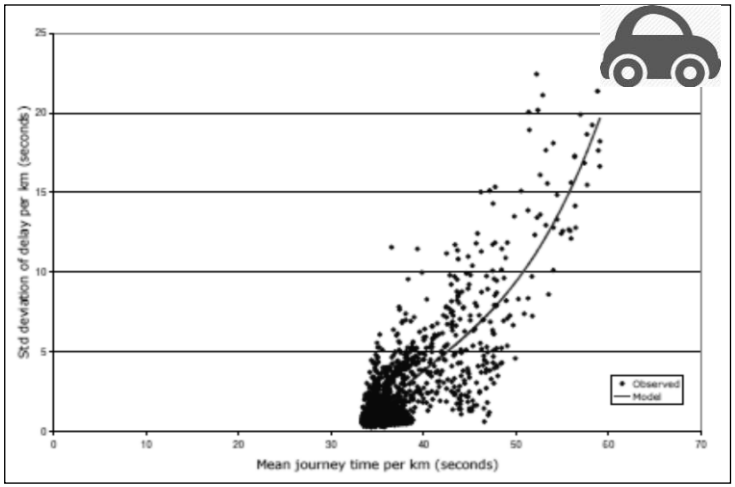
Peer *et al.* (2012), Netherlands



Mott MacDonald (2008), England



Mazloumi *et al.*(2010), Melbourne



Mott MacDonald (2008), England

Relationship mean-variance travel time

TTV valuation

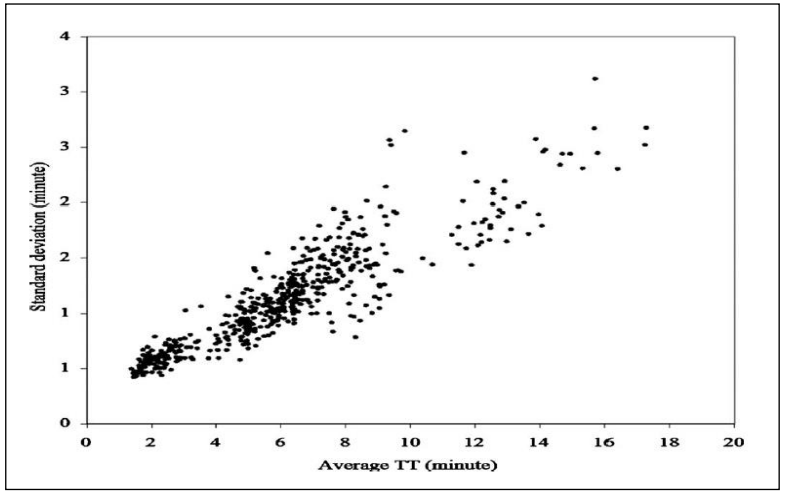
Scheduling model	Mean-variance model
$U_t = \delta C_t + \alpha T_t + \beta SDE_t + \gamma SDL_t + \ldots$	$U_t = \delta C_t + \alpha \mu_t + \rho \sigma_t + \ldots$ $\alpha/\delta : Value\ of\ time$ $\rho/\delta : Value\ of\ reliability$ $\rho/\alpha : Reliability\ ratio$

$$U_t = \delta C_t + \alpha \mu_t + \rho \sigma_t + \ldots$$

PLEASE CIRCLE EITHER CHOICE **A** OR CHOICE **B**

Choice A	Choice B
Average Travel Time **9 minutes** You have an equal chance of arriving at any of the following times:	Average Travel Time **9 minutes** You have an equal chance of arriving at any of the following times:
7 minutes early **4 minutes early** **1 minute early** **5 minutes late** **9 minutes late**	**3 minutes early** **3 minutes early** **2 minute early** **2 minutes early** **On time**
Your cost: **$0.25**	Your cost: **$1.50**

Small *et al* (1999)



Mazloumi *et al.*(2010)

TTV: Why does it matter for policy making?

1. Social benefits of reducing TTV (CBA)
2. Impact of TTV valuation on optimal design of transport systems
   - Congestion pricing reduced TTV (Transport for London 2007, Eliasson 2009)
   - Impact of TTV on congestion pricing?

- For simplicity, standard deviation of travel time is chosen in this paper.
  - It can be plugged in mean-variance model

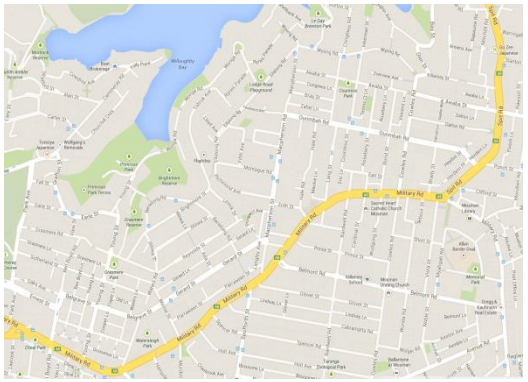
Measures of travel time variability

TTV measure	Source
Standard deviation of travel time	May et al.(1989) Mahmassani et al. (2012) Peer et al. (2012)
Difference between 90th and 10th percentile of travel time	Eliasson (2007) Tu et al. (2007) van Lint and van Zuylen (2005)
Coefficient of variation	May et al.(1989) Eliasson (2006)
Standard deviation of delay	Mott MacDonald (2008b; 2008a)
Variance of delay	Mott MacDonald (2008b; 2008a)
Travel time index (TTI) (Ratio of actual travel time to free-flow travel time)	Cambridge Systematics et al. (2013)
80% percentile TTI	Cambridge Systematics et al. (2013)
Buffer time index (Difference between 95th percentile travel time per km and average travel time per km, divided by travel time per km)	Lomax et al. (2003) van Lint et al. (2008)
Misery index (Average of the highest 5% or 20% of travel times, divided by free-flow travel time)	van Lint et al. (2008) Kim et al. (2013)
Planning time index (The 95th percentile travel time divided by free-flow travel time)	Lomax et al. (2003) Kim et al. (2013)

effect TTV on optimal congestion toll and bus service design

(Tirachini, Hensher and Bliemer, 2014)

- Social welfare maximisation model, Sydney
- MNL, 3 alternatives: bus, car and walk
  - Bus and car: crossed and own congestion
  - Congestion on road and queues at bus stops



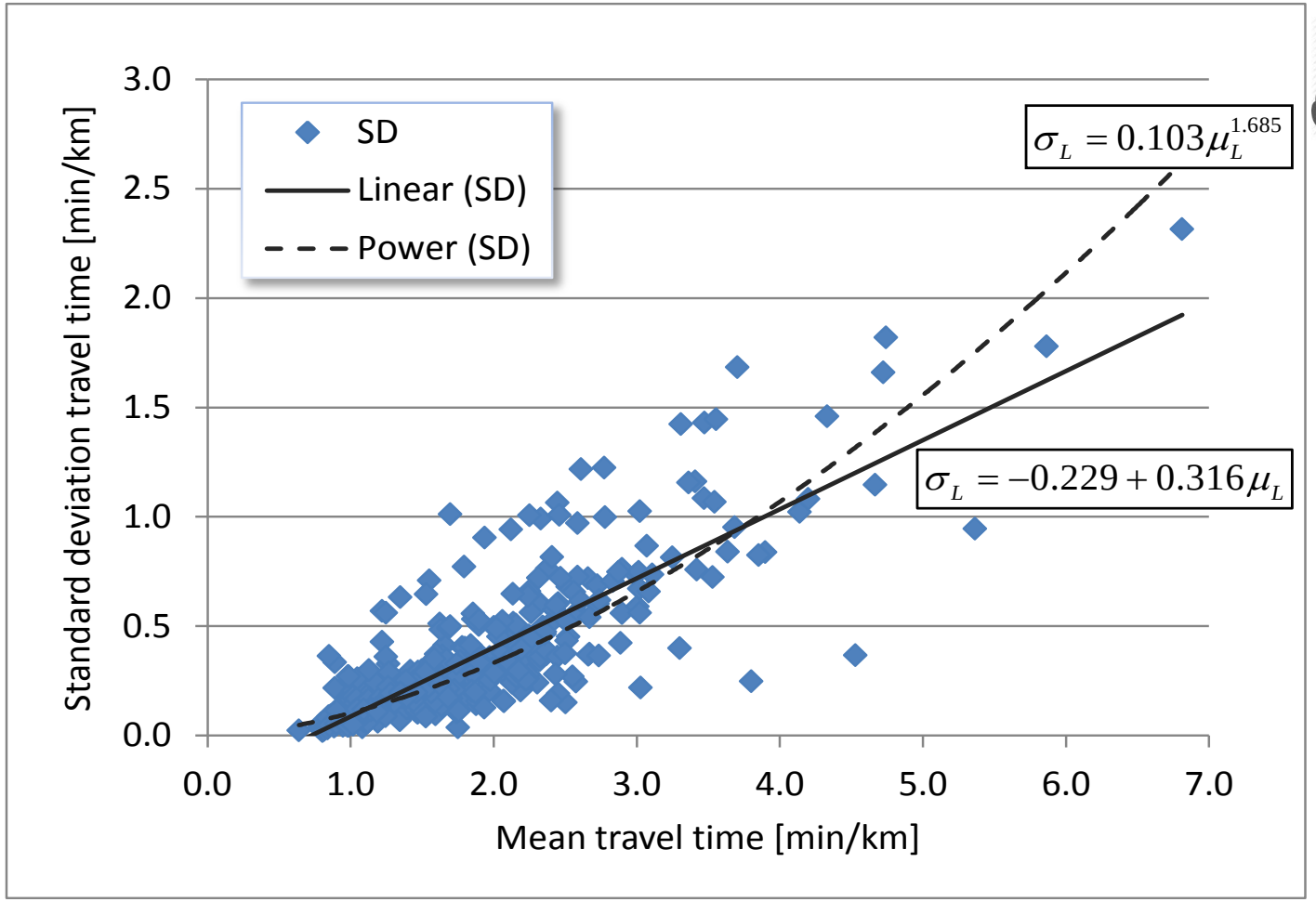
- Modal utility: **mean and SD travel time**

