LO1: Explore innovative ways to manage and control BRT services

Juan Carlos Muñoz, Ricardo Giesen and Felipe Delgado

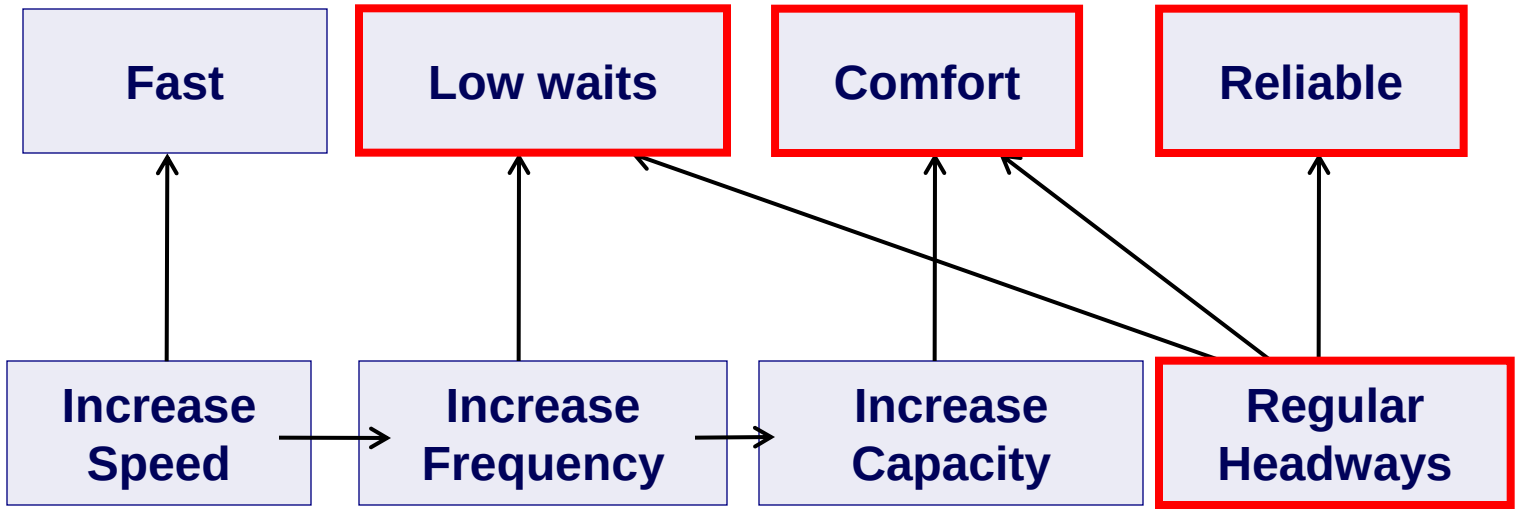
BUS RAPID TRANSIT
ACROSS LATITUDES AND CULTURES

Departamento de Ingeniería de Transporte y Logística
Pontificia Universidad Católica de Chile

Metro Attributes

Main drivers

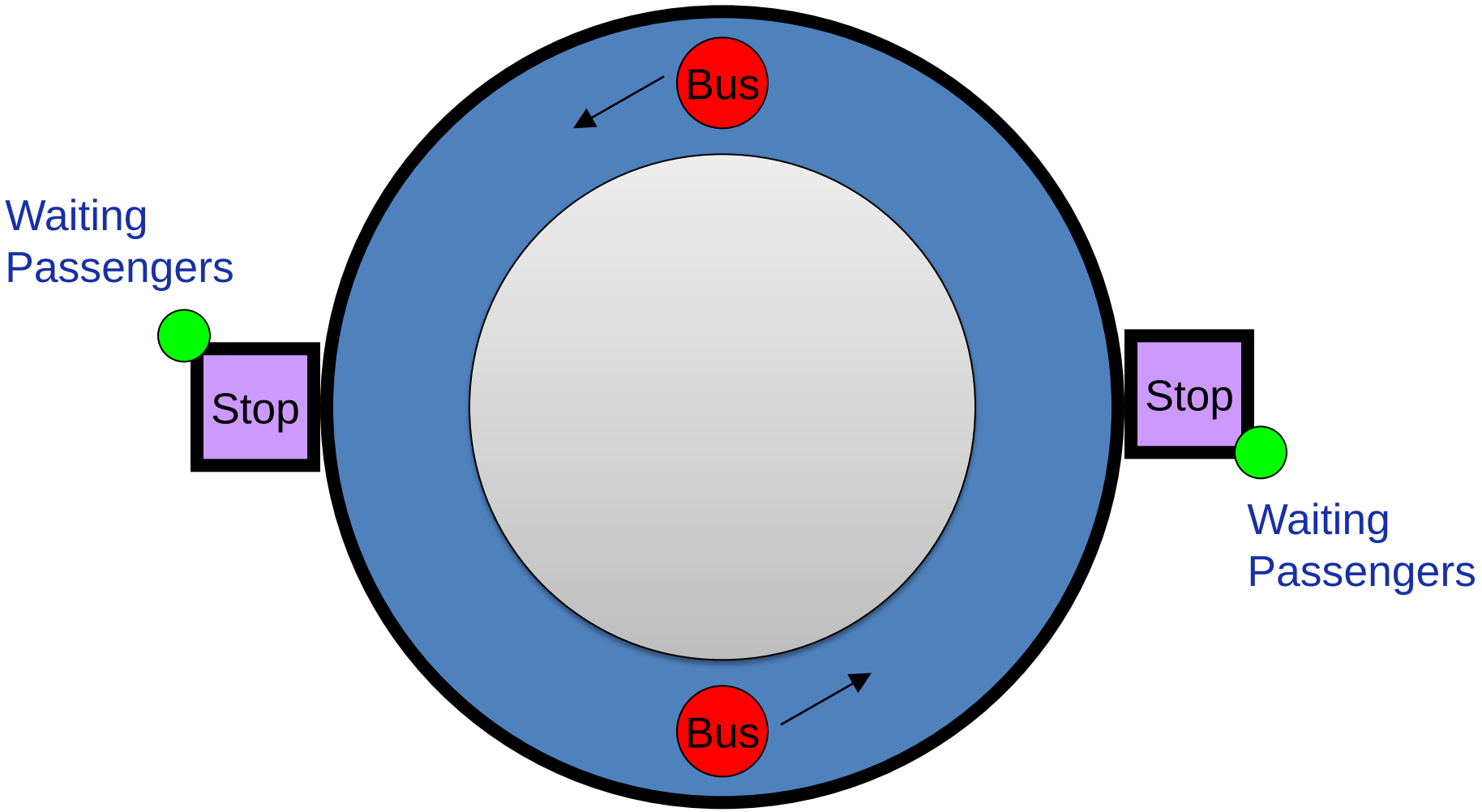
Actions



- Segregated ways/lanes
- Reduce dwell times
  - Fare payment off-bus
  - Buses with multiple doors
- Increase distance between stations
- Express services
- Traffic signal priority
- **Improved headway control**

