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A TRAIN OPERATIONS SIMULATION FOR MIAMI'S SR 836 CORRIDOR

Onala M. (Tony) Atala

Parsons Brinckerhoff
One Penn Plaza
New York, New York 10119, U.S.A.

John S. Carson

AutoSimulations, Inc.
1827 Powers Ferry Rd, Bldg 17, Suite 100
Atlanta, Georgia 30339, U.S.A.

ABSTRACT

This paper presents a general model of a rapid transit system with automatic train control and automatic train protection (ATC/ATP). It has been used to study potential transit technologies, track layouts, and block designs for ATC/ATP for the Miami State Road 836 East-West Multimodal Corridor Study Alternatives Analysis. Results of the study have been used in a Draft Environmental Impact Statement (AA/DEIS) and a preliminary engineering report.

The purpose of the "screening level" analysis presented here is to propose a few technologically sound, cost-effective public transit technologies that can be carried forward into the conceptual design process, allowing further analysis of technology and alignment options as additional information is generated.

1 INTRODUCTION

As demand for east-west travel in Miami has grown in recent years, streets and highways in the region's east-west corridor have become seriously congested. In addition to the special needs generated by the tourism industry, non-tourist travelers on the six-lane limited access roadway SR 836 and several other corridor roads now experience traffic delays throughout most of the day. At present, there are no adequate roadways or transit facilities to accommodate the anticipated growth in the corridor. Based on this and increased development in west Dade County, increased traffic between the Miami International Airport (MIA) and the Port of Miami (POM), increased travel to Miami Beach on a limited number of bay crossings, and operational deficiencies causing safety and merging problems at a number of locations along SR 836, there exists a need to examine transportation alternatives in the East-West Multimodal Corridor.

The East-West Multimodal Corridor is a 30.4 kilometer (19 mile) corridor that begins at the Florida Turnpike on the Florida International University campus and extends eastward to the Miami International Airport, the City of Miami Central Business District, the Port of Miami, Miami Beach and the Convention Center.

For the East-West Multimodal Corridor Study, four basic alternatives were considered:

- A "No-Build" alternative.
- A Transportation System Management (TSM) alternative.
- An expressway widening alternative.
- Multimodal alternatives.

As part of the Multimodal alternatives, the simulation model was used to evaluate three rail transit technologies:

- Standard light rail transit;
- Standard heavy rail transit;
- "Hybrid" heavy rail transit.

The model was also used to evaluate two alternative track alignments, alternative block designs and alternative operating strategies.

2 MODEL SCOPE

The model simulates the multi-train multi-service train operations for alternative alignments between Florida International University (FIU) and the POM including operations between the MIA and the Miami Intermodal Corridor (MIC) Station. Specifically, the three services are:

- East/West (E/W) service operating as a local service between FIU and station A at the Port of Miami, with train stops at the MIC and ten other intermediate stations.
- Airport/Seaport (A/S) service operating as an express service from the MIA to the POM, with one intermediate stop at the MIC. The A/S and E/W services have separate platforms at the MIC, then merge together east of the MIC onto the track to the POM. At the POM, there are four stations with each

train stopping at two, either at Stations A and B or at C and D.

- MIC-MIA Connector, a shuttle service from the MIA to the MIC/Shuttle platform providing service for passengers to the car rentals, for business travelers who need to take the train to the Central Business District (CBD), and any other leisure travelers between the MIA and the CBD or Miami Beach. This service shares the tracks with the A/S Service from the MIA to the MIC.

The scope of the model includes analyzing the behavior of the system between the MIC and the MIA with both the A/S and the MIC-MIA Connector services operating on the same tracks. It also includes identifying delays at other locations, with emphasis on the interlocking at the MIC and the interlocking immediately west of Station A at the POM.

3 MODEL DEVELOPMENT AND PROJECT ORGANIZATION

The model was developed using AutoMod™ from AutoSimulations, Inc. A new train movement system was used to facilitate model development, removing the need to program the low-level "physics" of acceleration and deceleration, which was handled by AutoMod's train system. Earlier studies based on other models were reported in Atala et al. (1992) and Carson and Atala (1990).