$$SW = \underbrace{\sum_{ij}\left(\frac{Y^{ij}}{-\delta}\right)\ln\sum_{m} e^{U_m^{ij}}}_{\text{consumer surplus}} + \underbrace{\sum_{ij}\left(y_{\text{car}}^{ij}\tau_{\text{car}} + y_{\text{bus}}^{ij}\tau_{\text{bus}}\right)}_{\text{operator revenues}} - \underbrace{\left(c_1(s_{\text{bus}})P + c_2(s_{\text{bus}})f_{\text{bus}}\left(t_{\text{bus}}^{1P} + t_{\text{bus}}^{P1} + t_s\right) + 2c_3(s_{\text{bus}})f_{\text{bus}}L\right)}_{\text{operator costs}}$$

producer surplus

Tirachini, A., Hensher, D. A. and Bliemer, M. C. J. (2014). Accounting for travel time variability in the optimal pricing of cars and buses. Transportation 41: 947-971.

travel time variability

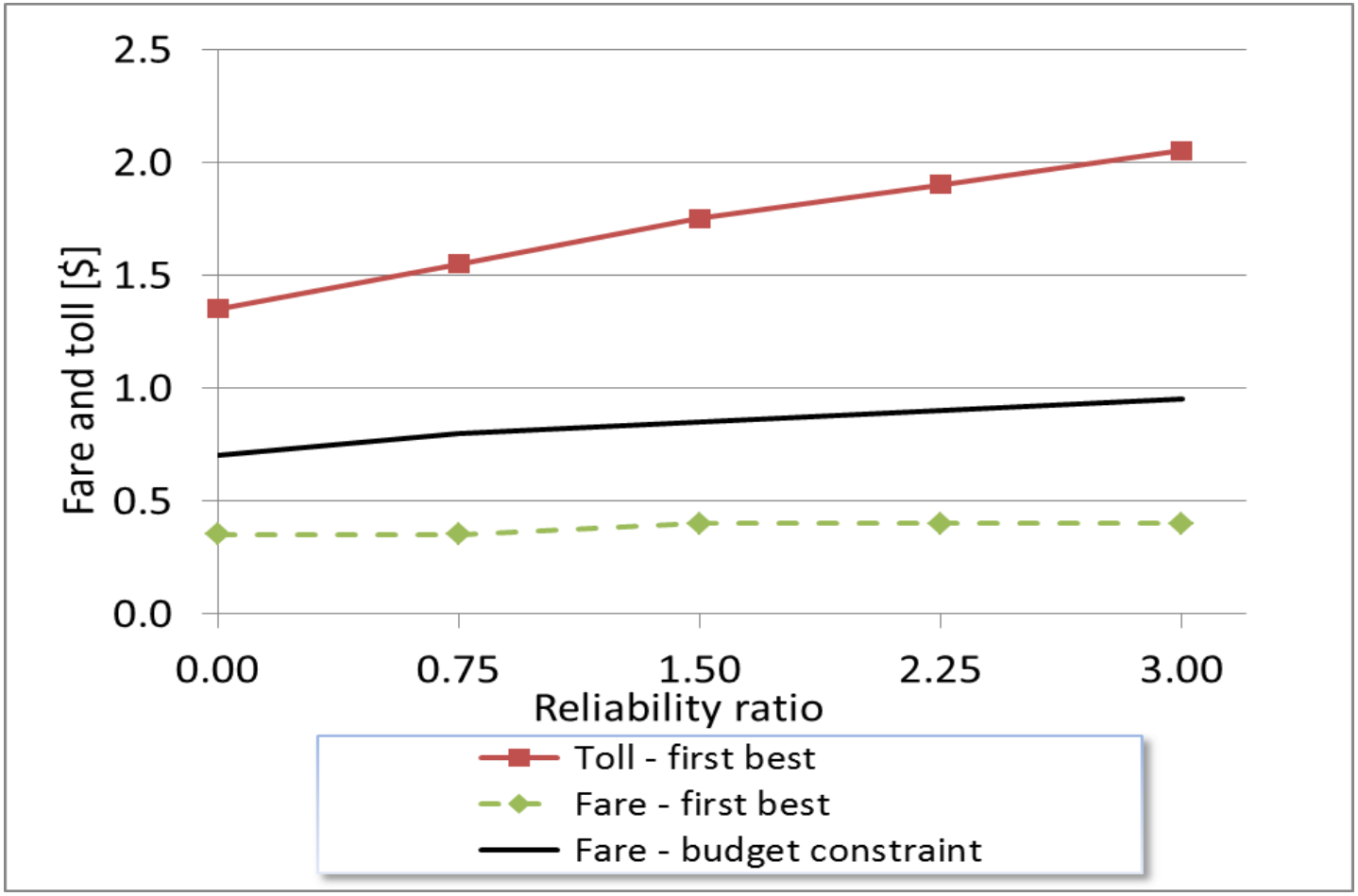


Time: min/km

Sydney (423 roads)

Tirachini, A., Hensher, D. A. and Bliemer, M. C. J. (2014). Accounting for travel time variability in the optimal pricing of cars and buses. Transportation 41: 947-971.

optimal pricing, numerical application Sydney



TTV: Serious implications for optimal pricing

Tirachini, A., Hensher, D. A. and Bliemer, M. C. J. (2014). Accounting for travel time variability in the optimal pricing of cars and buses. Transportation 41: 947-971.

research questions

- How does TTV look in Santiago?
  - Car
  - Integrated public transport system
    - Bus and/or metro routes
    - Walking, waiting, access
- What are the differences between modes?