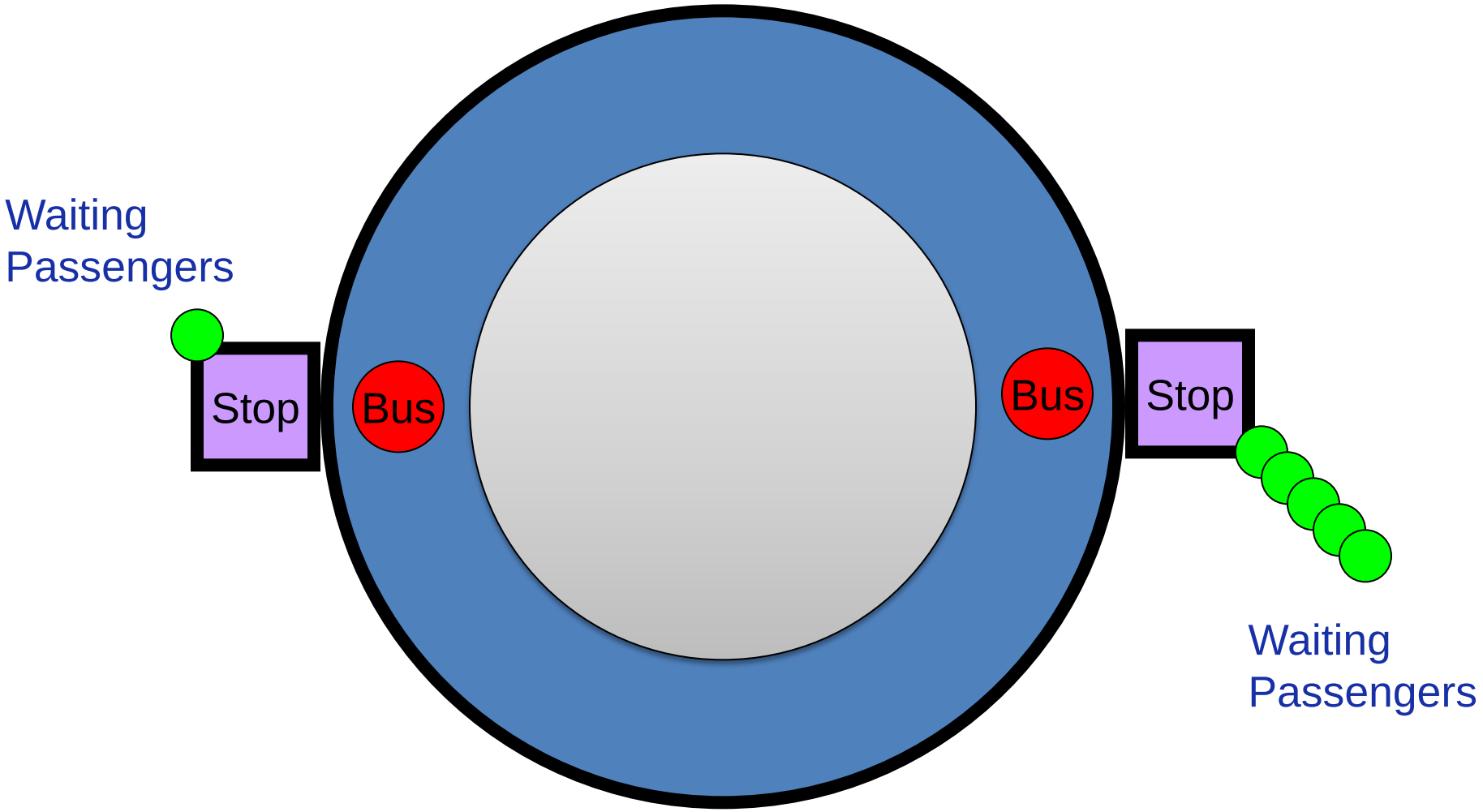
Is keeping regular headways that difficult?

