Appendix C
OPERATIONS ANALYSIS TO SUPPORT PROJECT GOALS

INTRODUCTION

The results of the Train Performance Calculator simulations that were performed in support of this supplement to the Transportation Plan are discussed in detail in this Appendix. Results for intercity, commuter, and freight trains are presented. The ability of the recommended improvements to support reliable, less than 90-minute intercity trip times, also is evaluated.

ABILITY TO MEET PROJECT GOALS

As agreed upon at meetings involving all the railroads, FRA, and PennDOT, operations analyses to assess the impact of the proposed projects on rail operations, and to help identify other additional improvements that will benefit future operations were performed. The analyses performed were:

- The Train Performance Calculator model, which assesses the performance of a single train over the route to measure trip time differences between the existing track configuration and the proposed configuration for a variety of train consists; and
- Manual analyses of existing and proposed 2015 schedules and operational requirements of high speed intercity and commuter trains to determine areas of operating conflicts and delays.

Train Performance Calculator Runs

A program of Train Performance Calculator (TPC) analyses was undertaken to evaluate the efficacy of the recommended track configuration and alignment to satisfy the recommended goal of regularly scheduled, safe, and dependable rail passenger service between Philadelphia and Harrisburg in less than 90 minutes. The results of the analyses to date are summarized in this Appendix.

Conditions for Simulations of "Goal Trains"

Goal trains are those scheduled to meet the recommended, less than 90-minute, trip time between Philadelphia and Harrisburg. TPC simulations of goal trains on the existing, and the upgraded, facility configurations were based upon the conditions described in the following subsections.

"Baseline" TPC Runs. Baseline TPC runs were performed with a train consist of four Amfleet cars powered by one F40PH diesel locomotive upon the existing facility configurations, i.e., prior to any improvements being made. Trip times to 30th Street Station were simulated. The Baseline conditions included:

- Existing Maximum Authorized Speeds (MASs); trains were limited to 90 miles per hour;
- Speed restrictions as shown on Amtrak's employee timetables that were in effect in spring of 1997;
- Positive stops and Civil speed restrictions were not enforced by the signal system in these simulations; and
- Six Intermediate stops - 1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport[1]; and 2.0-minute dwell at Paoli and Lancaster.
- Several Train consists were evaluated:
  - four Amfleet cars powered by one F40PH diesel locomotive;
  - four Silverliner IV Electric Multiple Unit (EMU) vehicles;
  - two IC-3D Diesel Multiple Unit (DMU) vehicles ; and
  - four Amfleet cars powered by one AEM-7 locomotive.

TPC Runs - MAS Increased to 110 mph. Another set of TPC runs to determine the amount of time savings to be experienced after increasing MAS to 110 mph. Trip times to 30th Street Station were simulated. The following conditions were used:

- MAS was increased to 110 mph; speeds on individual curves were calculated using a spreadsheet previously described in Appendix C.
- Speed restrictions due to track conditions were assumed to be removed as the result of an intensive program to restore the line to a state of good repair. As in the Baseline case, positive stops and curve speeds were not enforced.
- Improvements to spiral length and superelevation of selected curves, to optimize speed for curves without changing curvature, were assumed.
- Six Intermediate stops - 1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport; and 2.0-minute dwell at Paoli and Lancaster.
- Several Train consists were evaluated:
  - four Amfleet cars powered by one F40PH diesel locomotive;
  - four Silverliner IV Electric Multiple Unit (EMU) vehicles;
  - two IC-3D Diesel Multiple Unit (DMU) vehicles ;
  - four Amfleet cars powered by one AEM-7 locomotive; and

[1] A proposed station to provide rail access to the airport located east of Harrisburg, adjacent to the Keystone Corridor.

  - one generic Amtrak tilt train.[2,3]
- Speeds were set assuming three levels of unbalanced superelevation -
  - 3 inches;
  - 5 inches; and
  - 9 inches[4].
- Concrete ties were assumed to be installed in stretches of 110 mph operation and on curves where unbalanced superelevation would exceed 5 inches.

TPC Runs - Intermediate stops decreased to two. A third set of TPC runs to determine the amount of time savings to be experienced from decreasing the number of intermediate train stops to two after increasing MAS to 110 mph. Trip times to 30th Street Station were simulated. The following conditions were used:

- MAS was increased to 110 mph; speeds on individual curves were calculated using a spreadsheet previously described in Appendix C.
- Speed restrictions due to track conditions were assumed to be removed as the result of an intensive program to restore the line to a state of good repair. As in the Baseline case, positive stops and curve speeds were not enforced.
- Improvements to spiral length and superelevation of selected curves, to optimize speed for curves without changing curvature, were assumed.
- Two intermediate stops (2.0-minute dwell) at Paoli and Lancaster.
- Several Train consists were evaluated:
  - four Amfleet cars powered by one F40PH diesel locomotive;
  - four Silverliner IV Electric Multiple Unit (EMU) vehicles;
  - two IC-3D Diesel Multiple Unit (DMU) vehicles ;
  - four Amfleet cars powered by one AEM-7 locomotive; and
  - one generic Amtrak tilt train.