403 LA REINA
403 SANTIAGO
403
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ZN-5803


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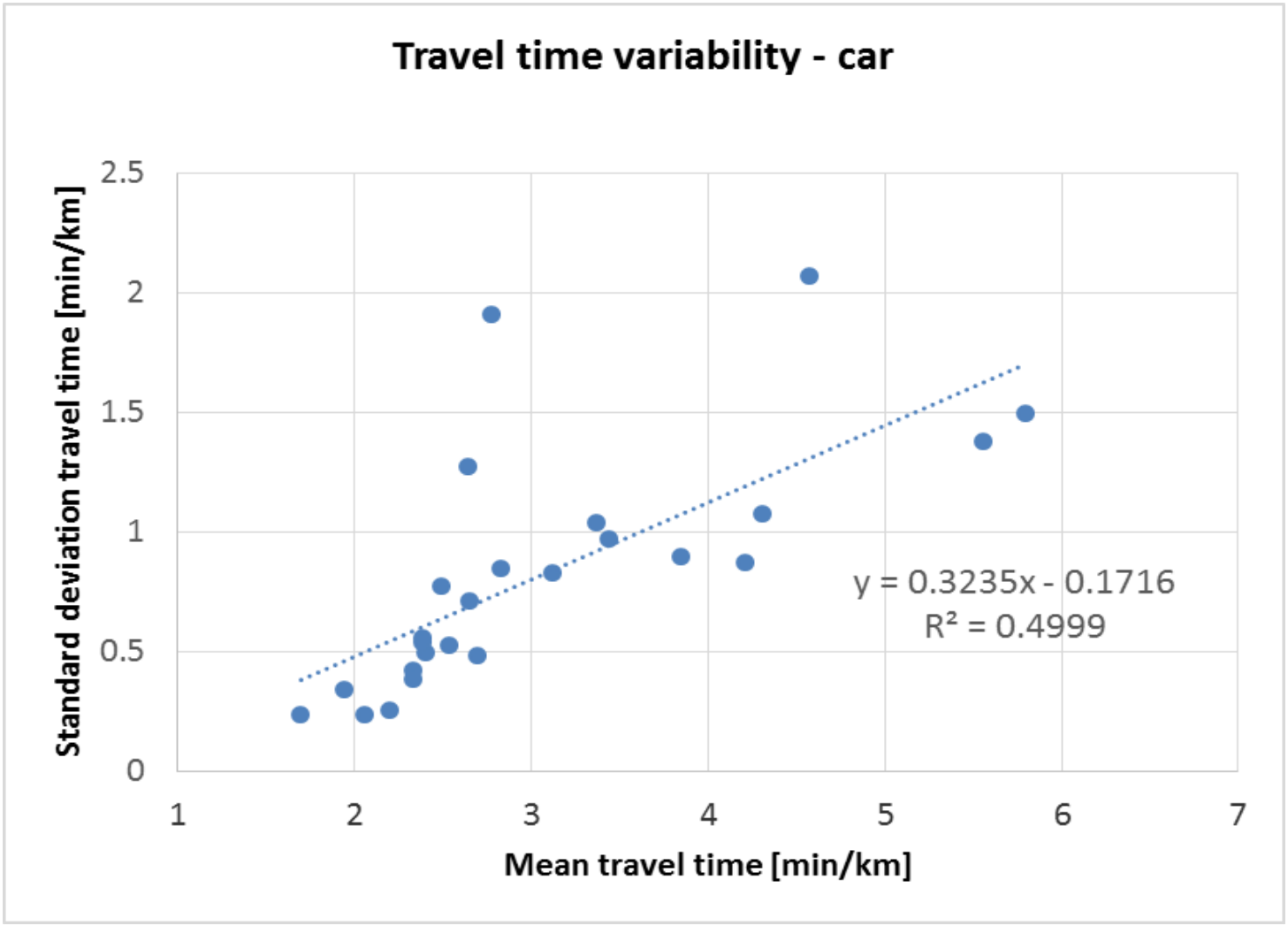
empirical analysis - Santiago car and public transport databases

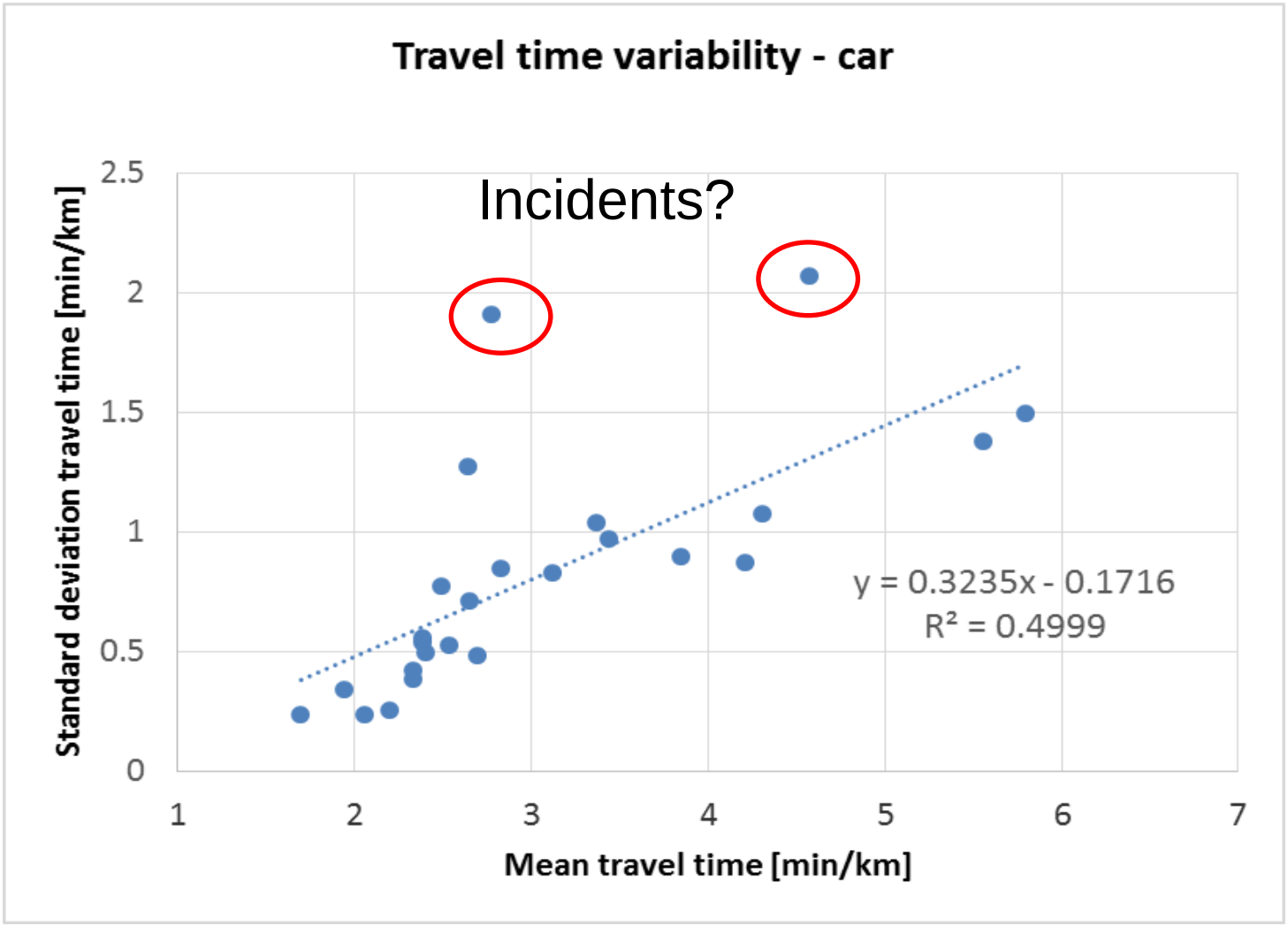
	Car database	Public transport database
Observation period	March 2010 - June 2014	May 2007 - December 2012
Time periods	Morning peak: 08:00 - 09:00 Afternoon peak: 18:00 - 20:00	Morning peak: 6:30 - 9:30 Off-peak: 9:30 - 12:30 Afternoon: 14:30 - 16:30 Afternoon peak: 17:30 - 20:30 Night: 20:30 - 01:00
Total number of observations	2,616	O-D pairs: 66 Trips stages: 35,340
Average speed (km/h)	Car morning peak: 24.1 Car afternoon peak: 20.7	Bus morning peak: 19.5 Bus off-peak: 21.6 Metro morning peak: 29.7 Metro off-peak: 32.3
Average trip length (km)	2.4	Bus: 5.6 Metro: 9.7

car TTV



SD as function of mean TT (min/km)