Bus Operations without Control



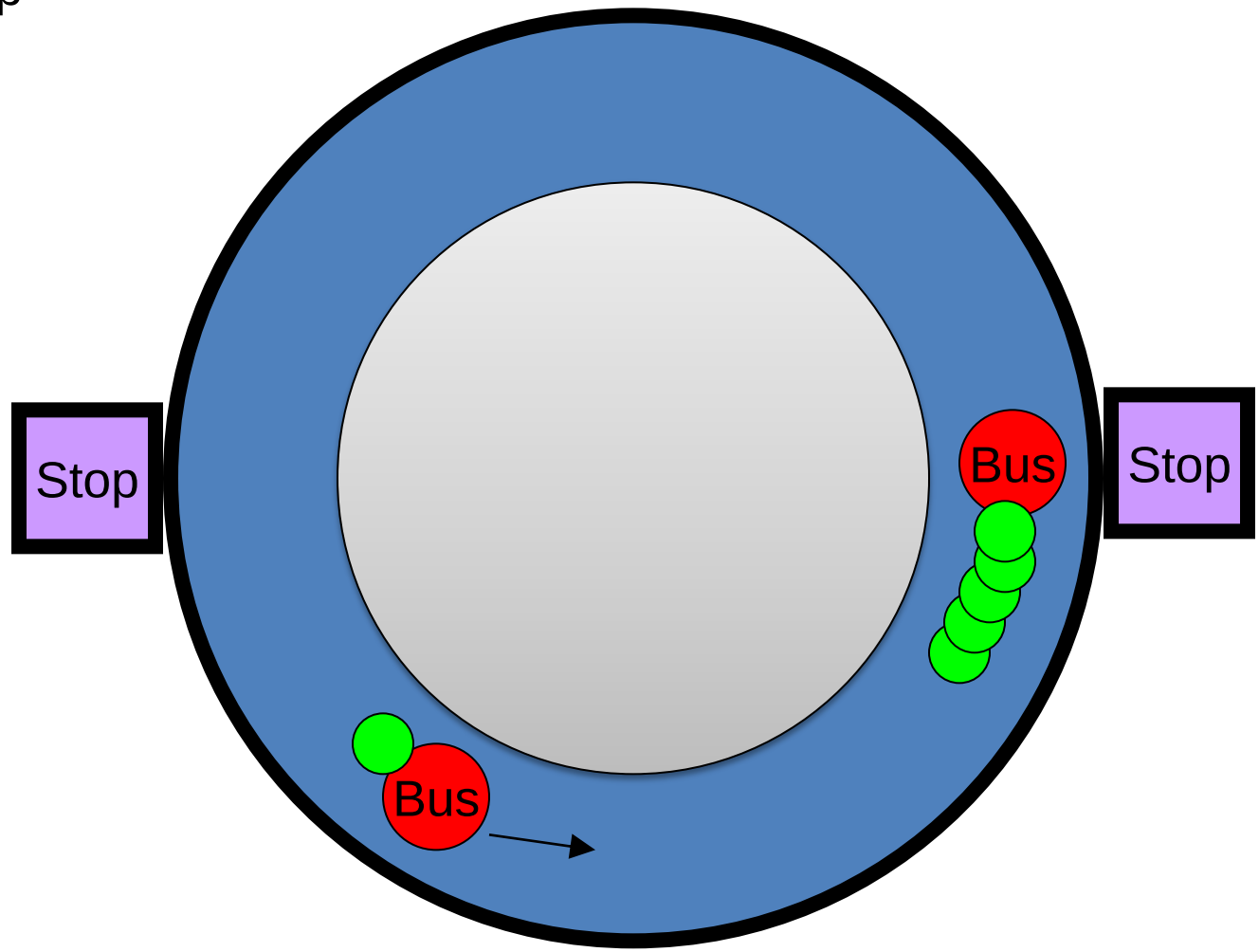
Bus Operations without Control

a small perturbation…

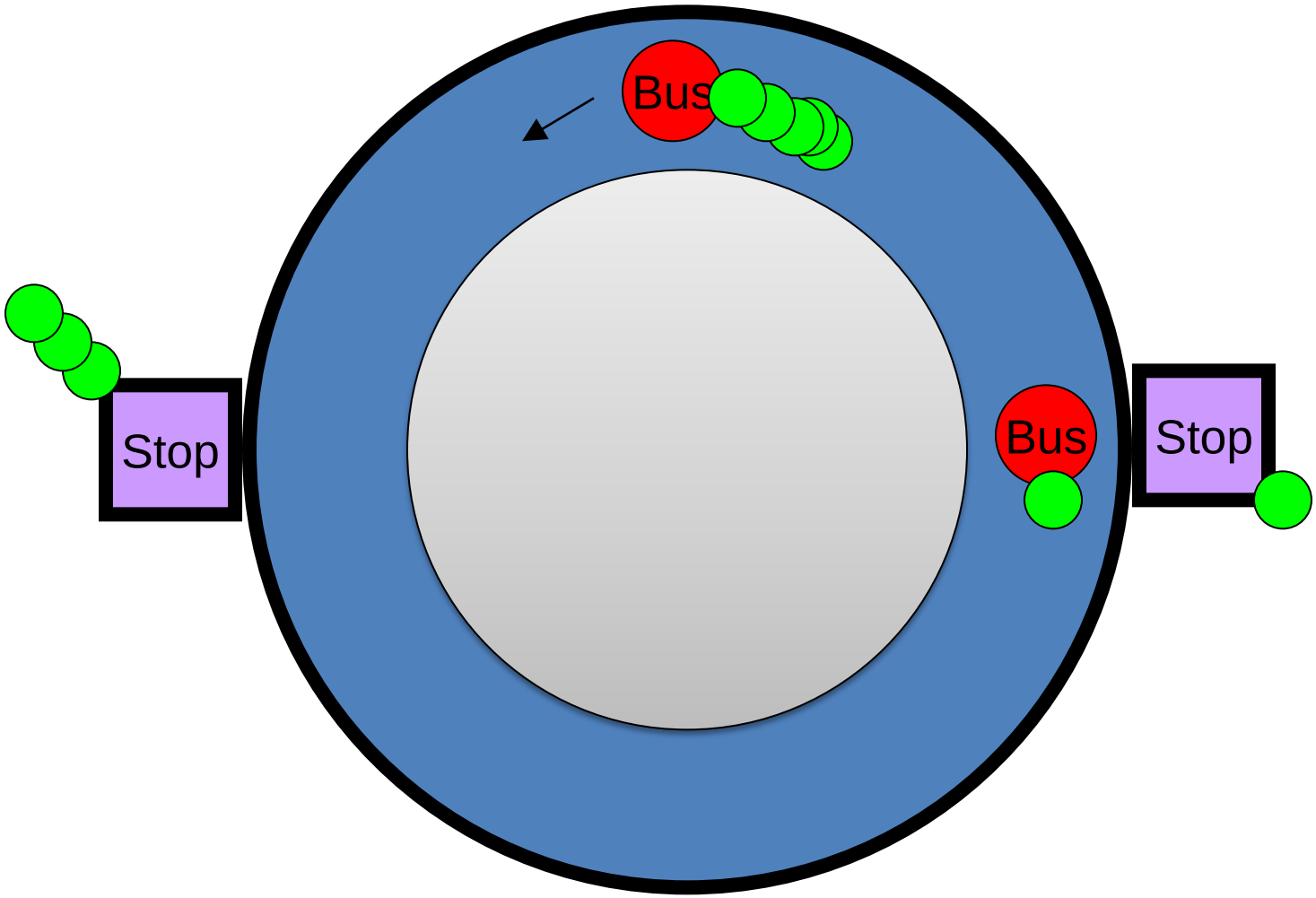


Bus Operations without Control

While one bus is still loading passengers the other bus already left its last stop

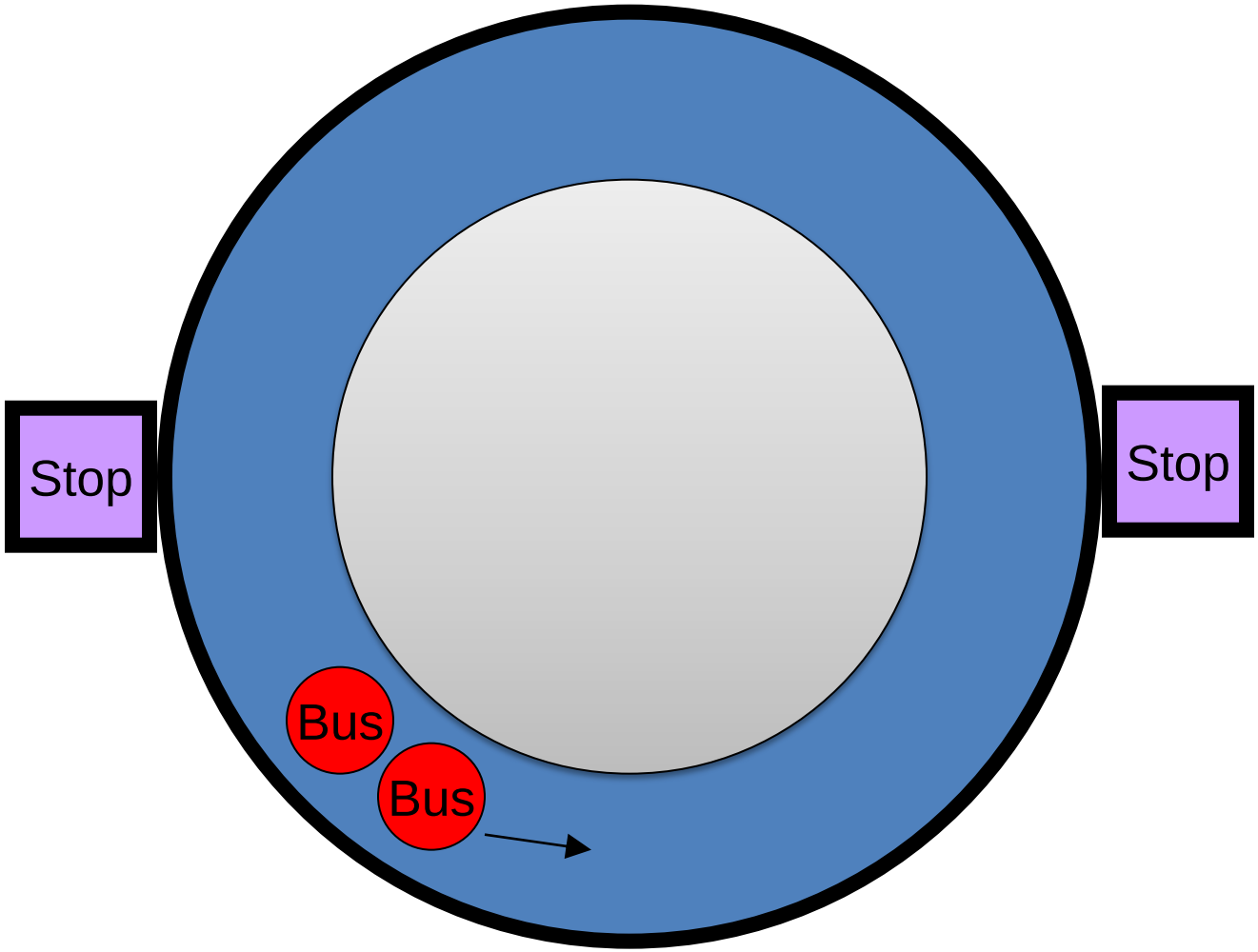


Bus Operations without Control



Bus Operations without Control

Without bus control, bus bunching occurs!!!



