Bus Signal Priority and Operational Control in the Old San Juan Corridor

Research Proposal

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1. Objectives

This study will look at the effect of signal priority and operational control on bus service quality. The study area will be the Old San Juan (OSJ) corridor. The corridor connects Old San Juan on the western tip of the Island with the northern end of the initial Tren Urbano alignment (see Figure 1). The OSJ corridor stretches from Old San Juan on the western tip of the Island towards the eastern end of the Island and then southeast through Santurce along two major connector roads, Avenida Ponce de Leon and Avenida Fernandez Juncos, to the proposed Sagrado Corazon station.

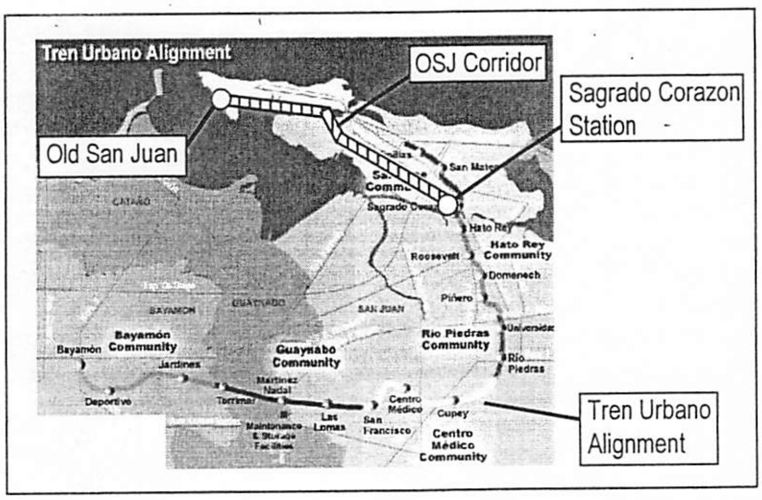


Figure 1 – Proposed Alignment and OSJ Corridor

The main objective of this study is *to demonstrate how priority and operational control can improve bus service quality along the Old San Juan (OSJ) corridor*. Evaluation measures will be (1) benefits to bus customers (travel time, schedule adherence, connection time), (2) impact on others (autos, other transit services) and (3) implementation issues.

2. Motivation

To manage congestion in the San Juan metropolitan region, the government of Puerto Rico is building a multimodal public transportation system, with Tren Urbano as the system's backbone. Using a fixed guideway system it will provide a fast and reliable transit service between several major centers.

The proposed alignment for the initial system however, does not extend northwest towards Old San Juan but ends at the proposed Sagrado Corazon Station. Old San Juan and the Island offer several attractions, which generate transportation demand and will require good access. Among them are tourist destinations, like Old San Juan itself, cruise ship terminals on the southern coast of the island, government destinations in the north of the island and the U.S. naval reserve in the east, as well as commercial attractions. The area will be connected with Tren Urbano through bus feeders, which will run along the major corridors on the island and in Santurce. Old San Juan is currently served by AMA and Metrobus routes, which run from Old San Juan to Hato Rey.

With its numerous attractions the island will have a high demand for transportation to this area. It will be imperative to provide an attractive and reliable transportation alternative to achieve two goals: (1) Establish transit as a viable alternative to decrease congestion; (2) Provide an excellent feeder service to Tren Urbano, which will improve Tren Urbano access and lead to an increase in ridership and (3) develop a transit market along the corridor for a future extension of Tren Urbano.

The Bus Feeder System report identified the need for 10 buses per hour along the OSJ corridor. [1] Also if demand is strong it will be desirable to have a bus meet every train at Sagrado Corazon, which would result in 4-minute headways during peak hours. To operate such a high service frequency along the corridor, measures are required that decrease delay and irregularities of bus operations. This will also be necessary to avoid overcrowding at the transfer from Tren Urbano to the bus feeder. During off-peak periods the transfer from bus to Tren Urbano should also be synchronized and therefore adhere to the schedule.