- Speeds were set assuming three levels of unbalanced superelevation -
  - 3 inches;
  - 5 inches; and
  - 9 inches.

  These all assume that selected curves would be upgraded to 6 inches of actual superelevation (identified as E_a on the tables).
- Concrete ties were assumed to be installed in stretches of 110 mph operation and on curves where unbalanced superelevation would exceed 5 inches.

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[2]A hypothetical train capable of operating at nine inches of unbalanced superelevation.

[3]At the time the TPC runs were made, data on Amtrak's proposed high-speed trainset was not available, therefore the characteristics of a hypothetical trainset used in the 1995 analysis of New Haven to Boston improvements was utilized.

[4]Only the generic tilt train was simulated at nine inches of unbalanced superelevation.

TPC Simulations of increasing intermediate train stops to 14. A fourth set of TPC simulations to evaluate the impact of increasing the number of intermediate train stops to 14, after increasing MAS to 110 mph was performed. Trip times to 30th Street Station were simulated. The following conditions were used:

- MAS was increased to 110 mph; speeds on individual curves were calculated using a spreadsheet previously described in Appendix C.
- Speed restrictions due to track conditions were assumed to be removed as the result of an intensive program to restore the line to a state of good repair. As in the baseline case, positive stops and curve speeds were not enforced.
- Improvements to spiral length and superelevation of selected curves, to optimize speed for curves without changing curvature, were assumed.
- Fourteen intermediate stops - 1.0-minute dwell at Malvern, Exton, Whitford, Downingtown, Coatesville, Parkesburg, Leaman Place, Mount Joy, Elizabethtown, Middletown, and Harrisburg Airport; and 2.0-minute dwell at Ardmore, Paoli, and Lancaster.
- Several Train consists were evaluated:
  - four Amfleet cars powered by one F40PH diesel locomotive;
  - four Silverliner IV Electric Multiple Unit (EMU) vehicles;
  - two IC-3D Diesel Multiple Unit (DMU) vehicles ;
  - four Amfleet cars powered by one AEM-7 locomotive; and
  - one generic Amtrak tilt train.
- Speeds were set assuming three levels of unbalanced superelevation -
  - 3 inches;
  - 5 inches; and
  - 9 inches.

  These all assume that selected curves would be upgraded to 6 inches of actual superelevation (identified as E_a on the tables).
- Concrete ties were assumed to be installed in stretches of 110 mph operation and on curves where unbalanced superelevation would exceed 5 inches.
- Although positive stops and curve speeds were not enforced, signal system improvements compatible with the recommended speeds were assumed.

The runs with one AEM-7 locomotive, the Diesel Multiple Unit consists being investigated by PennDOT, and the generic Amtrak tilt train cars were made for comparison purposes. The TPC runs illustrate the running times that could be expected given the relevant performance and physical characteristics of these types of rolling stock.

Conditions used in the TPC simulations, including MASs, speeds through curves, and unbalanced superelevation, are all a function of track structures, equipment structural capacity, and crashworthiness and represent the collective best judgment of experienced rail operators. Before high-speed operations are introduced, however, many of these conditions will have to be analyzed in greater detail, and tested to ensure the safety of the total system.

TPC Running Times and Schedule Times

TPC simulated running time is the best achievable time that may be expected of a given train operated over a railroad line with given physical characteristics. The TPC times reported in Tables C-1 through C-10 are therefore the most optimistic running times for each given train consist.

When train schedules are prepared using TPC simulated times as a basis for the train running times, it is necessary to add an allowance for minor operating irregularities, which may be expected to occur on a daily basis. Several terms are used for this allowance, the most common of which are "pad", "cushion time", or "slop". A discussion of the issue of the amount of pad that should be added to the TPC times is found in a later subsection. The addition of this allowance to the TPC running time will enable trains to perform reliably on a day-to-day basis. The pad also will enable trains to regain any lost time resulting from minor delays (i.e., temporary speed restrictions, diversions around maintenance work, etc.). Pad also provides for two additional components: the probability that not all of the configuration and alignment improvements incorporated into the model will prove physically feasible; and the realization that the model assumes that the train engineer operates the train in a consistent and precise manner in response to speed changes.

Description of the Goal Train Output Tables

The results of the TPC simulations are contained in Tables C-1 through C-10. The tables are organized to present the overall running times and time savings (compared with the Baseline TPC run) from Philadelphia to Harrisburg for the different train consists and facility configuration assumptions.