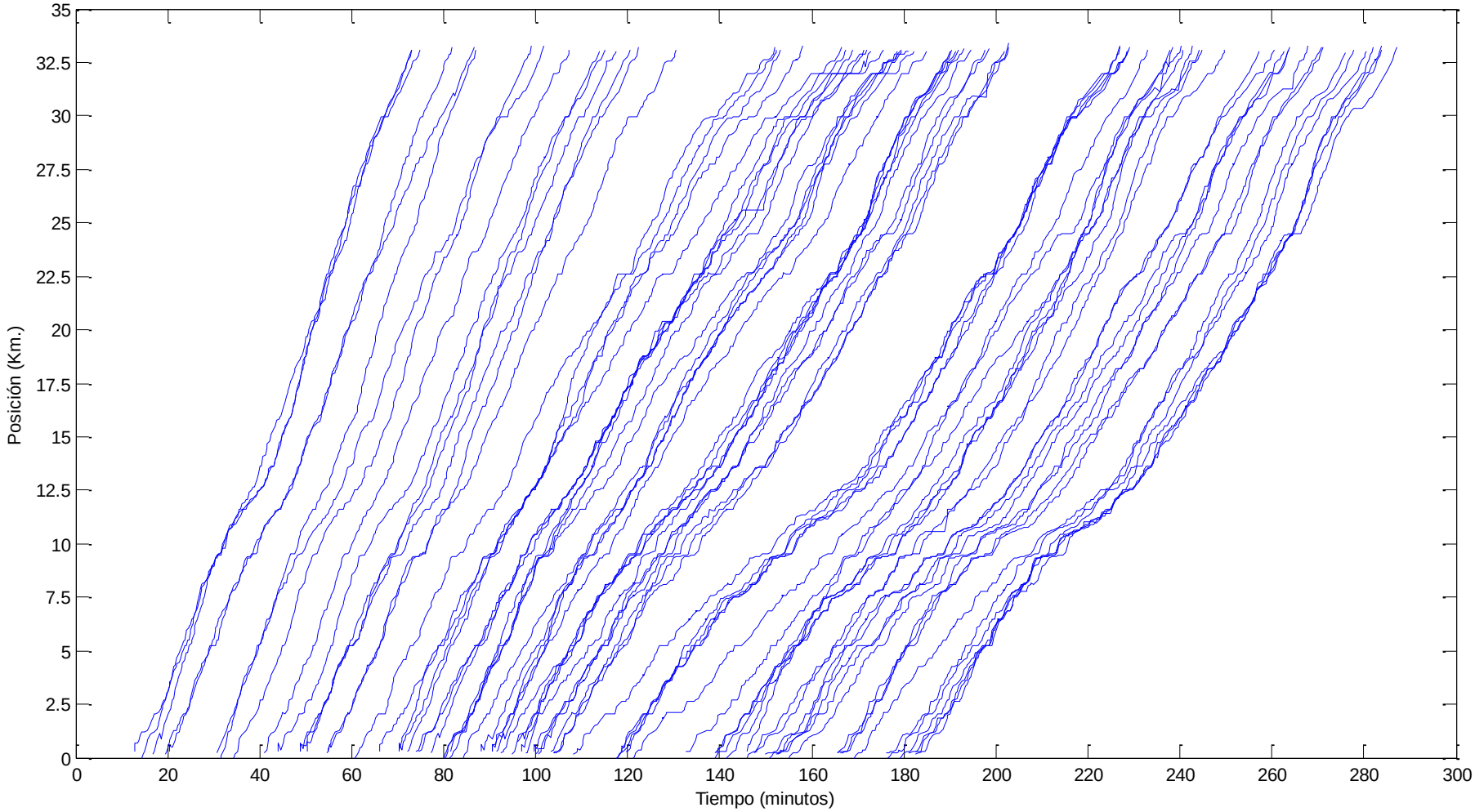
Santiago, Chile

Boston, MA; line 1 during winter

Boston, MA; line 1 during summer

In systems where bus capacity is an active constraint, this is specially serious

Time-space trajectories
Line 201, March 25th, 2009



6:30 AM

8:30 AM

Bus bunching

- Severe problem if not controlled
  - Most passengers wait longer than they should for crowded buses
  - Reduces reliability affecting passengers and operators
  - Affects Cycle time and capacity
  - Creates frictions between buses (safety)
  - Put pressure in the authority for more buses

Contribution: Control Mechanism to Avoid Bus Bunching!

2. Objective

- Propose a headway control mechanism for a high frequency & capacity-constrained corridor.
- Consider three control strategies:
  - Holding
  - Boarding Limits
  - Green extension for buses
- Explore their impact (as single strategies and jointly) in waiting, reliability, capacity and comfort
- Identify scenarios where each control strategy is recommended.

3. Approach

Based on real-time information (or estimations) about:

Bus position.

Bus loads.

# of Passengers waiting at each stop.

We run a rolling-horizon optimization model each time a decision (holding, boarding limits, traffic signals) must be made.

The model minimizes:

Time waiting for first bus + time waiting for subsequent buses +
+ time held + penalty for being prevented from boarding +
+ time waiting in cars

4. Experiment: Simulation Scenarios

One-way loop Transit corridor with 30 Stops

Scenario	Bus capacity is reached	Service frequency
1	Yes	High
2	No	High
3	Yes	Medium
4	No	Medium

4. Experiment: Control strategies

No control

Spontaneous evolution of the system.

Buses dispatched from terminal as soon as they arrive or until the design headway is reached.

No other control action is taken along the route.

Threshold control

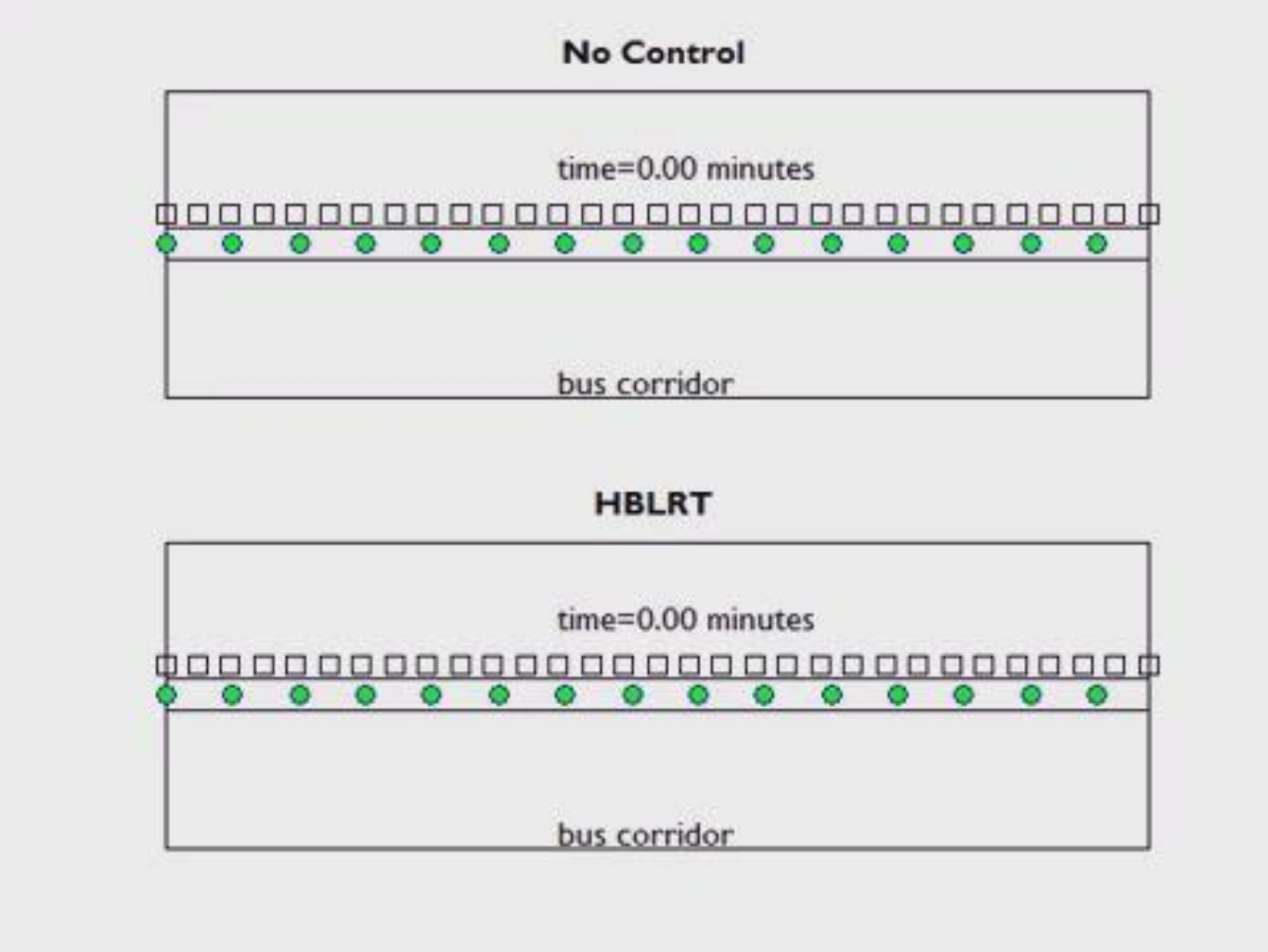
Myopic rule of regularization of headways between buses at every stop.

A bus can be held at every stop to reach a minimum headway with the previous bus.

Holding (HRT)

Solve the rolling horizon optimization model not including green extension or boarding limits.

5. Results: Simulation Animation



Simulation includes events randomness

2 hours of bus operation. 15 minutes “warm-up” period.