car TTV



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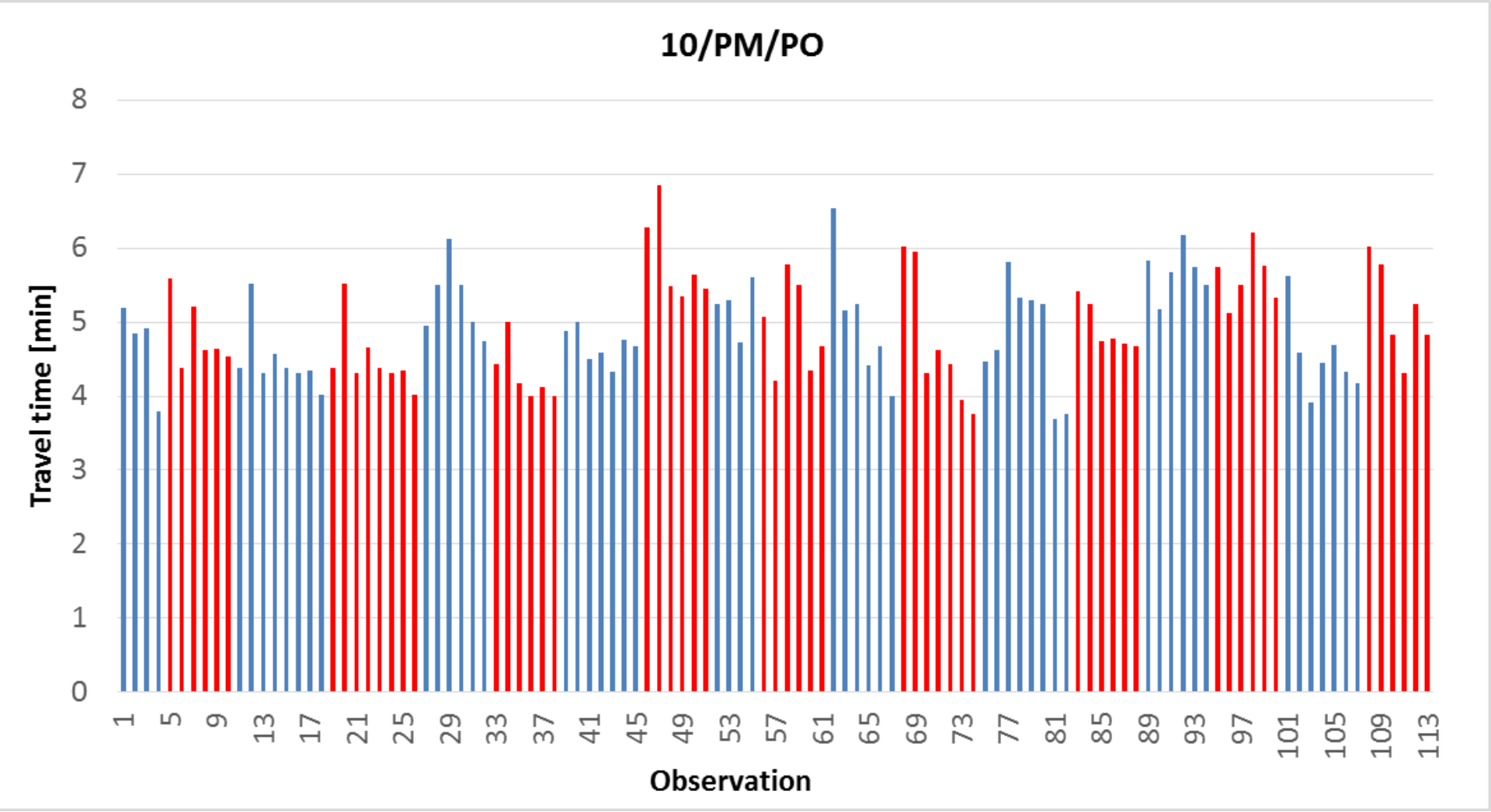
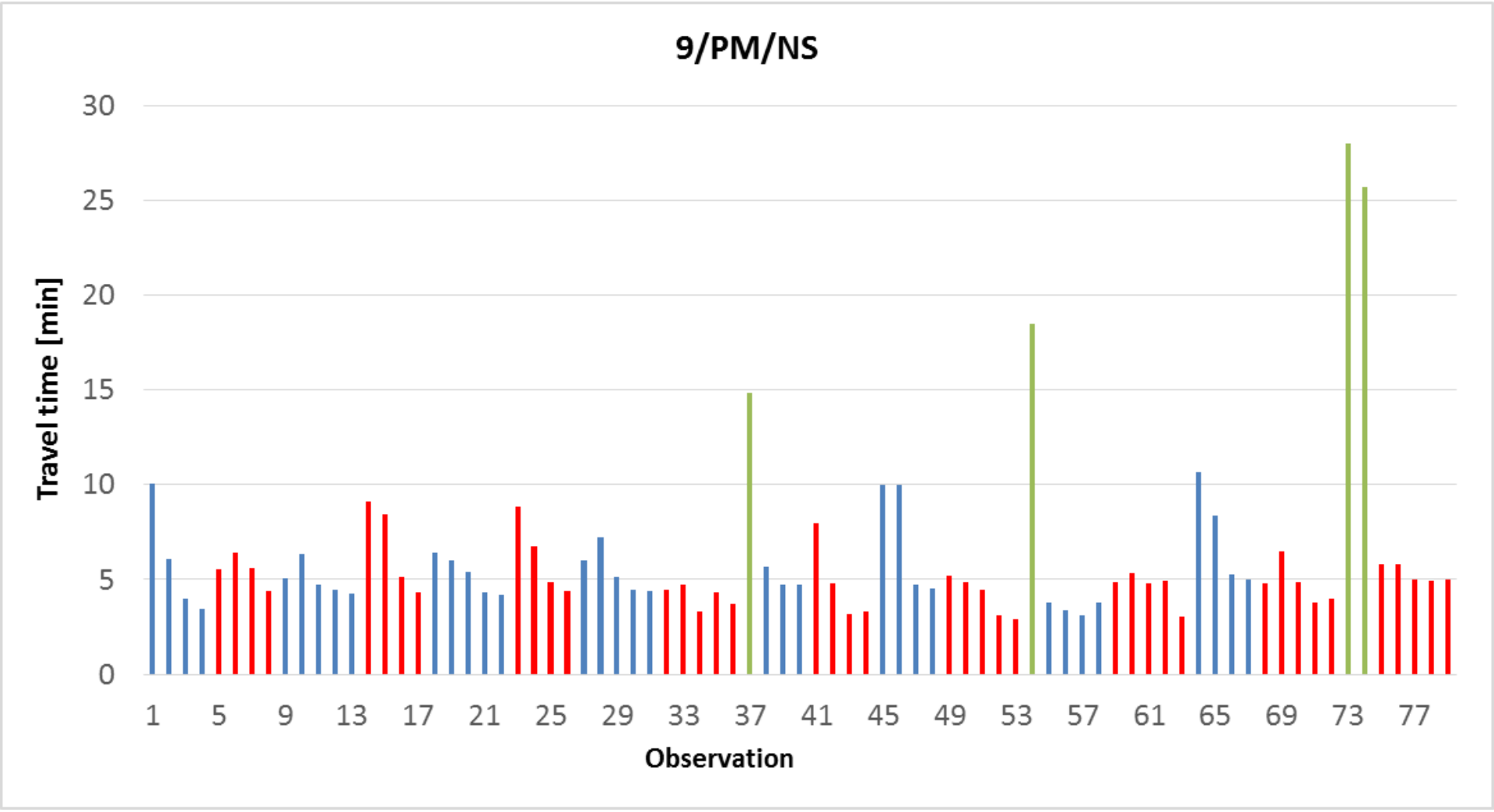