Slow and irregular bus service is usually caused by dispatching delays, intersection delays and dwell time variations, which amplify other irregularities. If a bus is late, more people will be waiting at a bus stop and the dwell time will be longer and so the bus will be even later. The reverse is true for an early bus, fewer people are waiting and the dwell time will be shorter, which makes the bus even earlier. Bus lanes (including contra-flow lanes) improve speed and reduce intersection delay and irregularity to some degree. Nevertheless further means of operational control that not only reduce sources of irregularities, but can counteract unavoidable irregularity are needed. [2]

Active signal priority at signalized intersections can significantly improve regularity of transit service. Active means that vehicles are detected and the detection will lead to a change in the signal program. They can be divided into absolute and conditional priority. Absolute priority gives priority to any transit vehicle regardless of its schedule adherence. While this improves the running time it is limited in its operational control, since it cannot, for example, hold early buses.

Conditional priority, however, offers this operational control by giving priority to late buses, but not to early buses. This provides the kind of push/pull correction needed to correct schedule deviation. If a bus is late, it will be 'pushed' through the intersection by getting a green light; if it is early it will be "pulled back' by not getting priority. This strategy not only improves schedule adherence but also causes less impact on other traffic than absolute priority, while it preserves most of the running time savings of absolute priority. Conditional priority is therefore an excellent means of operational control and will be used as the prime strategy for creating a reliable service on the OSJ corridor. [2]

3. Research Approach

(1) Review existing research and experiences

Experiences from other systems, including the current FTA Bus Rapid Transit Demonstration Program, priority control research in the US and Europe and strategies applied will be reviewed and summarized. The analysis of experiences from existing systems will help to narrow down successful strategies.

(2) Obtain and review critical data

Extensive data will be required for the proposed research. This includes the following:

DATA ITEM	SOURCE	STATUS
Street layouts (lane configuration)	K. Kruckemeyer	In progress
Transit infrastructure (stations, stop locations, bus lanes),	Multisystems	In progress
Traffic data at intersections (traffic flow, turning movements, signal timing plans)	DPWTPR	In progress
Transit operation data (schedules and passenger counts)	Multisystems	In progress

All data will be reviewed for consistency and extrapolated for the opening year of Tren Urbano in 2002.

(3) Optimize infrastructure

While signal priority and operational control will be the main focus of this study, it is important to recognize the impact of other measures on bus speed and reliability. Therefore the existing transit infrastructure and existing priority measures along the OSJ corridor will be analyzed. Based on this analysis areas will be identified that require additional infrastructure priority measures that could enhance service quality of bus operations along the OSJ corridor.

The main effort will be:

- Bus lanes: review, suggest and modify bus lanes as appropriate
- Stop spacing: Optimize stop spacing by applying the optimization method developed by Peter G. Furth and A. Rabee. [3]
- Vehicle design and fare payment system: Favorable vehicle design and fare payment systems, like low floors, wider doors, off-vehicle fare payment are desired, but not always feasible. It is beyond the scope of this study to research these issues. With the help of experts plausible assumptions therefore will be made.
- Stop location: the issue of near-side versus far-side location will be examined in context of priority design in Step (3).

(4) Design Signal Priority Control

The centerpiece of this study will be the design of signal control strategy for the roads carrying buses in the OSJ corridor. The goal is to find a strategy that improves transit service measures like schedule adherence, regularity, and crowding along the corridor, while minimizing the impact on other traffic.

This effort will mainly consist of the design of signal control programs for all critical intersections along the OSJ corridor based on the geometric design of Step (3). The design will incorporate the use of advanced using stream-based control, which allows for maximum flexibility.

The following aspects of control strategies will be designed:

- General control strategy: The design should allow for zero or low delay passage for buses that request priority while preserving most of the progression for general traffic. Different designs will be needed for transit running in bus lanes, in contraflow lanes, and in mixed traffic.

- Recovery strategy: The goal is to minimize impact on other traffic. An optimization of how to recover for truncated or skipped green times is required. The most important aspect is to avoid spillbacks, which means queuing of vehicles at one intersection into the next intersection.
- Detection strategy: Optimal location and timing of the detection is critical to achieving optimal capacity at an intersection. If a detector is located close to an intersection, prediction accuracy is good but reaction time short, while the opposite is true for a detector located further away. Detection on bus lanes can be done with simple loop detectors; in mixed traffic selective detection will be required. For conditional priority intelligent communication will be used in any case, since information about lateness, occupancy, etc. is needed. Another issue is the 'gap' definition. If demand on a certain approach falls below a defined parameter, then green time will be ended. It will therefore be necessary to determine how a 'gap' in a traffic stream is defined and measured.
- Condition strategy: The conditions that result in a priority status need to be defined as well as strategies for multiple priority requests at the same time.