Results

We will only show the impact of Holding only and for scenario # 1

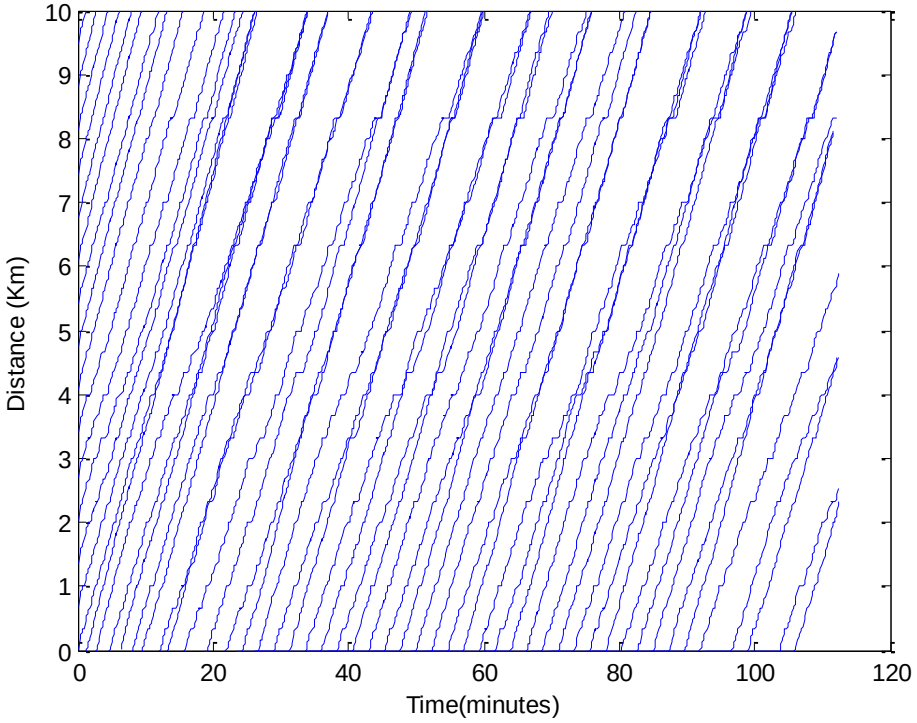
For the other scenarios, impacts are similar

For the other strategies impacts are even higher

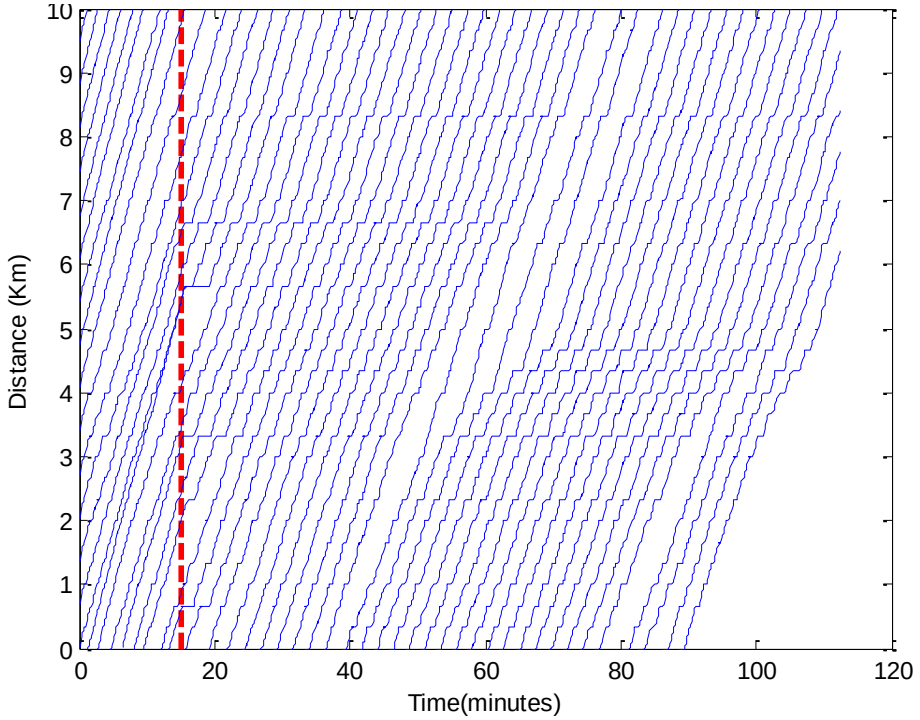
5. Results: Time savings

	No control	Threshold control	HRT
Wfirst	4552.10	1220.47	805.33
Std. Dev.	459.78	310.43	187.28
% reduction		-73.19	-82.31
Wextra	1107.37	661.70	97.49
Std. Dev.	577.01	1299.95	122.59
% reduction		-40.25	-91.20
Win-veh	270.57	6541.56	1649.28
Std. Dev.	36.00	868.74	129.56
% reduction		2317.74	509.57
Tot	5930.03	8423.73	2552.10
Std. Dev.	863.80	2377.11	390.01
% reduction		42.05	-56.96