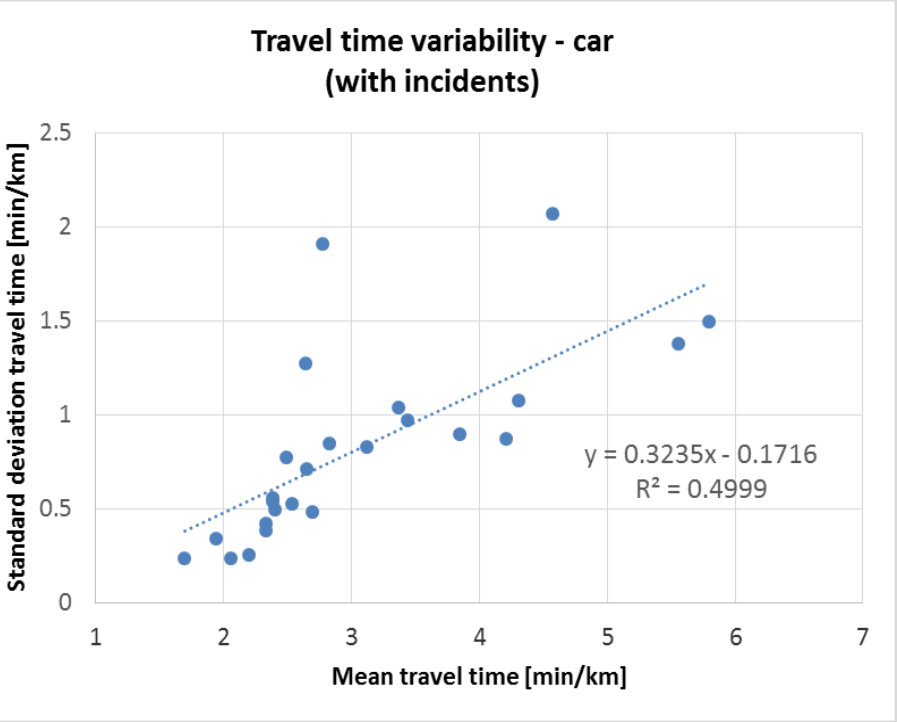
Travel time Route 10, morning peak



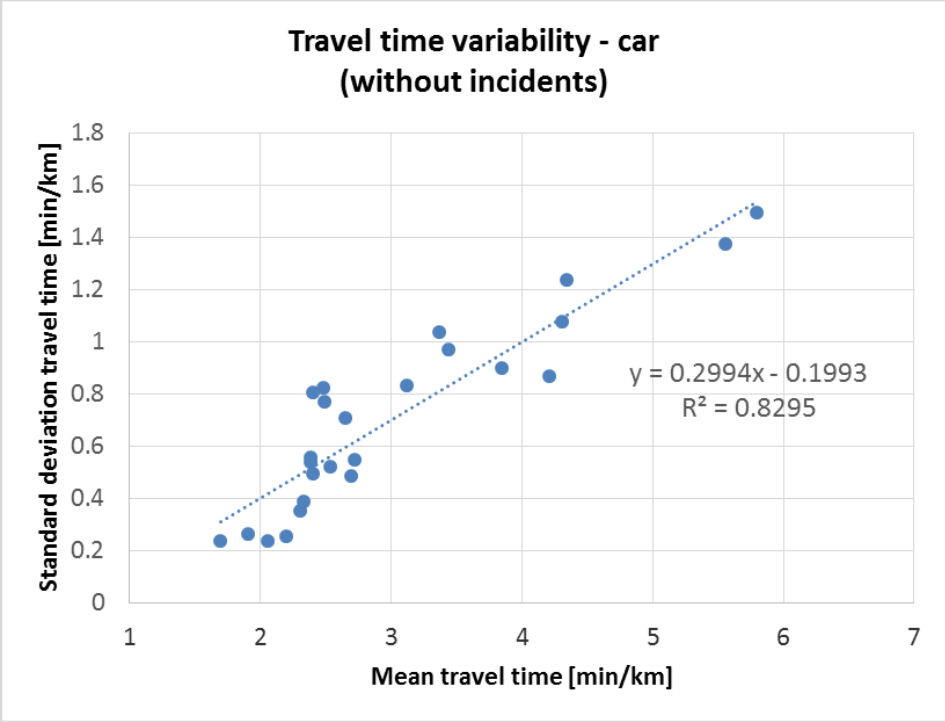
Travel time Route 9, morning peak

car TTV

All observations



Recurrent congestion only



SD as function of mean TT (min/km)

Slope 0.3 same as found in Sydney (universal constant?)

Increase 1 min/km mean TT → increase 18-20 sec/km SD

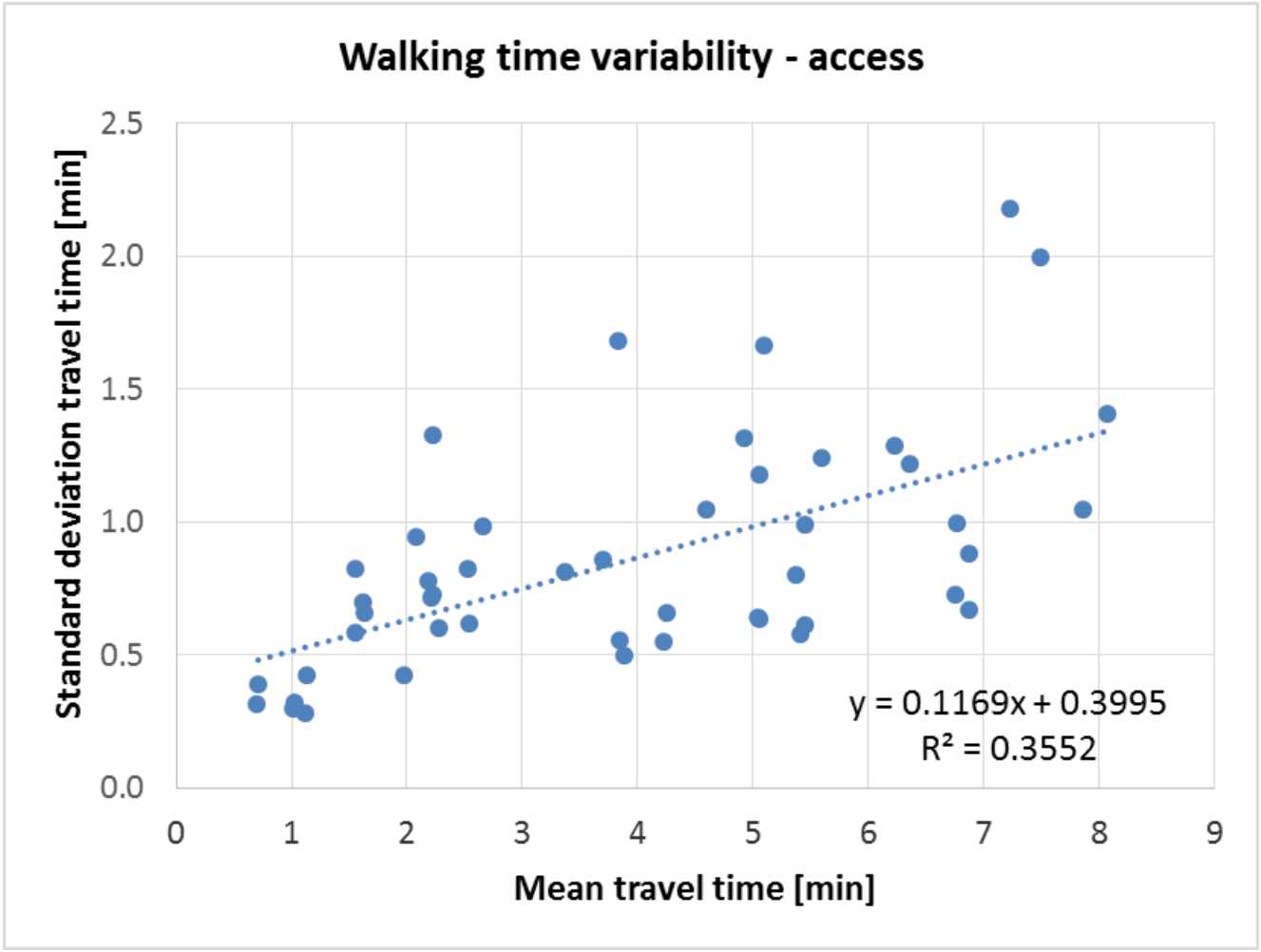
characterisation of travel time variability public transport

- **Trip from door to door, repeated observations**
- Survey public transport travel times, 2007-2012
- Each trip 200-400 times
- Trips of one, two or three legs

- Example: trip two legs (one transfer)
  1. Access walking
  2. Waiting
  3. In vehicle (bus or metro)
  4. Transfer walking
  5. Transfer waiting
  6. In vehicle (bus or metro)
  7. Egress walking