To provide results as early as possible in the areas expected to be the most congested, the model was developed in three phases:

- Phase I: A partial track alignment from the MIC to the POM with the A/S and E/W services, both operating simultaneously with peak period headway (minimum time between successive trains).
- Phase II: The complete track alignment from FIU to the Seaport and both the E/W and A/S services. It did not include the MIC/MIA Connector service.
- Phase III: Same as Phase II with the branch to MIA and addition of the MIC/MIA Connector service.

4 MODEL DESCRIPTION

The model is general and flexible, allowing a user to change the track layout and all other design and operating input data.

4.1 Model Features and Capabilities

The model has the following features and capabilities:

- Multi-train, multi-service operation, with each service having its own routing and turnbacks.
- Different or identical vehicle technologies for each service (for example, any combination of heavy rail, light rail and Automated Guideway System), reflected in the model by vehicle dimensions and performance characteristics.
- Automatic Train Control (ATC) and Automatic Train Protection (ATP) train operations based on a fixed block control lines/track circuits design.
- Up to nine maximum allowable speed commands with look-back speeds allowed at interlockings, curves, and platforms. (Easily extended to any number of allowed speed commands.)
- Civil speed restrictions at horizontal and/or vertical curves.
- Switching operations at crossovers, interlockings and turnbacks.
- Grades and their effect on train performance.
- Single tracking operations.
- Variable train car lengths, with 50, 75, and 90 feet vehicle lengths for the Miami application.
- Train schedules with the capability to add and/or drop trains to and from service at stations and terminals.
- User controlled operational scenarios, such as headway, dwell times, train dispatching schedules, and number of vehicles in a consist.
- On-screen train animation of trains. For this application, a scaled schematic representation of the E/W SR 836 Guideway was used.
- On-screen train graph, velocity profiles, and display of interlocking logic and approach timers.

4.2 Model Assumptions

This section lists the various operating and equipment assumptions used during experimentation:

- Preliminary Train Control Design.
- Airport/Seaport Service trains only stop at the Airport, MIC, and Seaport terminals.
- Weekday peak period headways are 3.0 minutes for all three services.
- Airport/Seaport Service headway of 2.5 minutes during the weekend peak periods with E/W trains at 10 minute headway.
- Turnback times at terminal locations (Airport, Seaport, and MIC) varied between 1 and 5 minutes.
- Schedules that add and drop trains from service at the following locations:

  1. A/S Service at the MIC eastbound, or from Terminal Stations B or D at the POM;
  2. E/W from the MIC station eastbound;
  3. MIC-MIA Connector from the "black-box" east of the MIC, westbound.

- 20 second dwell times at all intermediate stations.

- 30 second E/W service dwell times at the MIC.
- 1 minute Airport/Seaport service dwell times at the MIC.
- 1 minute dwell at terminals C and D during the PM peak period (cruise ships loading).
- 2 minute dwell times at terminal Stations A and B during the AM peak period (cruise ships unloading).
- Vehicle technologies (tractive effort curves and braking curves) equivalent to those for the existing Miami Metrorail system.

4.3 Model Input Files

The model is driven by eight different user modifiable files in two categories, Design and Operating Inputs:

Design Input Files:

- The Block Design File. This file contains the block layout, including track circuit name, track number and direction, control line ID number, control line speed commands, look-back codes, next control line ID number, block length, and codes for platform, switch, and curve locations.
- Grade Table. Defines grade points by the linear distance for each point of vertical intercept (PVI).
- Route Table. Defines the allowed routes through cross-overs and interlockings, and conflicting routes.
- Look-back Table. Defines look-back speeds for trains exiting platform blocks, switches and curves.
- Tractive Effort Table. Defines the tractive effort curve for any of the vehicle technologies. Tractive effort refers to acceleration and deceleration (braking) as a function of current velocity.
- Approach Timer Table. Optional table defining the location and timing for approach timers.

Operating Input Files:

- Dwell Table. Defines dwell times at each platform at each station for each of the three services.
- Schedule Table. Specifies train schedules and dispatch times for groups of trains of each service. It also includes the schedule for taking trains out of service or adding trains to any one of the services during a simulation run.