The running times and time savings to be achieved by various alternative train consists operating at 3 inches of unbalanced superelevation and present timetable speeds, before any facility improvements such as curve realignments are made are illustrated in Table C-1. The Baseline scenario is identified in the tables as the scenario with "1-F40PH + 4 Amfleet, 3" Eu, with 6 stops.

The running times and time savings to be achieved with 3 inches of unbalanced superelevation and an MAS of 110 are illustrated in Table C-2. The Baseline scenario is identified in the tables as the scenario with "1-F40PH + 4 Amfleet, 3" Eu, with 6 stops.

Table C-1
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
1997 Timetable Maximum Authorized Speeds
Six Intermediate Stops[5]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	54.67
4 Silverliner IV EMUs 3" Eu	1-48.1	4.1	56.72
2 IC-3D Flexiliner DMUs 3" Eu	1-49.0	3.2	56.27
1-AEM-7+4 Amfleet 3" Eu	1-47.4	4.8	57.11

Table C-2
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Increasing Maximum Authorized Speed to 110 mph
Six Intermediate Stops[6]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 3" Eu - 6 Stop	1-37.6	14.6	62.85
4 Silverliner IV EMUs 3" Eu	1-32.3	19.8	66.42
2 IC-3D Flexiliner DMUs 3" Eu	1-31.3	20.9	67.16
1-AEM-7+4 Amfleet 3" Eu	1-26.6	25.6	70.79

[5]Intermediate stops: 1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport; 2.0-minute dwell at Paoli and Lancaster.

[6]Intermediate stops: 1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport; 2.0-minute dwell at Paoli and Lancaster.

The six intermediate stop running times and time savings (also compared with the Baseline TPC run) resulting from improvements to curve geometry to permit operation at 110 mph and curve speeds computed for 5 inches of unbalanced superelevation are shown in Table C-3. In all cases, selected curves would have upgraded actual superelevation of 6 inches. These tables also illustrate the trip time savings in comparison with the Baseline scenario.

Table C-3
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Increasing Curve Unbalance (Eu) to 5 Inches
Maximum Authorized Speed of 110 mph
Six Intermediate Stops (1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport; 2.0-minute dwell at Paoli and Lancaster)

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 5" Eu	1-34.1	18.1	65.13
4 Silverliner IV EMUs 5" Eu	1-29.0	23.2	68.88
2 IC-3D Flexiliner DMUs 5" Eu	1-27.0	25.2	71.47
1-AEM-7+4 Amfleet 5" Eu	1-22.5	29.7	74.36

The impact of using the generic Amtrak tilt train at 9 inches of unbalanced superelevation, with six intermediate stops, is shown in Table C-4.

The running times and time savings to be achieved by decreasing the number of stops to two, with 3 inches of unbalanced superelevation and an MAS of 110, are illustrated in Table C-5. The Baseline scenario is identified in the tables as the scenario with "1-F40PH + 4 Amfleet, 3" Eu, with 6 stops. The two intermediate stop running times and time savings (also compared with the Baseline TPC run), resulting from improvements to curve geometry to permit operation at 110 mph and curve speeds computed for 5 inches of unbalanced superelevation are shown in Table C-6. In all cases, selected curves would have upgraded actual superelevation of 6 inches. These tables also illustrate the trip time savings in comparison with the Baseline scenario.

Table C-4
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Increasing Curve Unbalance (Eu) to 9 Inches
Maximum Authorized Speed of 110 mph
Six Intermediate Stops[7]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
Amtrak Generic Tilt Train	1-16.0	36.2	80.68

Table C-5
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Decreasing Number of Stops
Maximum Authorized Speed of 110 mph
Two Intermediate Stops[8]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 3" Eu	1-26.5	25.7	70.89
4 Silverliner IV EMUs 3" Eu	1-23.8	28.4	73.20
2 IC-3D Flexiliner DMUs 3" Eu	1-21.6	30.6	75.10
1-AEM-7+4 Amfleet 3" Eu	1-18.0	34.2	78.61

[7]Intermediate stops: 1.0-minute dwell at Exton, Downingtown, Elizabethtown, and Harrisburg Airport; 2.0-minute dwell at Paoli and Lancaster.

[8]Intermediate stops (2.0-minute dwell) at Paoli and Lancaster.

Table C-6
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Decreasing Number of Stops and Increasing Eu to 5"
Maximum Authorized Speed of 110 mph
Two Intermediate Stops[9]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 5" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 5" Eu	1-23.7	27.5	74.17
4 Silverliner IV EMUs 5" Eu	1-21.2	30.0	76.47
2 IC-3D Flexiliner DMUs 5" Eu	1-17.9	33.3	79.78
1-AEM-7+4 Amfleet 5" Eu	1-14.7	36.5	83.14

The impact of using the generic Amtrak tilt train at 9 inches of unbalanced superelevation, with two intermediate stops, is shown in Table C-7.