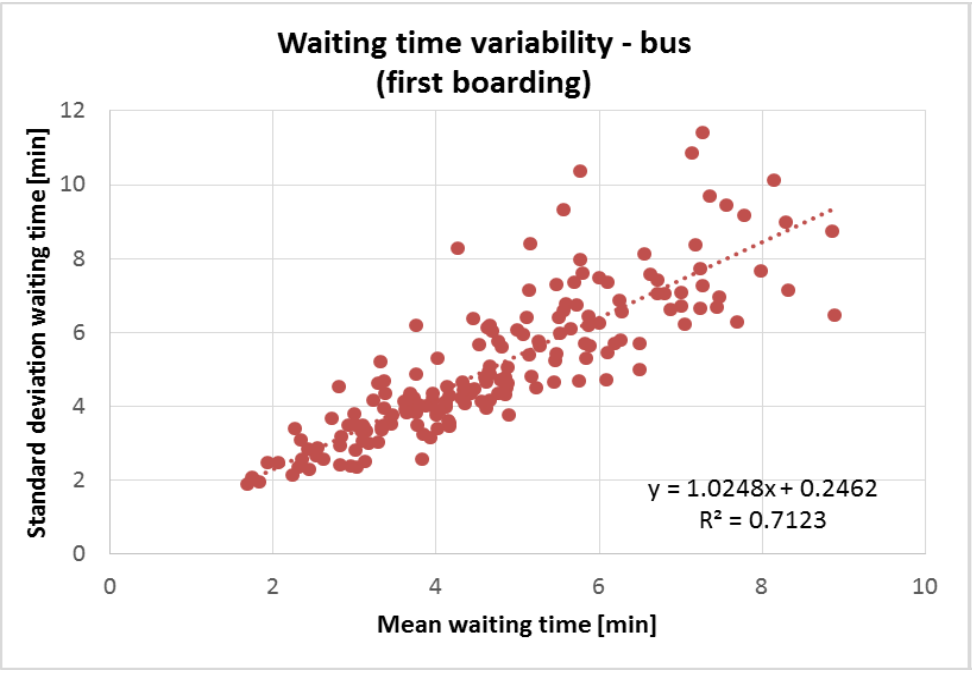
Analysis TTV per stage and mode

walking time variability

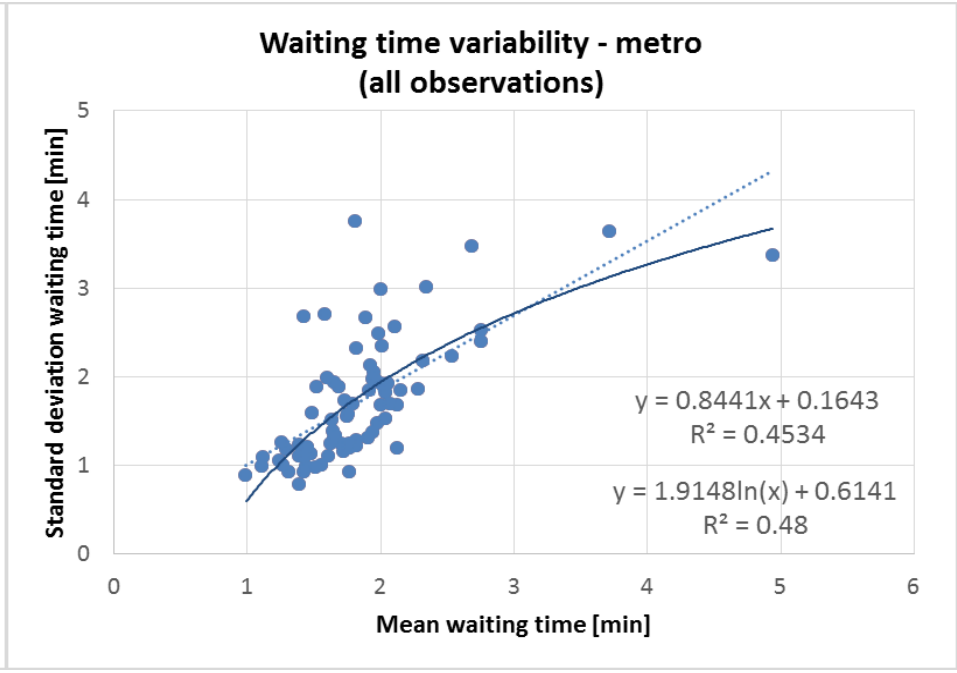


waiting time variability

Bus

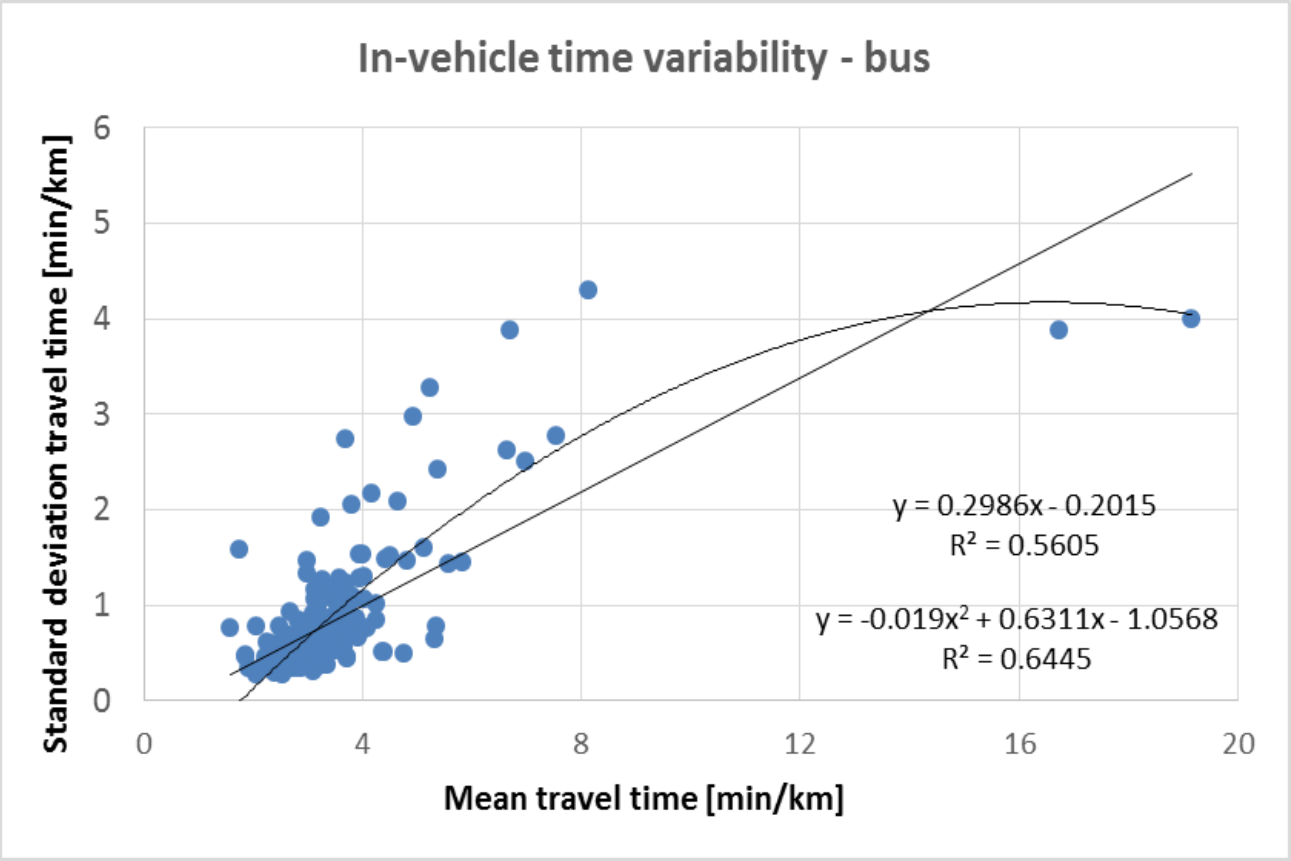


Metro

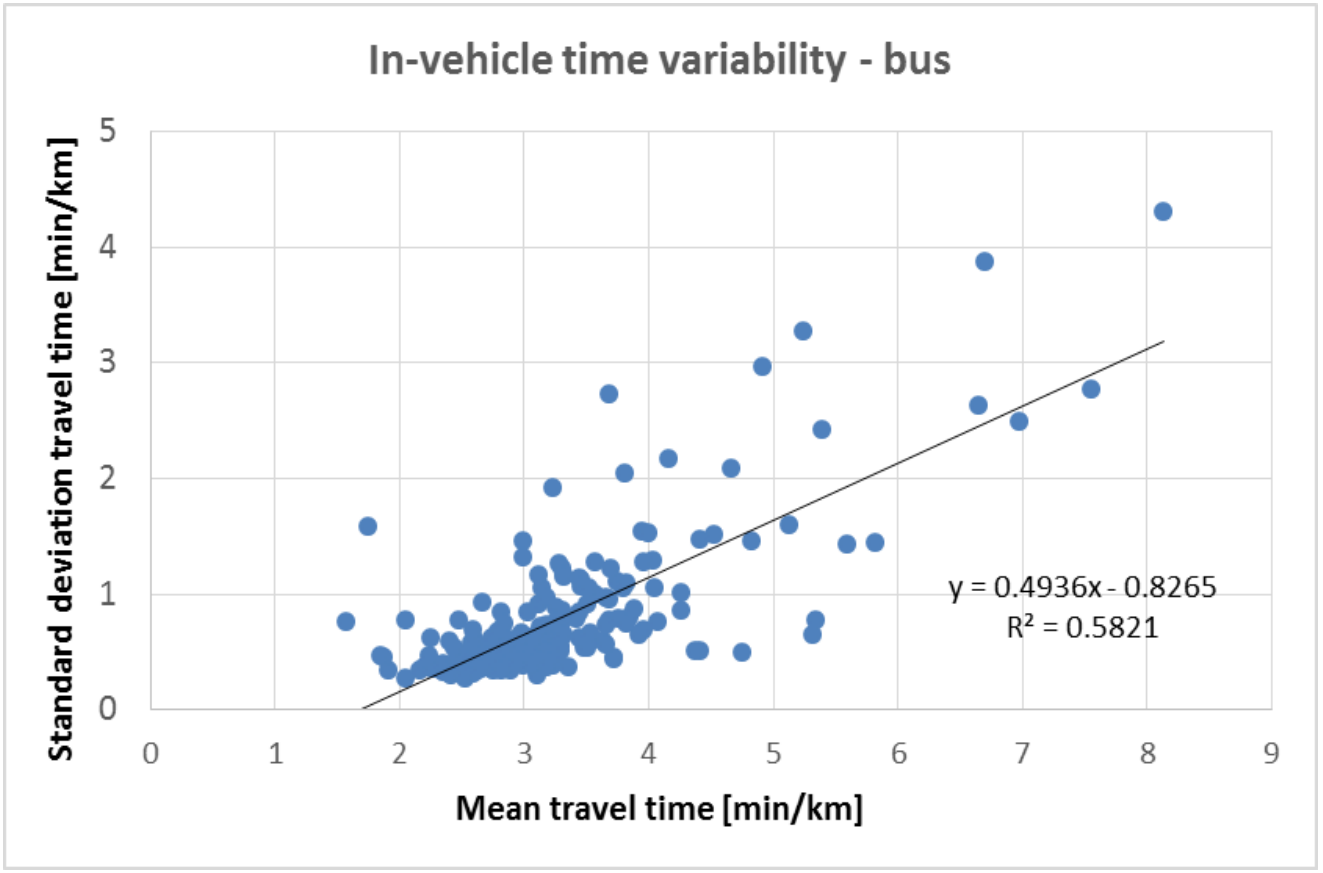


SD vs mean

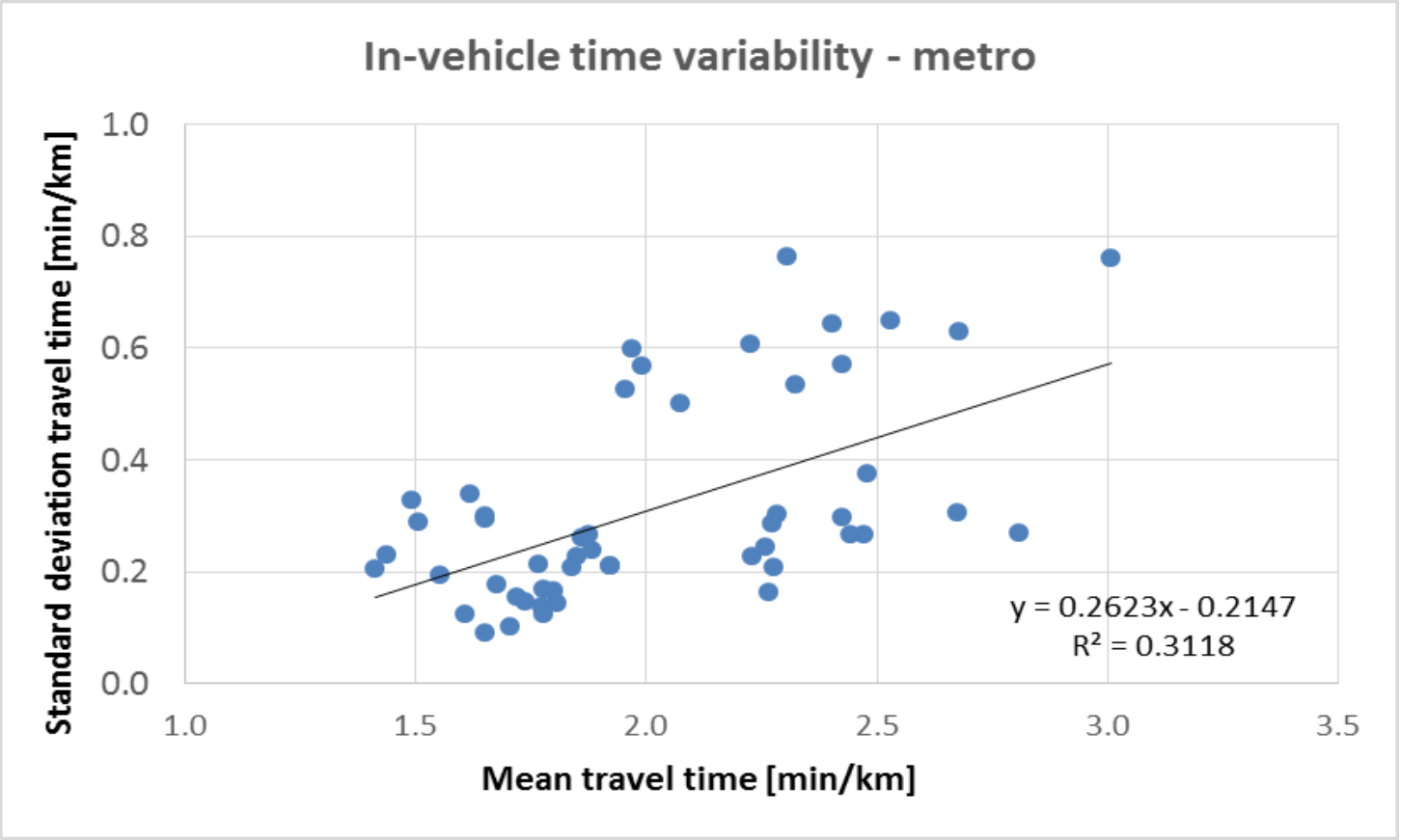
in-vehicle time variability - bus



in-vehicle time variability - bus



in-vehicle time variability - metro



Poor mean-SD relationship

Finally let us analyse the effect of every travel stage on the variability of total travel time

door-to-door TTV (public transport)

$$\sigma = b_0 + b_1 t_{walk-access} + b_2 t_{wait-bus} + b_3 t_{wait-metro} + b_4 t_{veh-bus} + b_5 t_{veh-metro} + b_6 t_{walk-trans}$$

Variable	Standard deviation		
	Parameter	t-ratio	p-value
Constant	2.706	3.556	.001
Average walking time (access)	.027	.330	.743
Average bus waiting time	**.524**	**7.235**	**.000**
Average metro waiting time	.855	1.472	.147
Average bus in-vehicle time	**.090**	**6.635**	**.000**
Average metro in-vehicle time	.009	.188	.852
Average walking time (transfer)	-.149	-1.286	.204
Number of observations	62		
Adjusted R-square	0.666		