4.4 Model Output Reports

For each simulation run, the model produces a number of output reports, including:

- Train delay report for each train delay, identifying train number, location of delay by track circuit, direction, time at which the delay starts and ends, length of delay in seconds, and next station stop. (For ease of use with spreadsheets, space and comma delimited versions are produced.)
- Summary of train delays by location and direction.
- Arrival and departure times to and from each station and block. Can be used to make a plot of a train graph, a distance-time plot of every train running over a period of time.
- Train Speed Summary. A list of all circuit blocks in which the maximum allowed speed is not reached; listed by block, control line, and direction, along with maximum speeds attained and allowed.
- Velocity Profile Report, to be used for analysis and plotting.

Train delay reports, arrival/departure report for train graphs, and the speed report are most useful for performing the post operations analyses. The arrival/departure report file may be read into a CAD package to produce a train graph on a plotter.

Additionally, the model produces on screen animation of the train movements, train graphs and speed profiles concurrent with the simulation run, a display of the approach timer, and windows displaying the interlocking logic as it occurs. This enables the analyst to observe any operational problems, such as congestion, queueing and delays, as well as their location and magnitude, while the simulation is running. The animation, interlocking and approach timer displays are also useful for debugging and verifying the model during its developmental stage and finding problems with the block design or route table that may cause trains to deadlock.

5 THE SIMULATION RUNS

It is anticipated that the E/W and A/S services will have non-overlapping peak periods, except for the period from 8:30 am to 9 pm and a similar period in the late afternoon. In most cases, simulations were run with a peak headway for one of the two services only. Peak periods were simulated at 2.5 or 3 minutes headway, while the off peak services were simulated at 6, 10, and 12 minutes headway. The morning period (AM) and afternoon periods (PM) were simulated separately due to different operating schedules and service routings.

5.1 PM Peak Period

Cruise ship passengers have a PM peak between approximately 12:00 noon and 3:00 PM on Friday and possibly Saturday afternoons. This represents the A/S service PM peak period. The E/W service PM peak is between approximately 4:00 and 7:00 PM Thus, when the A/S service PM peak headway is at 3 minutes, the E/W service headway is ten or twelve minutes. The overlap occurs when the E/W trains are added to the decreasing their headway from twelve to six to three minutes, while at the same time gradually taking A/S service trains out of service. The A/S and E/W trains are dispatched eastbound from the MIC during the PM peak period.

The A/S trains travel express into the POM in two groups, half stopping at Stations A and B, and the other half stopping at Stations C and D. Trains stopping and dwelling at Station A then continue on the single track segment into Station B, dwell, and turnback westbound towards the MIC and MIA bypassing Station A. The other half of the A/S Service turnback Westbound after stopping at Port Stations C and D .

The E/W service trains travel eastbound from FIU making all local stops, merge on a common track with the A/S trains east of the MIC, and continue into the POM Station A, dwelling there and then turning back westbound. This service makes eleven intermediate stops plus stops at terminal stations at FIU and the POM. The A/S and E/W services have conflicting moves through the interlockings east of the MIC and west of Station A at the POM.

5.2 AM Peak Period

Cruise ship passengers arrive at the Port of Miami on Monday morning at approximately 8:00 am and do not leave until approximately 9:00 am. At that time, the E/W service takes trains out of service until their headway is increased from 3 minutes to ten or twelve minutes. While the E/W service trains are reduced, the A/S trains are introduced into the system at 6-minute headway starting at 8:30 am and 3-minute headway starting at 9 am.

During the AM peak, the A/S and E/W services travel routes similar to those used during the PM peak with one exception: At the POM, all A/S trains take the bypass around Station A in the Inbound direction. Half of the trains dwell and turnback at Station B and then stop and dwell at Station A. The other half dwell and turnback at Station D, then stop and dwell at Station C, taking the bypass around Station A.

5.3 Simulation Scenarios

A total of thirty four simulations were run and analyzed, with variation in: headway; dwell times at terminal stations; offset dispatch time between services; and the number of trains per service.