Different priority levels like no priority, conditional priority, and headway-based vs. schedule-based control will be designed. No priority resembles the base case, which will be needed to calibrate the simulation model that will be developed later. The difference between headway and schedule adherence control is that while headway control might be easier to implement, it does not allow for synchronization with Tren Urbano. Once a bus is 2 minutes late, all following buses will be 2 minutes late, if the headway is kept. The focus will be on conditional priority strategies, since these offer the most effective operational control among all priority strategies.

(5) Simulation, Evaluation, Optimization

All priority strategies that have been designed for OSJ corridor in Step (4) will be evaluated and optimized using a simulation.

Simulation

The simulation will be conducted with the simulation software VISSIM [4]. VISSIM is a microscopic simulation model developed to model urban traffic und public transit operations. It was chosen because of its ability to track transit vehicles, allow for advance control logic and selective detection, and to model transit passenger to account for dwell time impacts of irregularity.

Evaluation

VISSIM provides extensive evaluation output files that report traffic and transit impacts like reduction of passenger delay, increase of traffic delay, regularity, and schedule adherence. The output of the simulation will also be used for further analysis with the software package TRITAPT (TRIp Time Analysis in Public Transport), which examines public transportation performance [5]. The software helps to identify delays at stops and intersection and to optimize running time.

Optimization

With the help of TRITAPT the proposed schedules will be fine-tuned. To have operational control using conditional priority the schedule should be such that on about 50% of the buses are late. Depending on the evaluation of the simulation and the TRITPAPT output changes will be made to the defined strategies. This process might be repeated several times to optimize these strategies.

(6) Assess Benefits/Impacts

Based on the results of the simulation and evaluation each priority strategy will be assessed in terms of benefits and impacts. This will be done by constructing the following evaluation scenarios: base case with no priority, best case, and intermediate cases that may require less investment and/or less traffic impact. A sensitivity analysis will be conducted with greater traffic and transit demand.

Benefits are, for example, reduction of passenger travel time, improved regularity, impacts are, for example, increase in delay of other traffic and the cost of such a system. The strategies will also be analyzed in terms of implementation issues like institutional barriers, operational concerns, and technological problems.

Finally the most effective strategy will be recommended. Our hope is to show that signal priority and operational control **can** improve bus service quality along the OSJ corridor without a major impact to other traffic and to make a convincing case to implement such a strategy.

4. First research results as of December 2000

The following describes the progress that has been made since the project started in September:

a) Review

I obtained and reviewed BRT and traffic/signal control literature. I met with Transportation Professionals from Multisystems that are familiar with BRT projects and VISSIM and gathered additional valuable information for my project.

b) Data acquisition

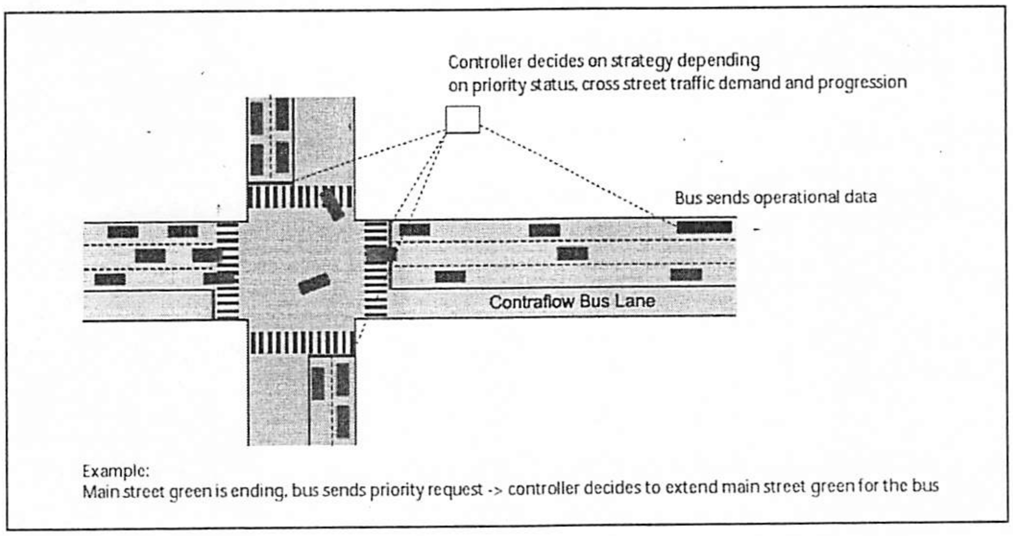
I obtained most of the relevant transit data from Multisystems. The only outstanding data is information about the transit terminals. So far I have not been able to receive any traffic data, but hope to make more progress during the field visit in January.