Table C-7
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Decreasing Number of Stops and Increasing Eu to 9 Inches
Maximum Authorized Speed of 110 mph
Two Intermediate Stops[10]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
Amtrak Generic Tilt Train	1-07.0	43.2	91.51

The running times and time savings to be achieved by increasing the number of stops to fourteen, with 3 inches of unbalanced superelevation and an MAS of 110, are

[9]Intermediate stops (2.0-minute dwell) at Paoli and Lancaster.

[10]Intermediate stops (2.0-minute dwell) at Paoli and Lancaster.

illustrated in Table C-8. The Baseline scenario is identified in the tables as the scenario with "1-F40PH + 4 Amfleet, 3" Eu, with 6 stops. The fourteen intermediate stop running times and time savings (also compared with the Baseline TPC run), resulting from improvements to curve geometry to permit operation at 110 mph and curve speeds computed for 5 inches of unbalanced superelevation are shown in Table C-9. In all cases, selected curves would have upgraded actual superelevation of 6 inches. These tables also illustrate the trip time savings in comparison with the Baseline scenario.

Table C-8
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Increasing Number of Stops
Maximum Authorized Speed of 110 mph
Fourteen Intermediate Stops[11]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 3" Eu	1-57.7	(2.0)	52.11
4 Silverliner IV EMUs 3" Eu	1-48.3	7.4	56.61
2 IC-3D Flexiliner DMUs 3" Eu	1-49.1	6.6	56.23
1-AEM-7+4 Amfleet 3" Eu	1-42.9	12.8	59.61

The impact of using the generic Amtrak tilt train at 9 inches of unbalanced superelevation, with fourteen intermediate stops, is shown in Table C-10.

TPC Results for the Goal Trains

The running times and time savings resulting from the facility configuration improvements and train stop assumptions are discussed in the following paragraphs.

[11] Intermediate stops 1.0-minute dwell at Malvern, Exton, Whitford, Downingtown, Coatesville, Parkesburg, Leaman Place, Mount Joy, Elizabethtown, Middletown, and Harrisburg Airport; 2.0-minute dwell at Ardmore, Paoli, and Lancaster.

Table C-9
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Increasing Number of Stops and Increasing Eu to 5"
Maximum Authorized Speed of 110 mph
Fourteen Intermediate Stops[12]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
1-F40PH+4 Amfleet 5" Eu	1-55.0	0.7	53.33
4 Silverliner IV EMUs 5" Eu	1-45.5	10.2	58.12
2 IC-3D Flexiliner DMUs 5" Eu	1-45.7	9.9	58.00
1-AEM-7+4 Amfleet 5" Eu	1-39.1	16.6	61.87

Table C-10
COMPARATIVE SIMULATED RUNNING TIMES
With Various Train Consists and Facility Configurations
Showing Effects of Decreasing Number of Stops and Increasing Eu to 9 Inches
Maximum Authorized Speed of 110 mph
Fourteen Intermediate Stops[13]

Train Consist Eu	Running Time	Difference From Baseline	Average Speed
1-F40PH+4 Amfleet 3" Eu - 6 Stop **Baseline**	1-52.2	N/A	53.24
Amtrak Generic Tilt Train	1-32.2	22.8	66.00

[12]Intermediate stops 1.0-minute dwell at Malvern, Exton, Whitford, Downingtown, Coatesville, Parkesburg, Leaman Place, Mount Joy, Elizabethtown, Middletown, and Harrisburg Airport; 2.0-minute dwell at Ardmore, Paoli, and Lancaster.

[13]Intermediate stops 1.0-minute dwell at Malvern, Exton, Whitford, Downingtown, Coatesville, Parkesburg, Leaman Place, Mount Joy, Elizabethtown, Middletown, and Harrisburg Airport; 2.0-minute dwell at Ardmore, Paoli, and Lancaster.

Comparative simulated running times with various train consists showing effects of various train consists operating at 3 inches of unbalanced superelevation (Eu), the present (spring 1997) maximum authorized speeds, and six intermediate stops are shown in Table C-1. No changes in track configuration or state of good repair improvements were assumed for these runs. The impact of varying train consists ranges from 3 to 5 minutes. The utilization of diesel rather than electric locomotives increases trip times by 4.8 minutes. The use of DMUs rather than diesel locomotives reduces the TPC time by three minutes.

Compared to the timetable scheduled performance of two hours and five minutes for seven-stop Keystone trains, the six-stop Baseline TPC run represents more than an eleven percent pad (discussed in subsequent subsections).