The simulation runs were made in four sets as follows:

- **Simulation Runs 1-6:** based on an earlier operating plan with both the A/S and the E/W trains operating at 3 minutes headway during the weekday peak periods. During the weekend peaks, the A/S trains operated at 2.5-minute headway and the E/W trains operating at 10-minute headway.
- **Runs 7-17 and 30-34:** based on the non-overlapping schedule between the A/S and E/W trains. The E/W trains operated at 3-minute headway for the first 2 hours (simulated time), then trains are taken out of service until the headway is increased to 6 minutes. Meanwhile, at approximately 1.5 hours into the simulation, the A/S trains were dispatched from both the POM and the MIC at 6-minute headways until enough trains were operating on the main line at a 3-minute A/S composite headway (composite headway is the headway of the combined sub-services).
- **Runs 50-63:** based on having all three services (A/S, E/W, and MIC-MIA Connector) operating simultaneously. These runs assume one of the two services (A/S or E/W) has reached their peak 3-minute headway while the other service operates at off-peak headway of 6, 10, or 12 minutes. The MIC-MIA Connector headway was varied between three and six minutes.

Table 1 summarizes the simulation scenario for each of the runs analyzed. Other assumptions common to all scenarios include:

- Peak Period: Weekday, AM peak period except when specified.
- MIC/MIA Connector at MIC: 20 seconds (Run Numbers 50-63).
- E/W Service Dwell at MIC: 30 seconds.
- E/W Dwell at FIU: 5 minutes.
- E/W Dwell at non-terminal stations: 20 seconds.
- A/S Dwell at Terminal Station B: 5 minutes (includes turnback).
- A/S Dwell at POM Station C: 2 minutes.
- A/S Dwell at Terminal Station D: 5 minutes (includes turnback).
- MIC-MIA Turnback East of MIC: 5 minutes.

6 ANALYSES AND RESULTS

Based on the simulation runs, the present track alignment would provide inadequate level of service.

Until the MIC-MIA service was introduced in runs 50-63, possible solutions to problems at the POM station A were found. This was accomplished by optimizing the operating plan scenarios and modifying the alignment at the port.

Between stations, trains seldom achieve their maximum allowable speed (MAS) of 70 mph. The speed profile in Figure 1 shows how trains accelerate, reach a maximum speed, and almost immediately start

Table 1: Simulation Scenarios

	DWELL TIMES (Seconds)				Headway (Minutes)			Remarks / Comments
Run #	A/S MIA	A/S A	E/W @ A	MIC-@	A/S	E/W	MIC-	
1	300	120	300	N/A	3	3	N/A	MIC-MIA and E/W West of MIC Excluded
2	300	60	300	N/A	2.5	10	N/A	AM Weekend - Same operation as above
3	300	120	300	N/A	3	3	N/A	PM Weekday - Same operation as above
4	300	60	300	N/A	2.5	10	N/A	PM Weekend - Same operation as above
5	300	60	60	N/A	4	4	N/A	AM Weekday - Same operation as above
6	300	120	60	N/A	3	3	N/A	AM Weekday - Same operation as above
7	300	120	300	N/A	3	3	N/A	A/S service introduced at 1.5-hr. starting with 6-min.
8	300	120	180	N/A	3	3	N/A	Same as run number 7, above.
9	300	120	150	N/A	3	3	N/A	
10	300	120	150	N/A	3	3	N/A	3 minute dwell at term. B&D instead of 5.
11	300	120	120	N/A	3	3	N/A	
12	300	120	120	N/A	3	4&6	N/A	E/W headway change from 4 to 8 minutes after 2 hr.
13	300	120	90	N/A	3	3	N/A	
14	300	120	30	N/A	3	3	N/A	5 minute initial offset between A/S trains.
15	300	120	30	N/A	6	3	N/A	
16	300	120	30	N/A	6	3	N/A	3 minutes initial offset between A/S trains
17	300	120	30	N/A	3	3	N/A	
30	300	120	30	N/A	3	3	N/A	Same as #17 with preferred dwelling at terminal A.
31	300	120	60	N/A	3	3	N/A	Same as #30 above.
32	300	120	300	N/A	3	3	N/A	
33	300	60	30	N/A	3	3	N/A	
34	300	60	30	N/A	3	3	N/A	
50	300	120	60	180	3	10	6	6 E/W trains; 14 A/S; 3 MIC-MIA; A/S at 1.5 hr.
51	300	120	60	180	3	12	6	5 E/W trains; 14 A/S; 3 MIC-MIA; " " " "
52	300	120	60	180	3	10	3	6 " " " " 6 " " " " "
53	300	120	60	180	3	12	3	5 " " " " 3 " " " " "
54	180	120	60	180	6	3	6	20 " " 7 " 3 " " " " "
55	180	120	60	180	6	3	3	20 " " 7 " 6 " " " " "
56	120	120	60	180	3	10	6	6 " " 14 " 3 " " " " "
57	120	120	60	180	3	12	3	5 " " 14 " 6 " " " " "
58	120	120	60	180	3	10	3	6 " " 14 " 6 " " " " "
59	120	120	60	180	3	12	3	5 " " 14 " 6 " " " " "
60	180	120	60	180	3	10	3	6 " " 14 " 3 " " " " "
61	60	120	60	180	3	12	3	5 " " 14 " 6 " " " " "
62	300	60	60	180	3	10	3	6 " " 14 " 6 " " " " "
63	300	60	60	180	3	12	3	5 " " 14 " 6 " " " " "

