

Optimizing the Automated Train Regulation System for Tren Urbano

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Objectives

The objective is to test and refine the parameters for use with the Automated Train Regulation system (ATR) controlling Tren Urbano train movements. ATR adjusts train speeds and dwell times for each train in a heavy rail system, according to different operating circumstances, control modes, and parameters. ATR is designed to keep trains running according to the operating plan and to return them to this schedule in the event of minor disruptions. This research will assess the ways to get the greatest benefit from ATR for Tren Urbano.

The questions that this research will answer include:

- What are appropriate “nominal” dwell times, for different stations and different service periods?
- Under what circumstances and severity of delay should corrective actions begin? How large should a headway be before ATR adjusts travel speeds to compensate, and how much larger before it adjusts dwell time? How small should a headway be before it adjusts dwell time, and how much smaller before it adjusts travel speed? (Matra)
- What positive trade-offs can be made between speed and reliability of operation? Are there track segments where it is appropriate to run a train at maximum speed the majority of the time?
- Under what circumstances and severity of delay is “manual” control more effective than ATR? (Angela Moore’s research will be critical to this question, and we expect to collaborate on this point.)

Motivation

Minor disturbances happen frequently during routine operations. A train's door malfunctions, increasing dwell time for that train; unexpectedly heavy boardings or alightings increase dwell time at a station; a train malfunctions and operates in degraded mode, slowing travel. If a train's headway becomes less than average, left to its own devices that train tends to catch up to the next train, dwelling less and less until only operational safety keeps the two apart. As the train behind it dwells longer and longer and falls farther behind, this disruption can ripple down the line, degrading service. Properly configured, ATR will correct for variations in headway and dwell time, maintaining the level of service.

ATR has not yet been customized for Tren Urbano. Nominal dwell times are set for thirty seconds, regardless of station or service period. Heavy rail typically operates with substantially shorter dwell times, increasing the speed of service. ATR adjusts train speeds exactly $\pm 8\%$, and the precise circumstances of adjustment – such as the length of a headway that would trigger corrective action – have not been specified (Matra).

Responding too late would compromise ATR's ability to recover; responding too soon would cause greater stochasticity in operations. Finally, it is unclear from just how serious a delay ATR can efficiently recover. Upon learning of a disruption, the OCC should be able to immediately determine whether manual intervention is required, to recover as quickly as possible and prevent service from deteriorating.

This research will determine these unknowns and others so that Tren Urbano can get the maximum possible benefit from ATR.

Approach

The approach is to create a detailed computer model of the Tren Urbano system, including passenger flows, operating under ATR. The model simulates a variety of routine disruptions and the system-wide effects of ATR's corrective actions. It accounts for different operations plans and different ridership levels at different periods; different lengths and locations of delay under different existing conditions; different boarding and alighting levels at different stations; difference in passenger reactions to being on a slow-

moving (and long-dwelling) train as compared to waiting longer for a train to arrive; etc. It is also be flexible enough to readily accept changes in patterns based on new ridership projections, operating plans, and ATR parameters. If run by a script, the model can systematically (and automatically) tests different inputs into ATR.

This model is not a system of equations, but a simulation model, a computer program written in C that simulates operations under ATR supervision. A linked list of records represents stations, and other records represent trains. A queue keeps track of events, such as arrivals and departures of trains, and the times and order in which they are to occur. This allows the model to run very quickly. As the model runs it tracks the travel times and delays which passengers experience. This model is flexible enough that it will be adaptable to Angela Moore's research.

This model is to be used exclusively for testing different ATR settings. It is not applicable to use in the field. It is distinct from the two Siemens models applicable to Tren Urbano. Of those two models, one is a training simulator for operators. My model is not useful for training purposes. The other Siemens model is a highly complex rapid transit model that does not leave Germany. That level of complexity is not necessary for this project, and that model is in high demand. However it may prove beneficial to "double check" the results of this research with that model, if possible.

Progress

I have learned the basics of Puerto Rico and Tren Urbano. I have Studied ATR, as it is explained by Iris Oritz's thesis and Matra Transport International's guidelines. I have met twice with Michael Francis of Alternative Technologies Inc. to discuss ATR and Tren Urbano operations. I have studied modeling in general and Adam Rahbee's model of the MBTA Red Line in particular. I have collaborated with Angela Moore to ensure that the model will meet her research's needs. I have chosen the best method for implementing the model, and outlined exactly how it works. I have implemented the model and am currently conducting preliminary tests.

Critical Issues

My knowledge of ATR is based on documents that I have read, which may be incomplete or simplifications. I am working to get more complete documentation, but with limited success so far. If my understanding of ATR proves to be incorrect, I may need to radically change the model in the future.

The model is based on current knowledge of the Tren Urbano operating plan, train speeds and predicted passenger flows. Any of these could change, and the model is sensitive to changes in each of these characteristics (in decreasing magnitude.)

Work Plan

- Introduction to Tren Urbano (September 2000)
 - Learn basics of Puerto Rico and Tren Urbano
- Preliminary research (September - October 2000)
 - Study operations procedures and challenges
 - Study ATR
- Model outline (October 2000)
 - Choose best modeling approach
- Research presentation and preparation (October 2000)
 - Present research outline and goals to Tren Urbano program
 - Modify plans and goals based on feedback
 - Finalize research proposal
- Ongoing research (November 2000)
 - Determine implications of button-operated doors on dwell time
 - Determine likely origin-destination matrix based on projected per-station ridership levels
 - Study other simulation models to gain insight on modeling process
 - Resolve outstanding questions about ATR
- Model design (November 2000)
 - Design all aspects of model

- Ensure that model will be expandable to later versions
 - Ensure that model will be applicable to Angela Moore's thesis
- Model implementation (November-December 2000)
 - Implement model version 1.0
- Initial testing (December-January 2000)
 - Test a limited number of potential ATR settings against a limited number of disruption scenarios
 - Identify settings with generally good performance
 - Test one or two sets of ATR settings against varying assumptions (such as ridership levels) to determine model's sensitivity to each assumption
- Visit preparation (December 2000)
 - Prepare poster
 - Finalize goals for Puerto Rico visit
- San Juan Visit (January 2001)
 - Augment current understanding of Puerto Rico and Tren Urbano
 - Verify and modify data on which the model relies
- Ongoing research (January-February 2001)
 - Continue research based on new information learned in Puerto Rico
- Model refinement (January-February 2001)
 - Determine what changes to implement based on San Juan visit and ongoing research
 - Implement model version 2.0
- Automated testing design (February 2001)
 - Determine for which disruption scenarios to optimize
 - Implement model version 3.0, which will automatically test all plausible ATR settings against target scenarios
 - Test optimal solutions against wider range of scenarios and assumptions
- Test optimum solutions against Siemens model (March 2001)
- Write conclusions (April-May 2001)

Relevant Materials

Matra Transport International (1997), "Sacem Presentation (System Operation.)" Tren Urbano Library. This presentation includes a highly detailed description of ATR and systems operation.

Ortiz, Iris (2000), "Analysis of Real Time Operations Control Strategies for Tren Urbano." M.S. Thesis, Department of Civil and Environmental Engineering, MIT. This thesis includes a detailed description of ATR, and makes the case that there is room for improvement over currently operations plans. The majority of information in this proposal can be attributed to this thesis.