Estimates of the time savings that may be achieved by increasing MAS to 110 mph, implementing an intensive state of good repair program, selectively increasing actual curve superelevation to 6 inches, selectively increasing spiral length on curves to satisfy design and comfort criteria as discussed in Appendix C are provided in Table C-2. Also included are track capacity improvements to improve trip time reliability and trip time improvements at Lancaster, Harrisburg Station, and the east of Overbrook Interlocking. These improvements provide total savings ranging from about 14.6 minutes to 25.5 minutes, compared with the Baseline. A diesel-hauled consist could potentially operate on a six-stop 1-hour 45-minute schedule. An AEM-7 (electric) hauled consist could achieve a 95-minute schedule between 30th Street and Harrisburg. Silverliners or DMUs could support a 1-hour 40-minute operation.

Estimates of the time savings that may be achieved by increasing MAS to 110 mph, implementing an intensive state of good repair program, increasing Eu to 5 inches, selectively increasing actual curve superelevation to 6 inches, selectively increasing spiral length on curves to satisfy design and comfort criteria as discussed in Appendix C are provided in Table C-3. Also included are track capacity improvements to improve trip time reliability, and trip time improvements at Lancaster, Harrisburg Station, and to the east of Overbrook Interlocking. These improvements provide total savings ranging from about 18.0 minutes to 29.7 minutes, compared with the Baseline. A diesel-hauled consist could potentially operate on a six-stop, 1-hour 40-minute schedule. An AEM-7 (electric) hauled consist could achieve an 90-minute schedule between 30th Street and Harrisburg. Silverliners and DMUs both could satisfactorily support a 95-minute operation.

The incremental effect of operating a generic tilt train at nine inches of unbalanced superelevation is illustrated in Table C-4. The generic trainset produced savings of 36.2 minutes and would should reliably operate a one-hour 25-minute schedule between Philadelphia and Harrisburg.

The incremental effect of decreasing the number of stops to two at three inches of unbalanced superelevation is illustrated in Table C-5. The improvement produces total savings ranging from about 23.7 minutes to 32.2 minutes, compared with the Baseline. Incremental savings from the six intermediate stop 3" Eu option range from 6.7 minutes (for the AEM-7 Option) to 9.1 minutes (for the diesel option). Minimizing the number of times the diesel must accelerate from a station stop has a significant impact on it operating performance.

The incremental effect of decreasing the number of stops to two at five inches of unbalanced superelevation is illustrated in Table C-6. The improvement produces total savings ranging from about 27.5 minutes to 36.4 minutes, compared with the Baseline 90 mph case. Incremental savings from the six intermediate stop 5" Eu option range from 6.7 minutes (for the AEM-7 Option) to 9.5 minutes (for the diesel option). Minimizing the number of times the AEM-7 must accelerate from a station stop has a less significant impact on it's operating performance than decreasing the number of diesel-hauled stops.

The incremental effect of decreasing the number of stops to two at nine inches of unbalanced superelevation is illustrated in Table C-7. The improvement produces total savings of 43.2 minutes, compared with the Baseline. The incremental savings from the six intermediate stop option is 7.0 minutes. Minimizing the number of times the generic tilt train must accelerate from a station stop has about the same impact on it's operating performance as decreasing the number of AEM-7-hauled stops.

The incremental effect of increasing the number of stops to 14 at 3 inches of unbalanced superelevation is illustrated in Table C-8. The increase in stops produces total savings ranging from about a loss of 2.0 minutes, for the diesel-hauled consist, to a savings of 12.8 minutes for the AEM-7 hauled consist, compared with the Baseline. Incremental time lost from the comparative six intermediate stop option range from 12.4 minutes (for the Silverliner 3" Option) to 16.6 minutes (for the diesel 3" Option). Increasing the number of times the diesel-hauled consist must accelerate from a station stop has a more significant impact on it's operating performance than increasing the number of electric-hauled stops.

The incremental effect of increasing the number of stops to 14 at 5 inches of unbalanced superelevation is illustrated in Table C-9. The increase in stops produces total savings ranging from about 0.7 minutes for the diesel-hauled consist to 16.6 minutes for the AEM-7 hauled consist, compared with the Baseline. Incremental time lost from the comparative six intermediate stop option range from 12.9 minutes (for the Silverliner 5" Option) to 17.3 minutes (for the diesel 5" Option).

The incremental effect of increasing the number of stops to 14, at nine inches of unbalanced superelevation, is illustrated in Table C-10. The increase in stops produces total savings of 22.8 minutes, compared with the Baseline. The incremental time loss from the comparable 9-inch six intermediate stop option is 13.4 minutes. Minimizing the number of times the generic tilt train must accelerate from a station stop has about the same impact on it's operating performance as decreasing the number of AEM-7-hauled stops.