decelerating, resulting in a triangular rather than the preferred trapezoidal speed profile. With the preferred profile, trains would accelerate, reach and maintain their MAS for a period of time and then decelerate to the next stop or to an assigned lower MAS.

Various simulation outputs were used to analyze the results, including:

- On-screen train animation.
- On-screen train graphs.
- Train delay reports.
- Speed profiles.
- Interstation travel times.

On-screen train animation and train graphs were used to analyze train movements, identify train delays and their queues, and draw conclusions on the overall system behavior.

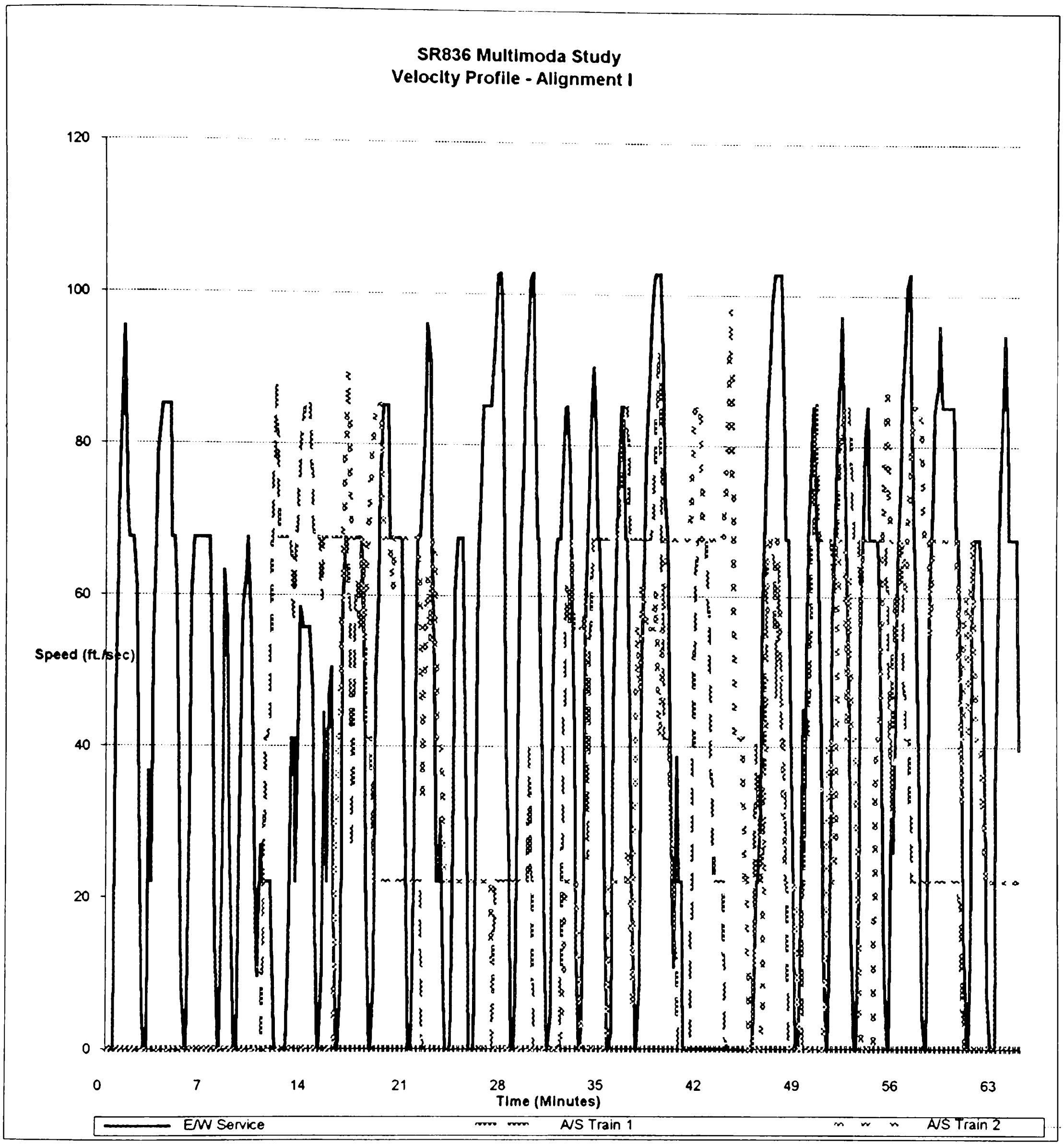

Figure 1: Velocity Profile for the E/W and A/S Services. Speed (ft/sec) vs. Time (min).

Train delays for runs 50-63 were analyzed most extensively because they included all three services and the full alignment between FIU and the Port of Miami. Delays were divided into two groups: all and those over 1 minute. They were analyzed by service, location and time of day.

The velocity profile in Figure 1 is the output of a single train simulation run that was made to analyze the velocity profile and the maximum speeds achieved by the train between stations. The results were compared against the maximum allowable speeds as dictated by the train control design, and the duration of time at which trains sustained the MAS were analyzed.

Interstation Travel Times: a three train simulation run (one E/W, and two A/S trains) was made to calculate the interstation travel times under normal, no delay conditions. These results were used to validate the model and to compare against scenarios that incurred delays.

Optimum Number of Trains: based on a three minute peak headway, a simulation run was made to determine the optimum number of trains that can operate on the system for any given service. The number of A/S trains was tested in this simulation run. It was found that the optimum number of A/S trains is 14. Operating with 14 A/S trains resulted in approximately the same throughput capacity as the run operating with 15 A/S trains. The throughput capacity with 14 A/S trains is 35 E/W and 61.5 A/S round trips, versus 33.5 E/W and 62.5 A/S round trips when 15 A/S trains were used, for a 4 hour period.