5. Results: Time-space trajectories



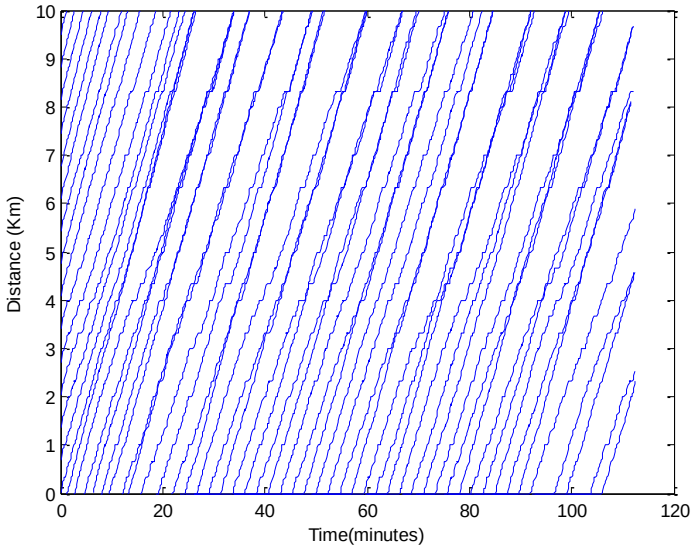
No Control



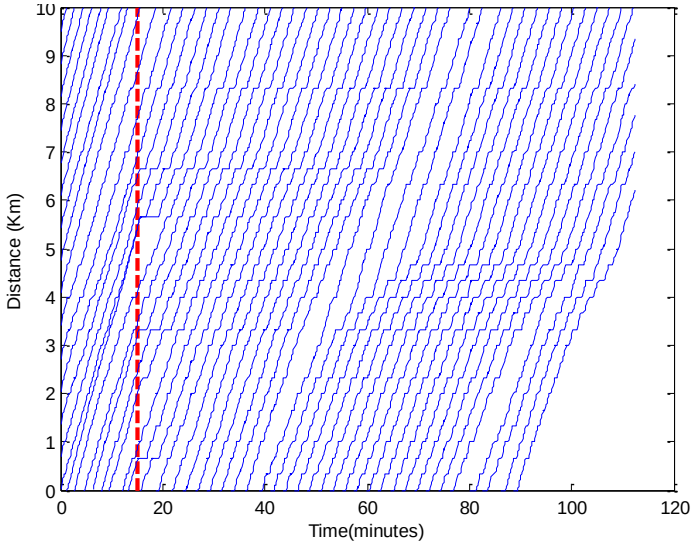
Threshold

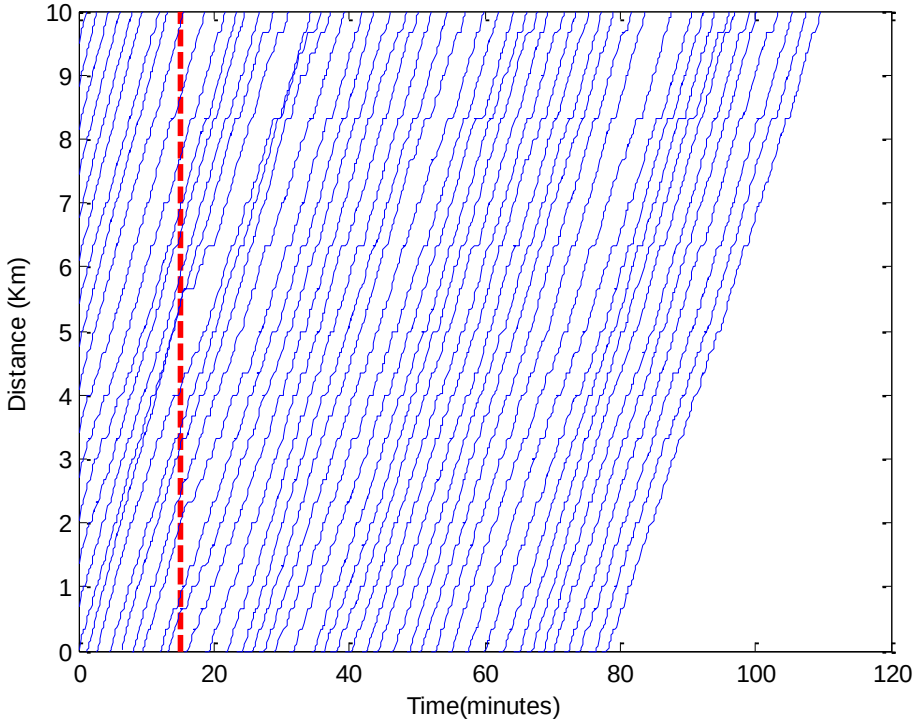
5. Results: Time-space trajectories

No Control



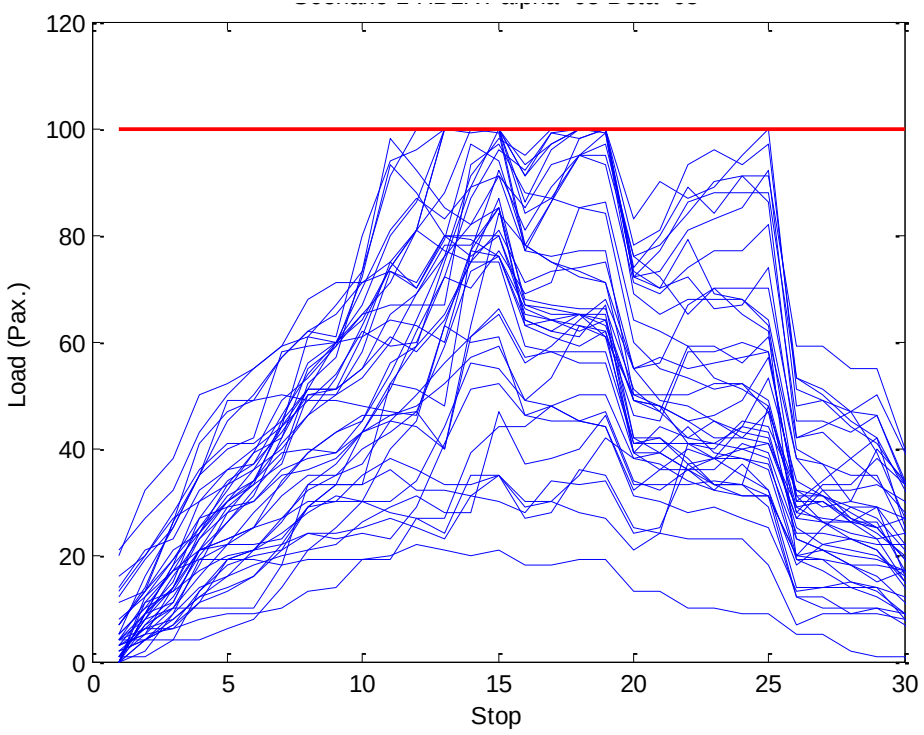
Threshold



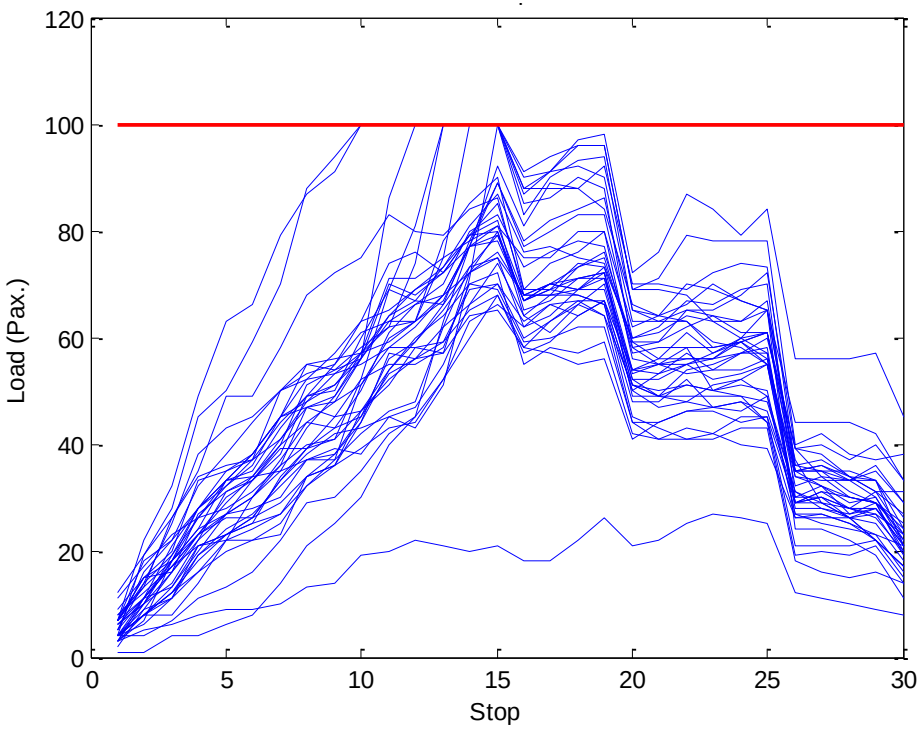


HRT

5. Results: Bus Loads



No Control



Threshold

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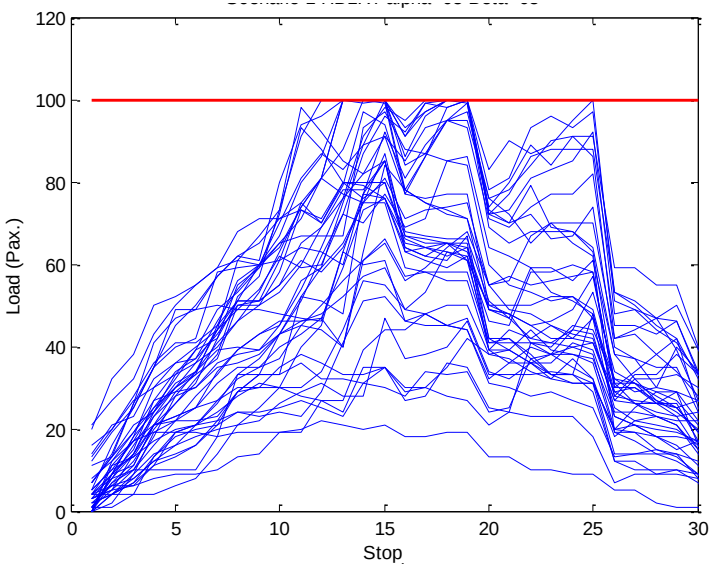
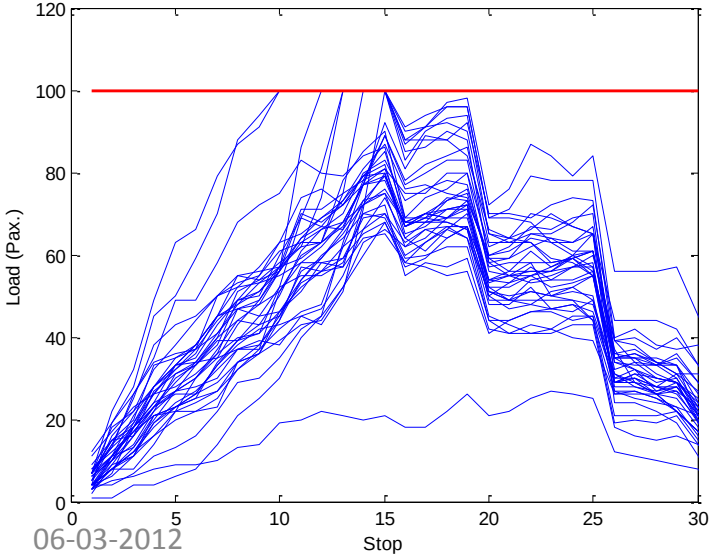
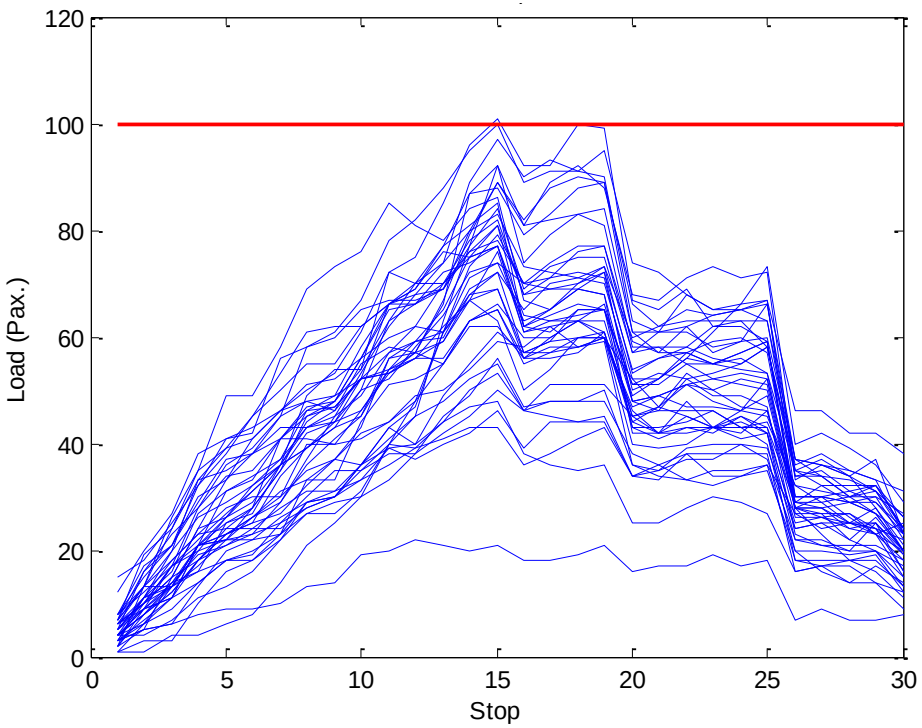
No Control