Speed Profile Graphs

Speed profile graphs comparing the performance of various train consists, train speeds, number of stops, and MAS are provided as Figures C-1 and C-2. The 29.7 minutes saved by having an electrified train operation, in place of a diesel operation, between Philadelphia and Harrisburg, restoring the track structure, signals, etc. to a state-of-good repair, and upgrading selected curves to six inches of actual superelevation is shown in Figure C-1. The effect of reducing the number of stops, with electrified operation, from six to two is shown in Figure C-2.

The vertical scale on each figure has been modified from the normal display in which speed on the vertical scale is uniform to a proportional scale in which the area under the curve created by the plot is equal to time. Since the scale between 0 and 25 mph would dominate the display and the distance traveled at speeds in that range is minimal that speed range is normally not plotted. When two TPC runs are plotted on the same chart, the revised scale enables the enhanced effect of trip improvements at lower speeds to be illustrated.

Performance of Commuter Trains

Budgetary limitations limited TPC runs to intercity trains.

Figure C-1: PHILADELPHIA 30TH ST TO HARRISBURG TIME SAVED

1 F40+4 AMCOACH Vs 1 AEM7+4 AMCOACH

1997 Time Table Speeds Vs 110-mph with 5" Eu

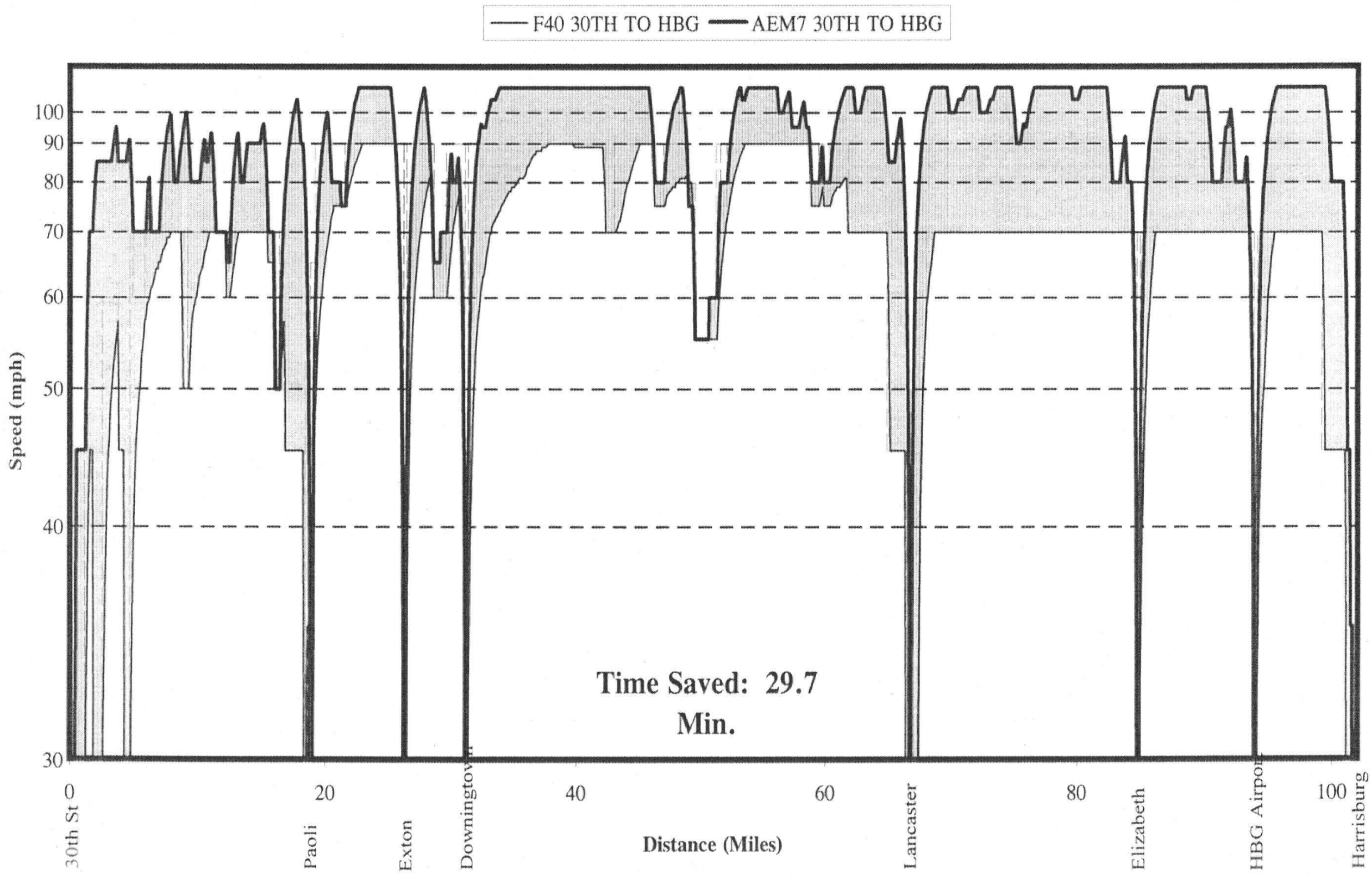

Figure C-2

PHILADELPHIA 30TH ST TO HARRISBURG TIME SAVED

1 AEM7+4 AMCOACH, 110-mph with 5" Eu

2 Stops Vs 6 Stops

2015 TRAFFIC LEVEL OPERATIONS

MONTE CARLO™ Simulations

When several services coexist on the same trackage, conflicts are likely. Delays from these conflicts can jeopardize the reliability of all services; therefore, a methodology is required that can measure the impact of these conflicts. With services as interrelated as those on the NEC and the Richmond Line, simulation of the entire interrelated system is the only valid methodology. That is not the case with the Keystone Corridor. The lack of intercity freight operations and the integrated nature of the intercity-commuter scheduling process lessens the need for a computerized analysis of train operations. Consequently, the MONTE CARLO™ simulation package was not applied to the Harrisburg corridor.

Therefore, in addition to the TPC model, manual analysis techniques were used to evaluate the effectiveness of individual projects initially considered necessary to achieve the trip time and reliability goals.

The purpose of the manual analyses was to provide information for each location analyzed as to:

- where delays potentially could occur;
- possible schedule changes to eliminate conflicts; and
- facility changes that could potentially eliminate conflicts.

Operations Evaluation Methodology

The starting point for the analyses were the existing corridor-wide facilities and the Year 2015 schedules, which were obtained from each entity (SEPTA, PennDOT, CR, and Amtrak).

The analyses attempted to determine for varying levels of service, at different times of the day whether commuter and intercity trains could be routed on regularly assigned tracks. If normal track assignments appeared infeasible, the potential for using other tracks to avoid delays was evaluated. If it appeared that, because of conflicting moves, no track was available, or if an interlocking was blocked, trains were assumed to wait until a route was available. The severity of potential operating problems was established based experience of the personnel performing the analyses.