Runs 1-6: These runs used peak headway for both E/W and A/S services as if they were to operate simultaneously. These runs were based on a former draft operating plan and not on how trains would operate once the system is in revenue service.

In this phase, train delays at the POM occurred within the first 10 minutes of simulated time. Delays greater than 1 minute were observed within 30 to 40 minutes. These delays were due to the following:

- Short side tracks at the approach to the POM. As soon as an E/W train was delayed, others did too, resulting in long queues. The queues increased gradually until the system reached saturation and capacity.
- Dwell at one side of the terminal station A platform. Each service was allowed to use only one side of the platform. No alternative/priority choice was allowed. The E/W trains were allowed to dwell at either side with priority given to the upper track, track 2, in later runs.

During this phase, no major delays were noticed at the MIC. This was due to the proper separation between the E/W and A/S services headway, and not simulating services west of the MIC.

Runs 7-17: The operating plan was modified for this set. The A/S trains were introduced into the system after the E/W trains had been operating for 1.5 hours. This schedule is a better representation of the train operation during peak periods. Services west of the MIC were also excluded from these runs.

The results of these runs indicate a reduction in the number of delays. Also, the majority of operational problems remained at the Port.

Runs 30-34: The E/W extension west of the MIC to FIU was included in this set. Trains operated in a similar fashion to runs 7-17 with a modification to the E/W dwell at the POM. This dwell was reduced to 30 seconds in run numbers 30, 33, and 34.

The majority of delays were at the POM. Delays between the port and the MIC due to problems at the POM were also observed.

Runs 50-63: This set included all three services A/S, E/W, MIC-MIA. Runs 50-61 represent the weekday AM peak, and runs 62-63 represent the PM peak.