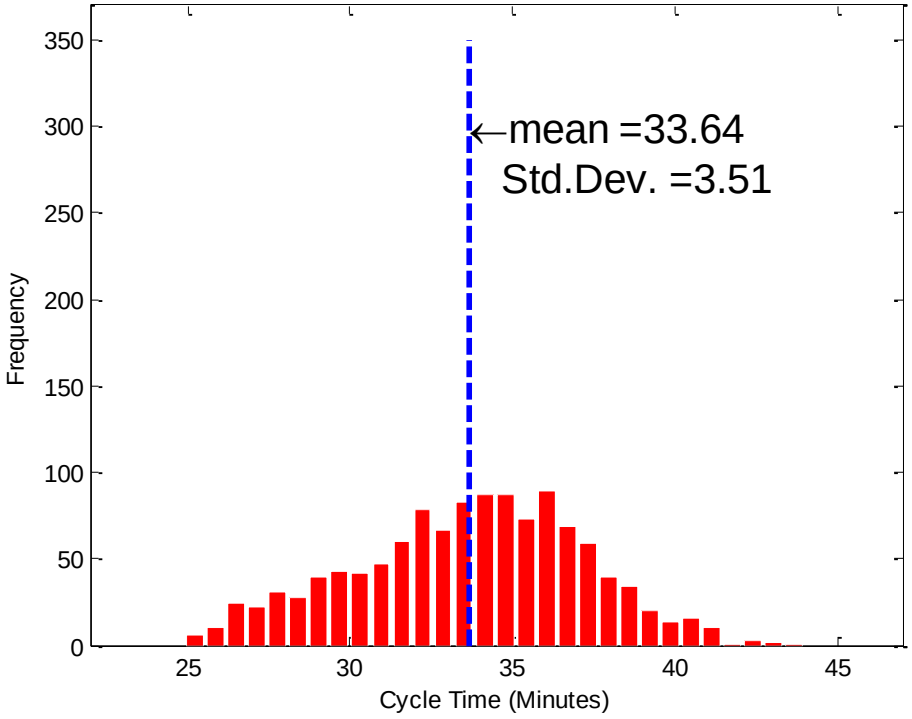
Threshold



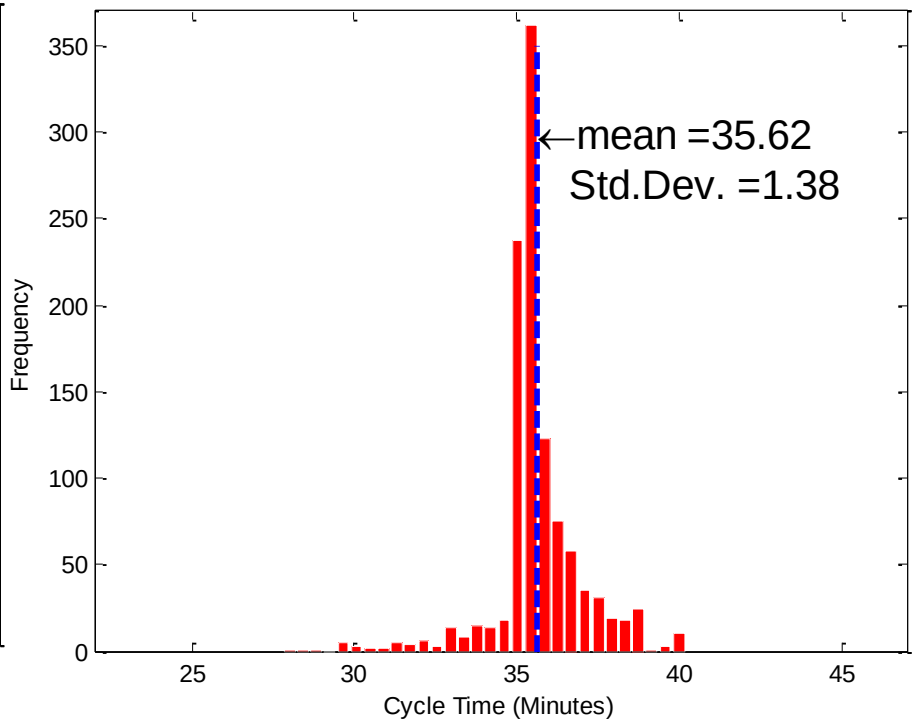


HRT

5. Results: Cycle Time



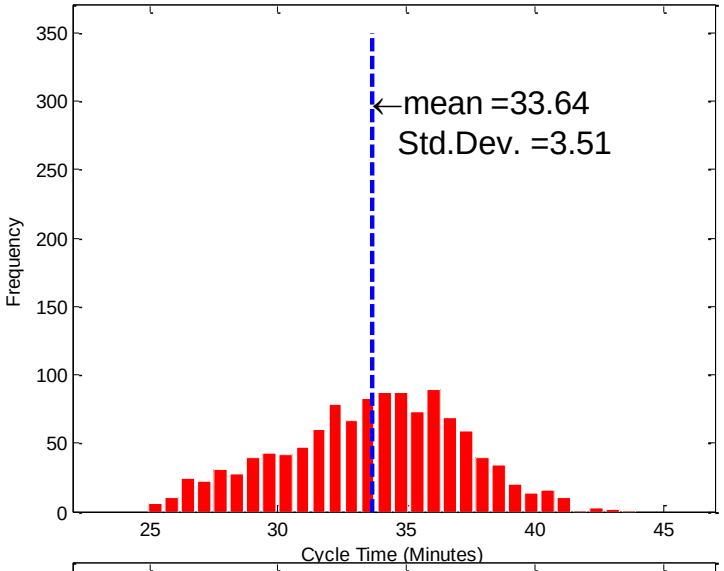
No Control



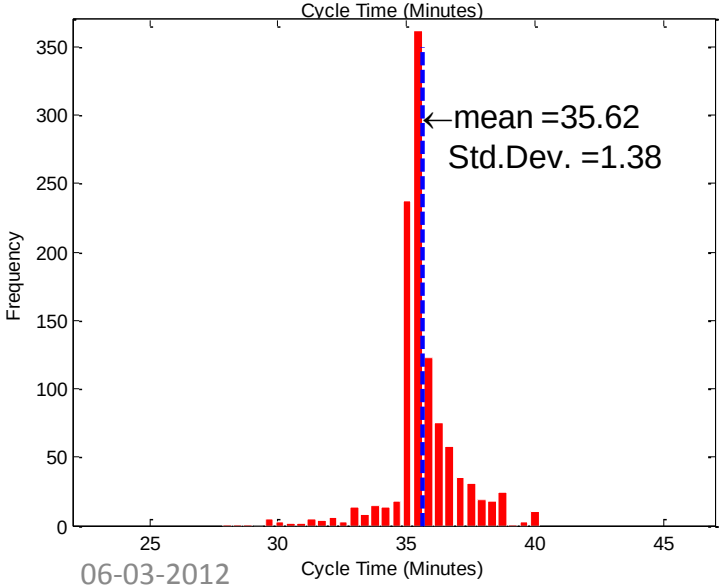
Threshold

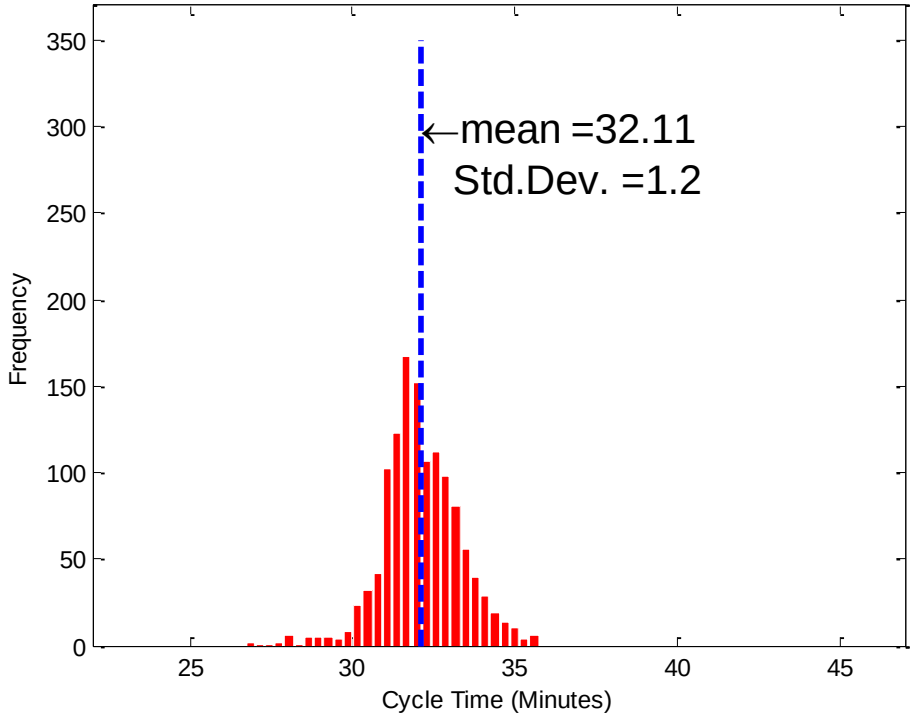
5. Results: Cycle Time

No Control



Threshold





HRT

5. Results: Waiting time Distribution

	% of passengers that have to wait between:					
	Period 15-25			Period 25-120		
	0-2 min	2-4 min	> 4 min	0-2 min	2-4 min	> 4 min
No Control	57.76	29.60	12.64	63.46	27.68	8.86
Threshold Control	78.15	20.64	1.21	82.52	16.46	1.02
HRT	79.24	20.29	0.47	87.30	12.62	0.08

6. Conclusions

Developed a tool for headway control using Holding, Boarding limits and green extension strategies.

Time savings reach over 50% just with holding

Extending it to green time extension and boarding limits savings can reach over 60% with only minor impact on car users

Huge improvements in comfort and reliability

The tool is fast enough for real time applications.

Publications and working papers

- Delgado, F., Muñoz, J.C., Giesen, R., Cipriano, A. (2009) Real-Time Control of Buses in a Transit Corridor Based on **Vehicle Holding and Boarding Limits**. *Transportation Research Record*, Vol 2090, 55-67

- Munoz, J.C. and Giesen, R. (2010). **Optimization of Public Transportation** Systems. *Encyclopedia of Operations Research and Management Science*, Vol 6, 3886-3896.

- Delgado, F., J.C. Muñoz and R. Giesen (2011) How much can holding and limiting boarding **improve transit performance**? Submitted to *Trans Res Part B*.

- Muñoz, J.C., C. Cortés, F. Delgado, F. Valencia, R. Giesen, D. Sáez and A. Cipriano (2011) **Comparison** of dynamic control strategies for transit operations. Submitted to *Trans Res Part C*.

Conferences and seminars

- Delgado F., Muñoz J.C., Giesen R. (2011) An Integrated Real Time **Transit Signal Priority Control** For High Frequency Transit Services. i) *Workshop Land Translog II*, Puerto Varas, Chile, 12-15 December. and ii) *Thredbo*, Durban, Sudáfrica, 11-15 September.
- Delgado F., Muñoz J.C., Wilson, N. and Wong, C. (2011) Operation Control Strategies **to Improve Transfers** Between High-Frequency Urban Rail Lines. *IFORS 2011*, Melbourne, Australia, 10-15 July.
- Raveau S., Delgado F., Muñoz J.C., Giesen R. (2010) **Aproximación Continua** al Fenómeno de Apelotonamiento de Buses. *XVI Congreso Panamericano de Transporte y Logística*, Lisboa, Portugal, 15-18 Julio.
- Muñoz J.C., Giesen R., Delgado F., Cipriano A., Cortés C., Sáez D., Valencia F. (2010) **Comparison of Control Strategies** for Real-time Optimization of Public Transport Systems. *TRISTAN VII*, Tromsø, Noruega, 20-25 June.

- Seminars at Berkeley, GeorgiaTech, MIT, Northwestern University, Bucaramanga and Bogota