BID FOR HOSTING

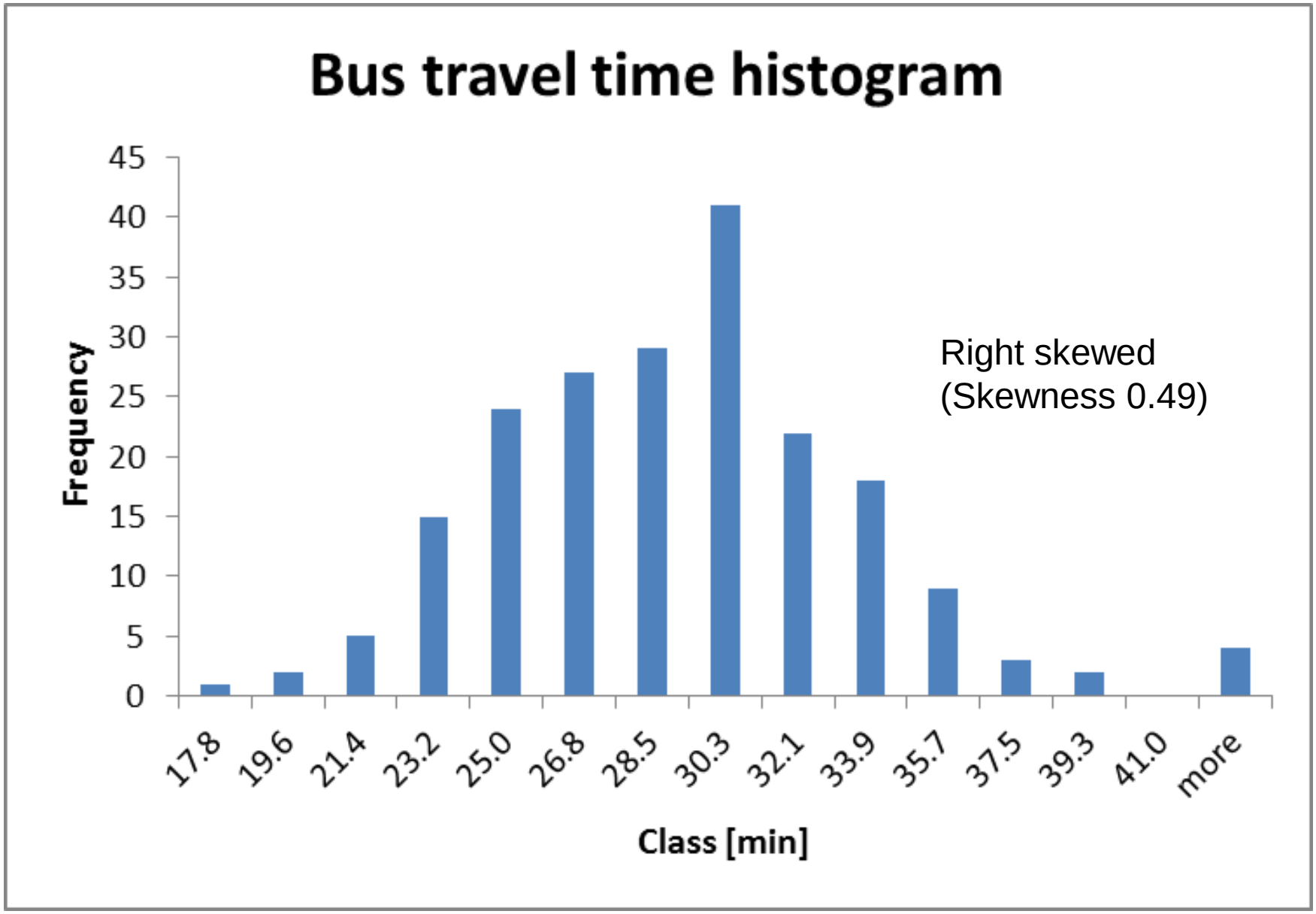
ITEA Annual Conference and School on Transportation Economics

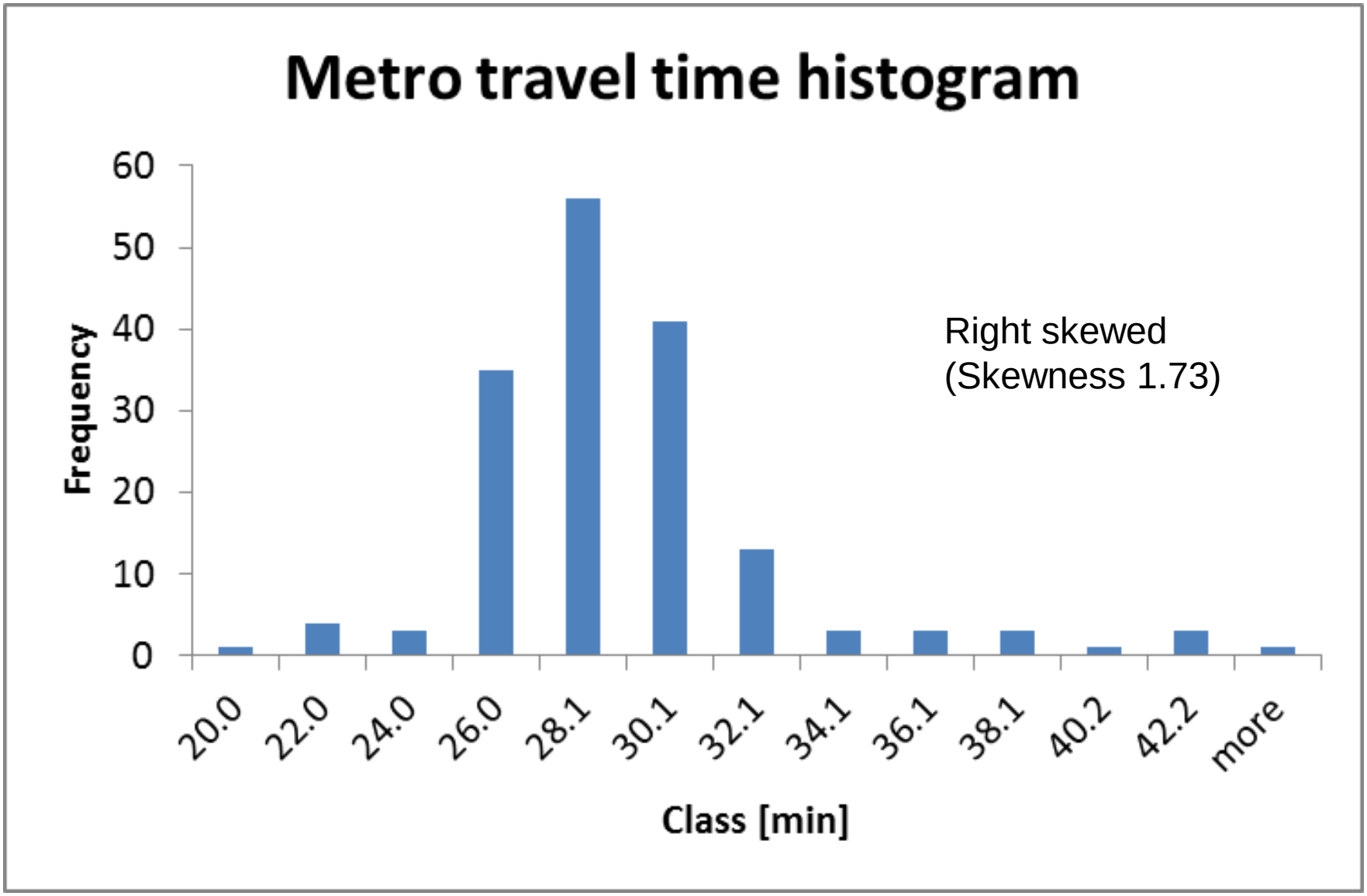
SANTIAGO CHILE

JULY 2016

Example Histograms

- Bus 403
- Metro Line 1


Bus travel time histogram
Frequency
45
40
35
30
25
20
15
10
5
0
17.8
19.6
21.4
23.2
25.0
26.8
28.5
30.3
32.1
33.9
35.7
37.5
39.3
41.0
more
Class [min]
Right skewed
(Skewness 0.49)


Metro travel time histogram
Frequency
60
50
40
30
20
10
0
20.0
22.0
24.0
26.0
28.1
30.1
32.1
34.1
36.1
38.1
40.2
42.2
more
Class [min]
Right skewed
(Skewness 1.73)