c) Infrastructure analysis

Based on the information from Multisystems I completed the transit infrastructure review apart from the terminals. The bus feeder routes mostly run in one-way mixed traffic in one direction and in a contraflow lane in the opposite direction. Therefore no major infrastructure modifications are required. This layout simplifies the control strategy approach since progression has to be taken into account for only a single direction.

d) Signal control strategies

I have started the design of several signal control strategies. Most of the work is done based on a typical intersection as shown below:



So far I have looked at the following aspects of signal control:

- Define general strategies and their feasibility (green extension/truncation, red truncation).
- Minimize the impact on progression.
- Maintain maximum program flexibility while serving pedestrian needs. The Pedestrian clearance time is very long (8-16 seconds) and therefore decreases flexibility.

- Define the gap parameter, which determines when traffic is light and therefore the green time should be ended.
- Avoid cycle overflow.

e) Simulation

Within VISSIM I have started the network coding and control program emulation using VAP. VAP is an add-on module of VISSIM for the simulation of programmable signal control. I am now completely familiar with the programming language and capabilities. I also tested and analyzed VISSIM evaluation files. With the help of a programmer from the University of Delft in the Netherlands we also made progress with the translation of VISSIM output files for the use in TRIPTAPT.

5. Advisor:

Professor Peter G. Furth

6. References/Bibliography:

Bibliography

- *Control Strategies for Transit Priority, Alexander Skabardonis*, Institute of Transportation Studies, University of California, Berkeley, Presentation at TRB 1999 conference, Jan 1999
- *Development and Evaluation of an Intelligent Bus Priority Concept*, Kevin N. Balke, Conrad L. Dudek, Thomas Urbanik, Texas A&M, Presentation at TRB 1999 conference, Jan 1999
- *Barriers to implementation of Signal Priority Systems for transit operations: Lessons learned from advanced traffic management systems*, David A. Noyce, Texas A&M, August 1996

References

1 *Tren Urbano Feeder System Report*, 05/27/99, pp 16-17

2 Peter G. Furth, Theo H.J. Muller, "Conditional Bus Priority at Signalized Intersections: Better Service Quality with Less Traffic Disruptions" accepted for publication, *Transportation Research Record*, 2000, and available in the preprint CD-ROM of the TRB annual meeting, January, 2000

3 Furth, P.G. and Rahbee, A.B. "Optimal Bus Stop Spacing Using Dynamic Programming and Geographic Modeling", accepted for publication, *Transportation Research Record*, 2000, and available in the preprint CD-ROM of the TRB annual meeting, January, 2000

4 http://www.itc-world.com/VISSIMinfo.htm,

5 Muller, Th.H.J. and Furth, P.G. "Trip-Time Analyzers: Key to Service Quality," accepted for presentation at the 2001 TRB annual meeting and subsequent publication in *Transportation Research Record*, and soon to be available in the preprint CD-ROM of the TRB annual meeting, January, 2001.

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Fecha : 14 de diciembre de 2000

A : Lydia Mercado

De : Gisela González
Gerente de Adiestramiento

Gisela González

Los documentos adjuntos son endosados a usted para su :

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Asunto:

Según solicitado hago entrega de los informes de progreso y resúmenes ejecutivos (si aplica) de los estudiantes del grupo VII del Programa de Desarrollo Profesional UPR/MIT/Tren Urbano.

Le estoy entregando una copia de todos los informes y un **"zip drive"** con todos los archivos.

De requerir información adicional favor de comunicarse con la que suscribe.

Gracias

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