2012

In-progress or future research I

- Microsimulation tests. Microsimulate our results with the tool developed by EMBARQ (MEng Student Felipe Ortiz)
- How can we smartly reduce the computational time to make its implementation feasible for real world cases (MEng Student Felipe Ortiz)
- How do you control buses in a corridor when there is more than one service. We need to consider that some passengers may take any of them and some need to take only one. (MSc Student Daniel Hernandez)
- How to control if a set of the drivers cannot be reached (communication failure) or do not cooperate. (Eng student William Phillips)
- How does the control mechanism operate if it is implemented with a delay (Eng student William Phillips)

In-progress or future research II

- How can we incorporate bulk arrival of passengers as in a Metro station connecting two lines or in a Metro line feeding a bus service. (Felipe Delgado and Eng student Nicolas Contreras)
- How can we control through traffic signals? How can we optimally mix it with traffic signals?
- When should we prefer to reserve some vehicles from our fleet to be inserted in the operations to deal with irregularity? (work with MIT as part of MISTI project)
- How can we use this control tool to deal with a big incident and a scheduled operation?
- Develop an educational tool. (Felipe Delgado)

Educational impact

- Educational tool
  - We will be developing an educational tool oriented to anyone interested in learning about this problem. The goal will be to understand the problem by seeing how buses bunch and how this impacts the level of service to passengers.
  - Then the user will try to control the buses manually and realize that the performance obtained is very poor if contrasted with a more robust and comprehensive approach.
  - The game should build intuitions regarding what works and what does not.
- We have added Felipe Delgado as a permanent faculty member at PUC.

Grants obtained

- FONDECYT (2012-2014) *Control strategies for buses in a corridor with multiple bus services*. (US$150,000 requested, funds actually granted are still unknown)
  - Ricardo Giesen (main researcher). Also Juan Carlos Muñoz, Felipe Delgado and Juan Carlos Herrera

- MISTI (2012-2013) *Urban Public Transport Operations Control* (US$30,000)
  - Nigel Wilson, John Attanucci, Juan Carlos Muñoz and Ricardo Giesen

From the papers to the streets

- Several interviews with the media during 2011
- Several interviews with authorities during 2011
- Four pilot plans are being planned for headway control during 2012:
  - Two trunk services of Transantiago (Buses Metropolitana and Inversiones Alsacia),
  - A BRT corridor in Bucaramanga, Colombia
  - Metro of Santiago

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