Model results include:

- The majority of delays occur for A/S trains approaching the MIC. The number of delays range from 19 (run #53) to 350 (run # 58), with the total delay for all trains ranging from 13.2 to 633 minutes. It is evident that operational problems are also serious at the MIC. This became clear once the MIC-MIA Service was introduced into the system, in contrast to observations made in the previous scenarios where the majority of delays were at the POM.
- With the MIC-MIA service running, the majority of delays at the POM were shifted from A to B and D. Fewer A/S trains arrived at the port due to delays at the MIC. This resulted in eliminating most of the delays caused by the E/W service at the Port.
- The majority of E/W service delays are between the MIC and the POM. An increase in the number of delays and stop-and-go train movements were also observed, implying an unreliable service.
- Increase in the E/W service delays at the MIC due to competition with the A/S trains leaving or approaching the MIC in either direction and MIC-MIA trains passing by the A/S MIC platforms. These delays were caused by conflicting routes through the interlocking just east of the MIC and delays to A/S trains caused by MIC-MIA trains.
- The number of delays for run #54 (with 20 E/W service trains) is not the highest. This is due to the reduction in the total number of round trips. Operating with 14 A/S trains or 20 E/W trains in their respective peak periods causes the system to reach its throughput capacity; more trains cause delays and congestion and do not decrease achieved headway or increase throughput.

7 CONCLUSIONS

The present alignment provides an inadequate level of service with 3-minute peak headway.

- A total of thirty four operating scenarios were analyzed to ensure that the problems are with the track alignment and not the scenarios. Delays are too numerous and sometimes lengthy. In most cases, they are less than one minute long. This indicates that on one hand there is much stop-and-go, and on the other, the system reaches capacity and halts. This was evident when train animation was turned on during the simulation runs.
- It is not feasible to operate the A/S and the MIC-MIA services on the same guideway through the MIC area, especially with the number of trains necessary to provide the passengers with a reliable service of 3 minutes headway for each of the three services.

Although an increase in headway is operationally feasible, cruise passengers would prefer trains more often so as to assure a comfortable train ride by being seated.

- The E/W service trains seldom reached the maximum allowable speed of 70 mph and when they did, it was for brief periods only. The A/S trains never reached 70 mph, as shown in Figure 1. A 60 mph MAS may prove more effective.

At the time of this writing, the model is being used to evaluate a new track alignment and modified track circuit block design to solve the design and operational problems identified in this first study.

REFERENCES

Atala, O.M., Joseph C. Brill and John S. Carson, 1992. A General Rapid Transit Simulation Model with Both Automatic and Manual Train Control. In *Proceedings of the 1992 Winter Simulation Conference*, ed. J. J. Swain, D. Goldsman, R. C. Crain, J. R. Wilson, 1307-1311.

Carson, J.S. and O.M. Atala, 1990. Using Computer Simulation for Rapid Transit Operating Strategies. In *Proceedings of the 1990 Winter Simulation Conference*, ed. O. Balci, R. P. Sadowski, R. E. Nance, 798-801.

AUTHOR BIOGRAPHIES

ONALA M. ATALA is a Lead Systems Engineer with the New York office of Parsons Brinckerhoff Quade & Douglas, a major transportation consulting firm. Mr. Atala holds a B.S. in Chemistry and an M.S. in Transportation Engineering from Georgia Institute of Technology. He has 18 years of professional experience in the areas of transit systems safety, transit technologies, and transit operations analysis. He has presented papers with the Transportation Research Board (TRB) and the American Public Transit Association. He is a member of the TRB, Institute of Traffic Engineers, and the American Society for Quality Control.

JOHN S. CARSON is a Senior Simulation Analyst with AutoSimulations, a leading simulation software and consulting company. He has developed or supervised the development of numerous large-scale simulation models in a variety of application areas, including manufacturing, material handling, warehousing, distribution, transportation and rapid transit, medical delivery systems, and reservations systems. He has served on the faculties of the Georgia Institute of Technology and the University of Florida. With Jerry Banks, he is the co-author of the widely-used text *Discrete-Event Systems Simulation* (Second Edition, Prentice-Hall, 1995). He is a member of IIE, SCS, and INFORMS. Dr. Carson received his Ph.D. in Industrial Engineering and Operations Research from the University of Wisconsin at Madison.