Terminal operations in Philadelphia and Harrisburg were not simulated as part of the study. It was expected that the terminals could accommodate the projected traffic levels. The capacity of the terminals cannot be ignored, and the interface of intercity and commuter passenger operations at the station and in the vicinity of the station are a potential problem ultimately that should be addressed by rail planners.

2015 Operations Between Philadelphia and Harrisburg

Achieving the running time goals under theoretical circumstances does not ensure meeting them in actual operations. The numerous interfaces with commuter trains between Philadelphia and Atglen affect trip times.

At several locations, where there was potential for delays, the first step was to determine if operating options could alleviate the perceived difficulties. When this process did not identify viable solutions, it was concluded that the delays could be minimized through configuration modifications. The recommended changes are documented in the body of this supplemental report.

TRIP TIME FINDINGS

Scheduling Pad

Background. In planning train schedules or analyzing the results of TPC runs, *pad* is defined as the difference between a published schedule time and the best achievable time between two terminals. When planning schedules, the amount of pad allows trains to incur small increments of delay en route and still maintain a high probability of on-time performance. When analyzing the results of TPC runs, two additional components of pad are considered: the expectation that not all of the configuration and alignment improvements incorporated into the model will prove physically feasible; and the expectation that the model assumes that every train engineer operates the train in a consistent and precise manner in response to required speed changes. These assumptions usually are too optimistic.

Traditionally, the most common way of adding pad to the schedule is to concentrate much of it toward the end of the run. The reason for this technique is that pad, which is distributed throughout a schedule and is consumed by waiting for scheduled departure times at intermediate stations, is unavailable to cover any delays that may occur toward the end of a run. Since, traditionally, the on-time performance of a train is measured by the time at the final terminal, many schedule makers and transportation supervisors prefer to have the pad allocated toward the end of the run.

In scheduling high-performance trains on a route with heavy commuter traffic, it may be more appropriate to distribute pad at the location(s) where delays are most likely to occur.

Pad Considerations. The amount of pad to be provided depends upon the nature of the railroad being operated. Traditionally, a percentage of the TPC is allotted for pad. Realistic estimates of pad cannot be made until a facility and schedules have been defined. Even then, determining the distribution of pad must be based on subjective evaluation and operating history.

Previous MONTE CARLO™ simulations for similar NEC studies have resulted in the conclusion that a pad in the range of 6 to 7 minutes, which represents 7-percent added to the TPC time for intercity trains in this corridor would be justified.

Achievement of Planned Keystone Corridor Improvements and Impact upon Pad. The TPCs expected that the presently projected curve speeds will be achieved. Experience has indicated that not all of these planned improvements will prove physically feasible and not all of the anticipated savings will be achieved in the real world. This is another reason why a pad of at least 7-percent is necessary during the planning phase of a project.

Pad Recommendations. For planning purposes it is better to overestimate pad than to underestimate it, unless doing so grossly distorts construction costs. Based on the FRA's previous analyses, a 6- to 7-minute (7-percent pad) is being used to determine whether or not a reliable less than 90-minute time between Philadelphia and Harrisburg is achievable.

Trip Time Goal Status

The TPC simulations have clearly indicated that completion of an extensive state of good repair program, the performance characteristics of the intercity rolling stock, and the amount of unbalanced superelevation, will be critical to achieving the trip time goal of less 90 minutes.

To determine whether a reliable intercity service of less 90 minutes can be operated, Table C-11 was prepared to summarize the overall running times for various alignment and train consist options. The results are shown for speeds computed for the three different unbalanced superelevation conditions and the 110 mph MAS option between Philadelphia and Harrisburg that have been simulated. The table also shows the amount of pad available for each run.

Using the 6- to 7-minute (7-percent) pad recommendation mentioned in the previous section, it is clear that only the six stop cases assuming electrified diesel-hauled operation in which 5 and 9 inches of unbalanced superelevation were used resulted in a run time that provides the recommended pad.

Table C-11
SIMULATED RUN TIMES
AND AVAILABLE PAD
Compared to 90-Minute Goal

Case	Simulated Run Time	Pad (minutes.)	Pad (% of TPC Time)
Baseline: 1-F40PH +4Amfleet, 3" Eu - 6 stop	107.2	N/A	N/A
110 mph/5" Eu/2 IC-3D/6 stops	87.0	3.0	3.4%
110 mph/3" Eu/1 AEM-7/6 stops	86.6	3.4	3.9%
110 mph/3" Eu/1 F40PH/2 stops	86.5	3.5	4.1%
110 mph/3" Eu/4 Silverliner IV EMUs/2 stop	83.8	6.2	7.5%
110 mph/5" Eu/1 F40PH/2 stops	83.7	6.3	7.6%
110 mph/5" Eu/1 AEM-7/6 stops	82.5	7.5	9.1%
110 mph/3" Eu/2 IC-3D/2 stops	81.6	7.4	10.2%
110 mph/3" Eu/AEM7/2 stops	78.0	12.0	15.4%
110 mph/5" Eu/2 IC-3D/2 stops	76.9	13.1	17.1%
110 mph/9" Eu/ Generic Tilt train/6 stops	76.0	14.0	18.4%
110 mph/5" Eu/AEM7/2 stops	73.7	16.3	22.0%
110 mph/9" Eu/ Generic Tilt train/2 stops	67.0	23.0	34.3%

Considering the above-mentioned uncertainties, and therefore applying the seven percent pad, only the electrified 110 mph six-stop options achieve the trip time goal of less than 90 minutes. Use of a train with tilt capabilities operating at 9-inches of unbalanced superelevation and a MAS of 110 mph, would enable a 6-stop 85-minute schedule to be established, and might enable a limited number of 80-minute 6-stop trains to be operated.

It does not appear that IC-3D consists would support a 6-stop, 90-minute service (at 5" Eu), however, 6-stop 95-minute would appear to be possible. A two-stop 85-minute IC-3D schedule would appear feasible. IC-3D diesel-powered trains would only be operated between the lower level of 30th Street Station and Harrisburg. They would be restricted from operating into the underground Suburban Street Station.

It should be noted that a number of potential changes in the conditions upon which the TPC results are based might occur, which would further erode the amount of available pad. For example:

- There may still be some question as to whether all of the curve modifications that are assumed in the TPC runs are feasible, from an engineering standpoint;
- If a 110 mile-per-hour MAS cannot be achieved, there would be some increase in TPC running time;
- If an unbalanced superelevation lower than 5 inches must be used, the trip time would suffer; and
- Adding station stops beyond six would increase running time.

It is believed that an on-time performance of at least 90 percent should be established as a goal for Keystone Corridor train services.

Track Capacity

Goal trains most likely could be integrated into today's corridor schedule through schedule adjustments, with implementation of the state of good repair program, and the construction of the planned track and configuration improvements. However, given the 2015 schedules provided by corridor users, there is insufficient capacity and operating flexibility at certain station locations to accommodate all users during peak periods, if the recommended improvements at those locations are not implemented. The Overbrook to Philadelphia segment improvements also must be implemented, if trip time and capacity goals are to be satisfied.

Insufficient capacity, resulting from lack of program implementation in these key locations, can be handled in two ways: reducing train frequencies and lengthening schedules to accommodate delay. Selection of either of these two options would be policy decisions, which would work against the project goals assumed for this study.